(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
09 November 2017 (09.11.2017)

WIPO | PCT

(10) International Publication Number
WO 2017/191505 A4

(51) International Patent Classification:
F24D 3/18 (2006.01) *F24D 19/10* (2006.01)

(21) International Application Number:
PCT/IB2017/000574

(22) International Filing Date:
05 May 2017 (05.05.2017)

(25) Filing Language: Slovenian

(26) Publication Language: English

(30) Priority Data:
P-201600123 05 May 2016 (05.05.2016) SI
P-201600155 20 June 2016 (20.06.2016) SI

(71) Applicant: **UNIVERSITY OF MARIBOR** [SI/SI]; Slomškov trg 15, 2000 Maribor (SI).

(72) Inventor: **GORICANEC, Darko**; Maroltova ulica 9, 2000 Maribor (SI).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

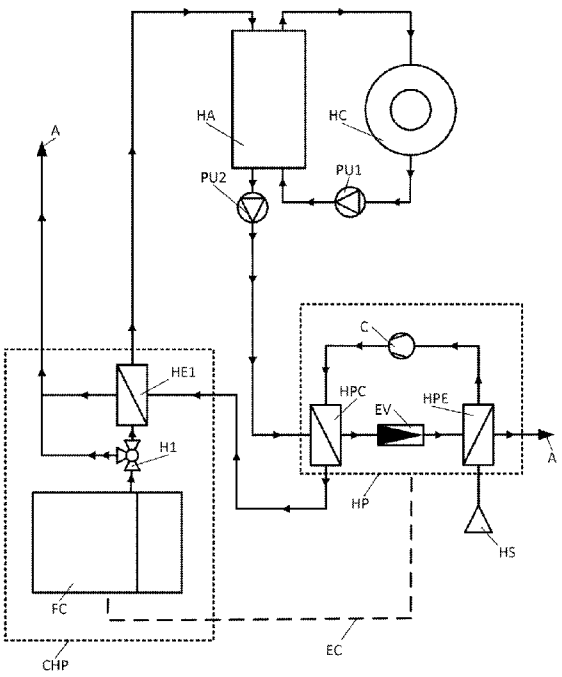
(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report (Art. 21(3))*
— *with amended claims (Art. 19(1))*

Date of publication of the amended claims:
22 February 2018 (22.02.2018)

(54) **Title:** METHOD AND APPARATUS FOR INCREASING THE EFFICIENCY OF THE COGENERATION POWER PLANT BY THE HEAT PUMP PRINCIPLE UTILIZATION FOR INCREASING THE COOLANT INLET TEMPERATURE

[Fig.2]



(57) Abstract: The method and apparatus for increasing the efficiency of a low-temperature or high temperature heating system, comprising a primary heat releasing unit (i.e. cogeneration unit with fuel cell (FC) or internal combustion engine (ICE)) for cogeneration of the heat and power, and at least one secondary heat releasing unit (i.e. heat pump (HP)) for utilization of at least one of the available waste/renewable energy heat sources (HS) from the ambient (A), where the heat generated by said heat pump is preferably used for preheating the heat transfer medium in the return line of the closed loop heating system, wherein a primary heat releasing unit is used to heat the heat transfer medium to the required temperature level of the heat distribution network. The apparatus according to the invention may comprise one or more heat pumps (HP) of the same or different types, and one or more primary heat releasing units in serial, parallel or cascade connection circuits.

WO 2017/191505 A4

AMENDED CLAIMS
received by the International Bureau on 17 December 2017 (17.12.2017)

