

Description

Title of Invention : Method and Apparatus for increasing the efficiency of the Cogeneration Power Plant by the Heat pump principle utilization for increasing the coolant inlet temperature

Technical Field

[0001] The main object of the invention relates to the methods and apparatus for increasing the heating/cooling power of the cogeneration and/or tri-generation power plants by employing the heat pump principle for exploiting the available renewable low temperature heat sources (i.e. from ambient/ground), wherein the heat generated by the heat pump principle utilization is preferably used for preheating, more particularly, for increasing the temperature of the heat transfer medium in the return line of the heat distribution network (i.e. district heating).

Background Art

[0002] Heat pumps that have been used in prior art to enhance the heating power of combined heat and power systems by utilizing the waste heat recovery and renewable heat sources exists in a number of designs. The solution according to the US20100003552 discloses a fuel cell with incorporated heat pump for fuel cell waste heat source (i.e. exhaust gas) utilization, where the key defect of the proposed solution is that the waste heat generated by the fuel cell is used for heat pump principle utilization, hence the COP of the heat pump is due to high temperatures of the heat transfer medium relatively poor in comparison to herein disclosed solution. It is important to notice, that the heat pump in US20100003552 is used to upgrade the heat of the fuel cell to the required temperature level of the heat transfer medium, wherein in contrast, herein disclosed solution uses the renewable heat sources from surrounding ambient for heat pump principle utilization, wherein the target temperature is achieved by utilization of the primary heat releasing unit/source (i.e. the fuel cell waste heat source at high-temperature heat level). In addition, the state of the art further comprises many other solutions, like EP2299098, DE2009002103, and US20060059911.

[0003] The solution according to the EP2299098 discloses a system for gas or liquid fuel driven cogeneration with incorporated heat pump for waste heat source utilization, wherein EP2299098 does not teach or discloses any hint which could lead skilled person from the art to introduce the heat, generated by the heat pump to the return line of the heat distribution circuit with aim to increase the overall efficiency of the power conversion and COP of the heat pump.

[0004] Similarly, solution according to the US20060059911 comprises a cogeneration unit with incorporated heat pump for renewable heat source utilization, wherein the heat generated by the heat pump is in contrast to herein disclosed solution not used to upgrade the heat and to increase the temperature of the heat transfer medium in return line of heat distribution circuit with an aim to increase the inlet temperature of the coolant medium to its maximum allowed value, but just to introduce the upgraded heat of renewable source (i.e. ground loops) to the storage tank as the heat source for the heat distribution circuit, hence the COP and overall efficiency of disclosed solution is substantially lower than for herein disclosed solution. Again, there is no hint which could lead skilled person from the art to realize herein disclosed solution.

Summary of Invention

[0005] Cogeneration and trigeneration systems, heat pumps, gas turbines, generators, and heat or internal or external combustion engines are well-known processes for converting the primary energy into mechanical or electrical energy into heat, and therefore the operation of these processes are not broadly explained under this patent application. Similarly, cogeneration systems of fuel cells stacks for the conversion of the primary energy source into electricity in heat and heat pumps used for pumping heat from a lower to higher temperature level are well-known technical solutions from state of the art, and therefore the operation of these procedures and processes is not broadly explained in the context of this patent application as well.

[0006] The apparatus according to the invention is preferably a cogeneration or trigeneration system assembly comprising at least one heat engine (i.e.: fuel cell,

internal combustion engine or external combustion engine, etc.) wherein its waste heat during device operation is preferably collected by heat exchangers, thus reused and transferred from its cooling and/or exhaust system to the closed loop circuit comprising heat transfer medium for transferring the heat within the piping network. Said closed loop circuit shall be considered as a heat distribution network being part of a partial house, central heating, district heating, or said network is a part of the installation for a vehicle, truck, or a vessel. Similarly, said heat transfer medium is preferably in a liquid state (i.e. water, a mix of water and glycol) wherein the heat is transferred throughout the piping network by heat transfer medium circulation. For easier understanding, the heat source of cogeneration/trigeneration (i.e. cooling/exhaust system) shall be considered as a primary heat releasing unit/source of the power plant, which is essentially used for heating the heat transfer medium in the heat distribution network to the required temperature level. In addition, device according to the invention further comprises at least one, preferably water source/type heat pump for renewable and waste heat source utilization, wherein at least a portion of the heat, generated by said heat pump, is used to increase the temperature of the heat transfer medium in the return line of said head distribution network to its maximum allowed value, where threshold and set-point values shall be defined in accordance with the specifications for components, provided by a manufacturer (i.e. – maximum allowed inlet temperature of the coolant (heat transfer medium) for internal combustion engine, fuel cell, ...). It can be understood, that heat generated by the heat pump in function of a secondary (i.e. auxiliary) heat releasing source is preferably used to reach and maintain the inlet temperature of the heat transfer medium in the return line oh heat distribution network at maximum possible temperature level, hence to achieve and utilize a best possible COP and overall system efficiency from energy harvesting point of view.

[0007] For heat pump principle utilization (i.e. liquid-vapor phase change cycle utilization) a single stage or two-stage heat pump is incorporated into the cogeneration assembly, or employed as a standalone sub-component of the power plant. In preferential embodiment, at least one renewable heat source is used for liquid-vapor phase change cycle utilization for heat pump principle employment, wherein advanced embodiments shall harvest all available heat sources, including

waste heat sources of the power plant (i.e.: exhaust gas, oil cooling system; charging air,) and from surrounding ambient/space (i.e. air, earth/ground heat, geothermal, groundwater, rivers, lakes or standing waters, geothermal waters, etc.).

[0008] In the continuation, the essence of the invention is described in more detail with the help of the accompanying drawings and with an explanation of the preferred and alternative embodiments.

[0009]

Technical Problem

[0010] The technical problem addressed in this patent application is the lack of a method and apparatus for increasing the overall efficiency of the power plants (i.e. cogeneration/trigeneration power plants), wherein none of the known solutions from prior doesn't disclose or give any hint for utilization of the heat generated by the incorporated heat pump for increasing the temperature of the primary heat transfer medium in the return line of the heat transfer medium distribution network (i.e. preheating the coolant in the supply line of said cooling system for the primary heat releasing unit to its maximum allowed inlet temperature). Cogeneration and/or tri-generation power plants known from prior art comprises a primary heat releasing unit, comprising a heat engine, fuel cell, internal combustion engine or external combustion engine, which is essentially used for heating the heat transfer medium to the required temperature level of the target heat distribution network, but none of known solutions does not give any hint which would lead the skilled person to use the heat pump principle with renewable heat source utilization for increasing the coolant inlet temperature, wherein the heat generated by the heat pump principle utilization is preferably introduced in the return line of the heat distribution network and used for increasing the temperature of the coolant of cooling system for said primary heat releasing unit to its maximum allowed value (i.e. maximum allowed inlet temperature of coolant for the cooling system of internal combustion engine, fuel cell, etc.).

Solution to Problem

[0011] Cogeneration and trigeneration systems, heat pumps, gas turbines, generators, and heat or internal or external combustion engines are well-known processes for converting the primary energy into mechanical or electrical energy into heat, and therefore the operation of these processes under this patent application are not broadly explained. Similarly, cogeneration systems on fuel cells for the conversion of the primary energy source into electricity in heat and heat pumps used for pumping heat from a lower to higher temperature level are well-known technological procedures from state of the art, and therefore the operation of these procedures and processes is not broadly explained within the context and scope of this patent application.

[0012] The device according to the invention is preferably a cogeneration or trigeneration system assembly comprising at least one heat engine, fuel cell, internal combustion engine or external combustion engine, wherein its waste heat generated by device operation is preferably collected by heat exchangers, thus reused and transferred from its cooling and/or exhaust system to the closed loop circuit comprising heat transfer medium for transferring the heat within the piping network. Said closed loop circuit shall be preferably considered as a heat distribution network being part of a partial house, central heating, district heating, or said network is a sub-auxiliary component adapted to fit a vehicle, truck, or a vessel. Similarly, said heat transfer medium is preferably a liquid (i.e. water, a mix of water and glycol) wherein the heat is transferred through the piping network by heat transfer medium circulation. For easier understanding, the heat source of cogeneration/trigeneration (i.e. cooling/exhaust system) shall be considered as a primary heat source of the combined heat and power plant, which is essentially used to increase the temperature of at least one heat transfer medium in the heat distribution network to the required temperature level.

