US 20030213245A1

(19) United States

(12) Patent Application Publication (10) Pub. No.: US 2003/0213245 A1

Yates et al. (43) Pub. Date: Nov. 20, 2003

(54) ORGANIC RANKINE CYCLE MICRO COMBINED HEAT AND POWER SYSTEM

(76) Inventors: **Jan B. Yates**, Reynoldsburg, OH (US); **William T. Hanna**, Gahanna, OH (US); **Donald Anson**, Worthington, OH (US)

Correspondence Address:
Killworth, Gottman, Hagan & Schaeff, L.L.P.
Suite 500
One Dayton Centre
Dayton, OH 45402-2023 (US)

(21) Appl. No.: **10/145,685**

(22) Filed: **May 15, 2002**

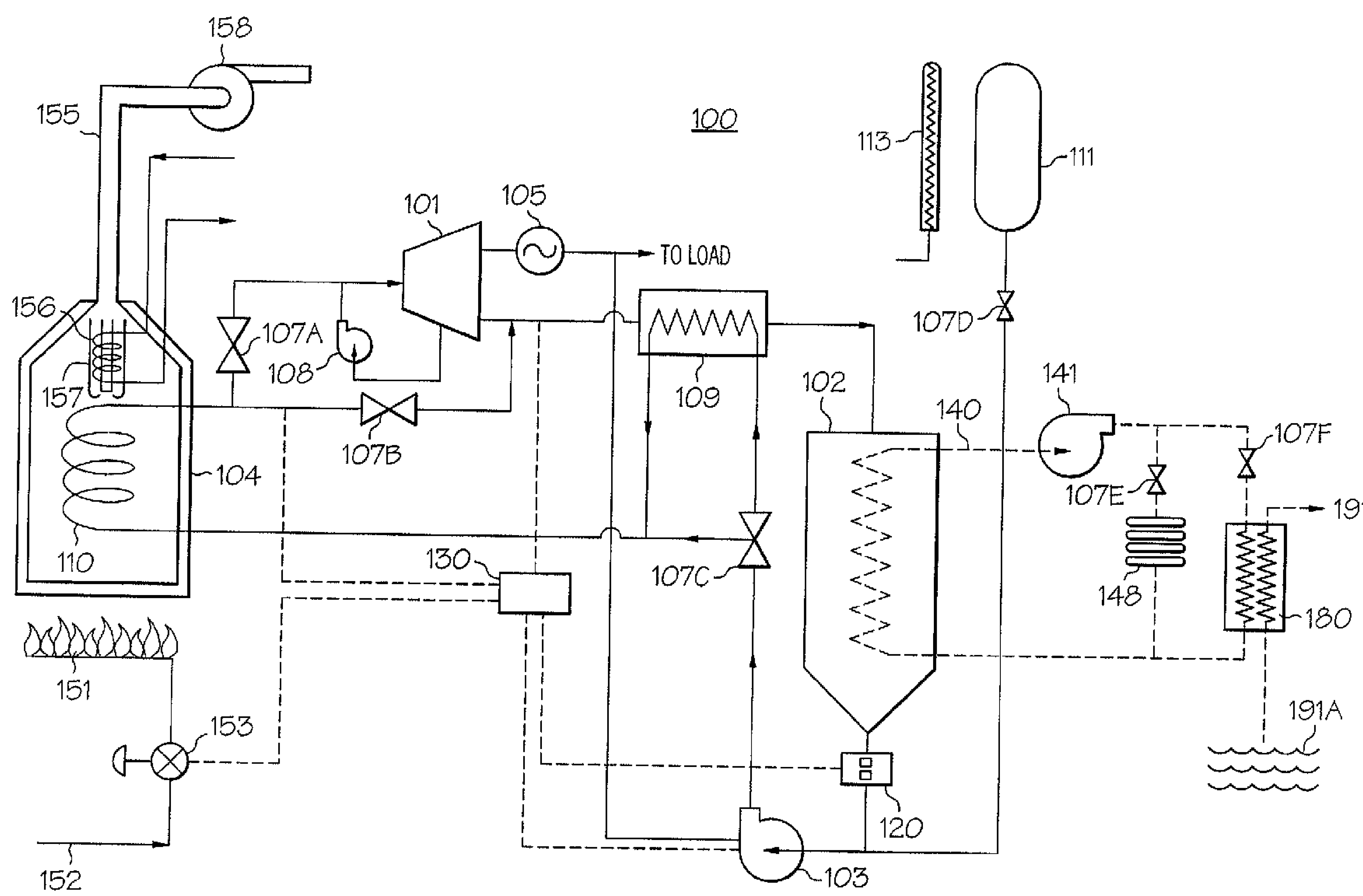
Publication Classification

(51) **Int. Cl.**[7] **F01K 25/08**; F01K 25/00

(52) **U.S. Cl.** **60/651**; 60/671

(57) **ABSTRACT**

A micro combined heat and power system includes at least a heat source, an expander, a condenser, a pump, recuperator and conduit