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A METHOD AND APPARATUS FOR COOLING A PROCESS STREAM

The invention relates to a method of cooling a process stream, such as a liquid or gaseous stream in a process plant such as a refinery, Liquefying Natural Gas plant or chemical plant, particularly a process stream
5 derived from the treatment of natural gas, and an apparatus for use in such a method.

The invention is aimed at providing a method and apparatus which can be designed to have a lower capacity compared to conventional units, while still providing
10 comparable cooling performance. Such a reduction in design capacity provides significant savings in capital expenditure, allowing the use of smaller equipments, such as heat exchangers, compressors and condensers.

The invention provides method of cooling a process
15 stream, the method comprising at least the steps of:
(a) heat exchanging a first coolant supply stream in a first cooling circuit against a process stream at a first process temperature to produce a first coolant return stream and a cooled process stream;
20 (b) passing the first coolant return stream to a first coolant return tank to provide warmed first coolant;
(c) withdrawing a portion of the warmed first coolant from the first coolant return tank as a warmed first coolant stream;
25 (d) heat exchanging a cooled second coolant stream in a second cooling circuit against the warmed first coolant stream to produce a cooled first coolant stream,
(e) passing the cooled first coolant stream to a first coolant supply tank to provide cooled first coolant;

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(f) withdrawing a portion of the cooled first coolant from the first coolant supply tank as the first coolant supply stream; wherein the rate of flow of the warmed first coolant stream in step (c) is controlled in response to the cooling duty available from the second cooling circuit and the flow from the supply to the return buffer is controlled by the required cooling of the process stream and wherein the difference between the minimum and maximum cooling duty of the process stream over a time period is larger than the difference between the minimum and maximum cooling duty of the second cooling circuit over said time period.

Conventionally, a first cooling circuit which is heat exchanged against a process stream is operated to provide a particular cooling duty, corresponding to the peak capacity required of the cooling circuit said peak capacity being set by the process stream. This is achieved by providing a corresponding heat rejection to a second cooling circuit, which is for instance a closed refrigeration cycle.

However, the amount of heat which can be rejected to the second cooling circuit can change as a result of external conditions, such as ambient temperature. Additionally, the required heat rejection from the process can change as a result of the same external conditions. Indeed, the temperature variance between day and night in some climates may be more than 10 °C, sometimes more than 20 °C, and even more than 30 °C.

At low ambient temperature the second cooling circuit can provide greater cooling to the first cooling circuit, however the required cooling of the process by the first circuit is less. In the method of the present invention, the rate of flow of the warmed first coolant

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stream from return to supply tank is controlled in response to the cooling duty available from the second cooling circuit; whereas the flow of the cooled first coolant from the supply to the return buffer is

5 controlled by the required cooling of the process. When more heat can be rejected to the second cooling circuit, the flow rate of the warmed first coolant stream can be increased, so that more warmed first coolant is heat exchanged against cooled second coolant in step (d),

10 providing more cooled first coolant which can be accumulated in the cooled first coolant buffer supply tank. When more heat needs to be rejected from the process, the cooled 1st coolant flow from supply to return buffer is increased.

15 When ambient temperatures increase, the amount of cooling provided by the second cooling circuit to the first cooling circuit decreases and the rate of flow of the warmed first coolant stream can be correspondingly reduced. Should the cooling duty placed on the first

20 cooling circuit by the process stream increase, the flow rate of the first coolant supply stream can be increased in order to ensure that the cooled process stream is provided at a controlled, preferably constant, temperature.

25 Increasing the flow rate of the first coolant supply stream, for example due to an increased cooling requirement of the process stream, may consume more cooled first coolant than is being supplied by the cooled first coolant stream (by heat exchange with the

30 second cooling circuit). However, the accumulated cooled first coolant in the cooled first coolant buffer supply tank allows the effective operation of the cooling apparatus to be maintained.

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The method of the present invention therefore enables a reduction in the capacity of the second cooling circuit compared to a conventional circuit which is designed to meet the peak load placed on the apparatus by the process stream. Instead of designing an apparatus for peak conditions e.g. maximum ambient temperatures (a capacity which is only partially used at lower ambient conditions), the first and second cooling circuits can be designed for a lower capacity. Any deficit of cooled first coolant (produced by heat exchange with the second cooling circuit) required to cool the process stream can be met by cooled first coolant from the cooled first coolant buffer supply tank. During lower ambient temperatures, the cooling capacity of the second cooling circuit can be higher than required by the first cooling circuit to cool the process stream, and so excess cooled first coolant can be produced and stored in the cooled first coolant supply tank.

Preferably the method is operated such that the sum of the amount of warmed first coolant in the first coolant return tank and the amount of cooled first coolant in the first coolant supply tank is held at a constant value. The relative amounts of first coolant can, of course, vary between the first coolant supply and return tanks.

The present invention therefore permits a cooling apparatus to be provided with a lower capacity than a conventional unit. For instance a capacity reduction to about 60% of the conventional capacity needed can be provided for the second cooling circuit, leading to large reductions in capital expenditure, even despite the additional buffer tanks and circulation pumps needed.

