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(71) Applicant: **Schutter Rotterdam B.V.**
2908 LS Capelle a/d Ijssel (NL)

(72) Inventor: **Van Beveren, Petrus Carolus**
4631 BB Hoogerheide (NL)

(74) Representative: **Donné, Eddy**
M.F.J.Bockstael
Arenbergstraat 13
2000 Anvers (BE)

(54) **Cooling system with low energy consumption**

(57) Cooling installation (1) for low energy consumption, consisting of a primary cooling circuit (2) in which there is an object (4) to be cooled, a compressor (6a), a primary condenser (7) and a primary turbine (8a) that drives an electricity generator or is directly coupled to the primary compressor, characterised in that the primary condenser (7) is coupled to a secondary cooling circuit (3) that follows a Rankine cycle or a TFC (Trilateral Flash Cycle system), whereby heat from the primary cooling circuit (2) is utilised in the secondary cooling circuit (3) that contains a secondary turbine (8b) that is coupled to an electricity generator, or is directly coupled to the primary compressor, and further contains a secondary condenser (10) and a pressure pump (12).

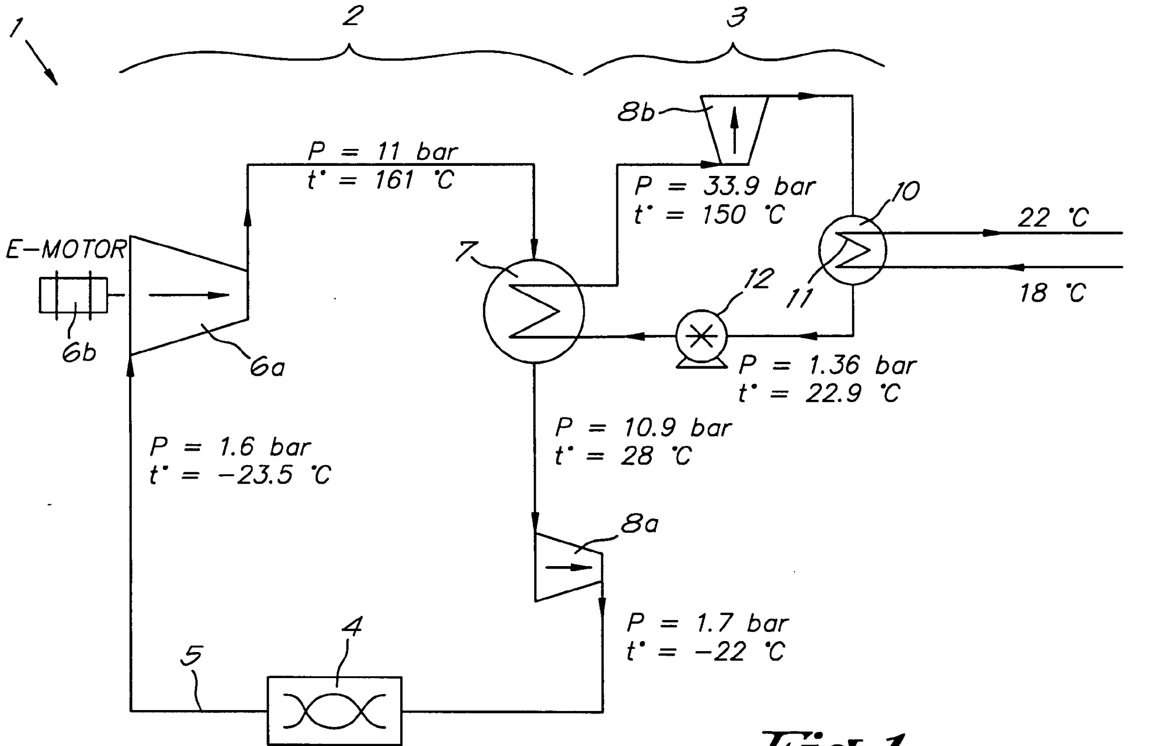

Fig.1

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Description

[0001] The present invention relates to a cooling system with low energy consumption.

[0002] More specifically the invention is intended for reducing the energy consumption of industrial cooling installations.

[0003] It is known that industrial cooling installations are used, for example, for cooling freezer rooms, crystallisation units or fractionation units such as with SSHE units (Surface Scraped Heat Exchange) or else for liquefying gases.