[0013] In addition, device according to the invention further comprises at least one, preferably water source/type heat pump for renewable and waste heat source utilization, wherein at least a portion of the heat, generated by said heat pump, is used to increase the temperature of the heat transfer medium in the return line of said head distribution network to its maximum allowed value, where threshold and

set-point values shall be aligned with the specifications for components, provided by individual manufacturer (i.e. – maximum allowed inlet temperature of the coolant (heat transfer medium) for internal combustion engine, fuel cell,...). It can be understood, that heat generated by the heat pump shall be considered as a secondary (i.e. back up) heat releasing source, which is preferably used to reach and maintain the inlet temperature of the coolant (i.e. heat transfer medium in the return line) at maximum possible temperature level, hence to achieve and utilize a best possible coefficient of performance (i.e. COP) and overall system efficiency from energy harvesting and power conversion point of view.

[0014] Apparatus according to the invention comprises at least one heat pump, further comprising a compressor, evaporator, expansion valve, condenser, and other sub-components from state of the art, wherein a single stage or two-stage heat pump is incorporated into the cogeneration assembly, or employed as a standalone sub-component of the power plant. In preferential embodiment, at least one low-temperature heat source of renewable energy is used for evaporation of said working medium in the process of heat pump principle utilization, wherein alternative embodiments shall harvest and exploit any of the available heat sources, including waste heat sources of the power plant, and heat sources from surrounding ambient/space (i.e. air, earth/ground heat, geothermal, groundwater, rivers, lakes or standing waters, geothermal waters, etc.).

Advantageous Effects of Invention

[0015] According to the invention the heat pump heats the cooling fluid downstream of the heat consumer (i.e. in the return line), wherein at least two advantages can be seen: the temperature at the return line is lower than at the supply line, so that the heat pump has to heat the fluid to lower temperatures (better COP). On the other hand, the control parameter is therefore the temperature of the cooling fluid at the entry of the cooling system for primary heat releasing unit (i.e. cooling system for internal combustion engine, fuel cell). This temperature is easier to control than the classic water temperature at the user (i.e. less fluctuation). It is therefore essential to notice, that at least a portion of the low-temperature heat available from ambient (i.e. ground water <10°C) is upgraded to the higher-temperature heat (i.e.: 60°C –

max. inlet coolant temperature) by the heat pump principle utilization, wherein generated heat is preferably introduced into the return line of the heat distribution network with aim to increase the inlet temperature of the coolant for cooling system of the primary heat source auxiliaries (i.e. fuel cell cooling system) preferably up to the maximum allowed value, specified by auxiliary component manufacturer, thus substantially higher efficiency of overall power conversion is achieved. Similarly, it is important to notice as well from apparatus perspective point of view, that at least one outlet of the condenser unit of said heat pump is adapted to be associated with the inflow of the cooling system for at least one primary heat releasing unit (i.e. cooling system of the fuel cell, internal combustion engine, etc.).

Brief Description of Drawings

[0016] **Figure 1** shows a schematics of a preferred embodiment of the device according to the invention. There are shown and marked: fuel cell (FC), cogeneration of heat and power (CHP), heat exchanger (HE1, HE2), heat pump (HP) with associated condenser (HPC), evaporator (HPE), compressor (C) and expansion valve (EV), valve (V1), hatch (H1), pumps (PU1 to PU2), electric cable (EC), heat accumulator (HA), external environment - ambient (A), and pipes of a heat distribution network between heat sources and heat consumer (HC) (i.e. load).

[0017] **Figure 2** shows a schematics of a simplified embodiment of the device according to the Figure 1. There are shown and marked: fuel cell (FC), heat exchanger (HE1), heat pump (HP), hatch (H1), pumps (PU1 in PU2), electric cable (EC), heat accumulator (HA), ambient (A), renewable energy source (HS) and pipes of a heat distribution network between heat sources and heat consumer (HC).

[0018] **Figure 3** shows a schematics of an advanced embodiment of the device according to the invention. There are shown and marked: fuel cell (FC) with adapted heat exchangers (HE1 and HE2), heat pump (HP) with the associated condenser (HPC), evaporators (HPE and HPEX), compressor (C) with expansion valve (EV), hatches (H1, H2), pumps (PU1 - PU3), electrical cable (EC), heat accumulator (HA), ambient (A) and the heat distribution network between the heat sources and heat consumer (HC).

[0019] **Figure 4** shows a schematics of an another embodiment of the device according to the invention, similar to the one shown in Figure 1, wherein cogeneration of heat and power (CHP) assembly comprises an internal combustion engine (ICE). There are shown and marked: cogeneration of heat and power (CHP), internal combustion engine (ICE) with adapted cooling system (CS), generator (G) for production of electricity, heat exchangers (HE1, HE2), heat pump (HP) with associated condenser (HPC), evaporator (HPE1), compressor (C), expansion valve (EV), hatch (H1), pumps (PU1 to PU2), heat accumulator (HA) ambient (A), renewable energy source (HS) and pipes of a heat distribution network between heat sources and heat consumer (HC).

[0020] **Figure 5** shows a schematics of the advanced embodiment of the device according to the Figure 4. There are shown and marked: cogeneration of heat and power (CHP) assembly comprising an internal combustion engine (ICE) with adapted cooling system (CS) and heat exchangers (HE1, HE2), generator (G) for production of electricity, electric cable (EC), heat pump (HP), evaporators (HPE1 in HPE2), compressor (C), expansion valve (EV), hatches (H1 to H2), pumps (PU1 - PU3), heat accumulator (HA), ambient (A), a renewable energy source (HS) and pipes of a heat distribution network between heat sources and heat consumer (HC).

Description of Embodiments

[0021]

Examples

[0022] In preferential embodiment, the cogeneration of heat and power (CHP) assembly comprises at least one primary heat source (i.e. fuel cell (FC) or internal combustion engine (ICE)) with adapted heat exchangers (HE1, HE2) for waste heat (i.e. flue gas) recuperation, and at least one heat pump (HP) with adapted evaporator (HPE) for renewable energy source (HS) utilization. As can be read out from the Figure 1 and Figure 4, the waste heat of said primary heat source for the cogeneration of the heat and power (CHP) assembly is at least partially introduced into the heat distribution network by heat exchangers (HE1, HE2), wherein the high-temperature heat of the flue gas is introduced into the supply line of the heat

distribution network by the first heat exchanger (HE1) (i.e. the temperature of the flue gas is reduced below 140°C), and similarly, the second heat exchanger (HE2) is preferably adapted to utilize the residual, low-temperature heat, by reducing the temperature of the flue gas as low as possible (preferably <35°C), wherein collected low-temperature heat is due to its low temperature level preferably introduced to the return line of said heat distribution network. It can be understood, that solution according to herein disclosed invention may comprise only one heat exchanger, as represented in Figure 2, or as an alternative, the heat distribution network may comprise a plurality of heat exchangers in serial, parallel or cascade connection. Thus, said low-temperature waste heat can be directly utilized and transferred to said heat distribution network if and until there exists a sufficient temperature difference for heat flux principle utilization (i.e. convection, conduction,), thus said heat distribution network may comprise plurality of bypass connections, like shown on Figures 1-5 (control valve/hatches (H1, H2) for flue gas volume flow manipulation), or like shown on the Figure 1 (control valve (V1) for heat transfer medium manipulation). However, it can be understood, that the mass/volume flow of any heat transfer medium in said heat distribution network can be successfully controlled and automatized by other means, like motorized control valves, sensors, pumps (PU1-PU3), etc..

[0023] As follows, the cogeneration of heat and power (CHP) assembly with incorporated means for flue gas waste heat source utilization (i.e. heat exchangers (HE1, HE2)) represents the primary heat releasing unit/source of the power plant, wherein other heat sources involved with the power plant (i.e. internal combustion engine (ICE) cooling system (CS)) are considered as part of the primary heat releasing unit/source as well.

