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(72) Inventors:
• **Garrett, Michael Ernest**
Woking Surrey GU22 7XR (GB)
• **Lavin, John Terence**
Guildford Surrey GU1 2NE (GB)

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(74) Representative: **Wickham, Michael et al**
c/o Patent and Trademark Department
The BOC Group plc
Chertsey Road
Windlesham Surrey GU20 6HJ (GB)

(71) Applicant: **The BOC Group plc**
Windlesham Surrey GU20 6HJ (GB)

(54) Process and apparatus for controlling the inlet temperature of an air compressor

(57) The inlet temperature of an air compressor 2 is controlled by vaporising in a mixing chamber 10 upstream of an air inlet 4 to the compressor 2 a sufficient

flow of cryogenic liquid (nitrogen or a mixture of oxygen and nitrogen) to maintain the inlet temperature at or below a chosen temperature.

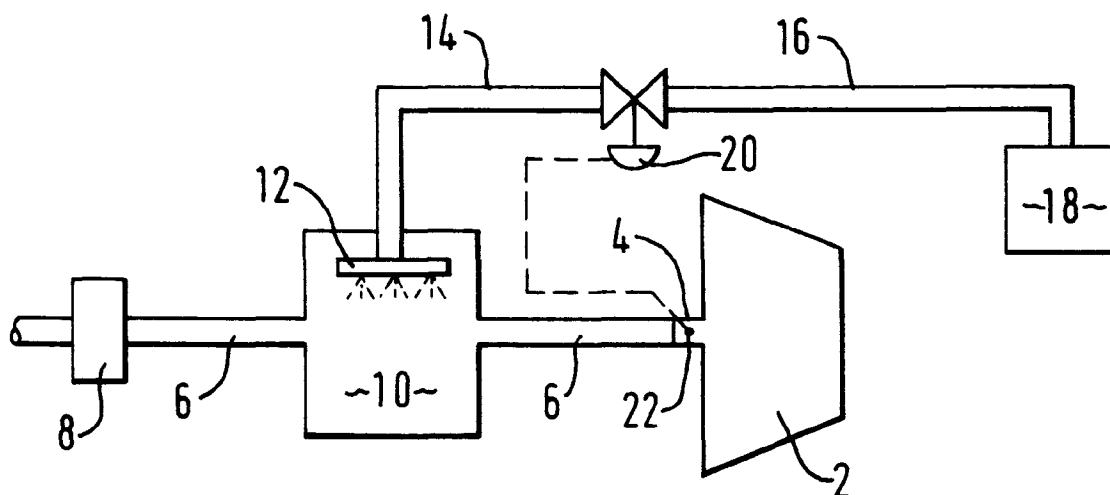


FIG. 1

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Description

This invention relates to a method of and apparatus for controlling the inlet temperature of an air compressor.

It has long been known that the performance of an air compressor decreases with increasing inlet temperature. It is therefore difficult to maintain at relatively high ambient temperatures the performance of plant which depends on the air compressor. A notable example of this problem arises in a cryogenic air separation plant for separating air by rectification. The rate of production of the products of separation have been found to fall markedly with increasing ambient temperature. A second notable example is in the operation of a gas turbine. The power generated by the gas turbine is found to fall markedly with increasing ambient temperature.

GB-A-2 274 407 relates to a process for separating the product gas, typically by pressure swing adsorption, from a gas mixture. The gas separation plant includes a gas compressor for compressing gas mixture to be separated. In one example, nitrogen is separated from air. In order to reduce the inlet temperature of the air, it is cooled by indirect heat exchange with a stream of liquefied gas having the same composition as the product. The resulting vapour is then mixed with the product. In the example of the production of nitrogen, therefore, the air feed to the air compressor is cooled by indirect heat exchange with a stream of liquid nitrogen and the resulting nitrogen vapour is mixed with the nitrogen product separated by pressure swing adsorption.

A disadvantage of this arrangement is that the necessary heat exchanger for effecting the indirect heat exchange creates an additional pressure drop in the gas separation plant which offsets the advantage of cooling the incoming air. Further, in view of the large temperature difference between liquid nitrogen and ambient air, the heat exchange is relatively inefficient and therefore a relatively large rate of flow of liquid nitrogen is required to effect the desired cooling of the air.