[0004] Traditionally industrial cooling is done by using a cooling circuit in which a cooling liquid, such as ammonia for example, evaporates whereby a quantity of heat is extracted from the object to be cooled, such as a freezer room for example.

[0005] The ammonia vapour is then compressed again by a compressor, whereby the temperature and pressure of the coolant increases, to then be cooled in a condenser to a temperature and pressure that, after releasing the pressure, is again suitable to be guided back to the object to be cooled in order to evaporate again and extract heat from the object to be cooled.

[0006] The energetic efficiency of such a cooling system is expressed as a "Coefficient of Performance" (COP), which reflects the ratio between the energy extracted and the energy that has to be supplied to the cooling system for this purpose. This ratio in a traditional cooling circuit is "3", depending on the conditions.

[0007] In this example 900 kW of heat is extracted from the object to be cooled, and to this end 304 kW is supplied in the form of electrical energy to drive the compressor.

[0008] Such traditional cooling installations present the disadvantage that a lot of energy is lost in the form of heat, as the compressor is frequently cooled with oil, whereby the heat generated is partly lost through the oil cooling of the compressor.

[0009] Another source of energy loss is the loss of heat that is stored in the compressed coolant, and which is partly released in a condenser that is cooled with for instance water, and is lost with the cooling water.

[0010] Another disadvantage of a traditional cooling installation is that the compressor requires oil cooling and lubrication.

[0011] A further disadvantage is that the cooling installation is quite large and thus takes up a lot of space.

[0012] The purpose of the present invention is to provide a solution to the aforementioned disadvantages and other disadvantages.

[0013] To this end the invention concerns a cooling installation for low energy consumption, consisting of a primary cooling circuit in which there is an object to be cooled, a compressor, a primary condenser and a primary turbine that drives an electricity generator or is directly coupled to the primary compressor, whereby the primary condenser is coupled to a secondary cooling circuit that follows a Rankine cycle or a "Trilateral Flash Cycle System" (TFC), whereby heat from the primary cooling circuit is utilised in the secondary cooling circuit that contains a secondary turbine that is coupled to an electricity generator, or is directly coupled to the primary compressor, and further contains a secondary condenser and a pressure pump.

[0014] An advantage of such a cooling system is that part of the heat that is carried off in the primary cooling circuit is converted into electrical energy by means of a primary and a secondary turbine. This double recuperation ensures that the coefficient of performance (COP) can be increased from 3 to 7.41 in the example below. This means that the quantity of external energy needed to achieve the desired cooling effect can be reduced by more than half.

[0015] Given the energy consumed by cooling installations around the world, an enormous quantity of primary energy can be saved in this way, and moreover a reduction of the CO_2 emissions coupled to it is achieved. A saving of tertiary coolant is also realised, as the heat converted into electricity no longer has to be cooled.

[0016] Another advantage of such a cooling installation is that the electrical energy generated can be reused locally to supply the compressor, which lowers the supply of externally purchased energy.

[0017] Another advantage of such a cooling installation is that besides to drive the primary compressor, no external energy has to be supplied, such as for example the input of energy from the environment by a heat pump.

[0018] Preferably the primary cooling circuit only contains one compressor and only one condenser, and the secondary cooling circuit only contains one turbine and this secondary cooling circuit only cools one condenser in the primary cooling circuit.

[0019] An advantage of such a cooling installation with only one primary condenser and only one compressor in the primary cooling circuit, is that multistage compressors are avoided, and multiple condensers are avoided.

[0020] Preferably the secondary cooling circuit contains only one secondary turbine.

[0021] Preferably, besides the electrical energy supplied to drive the compressor of the primary cooling circuit, no additional external energy is supplied to the primary cooling circuit such as external heat from a heat pump or any other energy source.

[0022] An advantage of such a cooling system is that the system can be of a much more compact construction (sometimes up to half as compact) compared to a traditional cooling system, whereby the space and materials required can be limited.

[0023] Preferably the primary coolant of the primary cooling circuit differs from the secondary coolant of the secondary cooling circuit.

[0024] Another advantage of the cooling installation with low energy consumption is that the primary coolant and the secondary coolant and the tertiary coolant can be optimally chosen according to their role.