[0024] As partially known from prior art, a cogeneration of heat and power (CHP) assembly may comprise a heat pump (HP) to increase the overall efficiency of available heat sources utilization, wherein said heat pump (HP) comprises at least one evaporator (HPE), adapted to receive the heat from at least one renewable heat source (HS), wherein received heat is upgraded to the higher temperatures (i.e.: 60°C) by heat pump principle utilization, and at least partially transferred to the heat distribution network. It is essential to notice, that the heat, generated by

the heat pump (HP) according to herein disclosed invention is preferably introduced to the return line of the heat distribution network (i.e. supply line from individual cooling system of primary heat source perspective point of view), and furthermore, the heat generated by the heat pump (HP) is preferably used to reach and maintain the maximum allowed inlet temperature for the cogeneration of heat and power (CHP) assembly auxiliaries components (i.e. maximum coolant inlet temperature for fuel cell (FC) cooling system; maximum coolant inlet temperature for internal combustion engine (ICE) cooling system (CS)), wherein the target set-point and threshold values has to be aligned and approved by auxiliary component manufacturer.

[0025] It is important to notice, that herein disclosed solution utilizes the heat pump principle for upgrading the low-temperature heat of available renewable heat sources (HS) from an ambient (A) (i.e. air, earth/ground heat, geothermal, groundwater, rivers, lakes or standing waters, geothermal waters, etc.) to the appropriate set-point target value, specified for the target cooling system for cogeneration of heat and power (CHP) assembly auxiliaries. As follows, the inlet temperature of the coolant for cooling system of at least one primary heat releasing unit is increased to its maximum allowed or reasonable value, at least when a power plant is operating at full load capacity.

[0026] According to the Figure 3 and Figure 5, at least a portion of the residual heat from cogeneration of heat and power (CHP) assembly (i.e. heat exchanger (HE2)) is used for vaporization of the working medium in the heat pump (HP) principle utilization. As follows, heat pump (HP) may comprise a plurality of evaporators (HPE1, HPE2) and/or condensers (HPC) for utilization of single or multiple, low-temperature waste and renewable heat sources (HS), wherein the heat upgraded by a heat pump (HP) principle utilization is still preferably used for preheating the coolant (i.e. heat transfer medium in the return line of heat distribution network) for cogeneration of heat and power (CHP) assembly auxiliaries (i.e. cooling system (CS)), up to its maximum allowed inlet temperature, as already explained before. Since the one of the main objectives of the method according to the invention is to introduce the heat, generated by the heat pump principle utilization to the return line of the heat distribution network (i.e. a supply line of the coolant for fuel cell (FC))

or internal combustion engine (ICE) cooling system (CS)), at least one of the heat pump (HP) condenser (HPC) is adapted to transfer the heat generated by the heat pump (HP) principle utilization to the return line of the heat distribution network.

[0027] For sake of easier understanding, the following details of sub-components for proposed solution are described shortly.

[0028] Apparatus according to the invention may comprise any type of a fuel cell (FC) in any range of nominal power including micro cogeneration plant dimensioned for nominal power under 10k, wherein complex embodiment of proposed solution may comprise plurality of fuel cell (FC) stack units in parallel, serial or cascade connection, or any combination thereof. As alternative, or as in addition to the fuel cell, the cogeneration of heat and power (CHP) assembly may comprise plurality of internal/external combustion engines (i.e.: Diesel engine, Sterling engine, etc.), wherein each may further comprise electric power generator (G), hence generated electric power may be in full or in part used for propulsion of the cogeneration of heat and power (CHP) assembly, including the compressor (C) of the heat pump (HP), and other auxiliaries of the apparatus according to the invention.

[0029] The individual unit of the primary heat source (i.e. fuel cell (FC); internal combustion engine (ICE)) may run on hydrogen, natural gas, biogas, methanol, dimethyl-ether, liquefied petroleum gas, gasoline, petrol, diesel, biodiesel or any other fuel, well known from state of the art. The apparatus according to the invention further comprises a heat accumulator (HA) for compensation of the heat demand of consumers (HC) and equalization of heat requirement peak demands designed for the target heat distribution network. Heat exchangers for waste heat source and/or renewable heat source (HS) utilization may comprise and type of heat exchangers well known from state of the art, wherein in case of utilization of condensing type heat exchanger apparatus shall further comprise additional means for waste flue gas condensate neutralization, deionizer, etc.. It can be understood, that disclosed method of increasing the efficiency of energy conversion can be adapted to any stationary or mobile applications, including ships, planes and other vehicles for means of transportation, wherein the heat consumer (HC) may be any auxiliary component of the target application (i.e. low-temperature or high-temperature district heating; HVAC, etc.). Said compressor (C) is preferably

powered by electric energy provided by generator (G) or fuel cell (FC), wherein in another embodiment said compressor shall be powered by and other available mechanical or electric source of power (i.e.: generator (G) driven by mechanical connection with internal combustion engine (ICE), electricity from grid, etc.). Said heat distribution network shall comprise a single or multiple loop heat transfer connection, which shall comprise a single or plurality of open loop connections (i.e.: sanitary hot water preparation) for heat distribution as well. As follows, heat distribution network shall comprise one or plurality of heat transfer mediums in liquid or gas aggregate state/condition (i.e.: preferable heat transfer medium in heat distribution network is water; preferable heat transfer medium for internal combustion engine (ICE) and its heat exchanger/cooling system (CS) is mix of water and glycol, etc.).

[0030] One skilled from the art can understand, that herein disclosed apparatus and method of increasing the efficiency of power conversion are in complete or in part operable in reverse direction, hence in case of operating the heat pump in reversible mode, the apparatus disclosed provides a heating and cooling mode of operation. As can be clearly seen from Figures 1-5, the heat pump principle utilization in reverse mode of operation provides a cooling power for heat consumer (HC) (i.e. district cooling; cooling system of the vehicle; HVAC; etc.), wherein the waste heat management of the apparatus auxiliaries has to provide a necessary backup cooling capacity of the cooling system (CS) for sustainable and stable operation of the device in any circumstances and under prescribed conditions. It can be understood, that apparatus according to disclosed invention may comprise single or plurality of its subcomponents (i.e.; fuel cell (FC), internal combustion engine (ICE), heat pump (HP), heat exchangers (HE), heat consumers (HC), etc.) in serial, parallel or cascade connection, wherein it is essential to notice, that at least one of included heat pump (HP) is used for renewable heat source (HS) utilization, wherein at least a portion of the upgraded heat generated by heat pump principle utilization is used to reach and sustain a maximum allowed inlet temperature of the cooling medium for apparatus auxiliary components of the apparatus (i.e. Fuel cell inlet temperature; cooling system (CS) inlet temperature, etc.). Thus, at least one of the heat pump (HP) condenser (HPC) is adapted to be coupled to the supply line of at least one of the primary heat source cooling system

(CS) in said heat distribution network with an aim to increase the inlet temperature of the coolant for the fuel cell (FC) (or internal/external combustion engine cooling system (CS) to its maximum allowed temperature (i.e. set point at maximum coolant inlet temperature with optional threshold value with optional different operating regime; max performance; max power; max. efficiency; min. operating costs; etc.).

[0031] All of the previously mentioned is initially described in the case of cogeneration of heat and electricity in the distribution network of high temperature or low temperature heating, whereby the described device and method without significant changes are also applicable to other mobile and stationary facilities, such as, for example, vehicles, vessels, dryers, industrial processes, greenhouses, etc..

Industrial Applicability

[0032] As can be read out from disclosed description, a method of improving the overall efficiency of power conversion by adopting the heat pump (HP) principle for a waste heat source and renewable heat source utilization comprises the following steps, which represents the key features of a method of using the apparatus according to the invention:

[0033] A fuel combustion process, where a cooling system (i.e. heat exchanger) of at least one primary heat source unit (i.e. fuel cell (FC), internal combustion engine (ICE), etc.) is used to collect the waste heat and to provide a primary heat releasing unit for heating at least one heat transfer medium in said heat distribution network, wherein at least one waste heat source arise when said primary heat releasing source/unit is turned on and operating by firing the fuel in the combustion or other exothermic process. Accordingly, plurality of heat releasing units with individual cooling systems in parallel, serial or cascade connection shall be used to provide an advanced embodiment of the primary heat releasing unit.