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Preferably, the method of the invention is a continuous method for at least 24 hours and contains at least one day and night cycle i.e. steps (a) to (g) are repeated over at least one day and night cycle. More preferably, the method is a continuous method with a duration of one week, preferably one month, more preferably 6 months, and even more preferably one year.

The process stream cooled in heat exchange step (a) may be any liquid or gaseous stream. For example, the process stream cooled in heat exchange step (a) may be a liquid or gaseous stream derived from the treatment of natural gas. Preferably, the process stream is an amine stream from an acid gas treatment unit or a sweet or sour natural gas stream.

The process stream is provided at a first process temperature, which is for example in the range of 20 to 65 °C. The process stream can be provided by pre-cooling a warm process stream with an air cooler. The effectiveness of an air cooler will vary depending upon ambient conditions, such as ambient temperature. This is because the air cooler is designed to provide a particular cooling duty under maximum ambient temperatures. At lower than maximum temperatures, the process stream will exit the air cooler with a lower temperature than that provided under peak conditions. Consequently, the cooling duty placed on the first cooling circuit by the process stream will be less. The flow rate of the first coolant supply stream can thus be reduced, lowering the consumption of cooled first coolant from the cooled first coolant supply tank. Cooled first coolant can therefore be accumulated in the cooled first coolant supply tank, for use when the cooling duty on the first cooling circuit increases.

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By providing a buffer supply tank and a buffer return tank, the present invention allows the flow rate of the first coolant supply stream, which cools the process stream, to be varied independently from the flow rate of the warmed first coolant stream, which ejects heat to the second cooling circuit.

The first cooling circuit is preferably a closed recirculating cooling circuit. Similarly, it is preferred that the second cooling circuit is a closed recirculating cooling circuit.

The first cooling circuit utilizes a first coolant. Preferably, the first coolant comprises water. More preferably, the first coolant consists essentially of water. In such cases, the first coolant may also contain standard water additives, such as antifoams, antiscalants, biocides and corrosion inhibitors. The first coolant supply stream would thus be a chilled water supply stream. The first coolant return stream would therefore be a warmed water return stream.

In the second cooling circuit is preferably a heat pump, more preferably a chiller system of the compression or absorption type. The heated second coolant stream produced in step (d) may be passed to a cooling system to regenerate the cooled second coolant stream. If the second coolant circuit is an absorption cycle, the second coolant may comprise water with a lithium bromide absorbent. If the second cooling circuit is a compression cycle, the cooling system may comprise a compressor, a condenser and an expansion device. In the latter case, the second coolant comprises a refrigerant, for example propane, ammonia, R-134a or any other commercially available refrigerant.

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It is preferred that heat exchange step (a) is carried out in a first heat exchanger. It is further preferred that heat exchange step (d) is carried out in a second heat exchanger. The heat exchange may be achieved through direct contact of the process stream and the first coolant supply stream in step (a) or the warmed first coolant stream and the cooled second coolant stream in step (d). Alternatively, indirect heat exchange may be used in steps (a) and (d), and this is preferred. Indirect heat exchange may be carried out in a shell and tube heat exchanger, an EM baffle heat exchanger, a plate and frame heat exchanger or a fin tube heat exchanger.

In a further embodiment, the present invention provides an apparatus for cooling a process stream, said apparatus at least comprising:

a first cooling circuit comprising a first heat exchanger, a first coolant return tank, a second heat exchanger and a first coolant supply tank,

said first heat exchanger having a first inlet which is connected to a process stream line, a first outlet which is connected to a cooled process stream line, a second inlet which is connected to the outlet of the first coolant supply tank and a second outlet which is connected to the inlet of the first coolant return tank,

said second heat exchanger having a first inlet which is connected to the outlet of the first coolant return tank, and a first outlet which is connected to the inlet of the first coolant supply tank; and

a second cooling circuit comprising the second heat exchanger and a cooling system,

said second heat exchanger having a second inlet connected to the outlet of the cooling system and a

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second outlet connected to the inlet of the cooling system.

It is preferred that the cooling system of the second cooling circuit comprises a compressor, a condenser, and an expansion device. The compressor can have an inlet connected to the second outlet of second heat exchanger and an outlet connected to an inlet of the condenser. The condenser can have an outlet connected to an inlet of the expansion device, with the expansion device having an outlet connected to the second inlet of the second heat exchanger.

Furthermore, an air cooler may be provided upstream of the first heat exchanger in the process stream, for example by connecting the first inlet of the first heat exchanger to the outlet of the air cooler.

In a further aspect of the invention, a first pump can be provided between the outlet of first coolant return tank and the first inlet of second heat exchanger. Furthermore, a second pump can be provided between the outlet of first coolant supply tank and the second inlet of the first heat exchanger. These pumps can control the flow rate of the first coolant supply stream and the warmed first coolant stream. The flow can also be controlled using control valves. It will be apparent that the first pump (or a further pump) could be placed in the cooled first coolant stream rather than the warmed first coolant stream. Similarly, the second pump (or a further pump) could also be placed in the first coolant return stream rather than the first coolant supply stream.

