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(71) Applicant: **AIR PRODUCTS AND CHEMICALS, INC.**
Allentown, PA 18195-1501 (US)

(72) Inventors:
- **Topham, Anthony Knut James**
Surrey KT12 2QA (GB)
- **Allam, Rodney John**
Guildford, Surrey GU2 5EU (GB)

(74) Representative: **Smart, Peter John**
W.H. BECK, GREENER & CO
7 Stone Buildings
Lincoln's Inn
London WC2A 3SZ (GB)

(54) Use of elevated pressure nitrogen rich gas streams to perform work

(57) The nitrogen rich stream produced by a cryogenic air separation unit is heated indirectly by burning low grade fuel gas in a burner (20) at low pressure and the heated, elevated pressure nitrogen rich stream produced is expanded in a turbine (24) to obtain useful work prior to the discharge of the nitrogen rich stream at an outlet (28).

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Description

The present invention relates to a process for obtaining work from an elevated pressure nitrogen rich gas stream from a cryogenic air separation unit or plant.

A cryogenic air separation plant can be designed with the nitrogen fraction obtained by separating the air being produced at close to atmospheric pressure with reduction in pressure from that of the distillation columns occurring through piping and heat exchangers to warm discharge conditions. Alternatively, the nitrogen stream can be deliberately back-pressured to allow all of the products from the air separation unit to be produced at pressure substantially greater than atmospheric. Elevated pressure plants have been used for applications where most of the separated air is required as products at elevated pressure. Such elevated pressure plants have a lower capital cost than plants operating at minimum pressures because of the smaller heat exchangers, columns and front end adsorbers and also have lower construction costs.

Proposals have been made in the past for integrating such cryogenic air separation plants with other industrial processes in such a way to obtain work from the pressurised nitrogen produced and similar proposals have also been made in connection with air separation units operating to produce nitrogen at lower pressures.

US-A-2520862 describes taking nitrogen from the high pressure column of a conventional minimum pressure air separation unit (ASU) and mixing it with some oxygen. A fuel is then burned in the high pressure gas mixture and the combustion products at about 500°C are expanded in a hot gas expander to atmospheric pressure. Optionally, an economiser heat exchanger is used to recover heat from the expander exhaust to preheat the nitrogen/oxygen mixture at high pressure prior to combustion.

US-A-3731495 describes taking nitrogen from an elevated pressure ASU and mixing the nitrogen with the products of combustion of a pressurised air/fuel stream before expanding the hot mixed gases to atmospheric pressure. The shaft power produced is used to compress air to produce a pressurised air stream which is divided for use in the air separation unit and the combustion step.

US-A-5040370 describes the indirect heating of a nitrogen stream withdrawn from a air separation plant at a pressure of from 2 to 7 bara using a hot fluid stream with no phase change, from a process as the heat source. The process producing the hot fluid stream at a temperature of up to 600°C is one which uses oxygen from the ASU and the hot nitrogen is expanded in a turbine with the performance of external work.

US-A-5076837 discloses an essentially similar process except that the heated nitrogen stream is at a pressure of at least 5 bara and a temperature of at least 700°C.

US-A-5268019 discloses combusting fuel gas which has been pressurised and expanding the combustion products in a turbine to produce work. Some nitrogen from an ASU is pressurised and supplied to the combustion products prior to the expansion through the turbine. Further nitrogen is heated by indirect heat exchange with the expanded combustion products to a temperature of 400°C and is then expanded through a turbine to produce further work. The oxygen from the air separation unit producing the nitrogen is used in a process which produces the gaseous fuel, such as the operation of a blast furnace.

GB-A-2266343 discloses heating a stream of nitrogen indirectly using low grade fuel gas produced by a blast furnace. However, here the fuel gas is compressed before being fed to the burner.

GB-A-2210455 describes burning a high grade fuel gas to heat indirectly in a closed system a working fluid which typically is helium, argon, hydrogen or a mixture of hydrogen and methane, which is expanded to derive work. The combustion products are at a pressure of from 1 to 100 bar. The concept of heating compressed nitrogen from an air separation unit is not disclosed.

GB-A-1560096 describes regassifying natural gas. Heat is provided by heating nitrogen as a working fluid but the nitrogen recirculates in a closed system and is not a compressed gas stream from an air separation unit. The nature of the heater and fuel used is not clear.

