

## ARRANGEMENT AND METHOD FOR TREATMENT OF COMPRESSED GAS

### Technical Field of the Invention

5 The invention relates to an arrangement for pre-processing compressed gas for separation in an air-gas or other gas-gas separation unit, such as and preferably by membrane filtering. The arrangement includes a heat recovery arrangement for use with a compressor for gas, and to a method of recovering heat from compressor cooling fluid for regulating the temperature of the compressed gas before entering the gas separation unit.

### 10 Background of the Invention

In the pre-processing of air or other gas for a membrane based air-gas or other gas-gas separation unit, it is important that air fed to the separation unit satisfies defined criteria. The dew point of the air must be such as to avoid condensation. The air must be filtered at an acceptable temperature to avoid aerosol and particle carry over. The air must be at a suitable operating temperature for efficient membrane separation. This is especially important and the temperature must be regulated before entering the separation unit to achieve best possible operation of the separation unit. The invention is concerned with heat recovery from the compressor cooling fluid for the continuous temperature regulation of the supply of air to satisfy these criteria.

### 20 Disclosure of the Invention

The invention provides an arrangement for use with a liquid cooled and/or lubricated compressor for compressing gas, and incorporating provision to add liquid for cooling purposes to the gas prior to entry of the gas into the compressor, in which downstream of the compressor there is a liquid/gas separator to separate the liquid from the gas and in which there is means to recover heat from the liquid, and in which there is at least one filter in the gas stream downstream of the liquid/gas separator, and there is a heater in the gas stream downstream of the filter in which the gas is heated using heat recovered from the liquid, whereby to regulate the temperature of the pressurised gas prior to gas entry into the separator unit.

It is preferred that there is a heat exchanger in the gas stream between the liquid/gas separator and the at least one filter, and in that heat exchanger cooling medium from an external source is used to cool the gas stream.

It is also preferred that there is a refrigerant dryer group arranged to cool the gas after the liquid has been separated from the gas, and before the gas is passed through the at least one filter.

35 The at least one filter may be a coalescing particle filter, or a carbon filter for removal of vapour from the cooling liquid.

The at least one filter may include two stage filtration, the first filter stage comprising a coalescing particle filter, and the second filter stage comprising a carbon filter for removal of vapour from the cooling liquid.

5 The invention includes the arrangement described above, in combination with a membrane gas separator unit arranged to receive gas from the heater using the heat recovered from the liquid prior to the liquid passing through the filter.

The invention includes the arrangement described above, in combination with a compressor for compressing the gas. The compressor may be a screw compressor, and the screw compressor may be cooled or cooled and lubricated by  
10 oil or other suitable cooling liquid.

The invention also includes a method of recovering heat from a compressed gas from a liquid cooled and/or lubricated compressor, and comprising the steps of adding liquid for cooling purposes to a gas or directly into the compressor prior to the gas entering into the compressor, separating liquid from the gas after the gas has  
15 left the compressor, recovering heat from the liquid, passing the gas through at least one filter, and, downstream of the filter, using heat recovered from the liquid before the gas passed through the filter to heat the gas, whereby the regulate the temperature of the pressurised gas.

#### **Advantages of the Invention**

20 Performance of the separation process is dependent upon a relatively narrow range of operating parameters, particularly feed air temperature and pressure. It is for this reason that efficient conditioning of feed air supplied to the separator is important. The specific embodiment of the invention described above includes efficient use of heat supplied to the air, arranges for filters for the compressed air to  
25 operate at near optimum conditions, and allows the separation membranes to function at near optimum air pressure, temperature and dryness. Use of heat withdrawn from the gas stream to reduce the gas temperature before the filters, to preheat the gas stream after the filters makes efficient use of the energy applied to the system. The temperature regulation of the gas before entering the separation unit  
30 may in several prior art cases some from an external heating source. It is in some cases possible that additional heating from an external source may be required. The need is however reduced and in many cases eliminated by the invention.

The invention is especially suited for building a module based system (compressor, arrangement for conditioning of compressed gas, separation unit)  
35 where the conditioning module does not require an external heating source.

#### **Brief Description of the Drawing**

A specific embodiment of an arrangement to pre-process air for a membrane nitrogen separator will now be described by way of example with reference to the

accompanying process flow drawing, which shows a compressor section and a nitrogen separator section.