[0034] A renewable heat utilization process comprises a process of collecting the heat of at least one low-temperature heat source from an ambient (A), wherein at least one heat exchanger is used to collect at least a portion of available heat of

source from group of renewable heat sources comprising: surrounding air, earth/ground heat, geothermal heat, groundwater, rivers, lakes, and standing waters. Accordingly, plurality of heat exchangers in parallel, serial or cascade connection shall be used to provide an advanced apparatus for renewable heat harvesting process utilization.

[0035] A waste heat recovery process comprises a process of collecting the waste heat, wherein at least one waste heat recovery unit (i.e. heat exchanger) is used to collect at least a portion of the heat of at least one waste heat source from group of waste heat sources comprising: a flue gas in exhaust system, charging air of charging air cooling system or lubrication oil in lubrication oil cooling system. Accordingly, plurality of waste heat recovery units in parallel or serial connection shall be used to provide an advanced apparatus for waste heat recovery process utilization.

[0036] A liquid-vapor phase change thermodynamic cycle utilization process, wherein at least one heat pump (HP) shall be used to provide a secondary heat releasing unit for heating at least one heat transfer medium in said heat distribution network, at least when said heat pump (HP) is turned on and operating. Accordingly, plurality of heat pumps (HP) units in parallel, serial or cascade connection is used to provide an advanced edition of the secondary heat releasing unit.

[0037] Usage of collected heat for liquid-vapor phase change utilization, wherein at least a portion of collected heat is used for the liquid-vapor phase change cycle utilization and wherein at least a portion of the heat generated by at least one heat pump (HP) in of the secondary heat releasing unit is used for increasing the temperature of the coolant (i.e. heat transfer medium) for cooling system of at least one primary heat releasing unit, preferably up to its maximum allowed inlet value.

[0038] Distribution of the heat in at least one closed loop circuit of said heat distribution network by circulation of at least one heat transfer medium, wherein the temperature of the heat distribution medium for cooling system of at least one primary heat releasing unit is substantially higher than the lowest temperature of the heat distribution medium in at least one heat consumer (HC). Hence, at least

a portion of the heat upgraded by a heat pump principle utilization is introduced to the return line of said heat distribution network, thus the inlet temperature of the heat transfer medium (i.e. coolant) for cooling the primary heat releasing unit is substantially higher than 35°C, at least when a design temperature of the heat distribution network is reached and said internal combustion engine (ICE) and heat pump (HP) are operating at full load.

[0039] In addition to represented method of using the apparatus according to the invention, few explanations and definitions are required, wherein combustion process is substantially a continuous process, while individual unit of said primary heat releasing unit normally operates in the range between its minimum and maximum rated operating power, preferably at nominal rated power in continuous operation. Similarly the liquid-vapor phase change thermodynamic cycle utilization process is substantially a continuous process, wherein said heat pump (HP) operates in the range between its minimum and maximum rated operating power, preferably at nominal rated power in continuous operation. If appropriate, the fuel combustion process in complex (i.e. advanced) heat and power cogeneration plant shall be provided by plurality of primary heat releasing units (i.e. fuel cells (CF), internal combustion engine (ICE), etc.), wherein the heat between individual units in the scope of heat distribution network is transferred in serial, parallel, or cascade connection with aim to transfer the heat between individual engine cooling systems. Similarly, the liquid-vapor phase change thermodynamic cycle utilization process shall be utilized by plurality of heat pump (HP) units to provide a secondary heat releasing unit for advanced large scale heat and power cogeneration plants (i.e. sized >1MW).

[0040] While one of the key features of method and apparatus according to the invention is establishment of predetermined set point value for individual primary heat releasing unit coolant temperature, the thermal energy balance adjustment is executed by adapting the power of said secondary heat releasing unit (i.e.: heat pump (HP)) and/or by adapting the power of individual unit of the primary heat releasing units (i.e. fuel cell (FC)), and/or by adapting the mass flow of the primary heat transfer medium through the cooling system of individual unit of said primary heat releasing unit, and/or by adapting the mass flow of the primary heat transfer

medium through the heat pump (HP) and/or by adapting the mass flow of the secondary heat transfer medium in at least one of the circuits for collecting the heat of at least one renewable or waste heat source. Accordingly the mass flow of the primary heat transfer medium in said heat distribution circuit is adapted by changing the flow velocity in said heat distribution circuit, and/or the mass flow of the secondary heat transfer medium in said closed loop circuit is adapted by changing the flow velocity in said closed loop circuit, wherein the velocity of heat transfer medium in heat distribution network is adapted by switching (i.e. on/off regulation) and/or by adjusting the power of at least one circulation pump for mass flow adjustment. Similarly the mass flow of the secondary heat transfer medium in said closed loop circuit for waste heat source utilization is adapted by stream flow regulation, wherein at least a portion of the secondary heat transfer medium stream is redirected in said closed loop circuit to provide a bypass connection for at least one waste heat recovery unit. Accordingly, the mass flow regulation of the primary heat transfer medium and/or the mass flow regulation of the secondary heat transfer medium for thermal energy balance adjustment is determined, controlled and executed by at least one control unit (i.e. electronic controller), wherein the position and/or the state (i.e. open/closed or on/off regulation) of the automated regulation means is adjusted in respect to the heat demand in said heat distribution network.

[0041] Apparatus according to the invention further comprises at least one control unit, wherein such a controller shall be autonomous device for thermal management regulation or alternatively, at least basic functions of the thermal management controller for determination process, comparison process and execution process could be incorporated and implemented to the main controller of the combined heat and power plant, or to any other subcomponents controller as well. In the determination process the environment and thermal conditions of heat distribution network is determined by the group of thermal, pressure or other sensors, wherein at least one input from at least one sensor of heat distribution network or internal combustion engine (ICE) is used for comparison process, where at least one value of at least one input parameter (i.e. preferably a temperature of the primary heat transfer medium in engine cooling system) is analyzed and compared to the limiting values, preferably being pre-defined and

stored in the control unit. Accordingly the execution process comprises a process of executing instructions stored in control unit to generate appropriate output signal, where at least one parameter for thermal energy balance adjustment is generated, executed and performed by control electronics in cooperation with automated regulation means in order to reach and maintain the threshold set-point value, wherein said threshold value is defined between the maximum value and the minimum value for set point equal value with aim to provide a hysteresis for thermal energy balance adjustment.

[0042] It can be understood that control unit (i.e. electronic module) may communicate with various output devices where the temperature of the heat transfer medium in the heat transfer network is determined, controlled and regulated by a group of automated regulation means comprising motorized valves, pumps and sensors, wherein regulation means are preferably adapted to be manipulated by at least one control unit. And furthermore, the heat distribution process in heat distribution network is provided by at least one heat transfer medium, preferably by plurality of heat distribution mediums (i.e. Figure 3 and figure 5). Accordingly the heat in said heat transfer network is transferred from primary heat releasing unit to the heat consumer (HC) by circulation of the primary heat transfer medium in at least one closed loop circuit, and similarly the heat from waste heat recovery unit is transferred to the heat pump (HP) by circulation of the secondary heat transfer medium in at least one closed loop circuit, wherein the heat upgraded by at least one heat pump (HP) is furthermore transferred from heat pump (HP) condenser unit to the primary heat transfer medium (i.e. increased coolant inlet temperature) and further upgraded in the cooling system of at least one primary heat releasing unit.

[0043] Summarizing, the renewable heat sources (HS) and the cooling circuits of cogeneration unit (CHP), herein represented as low temperature waste heat sources, are used for utilization of water source high temperature heat pump (HP), wherein its hot water output is preferably used for establishing and maintaining the highest possible or maximum allowed temperature of the primary heat transfer medium for individual primary heat releasing unit (i.e. fuel cell (FC), internal combustion engine (ICE), etc.) cooling system. It can be understood, that

all vital components of heat distribution circuit are preferably operably coupled for heat transfer medium circulation, wherein the compressor of the incorporated heat pump (HP) shall be driven by electric machine, powered by electricity from grid or generator (G), or alternatively if appropriate, a high temperature heat pumps (HP) compressor shall be mechanically coupled to and driven by internal combustion engine (ICE) as well. Furthermore, as can be clearly read out from previous description, the primary heat transfer medium in preferential embodiment is water and similarly, the secondary heat transfer medium in preferential embodiment is mix of water and glycol.

