The present invention relates to a closed circuit operating according to a Rankine cycle, comprising a circulation and compression pump (12) for a working fluid in liquid form, a heat exchanger (20) swept by a hot source (22) for evaporation of said fluid, expansion means (28) for expanding the fluid in vapour form and a cooling exchanger (32) for condensation of this fluid, traversed by a cooling fluid between an inlet face (38) and an outlet face (40).

According to the invention, this circuit comprises thermopiles (44) for capturing and converting (42) the calorific energy coming from cooling exchanger (32) to electric energy and said thermopiles are arranged in the heated cooling fluid stream coming from outlet face (40) of the cooling exchanger.
CLOSED CIRCUIT OPERATING ACCORDING TO A RANKINE CYCLE AND METHOD USING SAME

FIELD OF THE INVENTION

[0001] The present invention relates to a closed circuit operating according to a Rankine cycle.

[0002] It more particularly relates to such a circuit with a device allowing the caloric energy coming from this circuit to be recovered and converted to another energy.

[0003] As it is well known, a Rankine cycle is a closed-circuit thermodynamic cycle whose specific feature is to involve a (liquid/vapour) phase change of a working fluid.

[0004] This cycle is generally broken down into a stage wherein the working fluid used, generally water in liquid form, is compressed in an isentropic manner, followed by a stage where this compressed liquid water is heated and vaporized on contact with a source of heat. This water vapour is then expanded, in another stage, in an isentropic manner in an expansion machine, then, in a last stage, this expanded vapour is cooled and condensed on contact with a cold source.

[0005] To carry out these various stages, the circuit comprises a compressor for compressing the water in liquid form, an evaporator that is swept by a hot fluid for at least partial vaporization of the compressed water, an expansion machine for expanding the vapour, such as a turbine that converts the energy of this vapour into another energy such as a mechanical or electric energy, and a condenser by means of which the heat contained in the vapour is yielded to a cold source, generally outside air that sweeps this condenser so as to convert this vapour into water in liquid form.

BACKGROUND OF THE INVENTION

[0006] It is also well known, notably through document FR-2,884,555, to use the caloric energy conveyed by the exhaust gas of internal-combustion engines, in particular those used for motor vehicles, as the hot source providing heating and vaporization of the fluid flowing through the evaporator.

[0007] This allows to improve the energy efficiency of this engine by recovering a large part of the energy lost at the exhaust in order to convert it to an energy that can be used for the motor vehicle through the Rankine cycle circuit.

[0008] Furthermore, in this circuit, the heat contained in the water vapour is yielded to the outside air that sweeps the condenser so as to convert this vapour to water in liquid form. During this exchange, the water vapour yields calorific thermal energy to this air, and this hot air is then directly discharged to the atmosphere.

[0009] A large amount of caloric energy is therefore lost whereas it could be used advisedly.

[0010] Document U.S. Pat. No. 6,367,261 discloses an electric power plant comprising a condenser traversed by water vapour under pressure and swept by a cooling fluid coming from a cooling tower. This condenser comprises tubes on which thermoelectric modules for recovering the heat of the water vapour and converting it to electric energy are arranged.

[0011] The major drawback of this device is that a great temperature difference is required for this conversion to be achieved. The temperature and the pressure of the water vapour at the condenser inlet therefore have to be raised, but to the detriment of the efficiency of the steam turbine this power plant is provided with.

[0012] The present invention aims to overcome the aforementioned drawbacks by means of a circuit and of a method allowing to recover all or a major part of the caloric energy so as to convert it to a readily usable energy such as electric energy, without decreasing the overall performance of the circuit.

SUMMARY OF THE INVENTION

[0013] The present invention therefore relates to a closed circuit operating according to a Rankine cycle, comprising a circulation and compression pump for a working fluid in liquid form, a heat exchanger swept by a hot source for evaporation of said fluid, expansion means for expanding the fluid in vapour form and a cooling exchanger for condensation of this fluid, traversed by a cooling fluid between an inlet face and an outlet face, characterized in that it comprises thermopiles for capturing and converting the caloric energy coming from the cooling exchanger to electric energy and said thermopiles are arranged in the heated cooling fluid stream coming from the outlet face of the cooling exchanger.