WO95/05529 uses an inert gas such as helium, argon or neon in a closed system as a working gas which is indirectly heated.

EP-A-0208162 teaches burning fuel in a gas turbine and using the exhaust to heat a compressed gas which is preferably air.

US-A-4228659 describes a working fluid in a closed system being heated indirectly by a combustor. The concept of using nitrogen from an air separation unit and discharging it after use is not disclosed.

Where they relate to using nitrogen from an ASU, these disclosures therefore fall into two categories as regards the source of the heat for the nitrogen. In one category, fuel is combusted with air at elevated pressure with addition of the nitrogen for direct heating to produce a gas mixture which is then expanded through a turbine with, optionally, indirect heating of nitrogen also. We have appreciated that this gives rise to a number of disadvantages. The gas quality in the expander is less desirable due to the presence of fuel combustion products. The capital cost of the plant is increased by the need to provide for compression of the fuel gas and the air with which it will be burnt. Where a gas turbine is used for the combustion, that involves a very substantial capital cost. Also, the constraints on the purity of the nitrogen supplied to be mixed with the combustion products would exclude the possibility of safely adding substantial quantities of oxygen mixed with the nitrogen. Combustible gases having a low calorific value are often available only at close to atmospheric pressure from processes consuming oxygen produced in the ASU. It is therefore necessary to provide for substantial compression of such fuel gases before they can be used in this type of process.

The other category of disclosure involves heating the nitrogen by indirect heat transfer with a hot gas produced in another process. Here, only sensible heat content of the heating gas stream is transferred and there is no use of the chemical energy from the other stream in a combustion process. This means that the hot stream flow and temperature must be sufficient to provide all the required heat. In practice, this requires very large surface area indirect heat exchangers and high capital costs.

According to a first aspect of the present invention there is provided a process for obtaining work from an elevated pressure nitrogen rich gas stream obtained from a cryogenic air separation unit (ASU) comprising conducting cryogenic air separation to produce an elevated pressure nitrogen rich gas stream, supplying a fuel gas at pressure of up to 5 bara, or a liquid or solid fuel, to a combustion zone, burning said fuel, heating said nitrogen rich stream indirectly using heat derived from the burning of said fuel to form a heated, elevated pressure nitrogen rich stream, expanding said heated, elevated pressure nitrogen rich stream to perform external work and discharging said nitrogen rich stream.

It should be appreciated that the "nitrogen rich stream" may also contain gases other than nitrogen as further described below.

Preferably, the fuel is a fuel gas and is supplied to a burner at a pressure of up to 3 bara, more preferably from 1.1 to 2 bara, e.g. 1.1 to 1.2 bara.

Preferably, the fuel gas is obtained from a process in which the fuel gas is produced and is supplied to the burner without being pressurised in a compressor, although it may be desirable to employ a blower to promote a satisfactory flow of fuel gas into a burner used for its combustion.

Suitably, the fuel gas is at least predominantly supplied from a source of fuel gas having a heat content of from 2.5 to 16 MJ/Nm^3, i.e. is predominantly composed of fuel gas of low calorific value. Such low heat content fuel gases are difficult to burn in a burner. To assist in obtaining combustion of the low heat content fuel gas, a gas of higher calorific value may be used in addition in a lesser amount of for instance up to 10 percent by volume. Suitably, the additional higher heat content gas is supplied in an amount up to that which will double the heat content of the low heat content gas.

The higher heat content gas may be used to facilitate combustion of the lower heat content gas in various ways. It may simply be mixed with the lower heat content gas to produce a mixture of higher heat content. It may be supplied to its own pilot jet in the burner or it may be burnt to produce a heated gas containing residual oxygen which may be supplied to the burner to encourage combustion.

Suitable sources of the lower heat content fuel gas which is predominately used in the invention are off-gas from a blast furnace, typically having a heat content of from 2.5 to 6 MJ/Nm^3, COREX off-gas, typically having a heat content of about 8 MJ/Nm^3 or synthesis gas produced by the partial oxidation of solid or liquid fuels, typically heavy oil or coal but possibly also other materials such as waste material. Such gas is suitably produced in a IGCC process (integrated gasification combined cycle) and will typically have a heat value of around 10 to 16 MJ/Nm^3.

Generally speaking, there will be no requirement to boost the heat content of the fuel gas if it is over 4 to 6 MJ/Nm^3.