[0044] In the foregoing description those skilled in the art will readily appreciate that modifications may be made to the invention without departing from the concepts disclosed herein. Such modifications are to be considered as included in the following claims, unless these claims expressly state otherwise.

[0045]

[0046]

Reference Signs List

[0047]

Reference to Deposited Biological Material

[0048]

Sequence Listing Free Text

[0049]

Citation List

[0050]

Patent Literature

[0051] PTL1: US20100003552

[0052] PTL2: US20100003552

[0053] PTL3: EP2299098

[0054] PTL4: DE2009002103

[0055] PTL5: US20060059911

Non Patent Literature

[0056] NPL1:

Claims

[Claim 1] A method of using a heat and power generation apparatus for heating at least one heat consumer (HC) in a heat distribution network by adopting the principle of a heat pump (HP) principle utilization, the method comprising:

a fuel combustion process, wherein a cooling system (CS) of at least one primary heat source from group of a fuel cell (FC), internal combustion engine (ICE) and external combustion engine is used to provide a first heat releasing unit for heating at least one heat transfer medium in said heat distribution network, and wherein at least one waste heat source arise when said first heat releasing unit is turned on and operating by firing the fuel in the fuel combustion process;

a renewable heat utilization process, further comprising a process of collecting the heat of at least one heat source from an ambient (A), wherein at least one heat exchanger is used to collect at least a portion of available heat of renewable source from group of sources comprising: surrounding air, earth/ground heat, geothermal heat, groundwater, rivers, lakes, and standing waters,

a waste heat recovery process, wherein at least one waste heat recovery unit is used to collect at least a portion of the heat of at least one waste heat source from group of waste heat sources comprising a flue gas in exhaust system of said primary heat source, charging air or lubrication oil cooling system;

a liquid-vapor phase change thermodynamic cycle utilization process, wherein at least one heat pump (HP) is used to provide a secondary heat releasing unit for heating at least one heat transfer medium in said heat distribution network, at least when said heat pump (HP) is turned on and operating, **characterized in that**

the heat required for the liquid-vapor phase change cycle utilization is gained fully or in part by said renewable heat utilization process, wherein at least a portion of the heat collected in the renewable heat utilization process is used for liquid-vapor phase change thermodynamic cycle process utilization, and wherein at least a portion of the heat generated by at least one heat pump (HP) in the scope of the secondary heat releasing unit is used for heating the coolant of cooling system for at least one primary heat releasing unit;

the heat in at least one closed loop circuit of said heat distribution network is preferably distributed by circulation of at least one heat transfer medium, wherein the lowest temperature of the heat distribution medium in said cooling system of at least one primary heat releasing unit is substantially higher than the lowest temperature of the heat distribution medium in at least one heat consumer (HC) in the heat distribution network, hence at least one heat transfer medium in at least one return line of said heat distribution network is reheated by the heat pump (HP) principle utilization, and wherein the temperature of the heat transfer medium in said engine cooling system of at least one internal combustion engine (ICE) is substantially higher than 35°C, at least when a design temperature of the heat distribution network is reached and said primary and secondary heat releasing units are operating at full load.

[Claim 2] The method as in claim 1 **characterized in that**

the fuel combustion process is substantially a continuous process, wherein said primary heat releasing unit operates in the range between its minimum and maximum rated operating power, preferably at normal rated power in continuous operation;

the liquid-vapor phase change thermodynamic cycle utilization process is substantially a continuous process, wherein said heat pump (HP) operates

in the range between its minimum and maximum rated operating power, preferably at normal rated power in continuous operation;

the waste heat recovery process comprises a process of flue gas condensation, wherein collected is used for heat pump (HP) principle utilization and wherein the temperature of the flue gas is reduced below 23°C;

the waste heat recovery process is used for cooling principle utilization, wherein the heat recovery process is used for cooling the charging air for the fuel combustion process utilization;

the temperature of the heat transfer medium in the heat transfer network is determined, controlled and regulated by a group of automated regulation means comprising valves, pumps and sensors, wherein said regulation means are preferably adapted to be manipulated by at least one control unit.

[Claim 3] The method as in claim 2 **characterized in that**

the fuel combustion process is provided by plurality of primary heat sources comprising the group of the fuel cell (FC), internal combustion engine (ICE), external combustion engine, wherein the heat in the scope of the heat distribution network is transferred in serial and/or in parallel and/or in cascade connection in order to provide a first heat releasing unit;

the liquid-vapor phase change thermodynamic cycle utilization process is provided by plurality of heat pump (HP) units, wherein the heat in the scope of the heat distribution network is transferred in serial and/or parallel and/or cascade connection in order to provide the second heat releasing unit;

the heat distribution process in heat distribution network is provided by plurality of heat distribution mediums, wherein the heat in said heat transfer network is transferred from first heat releasing unit to the heat consumer

(HC) by circulation of primary heat transfer medium in at least one closed loop circuit, wherein the heat from waste heat recovery unit is transferred to the heat pump (HP) by circulation of the secondary heat transfer medium in at least one closed loop circuit, and wherein the heat upgraded by at least one heat pump (HP) is furthermore transferred to coolant of the cooling system for at least one primary heat releasing unit.

[Claim 4] The method as in claim 3 **characterized in that**

the temperature of the primary heat transfer medium in the engine cooling system of said internal combustion engine (ICE) is maintained at predetermined set point value, wherein thermal energy balance adjustment is executed by adapting the power of said heat pump (HP) and/or by adapting the power of said primary heat releasing unit and/or by adapting the mass flow of the primary heat transfer medium through the cooling system of said primary heat releasing unit and/or by adapting the mass flow of the primary heat transfer medium through the heat pump (HP) and/or by adapting the mass flow of the secondary heat transfer medium in said closed loop circuit for waste heat source utilization.

[Claim 5] The method as in claim 4 **characterized in that**

the mass flow of the primary heat transfer medium in said heat distribution circuit is adapted by changing the flow velocity in said heat distribution circuit and/or the mass flow of the secondary heat transfer medium in said closed loop circuit is adapted by changing the flow velocity in said closed loop circuit, wherein the velocity of heat transfer medium in heat distribution network is adapted by switching and/or by adjusting the power of at least one circulation pump.

[Claim 6] The method as in claim 4 **characterized in that**

the mass flow of the primary heat transfer medium in said heat distribution

circuit is adapted by stream flow regulation, wherein at least a portion of the primary heat transfer medium stream in the return line of said heat distribution circuit is redirected to the return line of said heat distribution circuit to provide a heat pump (HP) bypass connection, and/or wherein at least a portion of the primary heat transfer medium stream from said heat pump (HP) is redirected to a forward line of the heat distribution circuit to provide an engine cooling system bypass connection;

the mass flow of the secondary heat transfer medium in said closed loop circuit for waste heat source utilization is adapted by stream flow regulation, wherein at least a portion of the secondary heat transfer medium stream is redirected in said closed loop circuit to provide a bypass connection for at least one waste heat recovery unit.

[Claim 7] The method as in claim 5 and 6 **characterized in that**

the mass flow regulation of the primary heat transfer medium and/or the mass flow regulation of the secondary heat transfer medium for thermal energy balance adjustment is determined, controlled and executed by said control unit, wherein the position and/or the state of the automated regulation means is adjusted in respect to the heat demand in said heat distribution network, and wherein the method is applicable in reverse direction of operation for cooling mode operation.