The method and apparatus according to the invention avoid the need for such a heat exchanger.

According to the present invention there is provided a method of controlling the inlet temperature of an air compressor, comprising the step of vaporising in the air upstream of its entry into the compressor a sufficient flow of cryogenic liquid to maintain the inlet temperature at or below a chosen value, wherein the cryogenic liquid is nitrogen or comprises a mixture of oxygen and nitrogen.

The invention also provides apparatus for controlling the inlet temperature of an air compressor, comprising the air compressor and a mixing chamber having an outlet communicating with the air compressor, a first inlet communicating with the atmosphere, and a second inlet communicating with a source of liquid nitrogen or a source of cryogenic liquid comprising oxygen and nitrogen.

By directly vaporising the cryogenic liquid mixture in the air, efficient heat exchange is achieved and the use of an indirect heat exchange is avoided. Further, when the cryogenic liquid comprises a mixture of oxygen and nitrogen, the effect on the composition of the air to be compressed is either eliminated or kept to a minimum. If desired, the mole fraction of oxygen in the cryogenic liquid mixture may be the same as the mole fraction of oxygen in natural air. Accordingly, the cryogenic liquid may be liquefied natural air. Preferably, however, the cryogenic liquid is a mixture comprising nitrogen and oxygen having an oxygen mole fraction in the range of 0.14 to 0.20. Such mixtures offer advantages in safety of handling over corresponding mixtures having an oxygen mole fraction of 0.21 or higher.

Preferably the cryogenic liquid is sprayed into the mixing chamber. The mixing chamber may be a discrete unit may simply comprise a length of pipe. If desired, the mixing chamber may be thermally insulated.

Preferably, there is a temperature sensor located in or adjacent the inlet to the air compressor and downstream of the mixing chamber. The temperature sensor is preferably arranged to generate signals representative of the inlet temperature to a valve controller which operates a valve in a conduit placing the source of cryogenic liquid in communication with the second inlet so as to maintain the inlet temperature between chosen values, say, no more than 2K apart.

The air compressor may advantageously form the main air compressor of an air separation apparatus in which the air is separated by rectification at cryogenic temperatures, or the air compressor of a gas turbine. In the example of a gas turbine, the overall increase in the power produced may be greater than the power consumption in producing the necessary liquefied gas mixture. Typically, periods of high ambient temperature coincide with high demands for electricity. In many electricity pricing schemes, the price per unit electrical power is relatively high during periods of high demand and relatively low during periods of low demand. It is therefore particularly advantageous to liquefy the nitrogen or the mixture of oxygen and nitrogen (or its components) during periods of low demand for electricity.

The method and apparatus according to the invention will now be described by way of example only with reference to the accompanying drawings, in which:

Figure 1 is a schematic flow diagram of an apparatus according to the invention; and

Figure 2 is a graph showing the decline in the power output of a typical gas turbine with increasing ambient temperature.

Figure 1 of the drawings is not to scale.

Referring to Figure 1 of the drawings, there is shown an air compressor 2. The air compressor 2 may com-

prise a single compression stage or a plurality of compression stages. Downstream of the or each stage there is typically an aftercooler (not shown). The purpose of the or each aftercooler is to remove heat of compression from the air. The air compressor 2 has an air inlet 4 communicating with an inlet conduit 6 in which an air filter 8 is located. A thermally-insulated mixing chamber 10 is located in the conduit 6 intermediate the filter 8 and the air inlet 4. A spray header 12 is located within the mixing chamber 10. The spray header 12 communicates via a conduit 14 with a source 16 of liquid nitrogen or cryogenic liquid mixture under pressure. The source of cryogenic liquid mixture typically has a mole fraction of oxygen of 0.18, a mole fraction of argon of 0.01 and a mole fraction of nitrogen of 0.81. A valve 18 is located in the conduit 16. The valve 18 is of an automatically operable kind. It is controlled a valve controller 20 which receives signals from a temperature sensor 22 located in the inlet 4. In operation, the position of the valve is controlled so as to provide sufficient flow of cryogenic liquid mixture into the chamber 10 as to maintain the inlet temperature of the air compressor 2 at a chosen value.

