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Bonne et al.(10) **Pub. No.: US 2014/0283550 A1**(43) **Pub. Date: Sep. 25, 2014**(54) **METHOD AND INSTALLATION FOR
SEPARATING AIR BY CRYOGENIC
DISTILLATION**(30) **Foreign Application Priority Data**

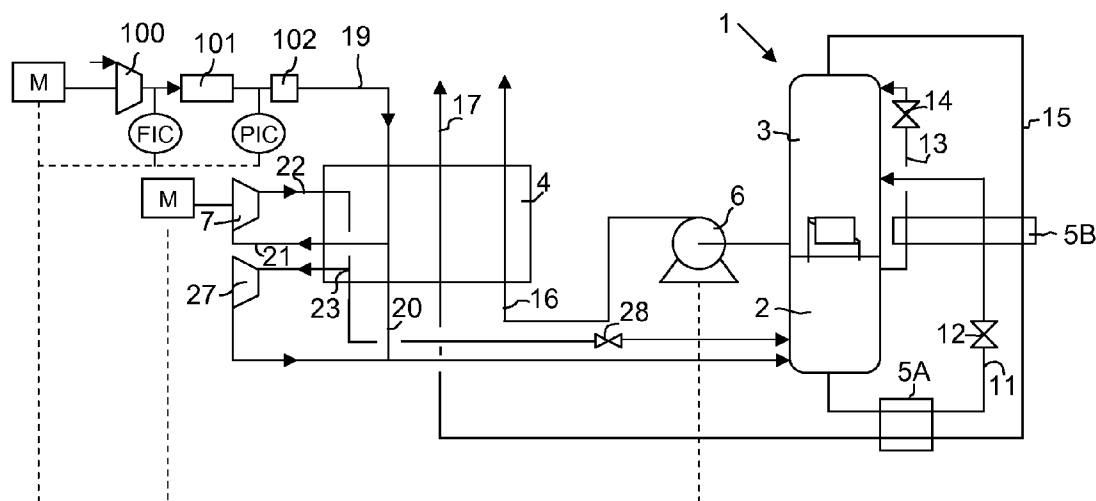
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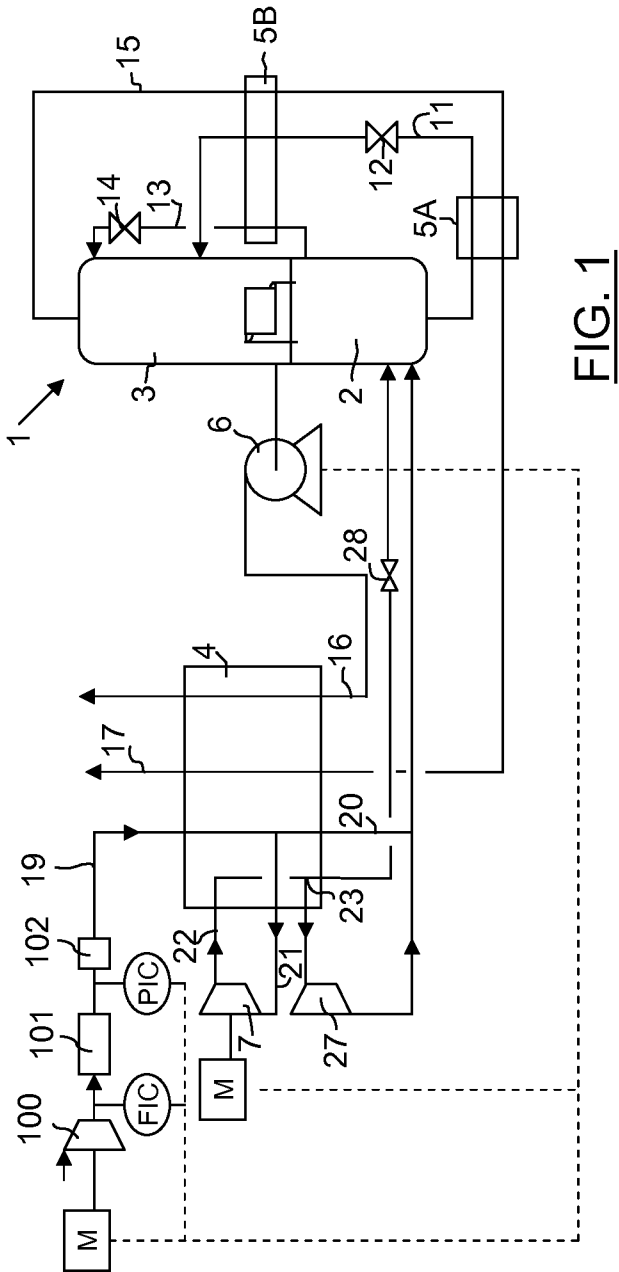
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USPC **62/643**(72) Inventors: **Frederic Bonne, Paris (FR); Nicolas
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Georges Claude, Paris (FR)**(57) **ABSTRACT**