[Claim 8] An apparatus assembly according to the invention comprising:

at least one cooling system of primary heat releasing unit from group of engines comprising: fuel cell (FC), internal combustion engine (ICE), external combustion engine, wherein individual primary heat releasing unit preferably comprises a cooling system, preferably heat exchanger with at least one inflow aperture and at least one outflow aperture;

at least one heat pump (HP), wherein said heat pump (HP) further comprises a lubrication oil cooling system, an evaporator unit and a condenser unit, wherein said condenser unit further comprises an inlet aperture and an outlet aperture, adapted to be associated with at least one heat distribution network, and wherein said evaporator unit further comprises at least one inflow aperture and at least one outflow aperture, adapted to be associated with at least one renewable heat source

characterized in that

said evaporator unit is adapted to be associated with at least one from group of renewable heat sources comprising: a surrounding air, an earth/ground heat, a geothermal heat, a groundwater, rivers, a lakes, and a standing waters;

said outlet of the condenser unit is adapted to be associated with said inflow of the primary heat releasing unit cooling system for transferring the heat of the condenser unit to the primary heat releasing unit cooling system by a primary heat transfer medium in a heat distribution network;

the inlet of said condenser unit and said outflow of the primary heat releasing unit cooling system are adapted to be associated with said heat distribution network, wherein said heat distribution network further comprises at least one thermal energy receiving unit, preferably a heat consumer (HC).

[Claim 9] The apparatus as in claim 8 **characterized in that**

said primary heat releasing unit further comprises at least one waste heat recovery unit, preferably a heat exchanger, adapted to be associated with said evaporator unit in a closed loop circuit.

[Claim 10] The apparatus as in claim 9 **characterized in that**

said heat distribution circuit comprises at least one forward line and at least one return line, wherein said forward line and return line interconnects the outflow of said primary heat releasing cooling system and inlet of said condenser unit via at least one heat consumer (HC), wherein said primary heat transfer medium circulate in said heat distribution circuit to transfer the heat of heat source to the heat consumer (HC);

said outflow of the primary heat releasing unit cooling system is operably coupled to the forward line of the heat distribution circuit;

said inlet of the condenser unit is operably coupled to at least one return line of heat distribution circuit;

said outlet of the condenser unit is operably coupled to the inflow of said engine cooling system wherein said heat distribution circuit comprises a primary heat transfer medium; and

said heat exchanger is incorporated to said primary heat releasing unit to receive at least a portion of the waste heat, wherein said heat exchanger is operably coupled to said evaporator unit in the closed loop circuit, wherein the heat collected in heat exchanger is transferred to the evaporator unit by heat transfer medium circulation in said closed loop circuit, and furthermore, the heat of said condenser unit is transferred to the primary heat releasing unit cooling system by heat transfer medium circulation in said head distribution circuit, wherein the temperature of said heat transfer medium at inflow of primary heat releasing unit cooling system is substantially higher than 35°C at least when the internal primary heat releasing unit and heat pump (HP) are turned on and powered at operating conditions.

[Claim 11] The apparatus as in claim 10 **characterized in that**

said heat distribution circuit comprises a plurality of the heat consumers (HC) in parallel connection and/or in serial and/or in cascade connection; said heat distribution circuit comprises a plurality of the heat pumps (HP) in parallel connection and/or in serial and/or in cascade connection, wherein closed loop circuit of said evaporator unit comprises a plurality of heat exchangers in parallel connection and/or in serial connection, and wherein at least one of the condenser unit outlet aperture is operably coupled to the inflow of said primary heat releasing unit (ICE) cooling system.

[Claim 12] The apparatus as in claim 11 **characterized in that**

said primary heat releasing unit is fuel cell (FC), adapted to transfer the waste heat to said heat distribution network.

[Claim 13] The apparatus as in claim 12 **characterized in that**

said fuel cell (FC) runs on hydrogen.

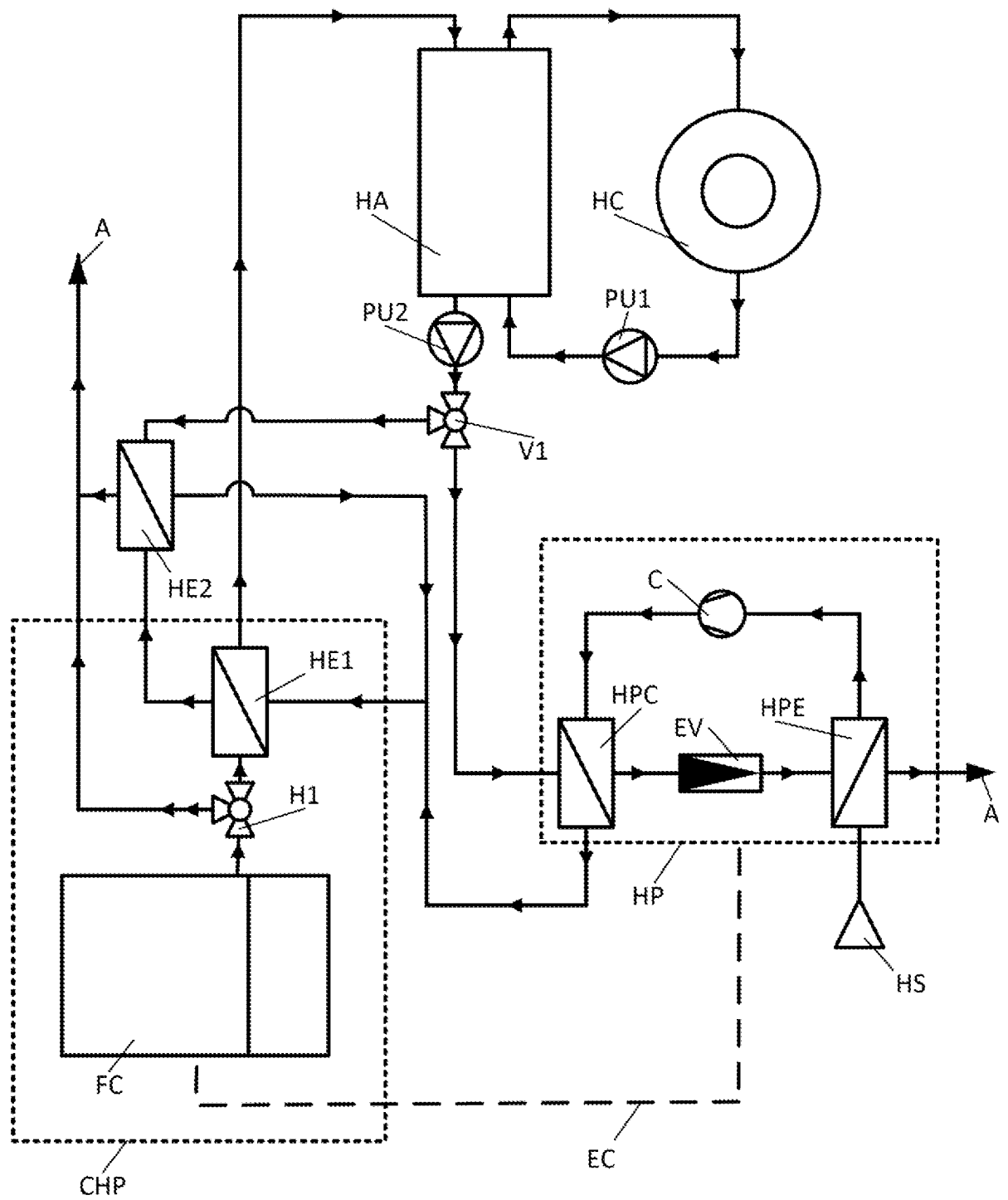
[Claim 14] The apparatus as in claim 11 **characterized in that**