In another aspect, the coolant flow through the first heat exchanger (process/first coolant) can be adjusted to maintain a constant controlled process outlet

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temperature ex first heat exchanger. Depending on the process flow rate, physical properties and specifically its temperature (downstream the air cooler) at the inlet of the first heat exchanger, the required heat transfer rate (to maintain a controlled process temperature ex first heat exchanger) in the first heat exchanger varies. The actual heat duty can be manipulated in different ways. Preferably, the temperature in the process stream exiting the first heat exchanger is measured by a sensor and said temperature sensor is connected to a processor which determines the cooled first coolant flow to the first heat exchanger and thereby manipulating the heat duty in first heat exchanger.). The person skilled in the art may readily find alternative control schemes.

In yet another aspect, a temperature sensor is provided in the cooled chilled water ex second heat exchanger (chilled water vs. refrigerant), said temperature being connected to a processor and said processor manipulating the chilled water flow through the second heat exchanger to maintain a constant chilled water supply temperature.

The duty of the refrigerant cycle can be manipulated in order to match the required cooling. For example level control on the chilled water supply tank can manipulate the duty (e.g. refrigerant compressor duty control system) of the refrigerant cycle, so varying the refrigerant supply to the refrigerant/chilled water heat exchanger.

The described control schemes maintain constant and controlled temperatures in the supply and the return tanks. Alternative control schemes may readily be found but always aiming at restoring the buffer of cooled

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first coolant in the supply tank when the duty of the second cooling circuit exceeds the cooling duty of the process.

Hereinafter the invention will be further illustrated by the following non-limiting drawings.

Figure 1 schematically shows a process scheme in accordance with an embodiment of the present invention.

Figure 2 shows a plot of the levels of the cooled and warmed primary coolant buffer tanks over time when carrying out the method of the present invention.

For the purpose of this description, a single reference number will be assigned to a line as well as a stream carried in that line. Same reference numbers refer to similar components.

Figure 1 is a schematic diagram showing an apparatus of the present invention 1 comprising a process cascade 2, a first cooling circuit 10 and a second cooling circuit 60. First cooling circuit 10 is used to cool process stream 6. Process stream 6 is a liquid or gaseous stream preferably in a refinery, natural gas treatment plant, liquefied natural gas, Gas-to-Liquids (also known as Shell Middle Distillate Synthesis) or chemical process plant, for example an amine stream from an acid gas treatment unit or a sweet or sour natural gas stream.

The present invention is directed towards the cooling of the process stream. Process stream 6 is provided at a first process temperature, which is preferably in the range of 20 to 65 °C. Process stream 6 is passed to first heat exchanger 20 via first inlet 7 where it is heat exchanged against a first coolant supply stream 52 to provide a cooled process stream 9 at first outlet 8. Cooled process stream 9 is produced at a second process

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temperature, which is preferably in the range of 0 to 35 °C, preferably 25 °C. Cooled process stream 9 can then be passed on to other units for further processing. For instance, when process stream 6 is an amine stream from an acid gas treatment unit, it can be passed to a regeneration column after cooling.

First cooling circuit 10 is used to provide the cooling duty necessary to cool process stream 6. First cooling circuit 10 is preferably a closed loop cooling circuit. First cooling circuit 10 comprises a first coolant which preferably comprises water, more preferably the first coolant consists essentially of water, even more preferably for low temperatures a mixture of water and glycol or other anti-freeze agent. In this case, the coolant water stream may also contain standard closed loop water additives, such as antiscalants, biocides and corrosion inhibitors.

First coolant supply stream 52, which is preferably a chilled water stream, is provided at a first coolant supply temperature, which can be in the range of 5 to 30 °C. First coolant supply stream 52 is passed to first heat exchanger 20 via second inlet 53, where it cools process stream 6 and is itself warmed to produce a first coolant return stream 22 at second outlet 21. First coolant return stream 22 has a first coolant return temperature, which can be in the range of 10 to 45 °C.

First coolant return stream 22 is passed to a first coolant return tank 30 via inlet 23. First coolant return tank 30 provides a storage buffer for the warmed first coolant. Return tank 30 may be provided with insulation, in order to minimise heat ingress from surroundings. Return tank 30 operates to buffer the warmed first coolant between the first and second heat

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exchangers. The warmed first coolant is drawn from return tank 30 via outlet 32 as warmed first coolant stream 32.

5 When the cooling duty placed on the first cooling circuit 10 by process stream 6 is greater than the heat which can be ejected to second cooling circuit 60, the rate of flow of first coolant return stream 22 will be more than the rate of flow of warmed first coolant stream 32, and the level of warmed first coolant in
10 return tank 30 will rise.