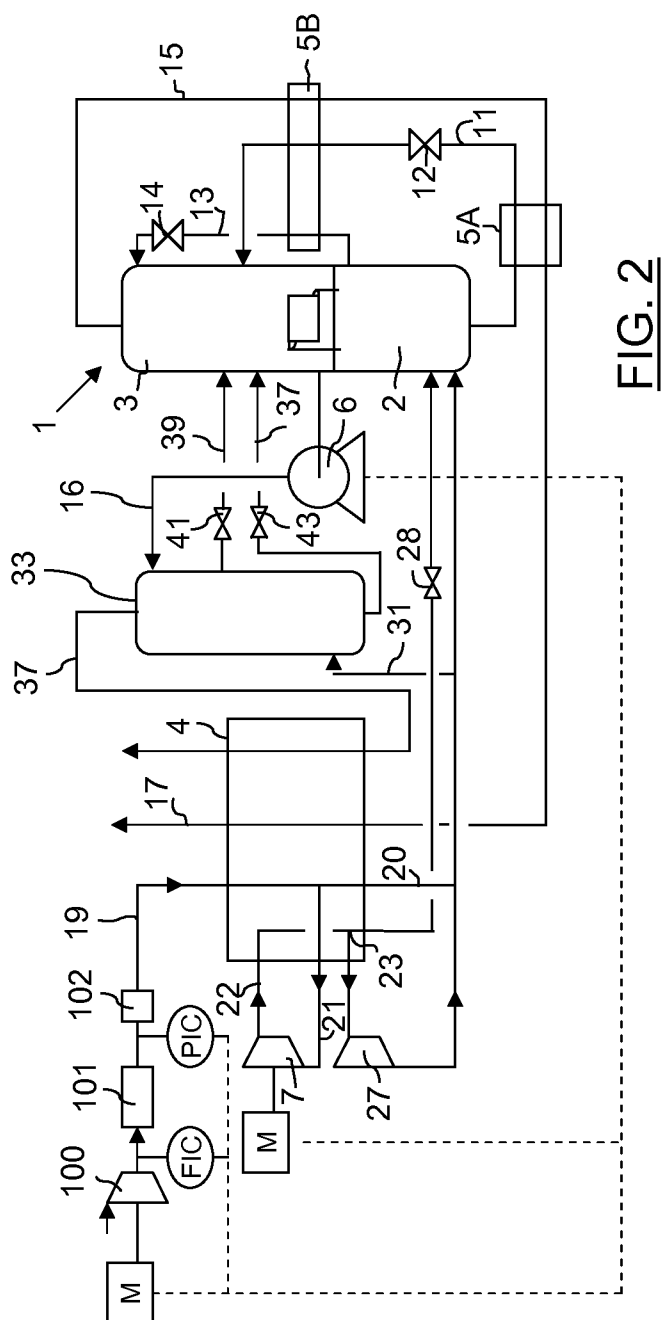
An installation for separating air by cryogenic distillation comprises a compressor, a heat-exchange line, a system of columns, an electric motor for driving the compressor, a pipe for taking off a liquid from the system of columns, a pump for pressurising the liquid drawn off and means for affording an exchange of heat between the air compressed by the compressor and the liquid pressurised by the pump and means for reducing the output pressure of the pump according to the frequency of the electricity supplying the electric motor.

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METHOD AND INSTALLATION FOR SEPARATING AIR BY CRYOGENIC DISTILLATION

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application is a §371 of International PCT Application PCT/FR2012/052707, filed Nov. 23, 2012, which claims the benefit of FR1160775, filed Nov. 25, 2011, both of which are herein incorporated by reference in their entireties.