[0025] For example, the primary coolant can be ammonia, while the secondary coolant can be optimised for a Rankine cycle, or a TFC cycle.

[0026] For example, for the secondary coolant an organic coolant can be chosen that evaporates and condenses at lower temperatures. Such an organic coolant can be chosen such that, upon expansion, the coolant stays in the super-critical region and thus never transforms to the liquid form.

[0027] Organic coolants also offer the advantage that they have a lower heat of evaporation than water, and thereby a greater share of the heat can be utilised for heating the secondary coolant, which is advantageous when it comes to utilising the residual heat.

[0028] These properties enable a Rankine cycle or a TFC cycle to be used with an organic secondary coolant to generate electricity from low value heat. The minimum temperature at which this process is practically possible is 80°C. The efficiency increases as the temperature of the available heat rises. At lower temperatures around 10% of the heat can be converted into electricity. At a higher temperature this can rise to more than 20%.

[0029] A compact organic Rankine cycle is known that uses toluene as a coolant and achieves an efficiency of 22%. Other organic coolants are used such as isopentane or butane or fluorine compounds.

[0030] The TFC system is intended for recovering energy from a low temperature heat source. The use of a mixture of pentane and neopentane has been described herein.

[0031] The tertiary coolant can differ from the secondary coolant and/or the primary coolant. The secondary condenser in the Rankine cycle or the TFC cycle can use water or air as a tertiary coolant, for example, that carries the residual heat away or can still be used as a heating source.

[0032] Preferably the compressor in the primary cooling circuit is of the dry type, which means that the compressor is not cooled with oil, and is not lubricated with oil either.

[0033] An advantage of this dry type of compressor is that the heat generated by the compression cannot be emitted into the oil used as a coolant or lubricant, and stays in the cooling circuit whereby a greater fraction of heat can be converted to electrical energy.

[0034] With the intention of better showing the characteristics of the invention, a preferred embodiment of a cooling installation according to the invention is described hereinafter by way of an example without any limiting nature, with reference to the accompanying drawing, wherein:

figure 1 schematically shows a cooling installation according to the invention.

[0035] Figure 1 shows a cooling installation 1 consisting of a primary cooling circuit 2 and a secondary cooling circuit 3. The primary cooling circuit 2 contains an object 4 to be cooled, in this case a fractionation unit, a primary coolant 5, a primary compressor 6a driven by an electric motor 6b, a primary condenser 7, and a primary turbine 8a.

[0036] The secondary cooling circuit 3 contains a secondary coolant 9, and goes through the primary condenser 7, a secondary turbine 8b, and a secondary condenser 10 through which a tertiary coolant 11 also flows. The secondary coolant 8 flows further to a pressure pump 12 and to the primary condenser 7 with which the secondary cooling circuit 3 is closed.

[0037] The operation of the cooling installation 1 can be described as follows.

[0038] The primary coolant 5, such as ammonia for example, is evaporated whereby heat is extracted from an object to be cooled, such as a fractionation unit for vegetable oils in this case. The evaporated primary coolant 5 is then carried to a primary compressor 6a, which is preferably of the dry type. This means that the compressor 6a is not cooled or lubricated by oil. As a result, the heat generated by the compression in the primary coolant 5 stays in the primary cooling circuit 2 and then more of this heat can be recovered by conversion into electricity.

[0039] The compressed primary coolant 5 is further guided to the primary condenser 7, where the primary coolant 5 is cooled by means of a secondary coolant 9 and is further guided to the primary turbine 8a. The primary coolant 5 is further expanded in the primary turbine 8a, which is coupled to a generator (not shown) to generate electricity. The expanded primary coolant 5 is further guided to the object 4 to be cooled where it evaporates again and the primary cooling cycle can begin again.

[0040] The secondary cooling circuit 3 contains a secondary coolant 9, such as an organic coolant for example, with which the primary coolant 5 is cooled in the primary condenser 7. The heated secondary coolant 9 is further guided to the secondary turbine 8b, where the secondary coolant 9 is expanded and drives the turbine 8b, which is coupled to a generator (not shown) in order to generate electricity, or is directly coupled to the primary compressor.