When the cooling duty placed on the first cooling circuit 10 by process stream 6 is less than the heat which can be rejected to second cooling circuit 60, the rate of flow of first coolant return stream 22 will be
15 less than the rate of flow of warmed first coolant stream 32, and the level of warmed first coolant in return tank 30 will fall.

After exiting return tank 30, warmed first coolant stream 32 is passed to first inlet 33 of second heat
20 exchanger 40, where it is cooled against cooled second coolant stream 72 to regenerate cooled first coolant stream 42 via outlet 41. Cooled first coolant stream 42 is produced at the first coolant supply temperature, which can be in the range of 5 to 30 °C, as discussed
25 above.

Cooled first coolant stream 42 is passed to first coolant supply tank 50 via inlet 43. Supply tank 50 provides a storage buffer for the cooled first coolant. It is preferred that supply tank 50 is provided with
30 insulation, in order to minimise heat ingress from the surroundings. Supply tank 50 operates to buffer the cooled first coolant between the second and first heat exchangers. The cooled first coolant is drawn from

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supply tank 50 via outlet 51 as first coolant supply stream 52.

When the cooling duty placed on first cooling circuit 10 by process stream 6 is greater than the heat which can be ejected to second cooling circuit 60, the rate of flow of cooled first coolant stream 42 will be less than the rate of flow of first coolant supply stream 52, and the level of cooled first coolant in supply tank 50 will fall.

When the cooling duty placed on first cooling circuit 10 by process stream 6 is less than the heat which can be ejected to cooling circuit 60, the rate of flow of cooled first coolant stream 42 will be greater than the rate of flow of first coolant supply stream 52, and the level of cooled first coolant in supply tank 50 will rise.

From the foregoing discussion, it will be apparent that the flow rate of warmed first coolant stream 32 should be equal to the flow rate of cooled first coolant stream 42 in order to provide a uniform flow through second heat exchanger 40. Similarly, the flow rate of first coolant supply stream 52 should be equal to the flow rate of first coolant return stream 22 in order to provide a uniform flow through first heat exchanger 20.

However, there is no requirement in the present invention that the flow rate of cooled first coolant supply stream 52 (or first coolant return stream 22) should be the same as warmed first coolant stream 32 (or cooled first coolant stream 42). Indeed, the method and apparatus of the present invention can provide unequal flows of streams 52 and 22 compared to streams 32 and 42. Consequently, the levels of warmed and cooled first coolant in return tank 30 and supply tank 50

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respectively can be varied in response to changes in the cooling duty required by process stream 6 and the heat which can be ejected to second cooling circuit 60.

By buffering the cooled first coolant in supply tank 50 and warmed first coolant in return tank 30, it is possible to compensate for changes in ambient temperature. The ambient temperature can effect both the cooling duty which can be provided by second cooling circuit 60 (and hence the amount of heat which can be ejected by the first coolant circuit) and the temperature of process stream 6 (and hence the cooling duty required of first refrigerant circuit 20).

For instance, at low ambient temperatures, such as at night, the second cooling circuit 60 can generate more cold. This is because lower temperatures can be achieved in the second cooling system, for example in the condenser of the discharge of the second coolant compressor, when the ambient temperature is lower. The generation of more cold in second cooling circuit 60 allows more heat to be removed from the first cooling circuit 10. Under these conditions, the cooling capacity of the of the second cooling circuit 60 can be higher than required by process stream 6, and cooled first coolant can be accumulated in supply buffer 50, because the rate at which warmed first coolant stream 32 is cooled in second heat exchanger 40 can be increased. The excess cooled first coolant in supply buffer 50 can be stored for use when the cooling duty on the first cooling circuit 10 increases, for instance at high ambient temperatures.

Instead of designing the second cooling circuit to generate all the cold required by first cooling circuit 10 under peak conditions (e.g. during operation at

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maximum ambient temperatures) i.e. a peak capacity which is only partially used during lower ambient temperatures, second cooling circuit 60 can be designed for a lower capacity in accordance with the present invention.

At high ambient temperatures, such as during the day, the second cooling circuit 60 will be operating closer to, or at its maximum capacity, which is still lower than the peak capacity of first heat exchanger 20. Any deficit of cooled first coolant produced by heat exchange against the second cooling circuit during high ambient temperature conditions is met by the buffered cooled first coolant from first coolant supply tank 50.

During lower ambient conditions, the cooling capacity of the second cooling circuit 60 is higher than actually required by process stream 6, so that additional cooled first coolant can be generated in second heat exchanger 40 to restore the level in first coolant supply tank 50.

As discussed above, the first coolant increases in temperature due to the cold ejected by the heat exchange between first coolant supply stream 52 and process stream 4. Second cooling circuit 60 provides cooling to the first coolant in first cooling circuit 10.

Second cooling circuit 60 is preferably a closed recirculating cooling circuit. Second cooling circuit 60 comprises second heat exchanger 40 and a cooling system 70. Cooling system 70 generates the cooled second coolant stream 72 which is fed to second inlet 73 of second heat exchanger 40. In second heat exchanger 40, cooled second coolant stream 72 is heat exchanged against warmed first coolant stream 32 to produce a heated second coolant stream 46 at the second outlet 45 of second heat exchanger 40 and cooled first coolant

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stream 42. Heated second coolant stream 46 is then returned to cooling system 70 via inlet 47.