### Description of the Specific Embodiment

5 To facilitate efficient performance of the membrane nitrogen separator, compressed air must be cooled down to remove liquid, the dew point temperature must be reduced in order to avoid liquid condensation, the air must be filtered at an acceptable temperature to avoid aerosol and particle carry over, and finally the air temperature must be increased to the operating temperature for membrane separation.

10 According to this example, air for the compressor section is drawn in through an inlet filter 9 to a single stage oil cooled/lubricated screw compressor 10. The compressed air with entrained oil passes to an oil/air separator 11, having a safety valve 12. The air passes on through a compressed air aftercooler 14 (also known as a 'combicooler'). The aftercooler 14 comprises an integrated water cooled  
15 heat exchanger which also functions as a temperature control unit for the compressed air.

The air then passes through a combined water separator/refrigerant cooler/dryer 15. This reduces the dew point to approximately 15degC below inlet temperature, so that condensation will not occur further downstream. The dryer 15  
20 is equipped with a dedicated cooling medium recycling unit with evaporator, compressor and condenser.

It should be noted that the dryer 15 is not essential. However, if the dryer is dispensed with, the air from the compressor 10 will be at its saturation point after leaving the cooler 14. In this circumstance the temperature of the air must be  
25 increased to avoid condensation further downstream. A problem may arise in that the increased temperature might be beyond the limitations of the polymer membranes preferably used in the nitrogen separator section.

Air from the dryer 15 passes through a check valve 16 and a ball valve 16a. The cooled air is now at a suitable temperature, pressure and dryness to pass  
30 through a coalescing particle filter 17 (for retention of oil aerosol carry over) and a carbon filter 18 (for removal of oil vapour). Elimination of the dryer 15 might also lead to inefficiencies in the filters 17 and 18 due to the higher operating temperatures.

After emerging from the carbon filter 18, the air passes through a feed air  
35 heater 19 to preheat the air for processing in the nitrogen separator section. The feed air heater 19 increases the compressed air temperature to 45 – 50degC. A control valve 21 regulates the air leaving the compressor section, and this air can be directed through a valve 22 to a duplex system (not shown) or through a valve 23 to the nitrogen separator section.

Oil from the oil/air separator 11 is led to a cooling heat exchange circuit. Cooling water from inlet 24 feeds the compressed air aftercooler 14 and an oil air/water heat exchanger 27 before leaving the compressor section by outlet 25. Oil from the oil/air separator 11 passes through a three way thermostatic valve 26 to enter  
5 the heat exchanger 27 or to return via inlet filter 9a to the compressor 10.

Following the invention, oil from the oil/air separator unit 11 can pass to an energy recovery unit 29 which is supplied with cooling water from a second three way temperature control valve 28. Water heated in the energy recovery unit 29 is carried past the filters 17 and 18, and is used to raise the temperature of the air in the feed air  
10 heater 19. Thus the filters 17 and 18 can operate at close to optimum temperatures, and the air can be preheated beyond those filters to enter the nitrogen separator section at a higher temperature which is suitable for operation of the separation membranes.

Drains 32, 33 and 34 lead from the refrigerant air dryer 15, the coalescing  
15 particle filter 17 and the carbon filter 18 respectively to an external drain valve 35.

Conditioned air from valve 23 is led to the nitrogen separator section. This comprises a membrane module bank 41, having a plurality of membrane air gas separators. Each separator consists of a bundle of hollow fibres contained in a metal housing. The housing has three external connections 42, 43 and 44. One connection is  
20 located at each end of the housing leading to the entrance 42 and exit 43 to and from the bore sides of the fibres respectively, and one side connection 44 leads to the shell side of the fibres. Each fibre consists of a composite layer of polymers. One relatively thick layer acts as a support, and the other layer (a thin film) functions as the separation controlling layer. At this stage it is important that the operation  
25 temperature does not exceed the maximum allowable temperature of the polymer.

Separation is effected by the selective permeation of the gases in air through the thin film of the composite polymer membranes. Nitrogen permeates at a slower rate than the other gases, and so nitrogen in the conditioned air entering at connection 42 passes along the bores and exits at the other end of the separator 43, while oxygen  
30 and other gases pass through the membranes, and are led through the separator's side connection 44 and so via a vent line to atmosphere.

The nitrogen separator section exit connection 43 is fitted with a product flow indicator 45, a flow control valve 46 and a pressure control valve 47. Quality monitoring analysers are fitted in a quality monitoring group 48 forming no part of this invention.

- 5            Nitrogen produced in the membrane separator 41 is led to a product outlet 49, or, during start-up when the quality is fluctuating, can be led to a vent 50 which also allows the other gases to escape to atmosphere.