TECHNICAL FIELD OF THE INVENTION

[0002] The invention, for example when the customer is a steelmaking industry, makes it possible to continue to produce the output of the oxygen and/or nitrogen demanded, even when significant changes in frequency occur, while preserving good specific energy with regard to the outgoing products.

[0003] The invention also has particular interest in the case where the pressure of gas produced by the separation unit is not the same as the pressure of use of the gas by the customer, for example because of the interposed presence of a buffer tank.

BACKGROUND

[0004] In a certain number of countries, the electrical networks are not sufficiently “strong” and meshed to avoid major disturbances on the frequency of the network during high demands or in hot weather, the two moreover often being concomitant,

[0005] The air separation units (ASUs) that are often found on such networks are greatly disturbed. In order to be able to continue to produce at the required specifications in terms of rate, pressure, or even purity with regard to both oxygen and nitrogen, it is necessary, during design thereof, to integrate these frequency constraints in the choice of the various machines, which is very detrimental in terms of output of the compressor on the nominal point, and several yield points may thus be lost, which gives rise to poor specific energy on the products emerging from the ASU.

[0006] U.S. Pat. No. 5,471,843 describes an air separation method in which the vaporisation pressure of the liquid oxygen is reduced if the demand for oxygen decreases. In the same way, the flow rate of air to be treated is reduced but the motor is driven by a constant-speed motor. Thus the logic sequence of events is the opposite to that of our invention and is not dependent on the observation of a drop in frequency.

[0007] EP-A-1845323 describes an air separation method in which the vaporisation pressure of the liquid oxygen depends on the pressure in the reservoir containing the vaporised oxygen. Neither the drive for the compressor nor regulation according to the frequency of the electricity are mentioned.

[0008] In this context, “rich in oxygen” means that the fluid contains at least 70% mol oxygen.

SUMMARY OF THE INVENTION

[0009] According to one subject matter of the invention, a method for separating air by cryogenic distillation is provided, in which

[0010] i) a flow of air is compressed in a compressor, is cooled from a heat-exchange line and sent to a system of

columns where it separates in order to form a nitrogen-enriched flow and an oxygen-enriched flow

[0011] ii) the compressor is driven by a motor supplied by electricity having a first frequency

[0012] iii) a liquid flow is drawn off from the system of columns, pressurised at a first pressure by a pump and either vaporised by indirect heat exchange with the air coming from the compressor in order to produce a gaseous product substantially at the first pressure, or, in the case of an oxygen-rich liquid flow, sent at the first pressure to the top of an auxiliary column supplied at the bottom by air coming from the compressor, gaseous oxygen being drawn off at the top of the column as a product and an intermediate liquid from the auxiliary column being sent to the system of columns,

[0013] characterised in that

[0014] iv) if the frequency of the electricity passes below a given threshold below the first frequency, the pressurisation pressure of the liquid flow is reduced to a second pressure lower than the first pressure.

[0015] According to optional features:

[0016] the compressor compresses air from atmospheric pressure,

[0017] the compressor compresses air from a pressure higher than 2 bar.

[0018] the liquid flow vaporises in the heat-exchange line,

[0019] the oxygen-rich liquid flow is sent at the first pressure to the top of the auxiliary column supplied in the tank with air coming from the compressor, gaseous oxygen being drawn off at the top of the column as a product and at least one liquid being sent from the auxiliary column to the system of columns,

[0020] if the frequency is equal to the first frequency, the liquid flow has a flow rate V and if the frequency is below the given threshold lower than the first frequency the liquid flow at least equal to $0.9 V$, or even at least equal to $0.95 V$ or even equal to V ,

[0021] the pressurisation pressure of the liquid is reduced if the air flow measured passes below a threshold with respect to the air flow required for reaching the nominal value of the liquid flow rate at the first pressurisation pressure,

[0022] the pressurisation pressure of the liquid is reduced if the air pressure passes below a threshold with respect to the air pressure required for achieving the nominal value of the liquid flow rate at the first pressurisation pressure,

[0023] the pressurisation pressure of the liquid is reduced only by modifying the operation of the pressurisation pump,

[0024] the output pressure of the pump is equal to the vaporisation pressure of the liquid pressurised by the pump,

[0025] the vaporised liquid serves as a product at the vaporisation pressure, without undergoing any pressure reduction downstream of the vaporisation.