However, it is within the scope of the invention to use any fuel, including high calorific value fuels such as natural gas, LPG, fuel oil and solid fuels.

The fuel is preferably burnt at close to atmospheric pressure, suitably such that the exhaust from the burner has a substantially unpressurised path to atmospheric discharge. This differs from previous proposals using a gas turbine in that the exhaust is not produced under pressure so that work may be extracted by expanding it.

The elevated pressure nitrogen rich stream used in the invention is obtained from a cryogenic air separation unit (ASU). The nitrogen rich stream may in addition to nitrogen contain at least one other gas from said ASU. Preferably, oxygen separated in said ASU is fed to a process which produces said fuel gas, or at least the lower heat content component of the fuel gas. Such a process may for instance be the operation of a blast furnace or other fuel gas producing processes of the kind described above. It may be that the oxygen output of the ASU cannot all be consumed in the fuel gas producing process, in which case it may be advantageous to add back a portion of the separated oxygen into the separated nitrogen to increase the quantity of gas from which work may be extracted.

Alternatively, compressed air from the ASU may be added to the nitrogen stream, thus producing a nitrogen stream containing oxygen and other air gases.

Yet again, the ASU may be operated to achieve less than a total separation of oxygen and nitrogen. Generally the nitrogen content of the nitrogen rich gas may be from that of air up to pure nitrogen, e.g. from 80% to 100% N_2 by volume, e.g. about 90%.

Work obtained by expansion of the heated, elevated pressure nitrogen rich stream may be used to power a compression train to provide compression within the ASU, e.g. of the air input to the ASU, nitrogen compression within the ASU or oxygen compression within the ASU. It may be used to run a generator which in turn may be used for the power supply purposes described above or to supply electricity generally.

The nitrogen rich stream prior to the heating step is preferably at a pressure from 2 to 20 bara. More preferably, the nitrogen rich stream is at a pressure from 2 to 7 bara. Generally, it will be at a pressure of from 2 to 5 bara, e.g. 3 bara if taken from the ASU without further compression or at a pressure from 5 to 7 bara if further compressed.

It is suitably at a temperature of from 400 to 1,000°C, more preferably at from 600 to 800°C.

The nitrogen rich stream may be expanded to perform said external work in a turbine which may be an axial turbine or a radial inflow turbine.

It is particularly preferred that heat should be recovered from the nitrogen rich stream after it has performed external work in the expansion step described above and should be transferred to the incoming nitrogen rich stream prior to the main heating of the nitrogen rich stream by the burning fuel gas. This may straightforwardly be accomplished by heat exchange between the outgoing nitrogen rich stream and the incoming nitrogen rich stream. Alternatively, the outgoing nitrogen rich stream may be added to the combustion products of the fuel gas with which the incoming nitrogen rich stream is heated. In a further method, heat from the outgoing combustion waste gas plus nitrogen rich stream may be used to evaporate a liquid such as water into the incoming nitrogen rich stream to increase the mass flow and hence the recoverable energy in that stream with or without any increase in temperature in the incoming nitrogen rich stream.

The power input from the burning of said fuel into the nitrogen rich stream may preferably be from 0.75 to 9 KW/kgmolN_2/hr, e.g. from 2 to 4 KW/kgmolN_2/hr.

The nitrogen rich stream is discharged after use to atmosphere or for use in another process.

Said first aspect of the invention includes apparatus for obtaining work from an elevated pressure nitrogen rich gas stream comprising a source of combustible fuel gas, at a pressure of up to 5 bara or of liquid or solid fuel means for burning said fuel gas or said liquid or solid fuel, a cryogenic air separation unit as a source of said elevated pressure nitrogen rich stream, means for heating said nitrogen rich stream indirectly using heat from said burning fuel to form a heated, elevated pressure nitrogen rich stream, means for expanding said heated, elevated pressure nitrogen rich stream to perform external work and means for discharging said nitrogen rich stream from the apparatus.

Said source of combustible fuel gas may be any of those described above including a connection to a blast furnace. The apparatus may further comprise a source of higher calorific value fuel gas as described above, either as the sole heating fuel supply or as an adjustment to a source of low calorific value fuel.

As indicated above, the apparatus includes an air separation unit as the source of said nitrogen rich stream and may further comprise means for compressing air fed to the air separation unit for separation and means for applying the work obtained by expansion of said heated, elevated pressure nitrogen rich stream for use to power said compression means.