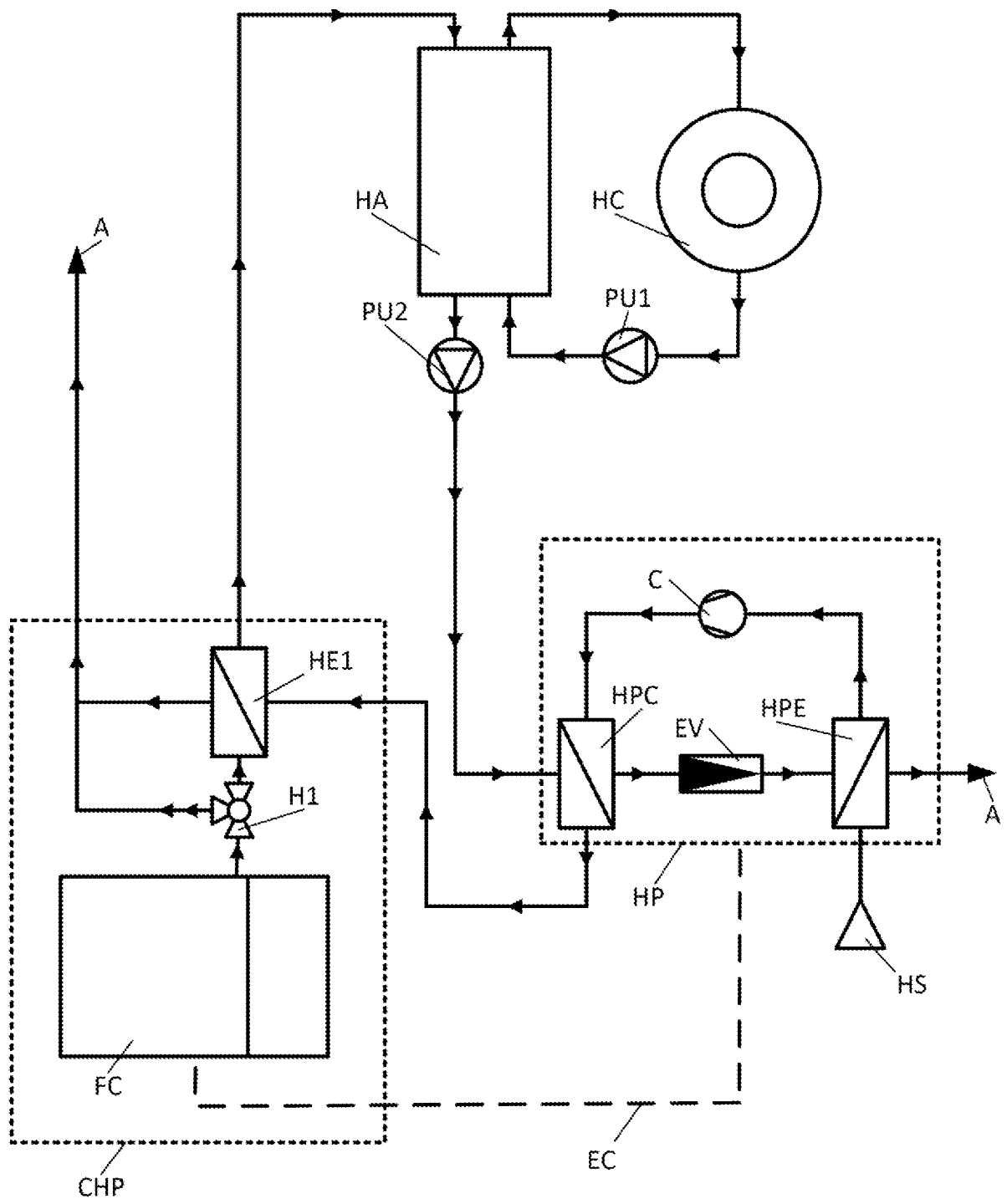
said primary heat releasing unit is internal combustion engine (ICE), designed as a gas fueled engine which runs on a gas fuel selected from group comprising a natural gas, liquefied petroleum gas, landfill gas, wood gas or biogas, wherein said engine cooling system is preferably designed as an engine jacket cooling system of said internal combustion engine (ICE);

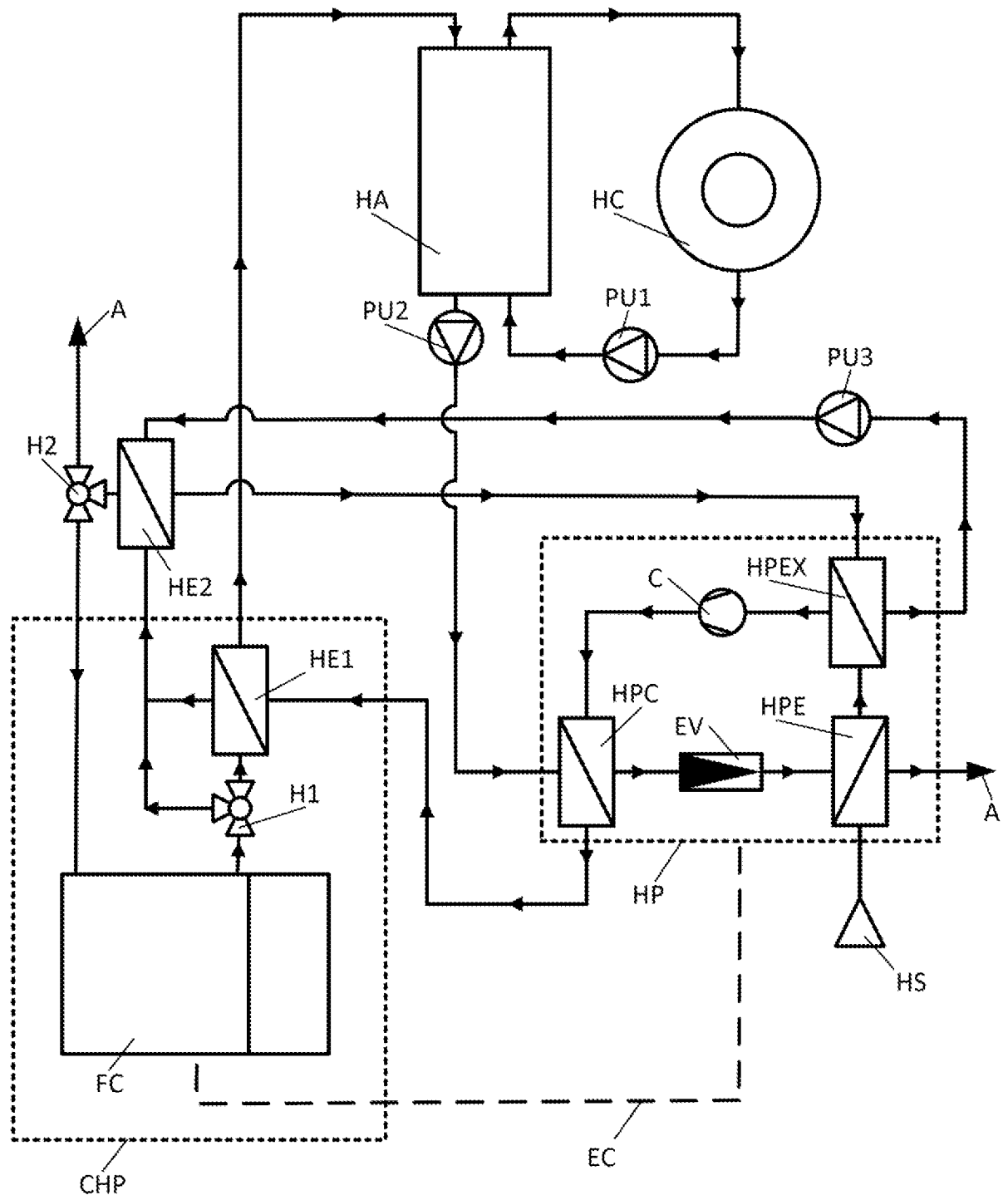
[Claim 15] The apparatus as in claim 8 **characterized in that**