[0026] According to another subject matter of the invention, an installation for separating air by cryogenic distillation is provided, comprising a compressor, a heat-exchange line, a system of columns, an electric motor for driving the compressor, a pipe for drawing off liquid from the system of columns, a pump for pressurising the liquid drawn off and means for affording a direct or indirect exchange of heat between the air compressed by the compressor and the pressurised liquid,

optionally means also for affording an exchange of mass if the pressurised liquid is rich in oxygen, characterised in that it comprises means for regulating the pressure of the liquid pressurised in the pump as a function of the frequency of the electricity supplying the electric motor.

[0027] Optionally the installation comprises:

[0028] means for regulating the pressure of the pressurised liquid by action of the control system on the flow rate and/or output pressure of the pump,

[0029] means for measuring the frequency supplying the electric motor, the means for regulating the pressurisation pressure of the liquid being capable of being started up if the frequency passes below a threshold,

[0030] a supercharger, means for sending air from the compressor to the supercharger and from the supercharger to the heat-exchange line, the supercharger being driven by the or a motor supplied by electricity having a or the frequency,

[0031] a heat-exchange line where the pressurised liquid vaporises against the air to be separated,

[0032] an auxiliary column supplied by a pressurised liquid rich in oxygen and air.

BRIEF DESCRIPTION OF THE DRAWINGS

[0033] These and other features, aspects, and advantages of the present invention will become better understood with regard to the following description, claims, and accompanying drawings. It is to be noted, however, that the drawings illustrate only several embodiments of the invention and are therefore not to be considered limiting of the invention's scope as it can admit to other equally effective embodiments.

[0034] FIG. 1 shows an embodiment of the invention.

[0035] FIG. 2 shows an embodiment of the invention.

DETAILED DESCRIPTION

[0036] The invention will be described in more detail with reference to the figures, which illustrates schematically an apparatus according to an embodiment of the invention.

[0037] As illustrated in FIG. 1, the separation apparatus comprises a compressor 100, a heat-exchange line 4, a supercharger 7, a turbine 27, a pump 6 and a double distillation column 1 comprising a medium-pressure column 2 and a low-pressure column 3. It will be understood that the double column could be replaced by a triple column and that other columns could be added, such as an argon-mixture column, etc. The thermal coupling means shown is to heat the bottom of the low-pressure column by means of nitrogen from the medium-pressure column, but other thermal coupling means can be envisaged.

[0038] The supercharger illustrated is a cold supercharger having an input temperature less than that of the hot end of the heat-exchange line 4. The invention also applies to the cases using a supercharger having an input pressure equal to or greater than that of the hot end of the heat-exchange line 4.

[0039] Air is compressed in the compressor 100, which is driven by an electric motor supplied by a source of electricity having a nominal frequency, for example 50 Hz (in Europe) or 60 Hz (in the United States). The compressed air is cooled and purified in order to form a flow 19 and then sent to the heat-exchange line 4.

[0040] The air cools in the heat-exchange line and is then divided into two, one part 20 continuing the cooling thereof as far as the cold end of the exchanger and being sent to the

medium-pressure column 2 in gaseous form. The rest of the air 21 sent to a cold supercharger 7, is supercharged at a high pressure and is then sent to the heat-exchange line as a flow 22. Part of the supercharged air 23 is expanded in a turbine 27 and sent to the medium-pressure column whilst the rest of the supercharged air continues its cooling as far as the cold end, is expanded in a valve 28 and is sent to the medium-pressure column.

[0041] Rich liquid 11 is sent from the bottom of the medium-pressure column via the valve 20 and the subcoolers 5A, 5B and liquid nitrogen 13 is sent to the top of the low-pressure column 3 via the valve 14. Low-pressure nitrogen 15 heats up in the subcoolers 5A, 5B and the heat-exchange line 4.

[0042] Liquid oxygen 16 is drawn off from the bottom of the low-pressure column 3, pressurised by the pump 6 and vaporised at a first high pressure in the heat-exchange line 4.

[0043] The supercharger 7 is also driven by an electric motor M supplied by an electric current.

[0044] If the frequency of the electricity supplying one of the two motors driving the compressor or the supercharger, the flow rate and/or pressure of the compressed air may be insufficient to vaporise the oxygen at the first high pressure.