Means may alternatively or additionally be provided for applying the work obtained by expansion of said heated, elevated pressure nitrogen rich stream to power other compression requirements of the air separation unit or to run an electrical generator.

Connections may be provided to supply oxygen separated in said air separation unit to apparatus producing said fuel gas or a major, low heat content component of it.

The apparatus may comprise a turbine as the means for expanding said heated, elevated pressure nitrogen rich stream to obtain work and may comprise means for extracting energy from the nitrogen rich stream after said expansion step and for transferring this to the incoming nitrogen rich stream.

In an alternative aspect, the invention includes a process of obtaining work from an elevated pressure nitrogen rich stream comprising supplying a fuel to a combustion zone to burn said fuel to form at said combustion zone a substantially unpressurised exhaust gas stream, heating an elevated pressure nitrogen rich stream obtained from an air separation unit (ASU) by transferring thereto heat produced in said combustion but without mixing said nitrogen rich stream and exhaust gas streams, and so forming a heated, elevated pressure nitrogen rich stream, expanding said heated, elevated pressure nitrogen rich stream to perform external work and discharging said nitrogen rich stream.

The exhaust gas stream will generally be at ambient pressure save for any excess over ambient pressure necessary to enable the exhaust gas stream to flow through the apparatus to be discharged to ambient. This flow will generally occur without the exhaust gas stream being expanded in apparatus extracting useful work from it.

According to this aspect of the invention, there will also be provided apparatus for obtaining work from an elevated pressure nitrogen rich stream comprising an air separation unit for producing an elevated pressure nitrogen rich gas stream, means for supplying fuel to a combustion zone, means defining a said combustion zone for burning said fuel to form at said combustion zone a substantially unpressurised exhaust gas stream, heat exchange means for heating said nitrogen rich stream by transferring thereto heat produced in said combustion but without mixing said nitrogen rich and exhaust gas streams, and so forming a heated, elevated pressure nitrogen rich stream, means for expanding said heated, elevated pressure nitrogen rich stream to perform external work, and for discharging said nitrogen rich stream from said apparatus.

Preferred features of this alternative aspect of the invention are as described in connection with the first aspect of the invention.

The invention will be further described and illustrated with reference to the accompanying drawings in which:-

Figure 1 is a schematic illustration of a first embodiment according to the invention;
Figure 2 is a schematic illustration of a second embodiment according to the invention;
Figure 3 is a schematic illustration of a third embodiment according to the invention; and
Figure 4 is a schematic illustration of a fourth embodiment of the invention.

The apparatus shown in Figure 1 has an inlet 10 for pressurised nitrogen from an air separation unit connected via a pipeline 12 to a heat exchanger 14 and via a pipeline 16 to a second heat exchanger 18 associated with a fuel burner 20. The nitrogen stream proceeds from the heat exchanger 18 via a pipeline 22 to the inlet of an axial turbine 24 in which the nitrogen stream is expanded performing external work and providing shaft power from the turbine. Thereafter the nitrogen proceeds via a pipeline 26 to the opposite side of the heat exchanger 14 and thence to discharge via an outlet 28. An inlet 30 is provided for air to support combustion and an inlet 32 is provided for a combustible fuel gas. Inlet 32 is typically connected to the outlet for off-gas from a blast furnace.

Air passes from the inlet 30 via a pipeline 34 to a third heat exchanger 36. The fuel gas passes from the inlet 32 via a pipeline 38 also to the heat exchanger 36 where both are warmed by heat exchange as described later. The air proceeds from the heat exchanger 36 via a pipeline 40 to supply burner 20 as does the fuel gas via a pipeline 42. The products of combustion of the fuel gas and air produced in the burner 20 pass in heat exchange relationship with the nitrogen stream in the heat exchanger 18 and then in heat exchange relationship in heat exchanger 36 to preheat the air and fuel gas supplies. From heat exchanger 36, the combustion products are discharged via outlet 46.

In use, the incoming nitrogen stream from inlet 10 is preheated in heat exchanger 14 by the outgoing nitrogen stream after expansion of the nitrogen stream in the turbine 24 and is then further heated in the heat exchanger 18 by the combustion of the fuel gas and air in the burner 20. Generally, the nitrogen will pass first through a zone in which heat transfer is largely by convection and will then pass on into a zone closer to the flame of the burner in which heat transfer is largely by radiation.