In the embodiment shown in Figure 1, the second cooling circuit is a compression cycle. More particularly, the compression cycle is a refrigeration cycle in which the second coolant is propane. In such a case, cooling system 70 will comprise a compressor, a condenser and an expansion device (not shown). The compressor has an inlet which is connected to the second outlet 45 of second heat exchanger 40. The compressor also has an outlet which is connected to the inlet of a condenser. The condenser has an outlet which is connected to the inlet of an expansion device, such as an expansion valve. The expansion device has an outlet which is connected to the second inlet 73 of second heat exchanger 40. The operation of such refrigeration systems is well known and will not be discussed in greater detail here.

A further advantage of the present invention is that by buffering the cooled first coolant in supply tank 50 and warmed first coolant in return tank 30, it is possible to compensate for changes in the temperature of process stream 6.

In the embodiment shown in Figure 1, an air cooler 80 is provided upstream of first heat exchanger 20 in process cascade 2. Process stream 6 is produced by air cooler 80 at outlet 5 and passed to first inlet 7 of first heat exchanger 20. Air cooler 80 is supplied by warm process stream 3 via inlet 4. Air cooler 80 cools warm process stream 3, preferably to a temperature in the range of 40 to 65 °C. However, the temperature to which warm process stream 3 is cooled will depend on the ambient air temperature drawn through air cooler 80.

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For instance, at lower ambient temperatures, such as during the night, the first process temperature of process stream 6, downstream of air cooler 80 will be lower than during high ambient temperature. This is because air cooler 80 can provide greater cooling to warm process stream 3 because the surrounding air is cooler than during the day. Thus, if a constant second process temperature for cooled process stream 9 is to be maintained downstream of first heat exchanger 20, the cooling duty required of first cooling circuit 10 during low ambient temperatures is less. Under such low ambient temperatures, the flow rate of first coolant supply stream 52 can be reduced, because the cooling duty placed on first cooling circuit 10 by process stream 6 is less. A reduction in the flow rate of first coolant supply stream 52 allows cooled first coolant to be accumulated in supply buffer tank 50, because the flow rate of first coolant supply stream 52 will be less than the flow rate of cooled first coolant stream 42.

At higher ambient temperatures, such as during the day, the first process temperature of process stream 6 will be higher than at night, because air cooler 80 will not be able to provide as much cooling to warm process stream 3. A higher cooling duty will therefore be placed upon first cooling circuit 10. In order to provide more cold to process stream 6 in order to maintain the second process temperature downstream of first heat exchanger 20 at a constant temperature, the flow rate of first coolant supply stream 52 can be increased. When this flow rate becomes greater than the flow rate of warmed first coolant stream 32 into second heat exchanger 40, the cooled first coolant in supply buffer tank 50 will

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be consumed and the level of first coolant in the tank will drop.

From the foregoing discussion, it is evident that the effect of ambient temperature on the cooling duty available from second cooling circuit 60 and the effect of ambient temperature on the first temperature of process stream 6 operate in combination. In particular, at lower ambient temperatures, second cooling circuit 60 can provide a higher cooling duty, allowing greater heat rejection in the first cooling circuit 10, increasing the level of cooled first coolant in supply buffer tank 50. At the same time, the cooling duty placed upon the first cooling circuit by process stream 6 is reduced because air cooler 80 can provide greater cooling, reducing the first process temperature of process stream 6, allowing more cooled first coolant to be accumulated in supply buffer tank 50.

These effects allow the level of cooled first coolant in supply tank 50 to be increased at lower ambient temperatures, such that when the temperatures increase during the day, and the cooling duty available from second cooling circuit 60 decreases, and the cooling duty placed on the first cooling circuit 10 by process stream 6 increases, a reserve of cooled first coolant is available in supply buffer tank 50 to meet the increased cooling demands.

In this way, the second cooling circuit of the present invention can be provided with a lower capacity than conventional units, which results in corresponding savings in capital expenditure, while still meeting the same operational requirements. This will be explained in greater detail in the following non-limiting Example.

Example 1

A closed loop chilled water circuit is provided as the first cooling circuit. The first coolant supply stream (chilled water) has a temperature of 25 °C, and the first coolant return stream (warmed water) has a temperature of 40 °C. A propane compression refrigeration cycle is provided as the second cooling circuit.

Following the method of the invention, an apparatus was constructed with a capacity of 58% of the equipment required for conventional peak capacity operation. In particular, a 70 MW chilled water/refrigerant heat exchanger (the second heat exchanger) and refrigerant system with a capacity of 70 MW heat rejection from circuit 1, with an additional 40 000 m³ chilled water supply and return tank capacity was found to provide equivalent performance including peak heat rejection from process up to 120 MW. Without the invention the second circuit (refrigerant, including compressors) would have been designed for 120 MW. The compressor and the rest of the propane cooling cycle (second cooling circuit) was so reduced to 58% of the equivalent equipment capacity required for conventional operation.