[0045] In this case, according to the invention, the pressurisation pressure of the pump 6 is reduced in order to vaporise the oxygen at a lower pressure. This reduction in pressure can be triggered by measuring the frequency of the electricity supplying the motor and/or by measuring the flow of compressed air 19, 22 and/or the pressure of the flow of compressed air 19, 22. Thus, if the frequency and/or the flow rate and/or the pressure passes below a given threshold (given thresholds), the pressure of the oxygen may be reduced while preserving a production flow rate "close" to the nominal flow rate.

[0046] Thus the apparatus can always function despite the reduced frequency, at the cost of producing vaporised oxygen at a lower pressure.

[0047] The invention also applies to the vaporisation of liquid nitrogen.

[0048] As illustrated in FIG. 2, it is also possible to effect an exchange of heat and mass between the air and the oxygen pressurised in an auxiliary column referred to as the "mixing column". Here the liquid oxygen 16 coming from the pump 6 is sent to the top of a column 33. The auxiliary column 33 is supplied at the bottom by a flow of air 31 at the pressure of the medium-pressure column.

[0049] However, other higher or lower operating pressures may be used. A flow of gaseous oxygen 37 is drawn off at the top of the column 33 and heated in the heat exchanger 4. An oxygen-enriched liquid 37 is drawn off from the bottom of the column 33, expanded in a valve 43 and sent to the low-pressure column 3. It is also necessary to draw off a liquid 39 at an intermediate level of the auxiliary column 33, to expand it in a valve 41 and to send it to the system of columns.

[0050] In this case, in the event of reduced frequency, the mixing column 33 operates at a reduced pressure in order to compensate for the reduction in pressure of the air flow 31.

[0051] The reduction in the frequency, for all cases of application of the invention, may last for a few minutes, a few hours, or even a few days. It goes without saying that the decision to reduce the pressurisation pressure will be taken according to the requirements of the customer and, if a reduc-

tion in product due to the reduction in frequency may be tolerated, it will not necessarily be essential to use the method of the invention.

[0052] Once the normal frequency is re-established, the pressurisation pressure is once again increased by reversing the actions taken to reduce the pressure in the event of reduction in frequency.

[0053] Ideally, the pressurised liquid flow will remain constant, whatever the frequency, but a drop of up to 5%, or even up to 10%, in the flow rate at normal frequency may sometimes be tolerated.

[0054] The reduction in the pressurisation pressure in the event of a drop in frequency may be triggered by detecting that a flow of air to be separated drops. Often a reduction with respect to the nominal flow may be compensated for at least partially by adjusting the compressors.

[0055] On the other hand, at a given threshold below the nominal rate, it would be necessary to proceed according to the invention since the regulation of the compressors can no longer suffice to make up for the drop in flow rate.

[0056] Likewise, in combination with the following method or alone, the reduction in the pressurisation pressure in the event of a drop in frequency can be triggered by detecting that the pressure of an air flow to be separated drops.

[0057] Often a reduction with respect to the nominal pressure may be compensated for at least partially by adjusting the compressors. On the other hand, at a given threshold below the nominal pressure it would be necessary to proceed according to the invention since regulation of the compressors may no longer suffice to make up for the drop in pressure.

[0058] While the invention has been described in conjunction with specific embodiments thereof, it is evident that many alternatives, modifications, and variations will be apparent to those skilled in the art in light of the foregoing description. Accordingly, it is intended to embrace all such alternatives, modifications, and variations as fall within the spirit and broad scope of the appended claims. The present invention may suitably comprise, consist or consist essentially of the elements disclosed and may be practiced in the absence of an element not disclosed. Furthermore, if there is language referring to order, such as first and second, it should be understood in an exemplary sense and not in a limiting sense. For example, it can be recognized by those skilled in the art that certain steps can be combined into a single step.

[0059] The singular forms “a”, “an” and “the” include plural referents, unless the context clearly dictates otherwise.

[0060] “Comprising” in a claim is an open transitional term which means the subsequently identified claim elements are a nonexclusive listing (i.e., anything else may be additionally included and remain within the scope of “comprising”). “Comprising” as used herein may be replaced by the more limited transitional terms “consisting essentially of” and “consisting of” unless otherwise indicated herein.

[0061] “Providing” in a claim is defined to mean furnishing, supplying, making available, or preparing something. The step may be performed by any actor in the absence of express language in the claim to the contrary a range is expressed, it is to be understood that another embodiment is from the one.