The burner may generally be one of a kind specifically designed for the combustion of low heat content fuel gases. It may be a regenerative burner in which the air supply and/or the fuel supply to the burner are preheated in a regenerative manner by a medium which has been heated by the combustion process. Alternatively, it may be a burner designed to combust other gaseous, liquid, or solid fuels.

In an alternative apparatus as shown in Figure 2, the heat exchanger 14 is omitted and the expanded nitrogen gas stream exiting from the turbine 24 is mixed with the products of combustion from the burner, suitably at a point between the radiation and convection sections of heat exchanger 18(a). The combustion products mixed with the nitrogen will then pass through further regions of the heat exchanger 18(a) to heat the incoming nitrogen stream which goes directly into the heat exchanger 18(a).

In an alternative apparatus as shown in Figure 3, the expanded nitrogen gas stream exiting from the turbine is mixed with the products of combustion from the burner upstream of the heat exchanger 18b. In this embodiment the heat exchanger 18(b) has no radiative section and heat transfer is predominantly by convection.

Figure 4 shows a further embodiment of the apparatus in which energy is recaptured from the expanded nitrogen stream in a third manner and in which there is no preheating of the air and fuel gas. In this embodiment the air and fuel gas are supplied directly to the burner 20. Nitrogen introduced at the inlet 10 passes through a pipeline 12 to a water saturator 50 having an inlet line 52 for heated water, through which water the nitrogen stream passes and becomes saturated. Water is removed from the saturator 50 through a line 54 and is passed to a pump 56 which circulates the water and pass through a line 58 to a heat exchanger 60 in which it is heated by the combustion products from the burner 20. The heated water passes through a valve 62 into the line 52 through which it is reintroduced into the saturator 50. Topping up water is introduced prior to the pump 56 via an inlet 64.

The saturated nitrogen leaves saturator 50 via line 65 and is heated in heat exchanger 14 against expander exhaust. It is further heated in heat exchanger 18 prior to being expanded in the turbine 24 and the expanded nitrogen stream is then supplied to the opposite side of the heat exchanger 18 to supply further heat to the incoming nitrogen stream.

Typical operating parameters of the apparatus shown in Figure 1 are set out below in Table 1 and typical operating parameters for the apparatus shown in Figures 2 and 4 are set out below in Tables 2 and 3.

TABLE 1

Stream No.	46	40	34	42	38	16	12	22	26	28
Mode Flow KMOL/HR										
N2	758.6	382.1	382.1	376.5	376.5	4747.6	4747.6	4747.6	4747.6	4747.6

TABLE 1 (continued)

Stream No. / Mode Flow KMOL/HR	46	40	34	42	38	16	12	22	26	28
O2	4.8	102.5	102.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AR	4.5	4.5	4.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CO2	195.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CO	6.1	0.0	0.0	201.3	201.3	0.0	0.0	0.0	0.0	0.0
H2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
H2O	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Flow KMOL/HR	969.3	489.1	489.1	577.8	577.8	4747.6	4747.6	4747.6	4747.6	4747.6
Temperature C	120.4	302.7	20.0	302.7	20.0	350.0	70.0	700.0	400.4	121.6
Pressure BAR	1.1	1.1	1.1	1.1	1.1	6.0	6.0	6.0	1.0	1.0

TABLE 2

Stream No. / Mole Flow KMOL/HR	22	26	46	40	34	42	38	12
N2	4747.6	4747.6	5598.7	432.4	432.4	418.7	418.7	4747.6
O2	0.0	0.0	5.4	116.0	116.0	0.0	0.0	0.0
AR	0.0	0.0	5.1	5.1	5.1	0.0	0.0	0.0
CO2	0.0	0.0	221.1	0.0	0.0	0.0	0.0	0.0
CO	0.0	0.0	2.8	0.0	0.0	223.9	223.9	0.0
H2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
H2O	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Flow KMOL/HR	4747.6	4747.6	5833.1	553.5	553.5	642.5	642.5	4747.6
Temperature C	700.0	400.4	161.4	147.4	20.0	147.4	20.0	70.0
Pressure BAR	6.0	1.0	1.0	1.1	1.1	1.1	1.1	6.0