Figure 2 is a plot showing the variation in the levels of the chilled water buffer supply tank 50 and the warmed water buffer return tank 30 over time for the apparatus of the Example. In this experiment, the maximum level of chilled water in chilled water supply tank 50 was set at 90% and the minimum level of warmed water buffer return tank 30 was set at 10%.

From Figure 2, it is apparent that the troughs in the level of buffer supply tank 50, which occur when the difference between the flow rate of chilled water supply

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stream 52 and warmed water return stream 32 are at a maximum, are mirrored by peaks in the level of warmed coolant in buffer return tank 30. This situation occurred at peak ambient temperatures during the day, when the cooling duty placed upon first cooling circuit 10 is at a maximum.

During lower ambient conditions at night, the level of chilled water in buffer supply tank 50 was restored as the cooling duty placed on first cooling circuit 10 decreased, and more cooling was provided by second cooling circuit 60, while less cooling was required by process stream 6.

The day and night cycles shown in the centre of the plot of Figure 2 occurred when extremely day-time ambient temperatures were experienced. The chilled water level in the buffer supply tank 50 was unable to return to a level of 90% over a single day/ night cycle. Such a situation arose when the cooling duty placed upon the first cooling circuit over a 24 hour period was greater than the available heat rejection to the second cooling circuit. However, the apparatus of the invention still functioned effectively because additional chilled water was stored in buffer supply tank 50. During the hottest day, the buffer supply tank level was reduced to a minimum level of approximately 35%, and recovered to a level of approximately 75% that night. Three subsequently hot days reduced the level of chilled water in the buffer supply tank to approximately 45%. However, the apparatus recovered to equilibrium levels of chilled water and warmed water thereafter when the ambient conditions return to a normal cycle.

The person skilled in the art will readily understand that many modifications may be made without departing

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from the scope of the invention. For example,
alternative constructions can be provided for the second
coolant system utilising an absorption system rather
than compression system described with reference to
5 Figure 1.

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C L A I M S

1. A method of cooling a process stream, the method comprising at least the steps of:

(a) heat exchanging a first coolant supply stream in a first cooling circuit against a process stream at a first process temperature to produce a first coolant return stream and a cooled process stream;

(b) passing the first coolant return stream to a first coolant return tank to provide warmed first coolant;

(c) withdrawing a portion of the warmed first coolant from the first coolant return tank as a warmed first coolant stream;

(d) heat exchanging a cooled second coolant stream in a second cooling circuit against the warmed first coolant stream to produce a cooled first coolant stream,

(e) passing the cooled first coolant stream to a first coolant supply tank to provide cooled first coolant;

(f) withdrawing a portion of the cooled first coolant from the first coolant supply tank as the first coolant supply stream; wherein the rate of flow of the warmed first coolant stream in step (c) is controlled in response to the cooling duty available from the second cooling circuit and the flow from the supply to the return buffer is controlled by the required cooling of the process stream and wherein the difference between the minimum and maximum cooling duty of the process stream over a time period is larger than the difference between the minimum and maximum cooling duty of the second cooling circuit over said time period.

2. A method according to claim 1 wherein the second cooling circuit is any chiller system, such as

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compression refrigeration systems with refrigerants such as propane, ammonia, R-134a or absorption chilling systems based on Lithium Bromide.

5 3. A method according to any one of the preceding claims wherein the first coolant comprises water.

4. A method according to claim 3, wherein the first coolant is a refrigerant, preferably propane, ammonia, R-134a or any other commercially available coolant and wherein the second coolant is cooling water or ambient
10 air.

5. A method according to any one of the preceding claims wherein the sum of the amount of warmed first coolant in the first coolant return tank and the amount of cooled first coolant in the first coolant supply tank is held
15 at a constant value.

6. A method according to any one of the preceding claims wherein steps (a) to (g) are repeated over at least one day and night cycle.

7. An apparatus (1) for cooling a process stream, such
20 as a stream derived from natural gas, the apparatus at least comprising:

a first cooling circuit (10) comprising a first heat exchanger (20), a first coolant return tank (30), a second heat exchanger (40) and a first coolant supply
25 tank (50),
said first heat exchanger (20) having a first inlet (7) which is connected to a process stream line (6), a first outlet (8) which is connected to a cooled process stream line (9), a second inlet (53) which is connected to the
30 outlet (51) of the first coolant supply tank (50) and a second outlet (21) which is connected to the inlet (23) of the first coolant return tank (30), said second heat exchanger (40) having a first inlet (33) which is