[0062] Optional or optionally means that the subsequently described event or circumstances may or may not occur. The description includes instances where the event or circumstance occurs and instances where it does not occur.

[0063] Ranges may be expressed herein as from about one particular value, and/or to about another particular value. When such particular value and/or to the other particular value, along with all combinations within said range.

[0064] All references identified herein are each hereby incorporated by reference into this application in their entireties, as well as for the specific information for which each is cited.

1-15. (canceled)

16. A method of separating air by cryogenic distillation, the method comprising the steps of:

- i) compressing a flow of air in a compressor, cooling said flow of air in a heat-exchange line, and then sending said flow of air to a system of columns where the flow of air separates in order to form a nitrogen-enriched flow and an oxygen-enriched flow;
- ii) driving the compressor by a motor supplied by electricity having a first frequency;
- iii) withdrawing a liquid flow from the system of columns, pressurizing said liquid flow to a first pressure by a pump and either vaporizing said liquid flow by indirect heat exchange with the flow of air coming from the compressor to produce a gaseous product substantially at the first pressure, or, in the case of an oxygen-rich liquid flow, sending the oxygen-rich liquid flow at the first pressure to the top of an auxiliary column supplied at the bottom by the flow of air coming from the compressor, withdrawing gaseous oxygen from the top of the auxiliary column as a product, and sending an intermediate liquid from the auxiliary column to the system of columns,

wherein if the frequency of the electricity passes below a given threshold below the first frequency, the pressurization pressure of the liquid flow is reduced to a second pressure lower than the first pressure.

17. The method according to claim 16, in which the compressor compresses the flow of air from atmospheric pressure.

18. The method according to claim 16, in which the compressor compresses the flow of air from a pressure above 2 bar.

19. The method according to claim 16, in which the liquid flow vaporizes in the heat-exchange line.

20. The method according to claim 16, in which the oxygen-rich liquid flow is sent at the first pressure to the top of the auxiliary column supplied in the bottom with the flow of air coming from the compressor, gaseous oxygen being drawn off at the top of the column as a product and at least one liquid being sent from the auxiliary column to the system of columns.

21. The method according to claim 16, wherein the frequency is equal to the first frequency, the liquid flow has a flow rate V and if the frequency is below the first frequency the liquid flow rate is at least equal to $0.9 V$, or even at least equal to $0.95 V$ or even equal to V .

22. The method according to claim 16, wherein the pressurization pressure of the liquid is lowered if the air flow rate measured passes below a threshold with respect to the air flow rate required to achieve the nominal value of the liquid flow rate at the first pressurization pressure.

23. The method according to claim 16, wherein the pressurization pressure of the liquid is lowered if the air pressure measured passes below a threshold with respect to the air pressure required to achieve the nominal value of the liquid flow rate at the first pressurization pressure.

24. The method according to claim **16**, wherein the pressurization pressure of the liquid is reduced only by modifying the operation of the pressurization pump.

25. The method according to claim **16**, wherein the output pressure of the pump is equal to the vaporization pressure of the liquid pressurization by the pump.

26. The method according to claim **16**, wherein the vaporised liquid serves as a product at the vaporization pressure, without undergoing any pressure reduction downstream of the vaporization.

27. An installation for separating air by cryogenic distillation, the installation comprising a compressor, a heat-exchange line, a system of columns, an electric motor configured to drive the compressor, a pipe configured to draw off liquid from the system of columns, a pump configured to pressurize the liquid drawn off and means for affording a direct or indirect exchange of heat between the air compressed by the compressor and the pressurized liquid, and means for regulating the pressure of the liquid pressurized in the pump as a function of the frequency of the electricity supplying the electric motor.

28. The installation according to claim **27**, comprising a means for regulating the pressure of the pressurized liquid by action of the control system on the flow rate and/or the output pressure of the pump.

29. The installation according to claim **27**, comprising a means for measuring the frequency supplying the electric motor, the means for regulating the pressurization pressure of the liquid being capable of being started up if the frequency goes below a threshold.

30. The installation according to claim **27**, comprising a supercharger and means for sending air from the compressor to the supercharger and from the supercharger to the heat-exchange line, the supercharger being driven by the or a motor supplied by electricity having a or the frequency.

31. The installation according to claim **27**, further comprising means for affording an exchange of mass if the pressurized liquid is rich in oxygen.

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