TABLE 3

Stream No.	22	26	46	28	58	52	34	32	12	54	65
Mode Flow KMOL/HR											
N2	4747.6	4747.6	960.6	4747.6	0.0	0.0	489.8	470.8	4747.6	0.0	4747.6
O2	0.0	0.0	6.1	0.0	0.0	0.0	1313	0.0	0.0	0.0	0.0
AR	0.0	0.0	5.8	0.0	0.0	0.0	5.8	0.0	0.0	0.0	0.0
CO2	0.0	0.0	250.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CO	0.0	0.0	13	0.0	0.0	0.0	0.0	251.7	0.0	0.0	0.0
H2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
H2O	262.1	262.1	0.0	262.1	1403.8	1403.8	0.0	0.0	0.0	262.1	262.1
Total Flow KMOL/HR	5009.6	5009.6	1224.3	5009.6	1403.8	1403.8	626.9	722.6	4747.6	262.1	5009.6
Temperature C	700.0	405.7	120.0	125.7	45.0	150.0	20.0	20.0	70.0	20.0	69.1
Pressure BAR	5.9	1.0	1.1	1.0	8.0	6.0	1.1	1.1	6.0	6.0	5.9

Example 1

In a typical example of the operation of the invention using apparatus as shown in Figure 1, nitrogen is supplied at a pressure of 6 bara at 70°C and is heated to 350°C by indirect heat exchange with the nitrogen stream exiting from the turbine which is cooled from 400°C to 122°C in the heat exchanger 14. The preheated nitrogen enters the convection section and then the radiant heat transfer section of the heater provided by the burner 20 and the heat exchanger 18 where it is heated to 700°C.

The hot nitrogen stream is then passed through the axial flow turbine 24 where it generates shaft power which is used to provide part of the energy required by the ASU air compressor.

The fuel gas used in the burner is a fuel gas having a lower heating value of 4.4 MJ/Nm^3, e.g. blast furnace gas, possibly mixed with either a small quantity of coke oven gas or natural gas to aid combustion. The fuel gas stream and the combustion air stream both initially at 20°C are preheated in the heat exchanger 36 to 303°C before entering the burner 20. The flue gases from the burner leave the heat exchanger 36 at 120°C and are vented to atmosphere. The performance achieved in this unit is as follows:-

Nitrogen flow = 4747.6 kgmols/hr
Nitrogen inlet pressure = 6 bara
Nitrogen inlet temperature = 700°C
Shaft power output = 12.2 MW
Fuel gas heating (LHV) = 15.83 MW

Whilst the invention has been described with reference to the specific embodiments illustrated above, it should be appreciated that many variations and modifications of the invention are possible within the scope of the invention.

Advantages of the invention as illustrated are that the expansion of the nitrogen in an expander with high adiabatic efficiency recovers internal energy from the ASU waste nitrogen stream which is available at elevated pressure. Pre-heating the nitrogen to the maximum temperature which can be tolerated by the expander maximises the amount of shaft power produced. By indirectly heating the nitrogen, first against low pressure expander exhaust and secondly in a fired heater, the efficiency of the conversion of thermal to shaft energy is maximised. This is assisted by preheating the combustion air and fuel gas against the flue gas of the fired heater. The use of the fired heater with indirect heating of the nitrogen means that no compression of the fuel gas or combustion air is required thus maximising the efficiency of the process. This is particularly important when utilising very low heating value fuels such as blast furnace gas.

Claims

1. A process of obtaining work from an elevated pressure nitrogen rich gas stream obtained from a cryogenic air separation unit (ASU) comprising conducting cryogenic air separation to produce an elevated pressure nitrogen rich gas stream, supplying a fuel gas at a pressure of up to 5 bara or a liquid or solid fuel to a combustion zone, burning said fuel, heating said nitrogen rich stream indirectly using heat derived from the burning of said fuel to form a heated, elevated pressure nitrogen rich stream, expanding said heated, elevated pressure nitrogen rich stream to perform external work and discharging said nitrogen rich stream.

2. A process as claimed in Claim 1, wherein said fuel is fuel gas supplied to the combustion zone at a pressure of up to 3 bara.

3. A process as claimed in Claim 2, wherein said fuel gas pressure is from 1.1 to 2.5 bara.

4. A process as claimed in Claim 2, wherein said fuel gas pressure is from 1.1 to 1.2 bara.

5. A process as claimed in any preceding claim, wherein the fuel gas is at least predominantly supplied from a source of fuel gas having a heat content of from 2.5-12 MJ/Nm^3.