In a typical example, it is desired to maintain the inlet temperature of the compressor 2 at 293K. The ambient temperature is 303K. In order to provide the necessary cooling, approximately 24 sm³/hr of the cryogenic liquid are required that each 1,000 sm³/hr of air, i.e. the cryogenic liquid is supplied at a rate of about 2.4% of that at which air is drawn into the compressor 2 at the ambient temperature. If the compressor forms part of an air separation plant an increase in the production of the components of air (oxygen, nitrogen and argon) in the order of up to about 6% is made possible. This is substantially greater than is possible when the apparatus according to GB-A-2 274 407 is used.

In Figure 2, there is shown the power output in terms of percentage of design plotted against compressor inlet temperature for a gas turbine. At 60°F (15°C) the output is 100% of design. At 70°C the output falls to approximately 96% of design. It can therefore be appreciated that operating the compressor of a gas turbine in accordance with the invention provides a considerable advantage in terms of the power output of the gas turbine which exceeds the cost of producing the cryogenic liquid.

Claims

1. A method of controlling the inlet temperature of an air compressor, comprising the step of vaporising in the air upstream of its entry into the compressor a sufficient flow of cryogenic liquid to maintain the inlet temperature at or below a chosen value, wherein the cryogenic liquid is liquid nitrogen or comprises a mixture of oxygen and nitrogen.
2. A method as claimed in claim 1, in which the cryo-

genic liquid mixture is a mixture comprising nitrogen and oxygen having an oxygen mole fraction in the range of 0.14 to 0.20.

3. Apparatus for controlling the inlet temperature of an air compressor, comprising the air compressor and a mixing chamber having an outlet communicating with the air compressor, a first inlet communicating with the atmosphere, and a second inlet communicating with a source of liquid nitrogen or a cryogenic liquid comprising oxygen and nitrogen.
4. Apparatus as claimed in claim 3, additionally including means for spraying the liquid nitrogen or cryogenic liquid into the mixing chamber.
5. Apparatus as claimed in claim 3 or claim 4, additionally including a temperature sensor located in or adjacent the inlet to the air compressor and downstream of the mixing chamber, the temperature sensor being arranged to generate the signals representative of the inlet temperature to a valve controller able to operate a valve in a conduit placing the source of the cryogenic liquid or liquid nitrogen in communication with the second inlet.
6. An air separation apparatus including apparatus as claimed in any one of claims 3 to 5.
7. A gas turbine including apparatus as claimed in any one of claims 3 to 5.