[0014] The thermopiles can be arranged on the outlet face of the cooling exchanger.

[0015] The cooling fluid can be air or water.

[0016] The hot source can come from the exhaust gas of an internal-combustion engine.

[0017] The invention also relates to a method using a closed circuit operating according to a Rankine cycle, said circuit comprising a circulation and compression pump for a working fluid in liquid form, a heat exchanger swept by a hot source for evaporation of said fluid, expansion means for expanding the fluid in vapour form and a cooling exchanger swept by a cooling fluid between the inlet face and the outlet face thereof for condensation of this fluid, characterized in that it consists, during operation of the circuit, in capturing, by means of thermopiles arranged in the heated cooling fluid stream coming from the outlet face of the cooling exchanger, the caloric energy coming from said exchanger so as to convert it to electric energy.

[0018] The method can consist in using the caloric energy of the exhaust gas of an internal-combustion engine for the hot source sweeping the heat exchanger.

BRIEF DESCRIPTION OF THE SOLE FIGURE

[0019] Other features and advantages of the invention will be clear from reading the description hereafter, given by way of non-limitative example, with reference to the sole FIGURE showing a device for recovering the caloric energy coming from a closed circuit operating according to a Rankine cycle.

DETAILED DESCRIPTION

[0020] In the sole FIGURE, Rankine cycle closed circuit 10 comprises a circulation and compression means 12 for a working fluid, water here, circulating clockwise (arrows A) in this circuit. This means, referred to as compressor in the rest of the description, allows to compress this water between an inlet 14 and an outlet 16 where this water, still in liquid form, is at high pressure.

[0021] This compressor is advantageously driven in rotation by any known means such as an electric motor 18.
This circuit also comprises a heat exchanger 20, referred to as evaporator, traversed by the compressed water that flows out in form of compressed vapour.

This evaporator is swept by a hot source 22 coming from the exhaust gas circulating in exhaust line 24 of an internal-combustion engine 26.

Advantageously, this engine is an internal-combustion engine of a motor vehicle.

This circuit also comprises an expansion machine 28, or expander, receiving at the intake thereof the high-pressure compressed water vapour, which flows out in form of low-pressure expanded vapour.

By way of example, this expander is an expansion turbine whose rotor (not shown) is driven in rotation by the water vapour. This rotor is advantageously connected to any known device allowing to convert the mechanical energy recovered to another energy, such as an electric generator 30 for example.

The circuit also comprises a cooling exchanger 32, referred to as condenser in the rest of the description, with an inlet 34 for the expanded low-pressure vapour and an outlet 36 for the vapour converted to water in liquid form after passing through this condenser. The condenser is here, by way of example, a finned tube type exchanger wherein the vapour circulates in the tubes and wherein a cooling fluid sweeps the tubes and the fins. Advantageously, this exchanger condenser forms a parallelepipedic assembly with an inlet face 38 opposite a cooling fluid Ff and an outlet face 40 where the heated cooling fluid is discharged from this condenser.

In the case of the example described, this cooling fluid is outside air at ambient temperature that flows through the condenser between inlet face 38 and outlet face 40 thereof by cooling the expanded vapour. This cooling has the effect of condensing the vapour and of converting it to a liquid at outlet 36 of this condenser. Thus, due to the thermal exchange between the vapour and the air, the latter captures the caloric energy contained in this vapour and ends at face 40 of the condenser in a hot air stream (shown in the FIGURE) by a multiplicity of arrows Fc.

Of course, any other cooling fluid such as water can be used for condensation of the vapour.

This circuit also comprises means 42 for converting the caloric energy supplied by the condenser. More particularly, these means allow to recover the caloric energy contained in the hot air stream and to convert it to another energy, such as mechanical or electric energy.

Advantageously, these conversion means comprise a succession of thermopiles 44 arranged in hot air stream Fc and allowing electric energy to be obtained from the caloric energy of the condenser.

More particularly, these thermopiles are arranged on outlet face 40 of the condenser or close thereto, without hindering the circulation of air between the inlet and outlet faces thereof.

Without departing from the scope of the invention, these thermopiles can be elements incorporated in the condenser or constituent elements of this condenser.