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connected to the outlet (31) of the first coolant return tank (30), and a first outlet (41) which is connected to the inlet (43) of the first coolant supply tank (50);

and

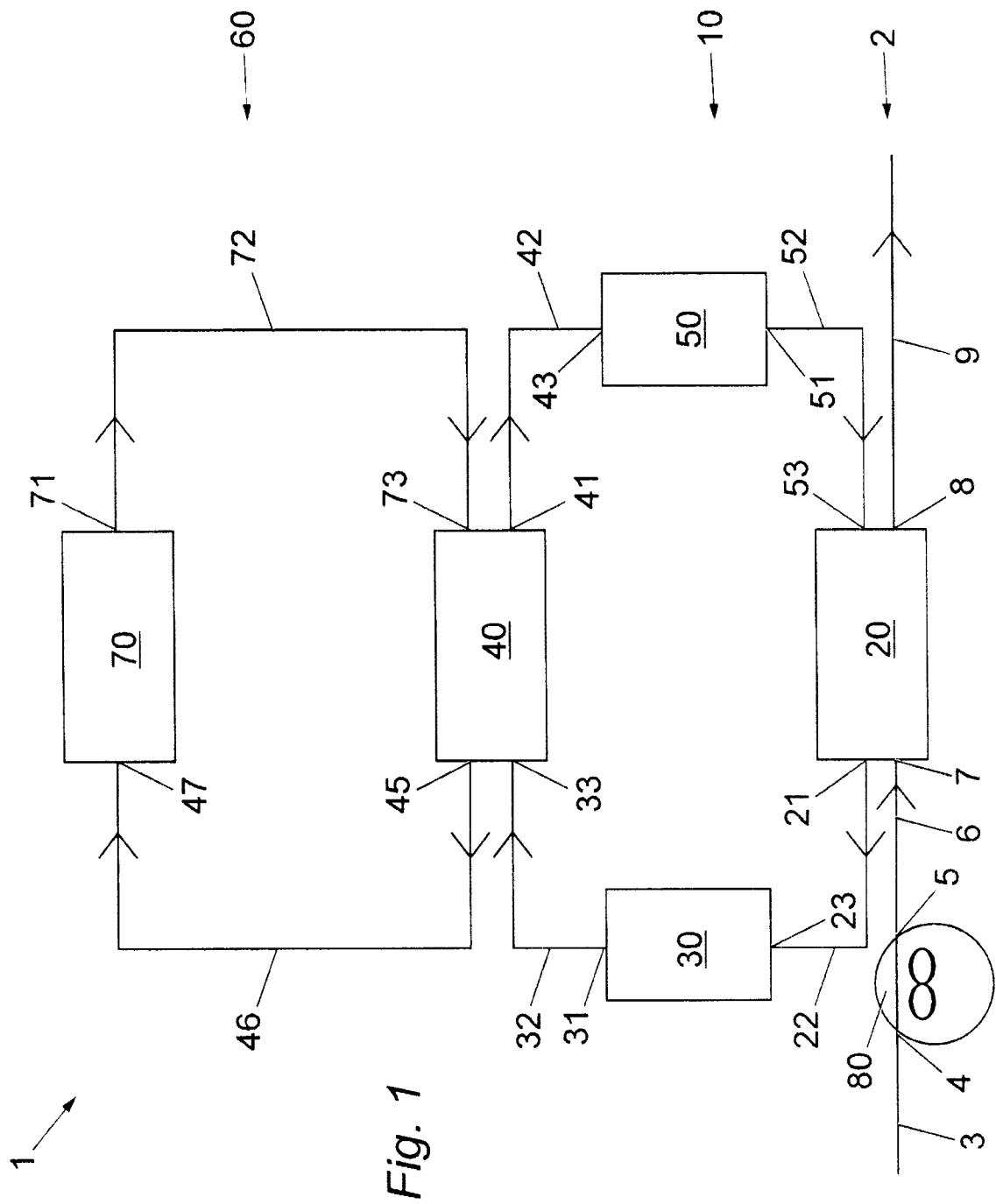
5 a second cooling circuit (60) comprising the second heat exchanger (40) and a cooling system (70), said second heat exchanger (40) having a second inlet (73) connected to the outlet (71) of the cooling system and a second outlet (45) connected to the inlet (47) of the cooling
10 system (70), wherein the cooling system (70) of the second cooling circuit (60) comprises a compressor, a condenser, and an expansion device, said compressor having an inlet connected to the second outlet of second heat exchanger (40), an outlet connected to an inlet of
15 the condenser, said condenser having an outlet connected to an inlet of the expansion device and said expansion device having an outlet connected to the second inlet (73) of the second heat exchanger (40) and wherein the first inlet (7) of first heat exchanger (20) is
20 connected to the outlet (5) of an air cooler (80).

8. An apparatus according to claim 7 wherein a first pump is provided between the outlet (31) of first coolant return tank (30) and the first inlet (33) of second heat exchanger (40) and a second pump is provided
25 between the outlet (51) of first coolant supply tank (50) and the second inlet (53) of the first heat exchanger (20), wherein a temperature sensor is provided in stream line (9) at the outlet (8) of heat exchanger (20) to detect the temperature in process stream line
30 (9), said temperature sensor being connected to a first processor which determines the net supply of first coolant via the first pump to first heat exchanger (20) and wherein a temperature sensor is provided between the

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outlet (41) of second heat exchanger (40) and the inlet (43) of first coolant supply tank (50), said sensor being connected to a second processor which determines the supply of first coolant via the second pump to
5 second heat exchanger (40) and wherein a level sensor is provided in first coolant supply tank (50), said level sensor being connected to a third processor which determines the duty of the cooling system (70).