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

a heat distribution process, wherein at least one heat distribution network is used to transfer the heat to the target heat consumer (HC) by the stream of at least one heat transfer medium in the heat distribution network;

a primary heat generation process, wherein at least one heat and power apparatus is used to provide a primary heat releasing unit, wherein at least one cooling system (CS) of at least one primary heat generation process is used to provide a primary heat releasing unit for heating at least one heat transfer medium, wherein the heat generated by the primary heat releasing unit is introduced to the feed line of the heat distribution network by the outlet of the cooling system (CS), and wherein at least one waste heat source in form of exhaust gas arise, at least when primary heat releasing unit is turned on and converting the fuel into the heat whilst operating by firing the fuel in an energy conversion process;
a waste heat recovery process, wherein at least one waste heat recovery unit is used to extract and collect at least a portion of the heat of at least one waste heat source comprising a flue gas in exhaust system of said primary heat generation process;

a secondary heat generation process, wherein at least one heat pump (HP) is used to provide a secondary heat releasing unit, wherein at least one condenser of the heat pump (HP) is used to provide a secondary heat releasing unit for heating at least one heat transfer medium in the heat distribution network, wherein liquid-vapor phase change thermodynamic cycle of working medium is used for upgrading the heat of available heat sources to the higher grade temperature level, wherein the heat generated

by the secondary heat releasing unit is introduced to the cooling system (CS) of primary heat releasing unit, hence the heat generated by the heat pump (HP) principle utilization is used for preheating the heat transfer medium of the cooling system (CS) to the target temperature level, at least when said heat pump (HP) is turned on and operating in heating mode at nominal power conditions;

a renewable heat utilization process, further comprising a process of extracting and collecting the heat from at least one renewable heat source (HS), wherein at least a portion of collected heat is used for evaporation of working medium in liquid-vapor phase change thermodynamic cycle principle utilization, **characterized in that**

at least a portion of the heat collected in the waste heat recovery process is utilized by extracting the heat of flue gas in the exhaust system of primary heat releasing unit, wherein at least a portion of the heat collected by at least one waste heat recovery unit is transferred to at least one evaporator unit of the heat pump (HP) by the circulation of the heat transfer medium in a substantially closed loop network connection comprising at least one waste heat recovery unit and at least one evaporator unit, hence at least a portion of the waste heat from primary heat releasing unit is directly used for evaporation of the working medium for liquid-vapor phase change thermodynamic cycle utilization, wherein the heat generated by liquid-vapor phase change thermodynamic cycle is introduced to the cooling system (CS) by condensation of the working fluid within at least one condenser unit of the heat pump (HP) for utilization of the secondary heat generation process, wherein the heat transfer medium is heated to the final temperature level by the cooling system (CS) of the primary heat generation process.

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

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

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 primary heat generation 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, 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 (CS) 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 for cogeneration plant waste heat source utilization comprising:
at least one primary heat generation device, further comprising at least one exhaust system and at least one cooling system (CS), wherein said cooling system (CS) further comprises an inlet aperture and outlet aperture being adapted to be connected with heat distribution network comprising primary heat transfer medium for heating at least one heat consumer (HC);

at least one heat pump (HP) further comprising an evaporator unit and a condenser unit, wherein said condenser unit further comprises an inlet aperture and an outlet aperture being adapted to be connected to said heat distribution network, and wherein said evaporator unit further comprises an inlet aperture and an outlet aperture;

at least one heat exchanger unit for extracting a heat from renewable heat source, wherein said heat exchanger comprises an inlet aperture and outlet aperture, wherein said outlet aperture is adapted to be connected with at least one inlet of said evaporator unit;

at least one waste heat recovery unit, adapted to be associated with said exhaust system of primary heat generation device and furthermore being adapted to be connected with evaporator unit of said heat pump (HP) **characterized in that**

said evaporator inlet aperture is adapted to be connected with at least one waste heat recovery unit outlet aperture for transferring the collected heat from said waste heat recovery unit to said evaporator unit by a heat transfer medium in the closed loop circuit;

said outlet of the condenser unit is adapted to be connected with said inflow of the primary heat releasing unit cooling system (CS) for transferring the heat of the condenser unit to the primary heat releasing unit cooling system (CS) by a primary heat transfer medium in a heat distribution network.

[Claim 9] The apparatus as in claim 8 **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.

[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 primary heat generation device cooling system (CS) 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 generation device cooling system (CS) 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 generation device.

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

said primary heat generation device is a 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 generation device 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 for heat transfer in heat distribution network is water or 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.