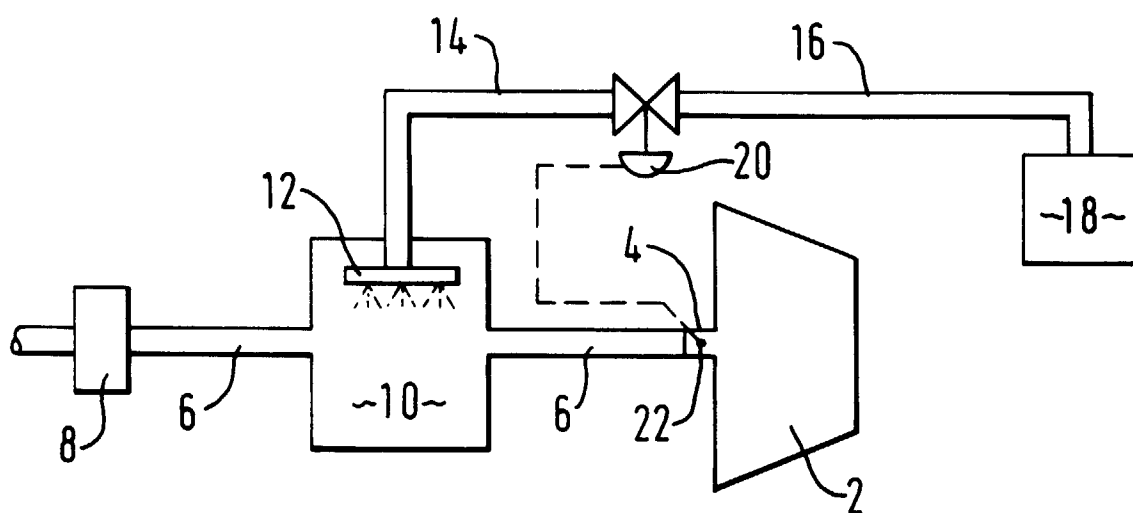


FIG. 1

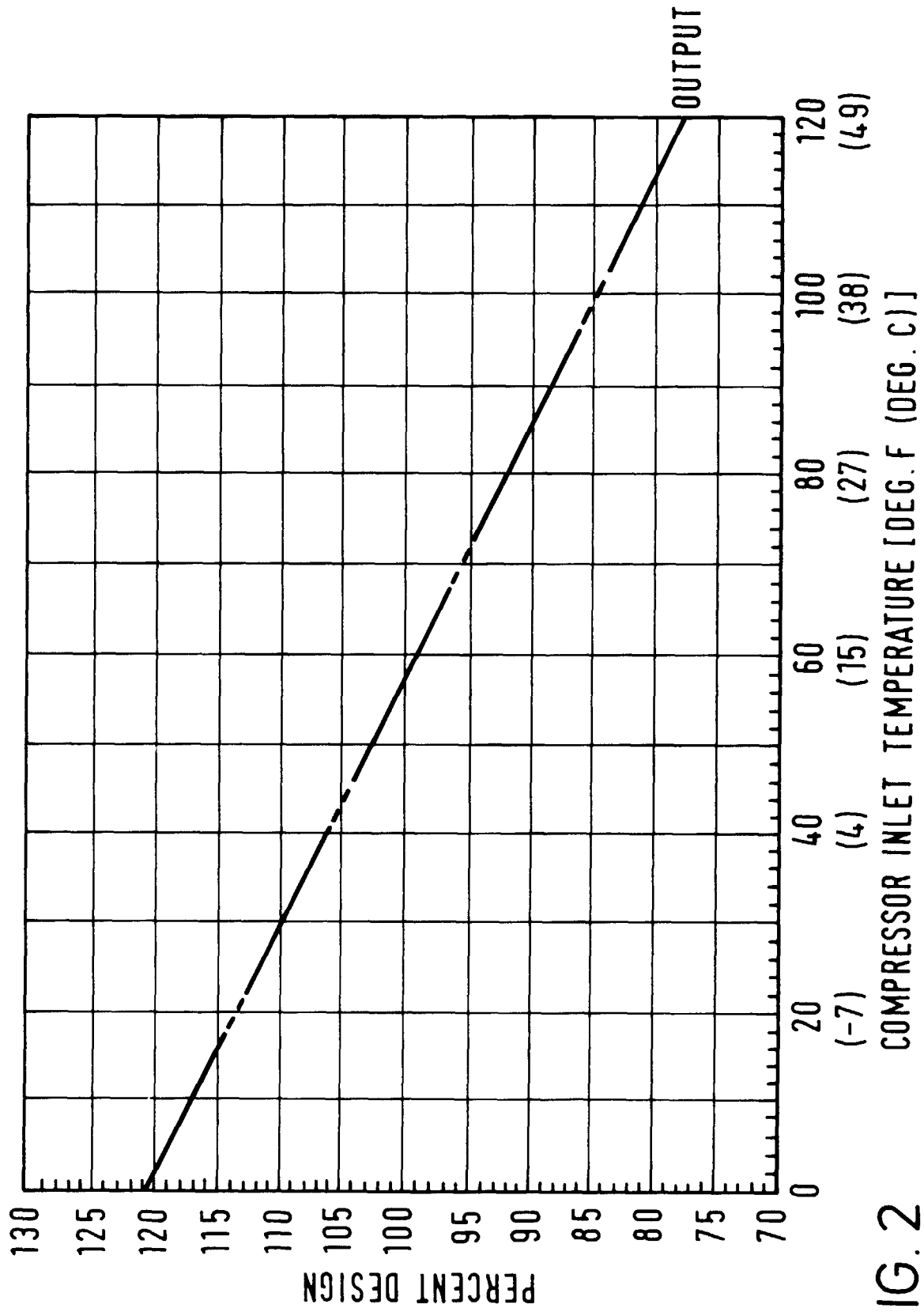


FIG. 2