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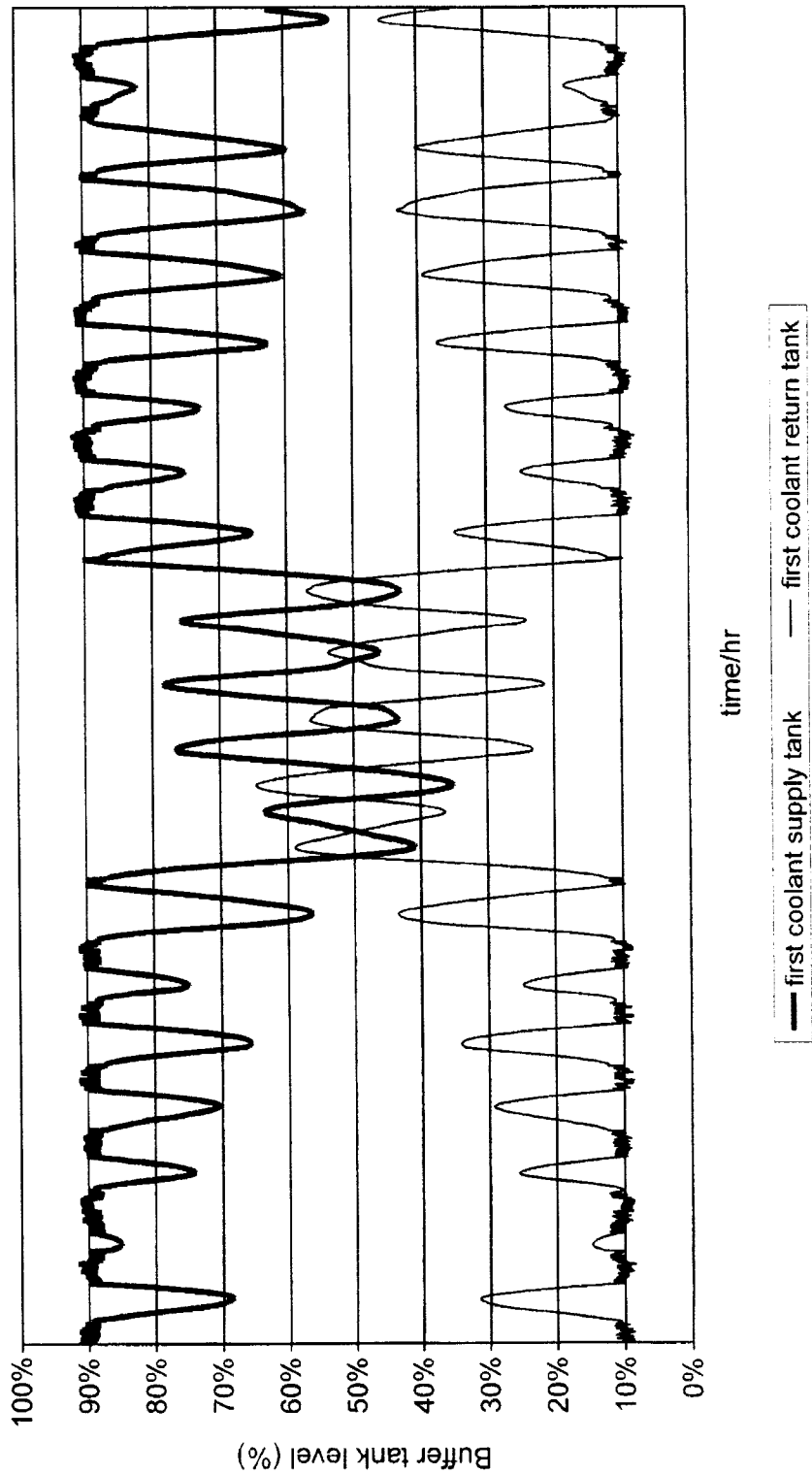


Fig. 2

INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2008/065562

A. CLASSIFICATION OF SUBJECT MATTER

INV. F25B25/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F25D F25B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 1 134 514 A (NESTLE SA [CH]) 19 September 2001 (2001-09-19) paragraphs [0015] - [0034]; figure 1 -----	1-8
A	US 2007/056312 A1 (KOBAYASHI MAKOTO [JP]) 15 March 2007 (2007-03-15) the whole document -----	1-8
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Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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"P" document published prior to the international filing date but later than the priority date claimed

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

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Date of the actual completion of the international search

3 March 2009

Date of mailing of the international search report

31/03/2009

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

Authorized officer

Ritter, Christoph

INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2008/065562

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

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