## CLAIMS

1. An arrangement for pre-treatment of gas prior to processing in a gas-gas separation unit, mainly a nitrogen separation unit, which arrangement is fed with compressed gas added with a cooling liquid prior to compression of the gas, which arrangement comprise a liquid/gas separator (11) downstream of the entry of the compressed gas, separating the cooling liquid from the compressed gas, and there is a heat exchanger (14) in the gas flow downstream of the liquid/gas separator (11) for cooling the gas where the cooling medium in the heat exchanger (14) is fed from an external source,
- 10 characterised in that there is an energy recovery unit(29), mainly a heat exchanger, for recovering heat from the separated cooling liquid by cooling down the separated cooling liquid from the liquid/gas separator (11) and heating a fluid in a separate fluid circuit, and that there is a feed air heater (19), mainly a heat- exchanger, downstream of the heat exchanger (14) in the gas flow, which feed air heater (19) is in fluid
- 15 connection with the separate fluid circuit for controlled heating of the gas flow with the heat regenerated from the compressor cooling liquid in the energy recovery unit (29) via the fluid in the separate circuit, and that there is a temperature control valve (28) in connection with the feed air heater (19) in the separate circuit controlling the heating of the gas flow in the feed air heater (19) to a correct and stabile temperature.
- 20 2. An arrangement as claimed in claim 1, characterised in that the fluid in the separate circuit is a liquid.
3. An arrangement as claimed in claim 1-2, characterised in that there is a refrigerant dryer group (15) arranged to cool the gas after the gas has been separated from the liquid in the liquid/gas separator (11).
- 25 4. An arrangement as claimed in any one of the preceding claims, characterised in that downstream of the liquid/gas separator (11) there is at least one filter in the gas flow which filter preferably is a coalescing particle filter.
5. An arrangement as claimed in claim 4, characterised in that the at least one filter is a carbon filter for removal of vapour from
- 30 the cooling liquid.
6. An arrangement as claimed in any one of claims 4-5, characterised in that the at least one filter includes two stage filtration, the first filter stage comprising a coalescing particle filter, and the second filter stage comprising a carbon filter for removal of vapour from the cooling liquid.

7. An arrangement as claimed in any one of the preceding claims, in combination with a membrane gas separator unit arranged to receive gas from the arrangement.
8. An arrangement as claimed in any one of the preceding claims, in combination with a compressor for compressing the gas.
- 5 9. An arrangement as claimed in claim 8, characterised in that the compressor is a screw compressor.
- 10 10. Method for pre-treatment of gas prior to processing in a gas-gas separation unit, mainly a nitrogen separation unit, in which compressed gas added with a cooling liquid prior to compression is entered, where the cooling liquid is separated from the compressed gas in a liquid/gas separator (11) downstream of entry and the gas flow is further downstream cooled in a heat exchanger (14) where the cooling medium in the heat exchanger (14) is received from an external source, characterised in that a fluid in a separate circuit is heated by the separated cooling liquid in an energy recovery unit (29), mainly a heat exchanger, and the temperature of the gas flow is controlled downstream of the cooling heat exchanger (14) by heating the gas flow in a feed air heater (19) by using heat recovered from the compressor cooling fluid, which feed air heater (19) is in fluid connection with the energy recovery unit (29) in the separate circuit, and the heating of the gas flow in the feed air heater (19) in the separate circuit is controlled by a temperature control valve (28) in connection with the feed air heater (19) in the separate circuit in order to heat the gas flow to a correct and stable temperature.
- 15 11. Method as claimed in claim 10, characterised in that the fluid in the separate circuit is a liquid.
- 20 12. Method as claimed in claims 10-11, characterised in that the gas is cooled in a refrigerant dryer group(15) after the gas has been separated from the liquid in the liquid/gas separator (11).
- 25 13. Method as claimed in any one of the preceding claims 10-12, characterised in that the gas is filtered downstream of the liquid/gas separator (11) in at least one filter in the gas flow which filter preferably is a coalescing particle filter.
- 30 14. Method as claimed in claim 13, characterised in that vapour from the cooling liquid is filtered in the at least one filter which preferably is a carbon filter.
15. Method as claimed in claims 13-14, characterised in that the at least one filter includes two stage filtration, the

first filter stage comprising a coalescing particle filter, and the second filter stage comprising a carbon filter removing vapour from the cooling liquid.