6. A process as claimed in Claim 5, wherein the fuel gas having said heat content is off-gas from a blast furnace, COREX off-gas or synthesis gas from the partial oxidation of solid or liquid fuels.

7. A process as claimed in Claim 6, wherein the gas is burnt without being compressed.

8. A process as claimed in Claim 6 or Claim 7, wherein the fuel gas having said heat content is mixed with a lesser quantity of gas having a substantially higher heat content.

9. A process as claimed in Claim 8, wherein said higher heat content gas is coke oven gas, natural gas or lpg.

10. A process as claimed in Claim 8 or Claim 9, wherein said fuel gas having said heat content of from 2.5 to 16 MJ/Nm^3 has a heat content of from 2.5 to 4 MJ/Nm^3 and is mixed with sufficient gas having a substantially higher heat content to raise the heat content of the resulting mixture to from 4 to 6 MJ/Nm^3.

11. A process as claimed in any one of Claims 8 to 10, wherein the said lesser quantity is up to a quantity sufficient to double the heat content of the fuel gas to which the higher heat content gas is added.

12. A process as claimed in any one of Claims 1 to 3, wherein said fuel is natural gas, lpg, fuel oil or lpg.

13. A process as claimed in any preceding claim, wherein said nitrogen rich stream in addition to nitrogen contains at least one other gas from said ASU.

14. A process as claimed in any preceding claim, wherein the work obtained by expansion of said heated, elevated pressure nitrogen rich stream is used to power compression of gas in said air separation unit.

15. A process as claimed in any preceding claim, wherein oxygen separated in said air separation unit is fed to a process producing said fuel.

16. A process as claimed in any preceding claim, wherein said nitrogen rich stream prior to said heating step is at a pressure of from 2 to 20 bara.

17. A process as claimed in Claim 16, wherein said nitrogen rich stream prior to said heating step is at a pressure of from 2 to 7 bara.

18. A process as claimed in any preceding claim, wherein said nitrogen rich stream is at a temperature of from 400 to 1000°C prior to said expansion.

19. A process as claimed in Claim 18, wherein the nitrogen rich stream is at a temperature of from 600 to 800°.

20. A process as claimed in any preceding claim, wherein said heated, elevated pressure nitrogen rich stream is expanded in a turbine to perform said external work.

21. A process as claimed in any preceding claim, wherein heat remaining in the nitrogen rich stream after the performing of said external work in said expansion step is transferred to said elevated pressure nitrogen rich stream prior to the said heating of the nitrogen rich stream using heat from the burning of the said fuel gas.

22. A process as claimed in any preceding claim, wherein the power input from the burning of said fuel is from 0.75 to 9 KW/kgmolN_2/hr.

23. Apparatus for obtaining work from an elevated pressure nitrogen rich stream comprising a source of combustible fuel gas (32), at a pressure of up to 5 bara, or liquid or solid fuel means (20) for burning said fuel gas or said liquid or solid fuel, a cryogenic air separation unit as a source of a said elevated pressure nitrogen rich stream, means (18) for heating said nitrogen rich stream indirectly using heat from said burning fuel to form a heated, elevated pressure nitrogen rich stream, means (24) for expanding said heated, elevated pressure nitrogen rich stream to perform external work and means (28) for discharging said nitrogen rich stream from the apparatus.

24. Apparatus as claimed in Claim 23, further comprising an additional source of gas having a heat content of substantially above 4 MJ/Nm^3.

25. Apparatus as claimed in Claim 23 or Claim 24, further comprising means for compressing air fed to be separated in said air separation unit and means for applying the work obtained by expansion of said heated, elevated pressure nitrogen rich stream for use to power said compression means.

26. Apparatus as claimed in any one of Claims 23 to 25, wherein oxygen separated in said air separation unit is fed to a apparatus producing said fuel gas.

27. Apparatus as claimed in any one of Claims 23 to 26, wherein said means (24) for expanding said heated, elevated pressure nitrogen rich stream comprises a turbine.

28. Apparatus as claimed in any one of Claims 23 to 27, wherein comprising means (14) for extracting energy from said nitrogen rich stream after said expansion step and for transferring said energy to said incoming nitrogen rich stream.