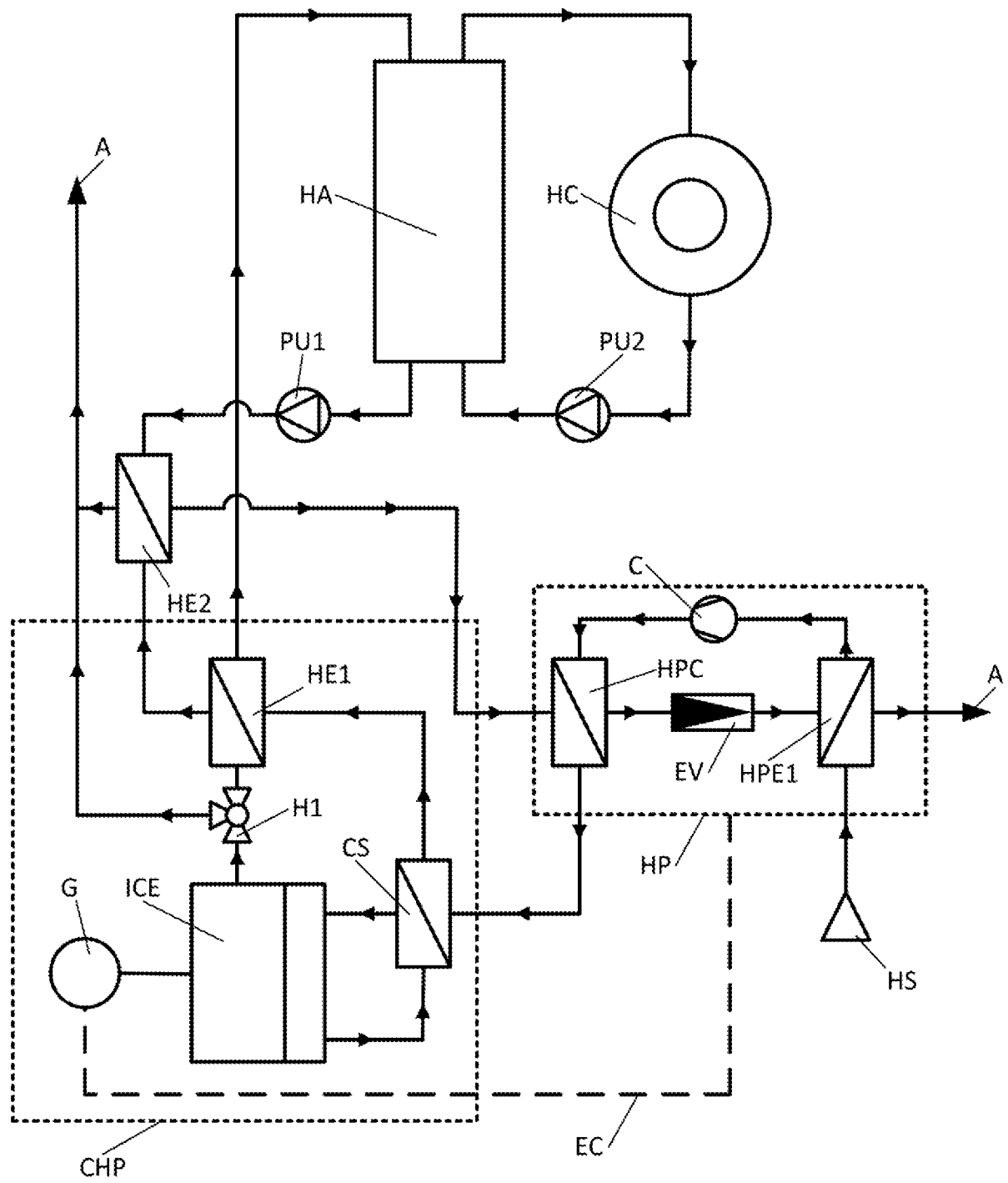
the primary heat transfer medium in preferential embodiment is water; the secondary heat transfer medium in preferential embodiment is mix of water and glycol; and at least one of said heat exchanger is designed as a condensing heat exchanger (HE2), wherein said closed loop circuit of heat transfer network is sub-component of a group comprising a partial house,

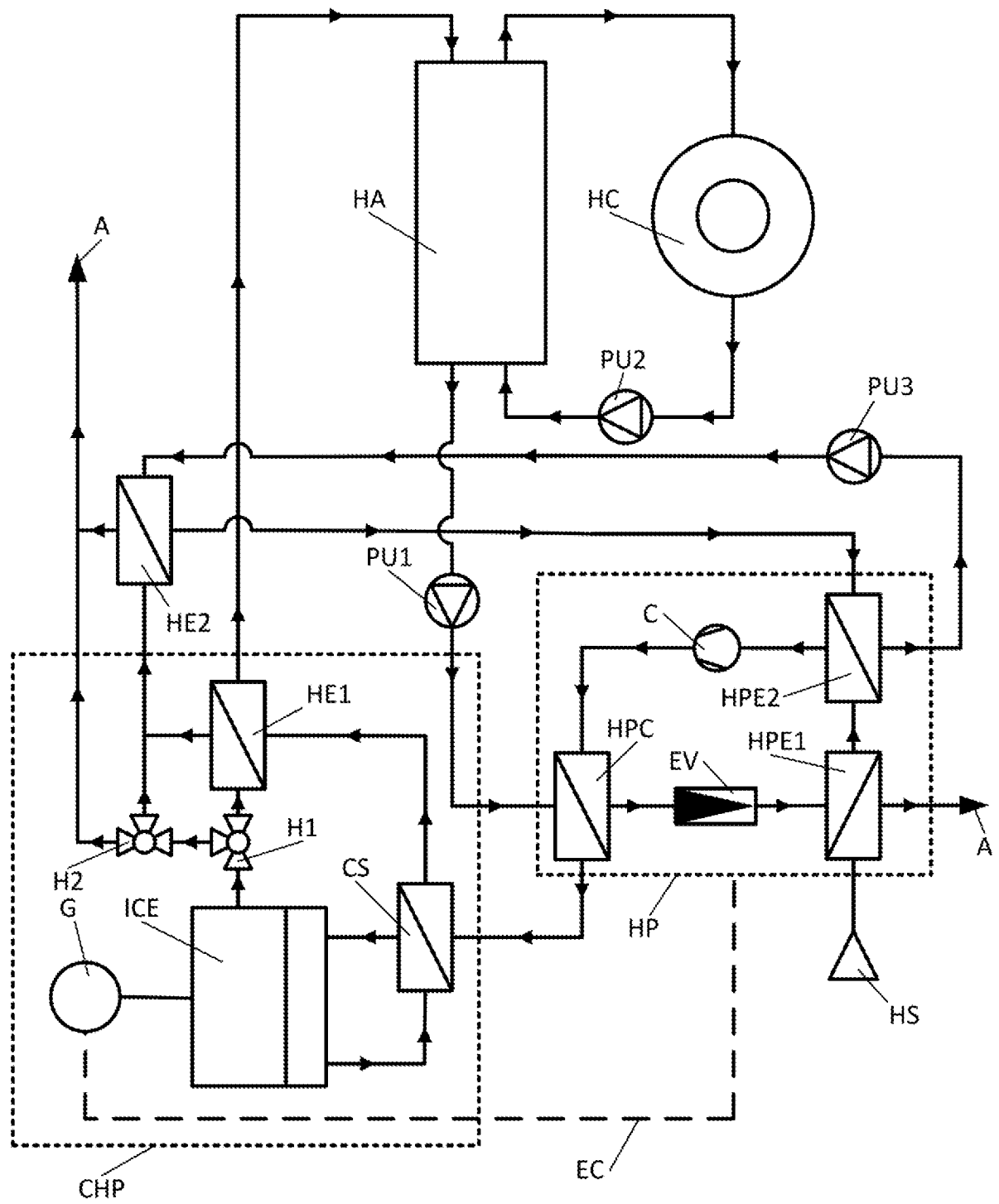
central heating, district heating, or said network is a part of the installation for a vehicle, truck, or a vessel.











INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2017/000574

A. CLASSIFICATION OF SUBJECT MATTER
INV. F24D3/18 F24D19/10
ADD.

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)
F24D

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 practicable, search terms used)

EP0-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE 10 2012 106894 A1 (SCHMID WALTER [CH]) 7 February 2013 (2013-02-07) paragraph [0019] - paragraph [0028]; figure 1	1-15
X	DE 39 12 113 A1 (BRETTEG EKKEHARD DIPL ING [DE]) 7 December 1989 (1989-12-07) the whole document	1-15



Further documents are listed in the continuation of Box C.



See patent family annex.

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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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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

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/IB2017/000574

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE 102012106894 A1	07-02-2013	AT 512195 A1	15-06-2013
		CH 705372 A2	15-02-2013
		DE 102012106894 A1	07-02-2013

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