[0041] The expanded secondary coolant 9 is then guided to a secondary condenser 10 where it is cooled by means of a tertiary coolant 11. In this case the tertiary coolant 11 consists of water, but air can also be used as a coolant.

[0042] The secondary coolant 9 is further guided to a pressure pump 12 that leads the coolant further through the primary condenser 7 in order to cool the primary coolant 5 again, with which the secondary cooling circuit 3 is closed.

[0043] The following table shows how much energy in kW is supplied to the primary compressor 6a and the pressure pump 12, and how much energy in kW is recovered by the primary turbine 8a and the secondary turbine 8b, such that the total net supplied energy in kW can be calculated and compared to the quantity of energy that is extracted from the object 4 to be cooled.

Table I: energy expressed in kW consumed (-) and produced (+) in the cooling installation according to the invention.

Prim. Compress. (6a)	Pressure pump (9)	Prim. Turbine (8a)	Sec. Turbine (8b)	Cooling unit (4)	Net supplied	COP	Tert. Cool. Saved
-304.40	-20.5	14.51	189.00	900.00	-121.39	7.41	40.63 $m^{3\ H2O}$/h 4°C

[0044] Dividing the total energy extracted from the cooling (900 kW) by the net added energy (121.39 kW), yields the value of the coefficient of performance (COP) of the cooling installation according to the invention, that is now 7.41, which is more than double a traditional cooling installation that has a COP of 3.

[0045] The present invention is by no means limited to the embodiment described as an example and shown in the drawings, but a cooling installation according to the invention can be realised in all kinds of variants, without departing from the scope of the invention.

Claims

1. Cooling installation (1) for low energy consumption, consisting of a primary cooling circuit (2) in which there is an object (4) to be cooled, a compressor (6a), a primary condenser (7) and a primary turbine (8a) that drives an electricity generator or is directly coupled to the primary compressor, **characterised in that** the primary condenser (7) is coupled to a secondary cooling circuit (3) that follows a Rankine cycle or a TFC (Trilateral Flash Cycle system), whereby heat from the primary cooling circuit (2) is utilised in the secondary cooling circuit (3) that contains a secondary turbine (8b) that is coupled to an electricity generator, or is directly coupled to the primary compressor, and further contains a secondary condenser (10) and a pressure pump (12).

2. Cooling installation (1) according to claim 1, **characterised in that** the primary coolant (5) of the primary cooling circuit (2) differs from the secondary coolant (9) of the secondary cooling circuit (3).

3. Cooling installation (1) according to claim 1, **characterised in that** the secondary cooling circuit is cooled by a tertiary coolant (11).

4. Cooling installation (1) according to claim 1, **characterised in that** the tertiary coolant (11) is different to the secondary coolant (9) and/or the primary coolant (5).

5. Cooling installation (1) according to claim 1, **characterised in that** the secondary coolant (9) is an organic coolant.

6. Cooling installation (1) according to claim 1, **characterised in that** the secondary coolant (9) is chosen such that, upon expansion, it remains in a supercritical state.

7. Cooling installation (1) according to claim 1, **characterised in that** the compressor (6a) in the primary cooling circuit (2) is of the dry type, which means that the compressor is not cooled with oil, and not lubricated with oil either.

8. Cooling installation (1) according to claim 1, **characterised in that** the primary (8a) and secondary turbines (8b) deliver their electricity to the same power source, that is also partly responsible for supplying the compressor (6a) in the primary cooling circuit (2) and/or the pressure pump (12) in the secondary cooling circuit (3).

9. Cooling installation (1) according to any one of the foregoing claims, **characterised in that** the primary cooling circuit (2) contains only one compressor (6a) and only one condenser (7).

10. Cooling installation (1) according to any one of the foregoing claims, **characterised in that** the secondary cooling circuit (3) contains only one turbine (8b) and cools only one condenser (7) in the primary cooling circuit (2).

11. Cooling installation (1) according to any one of the foregoing claims, **characterised in that** in addition to the electrical energy supplied to drive the compressor (6a) of the primary cooling circuit (2), no additional external energy is supplied to the primary cooling circuit (2) such as external heat from a heat pump or any other energy source.