29. A process of obtaining work from an elevated pressure nitrogen rich stream comprising supplying a fuel to a combustion zone to burn said fuel to form at said combustion zone a substantially unpressurised exhaust gas stream, heating an elevated pressure nitrogen rich stream obtained from an air separation unit (ASU) by transferring thereto heat produced in said combustion but without mixing said nitrogen rich stream and exhaust gas streams, and so forming a heated, elevated pressure nitrogen rich stream, expanding said heated, elevated pressure nitrogen rich stream to perform external work and discharging said nitrogen rich stream.

30. Apparatus for obtaining work from an elevated pressure nitrogen rich stream comprising an air separation unit for producing an elevated pressure nitrogen rich gas stream, means for supplying fuel to a combustion zone, means (20) defining a said combustion zone for burning said fuel to form at said combustion zone a substantially unpressurised exhaust gas stream, heat exchange means (18) for heating said nitrogen rich stream by transferring thereto heat produced in said combustion but without mixing said nitrogen rich and exhaust gas streams, and so forming a heated, elevated pressure nitrogen rich stream, means (24) for expanding said heated, elevated pressure nitrogen rich stream to perform external work, and means (28) for discharging said nitrogen rich stream from said apparatus.

FIG 1

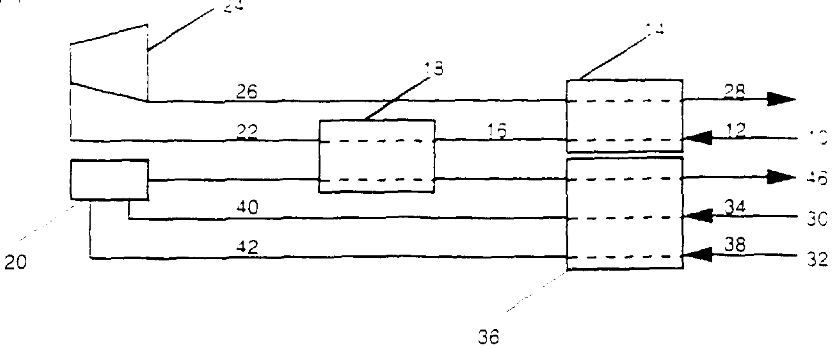

FIG 2

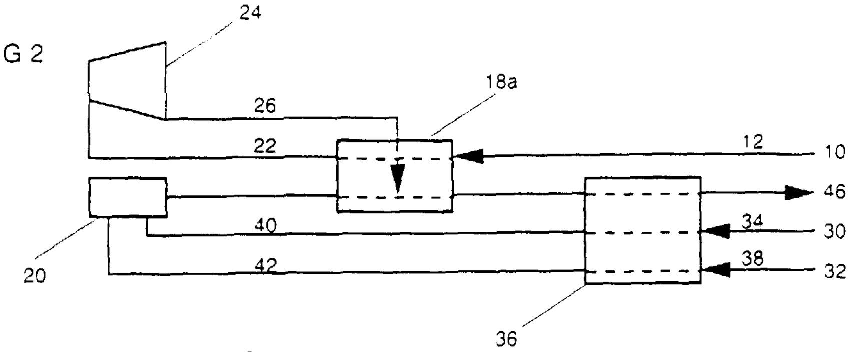

FIG 3

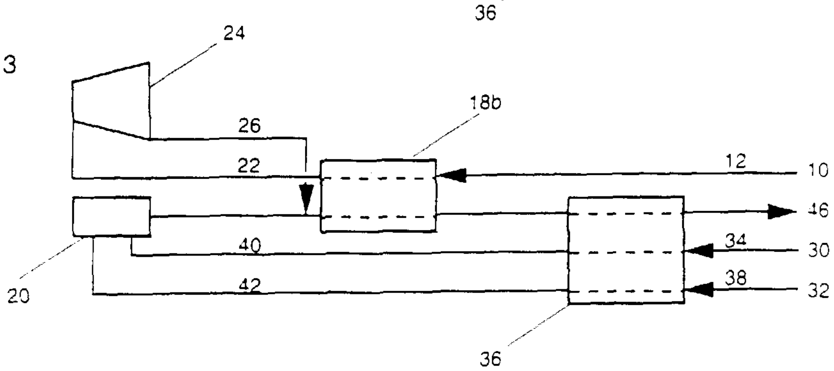

FIG 4