These thermopiles have the effect of converting in situ the heat they capture to electric energy, notably by Seebeck effect. This electric energy is then usable by means of electric conductors 46 connected to the thermopiles.

Fluid circulation lines 48, 50, 52 and 54 allow to connect successively the various elements of this circuit so that the working fluid circulates, in liquid or vapour form, in the direction shown by the arrows.

Thus, the assembly made up of circuit 10, with device 42 intended for caloric energy recovery and conversion to electric energy, and of internal-combustion engine 26 with its exhaust line 24 equips advantageously a motor vehicle.

During operation, the water circulates in the circuit in a clockwise motion considering the FIGURE (arrows A) under the effect of compressor 12 driven in rotation by its electric motor 18.

In this configuration, the water leaves compressor 12 in compressed liquid water form at a pressure of the order of 10 bars and a temperature close to 30°C. This compressed water circulates in line 48 and ends in evaporator 20. This compressed water flows through evaporator 20 and leaves this evaporator in form of high-pressure compressed vapour, at a temperature of about 300°C. This vaporization is achieved under the effect of the heat coming from the exhaust gas of engine 26 sweeping the evaporator. The water vapour then flows through expander 28 while transmitting thereto the energy it contains, this energy being used for driving generator 30. The expanded water vapour leaving this expander flows through condenser 32 which leaves it in liquid water form. This liquid water is then brought through line 54 to compressor 12 in order to be compressed.

When passing through the condenser, the vapour is at about 100°C. at inlet 34 and it flows out through outlet 36 for a large part in liquid form at a temperature of 30°C. During this passage, the calories contained in the vapour have been captured by the cold air (arrow Ff) that sweeps the condenser between inlet face 32 and outlet face 40 thereof. This air warms up as it progresses in the condenser so as to reach outlet face 40 in form of an air stream Fc heated by the vapour.

Due to the presence of thermopiles 44, the hot air (arrows Fc) flows through these thermopiles by yielding thereto a large part of its caloric energy and it ends, after flowing therethrough, in an air stream Fc' that is at a lower temperature than hot air stream Fc.

The heat thus captured is then converted to electric energy by these thermopiles.

This electric energy is conveyed by conductors 46 to any device using current, such as batteries or motor vehicle accessories.

It can be noted that the water vapour that enters the condenser is at a nearly invariable temperature (of the order of some degrees around 100°C.). This allows to use thermopiles with a maximum efficiency zone within a narrow hot air temperature range.

1. A closed circuit operating according to a Rankine cycle, comprising a circulation and compression pump for a working fluid in liquid form, a heat exchanger swept by a hot source for evaporation of said fluid, expansion means for expanding the fluid in vapour form and a cooling exchanger for condensation of this fluid, traversed by a cooling fluid between an inlet face and an outlet face, characterized in that it comprises thermopiles for capturing and converting the caloric energy coming from cooling exchanger to electric energy and that said thermopiles are arranged in the heated cooling fluid stream coming from outlet face of the cooling exchanger.
2. A circuit as claimed in claim 1, characterized in that thermopiles are arranged on outlet face of the cooling exchanger.

3. A circuit as claimed in claim 1, characterized in that the cooling fluid is air.

4. A circuit as claimed in claim 1, characterized in that the cooling fluid is water.

5. A circuit as claimed in claim 1, characterized in that hot source comes from the exhaust gas of an internal-combustion engine.

6. A method using a closed circuit operating according to a Rankine cycle, said circuit comprising a circulation and compression pump for a working fluid in liquid form, a heat exchanger swept by a hot source for evaporation of said fluid, expansion means for expanding the fluid in vapour form and a cooling exchanger swept by a cooling fluid between inlet face and outlet face thereof for condensation of this fluid, characterized in that it consists, during operation of the circuit, in capturing, by means of thermopiles arranged in the heated cooling fluid stream coming from outlet face of the cooling exchanger, the calorific energy coming from said exchanger so as to convert it to electric energy.

7. A method as claimed in claim 6, characterized in that it consists in using the calorific energy of the exhaust gas of an internal-combustion engine for the hot source sweeping heat exchanger.

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