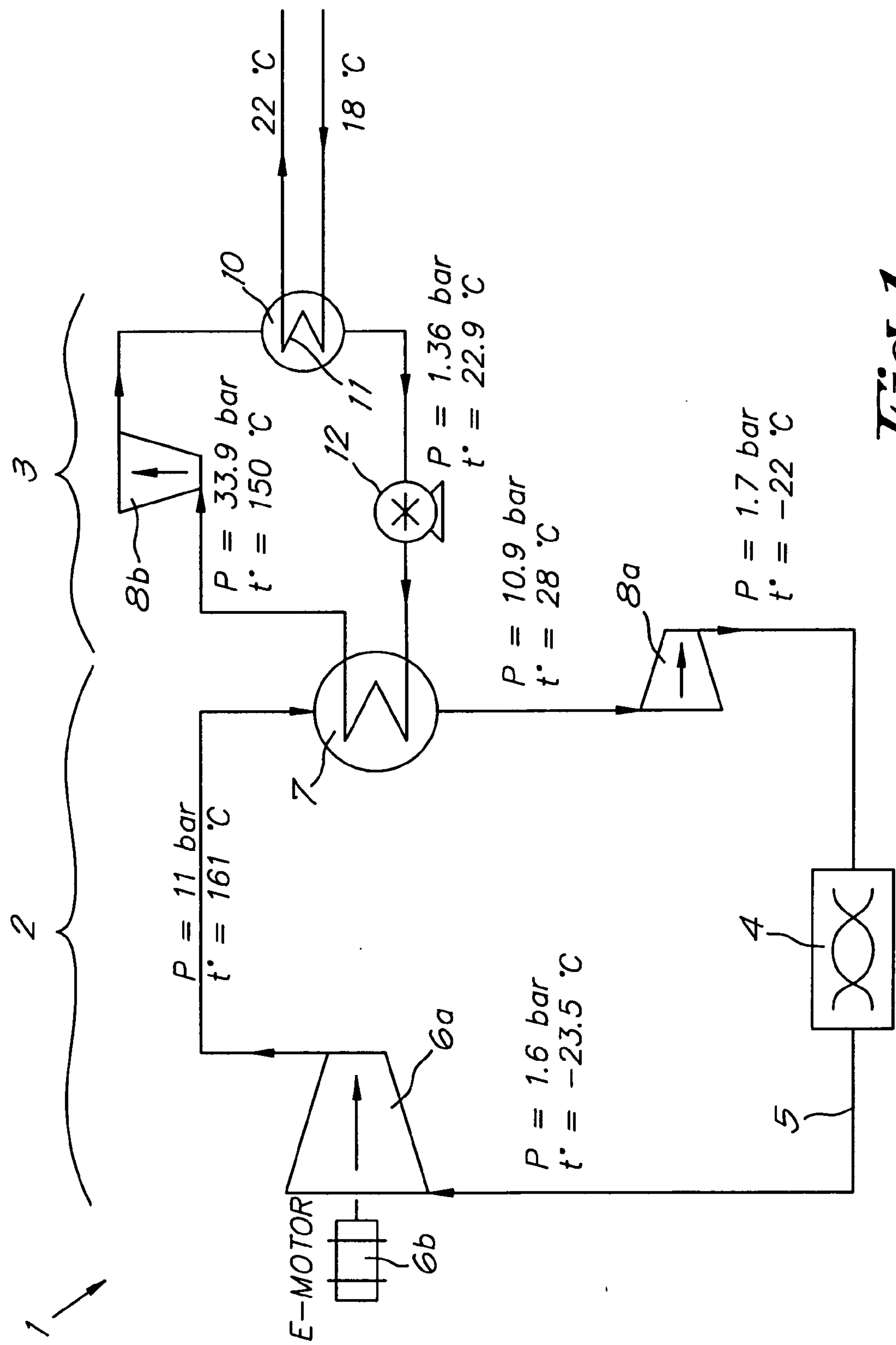
22 °C
18 °C
10
11
12
P = 1.36 bar
t° = 22.9 °C
3
8b
P = 33.9 bar
t° = 150 °C
P = 10.9 bar
t° = 28 °C
8a
P = 1.7 bar
t° = −22 °C
2
P = 11 bar
t° = 161 °C
7
4
5
6a
P = 1.6 bar
t° = −23.5 °C
E−MOTOR
6b
1

Fig.1