for circulating a working fluid. After the working fluid is expanded, its thermodynamic properties allow it to remain in a superheated state so that it selectively can give up at least a portion of its excess heat first to the recuperator and then to the condenser, which can then subsequently exchange heat with a circulating air, water or related loop to provide space heat or domestic hot water that can be used, for example, to heat a dwelling. The amount of heat exchange in the recuperator can be adjusted to allow the output ratio of heat to electricity to be varied while maximizing overall system efficiency. Additional componentry, such as an accumulator, enhances system operability by smoothing out working fluid flow rates during transitional operation, such as start-up and shut-down.



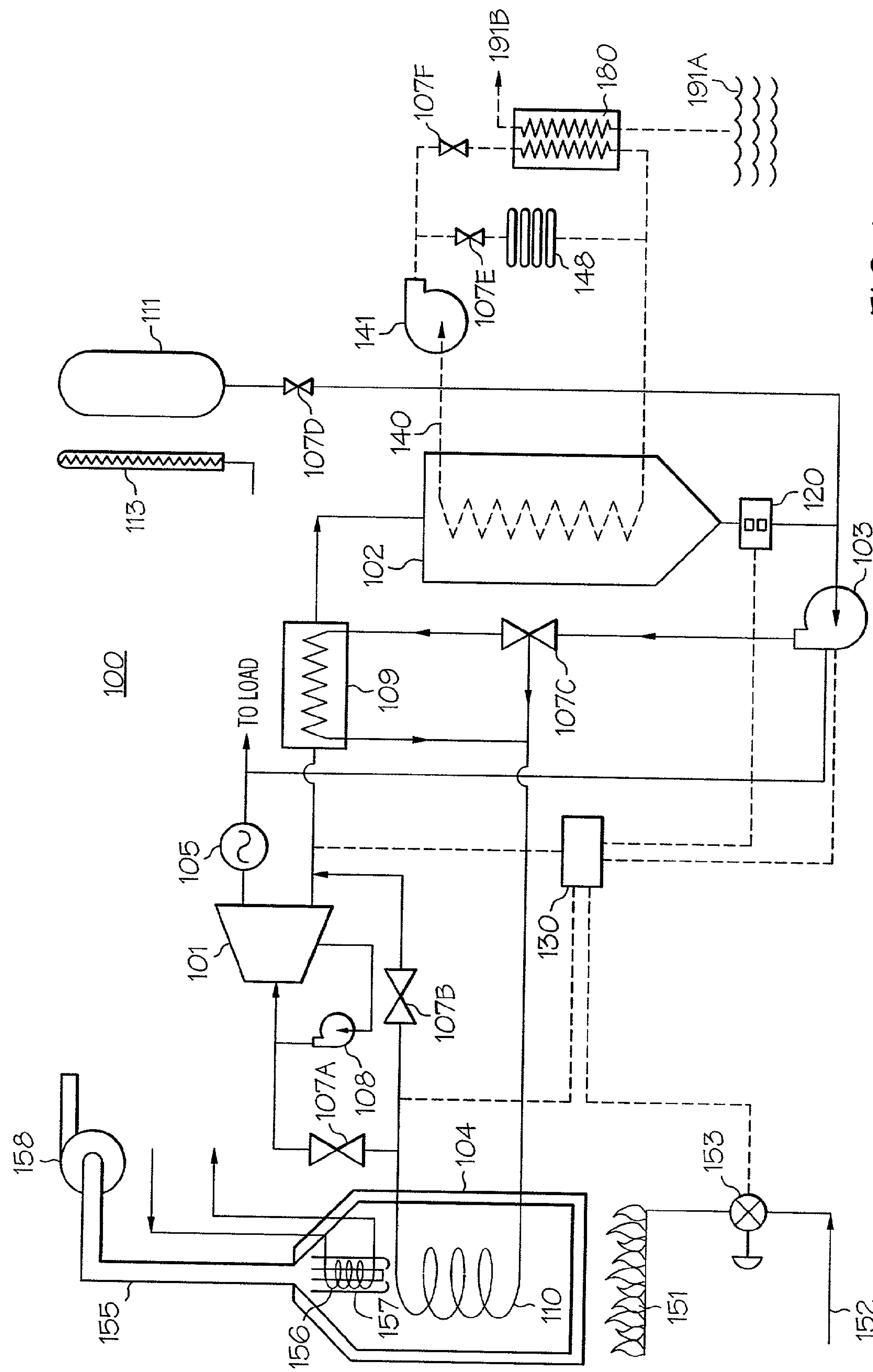
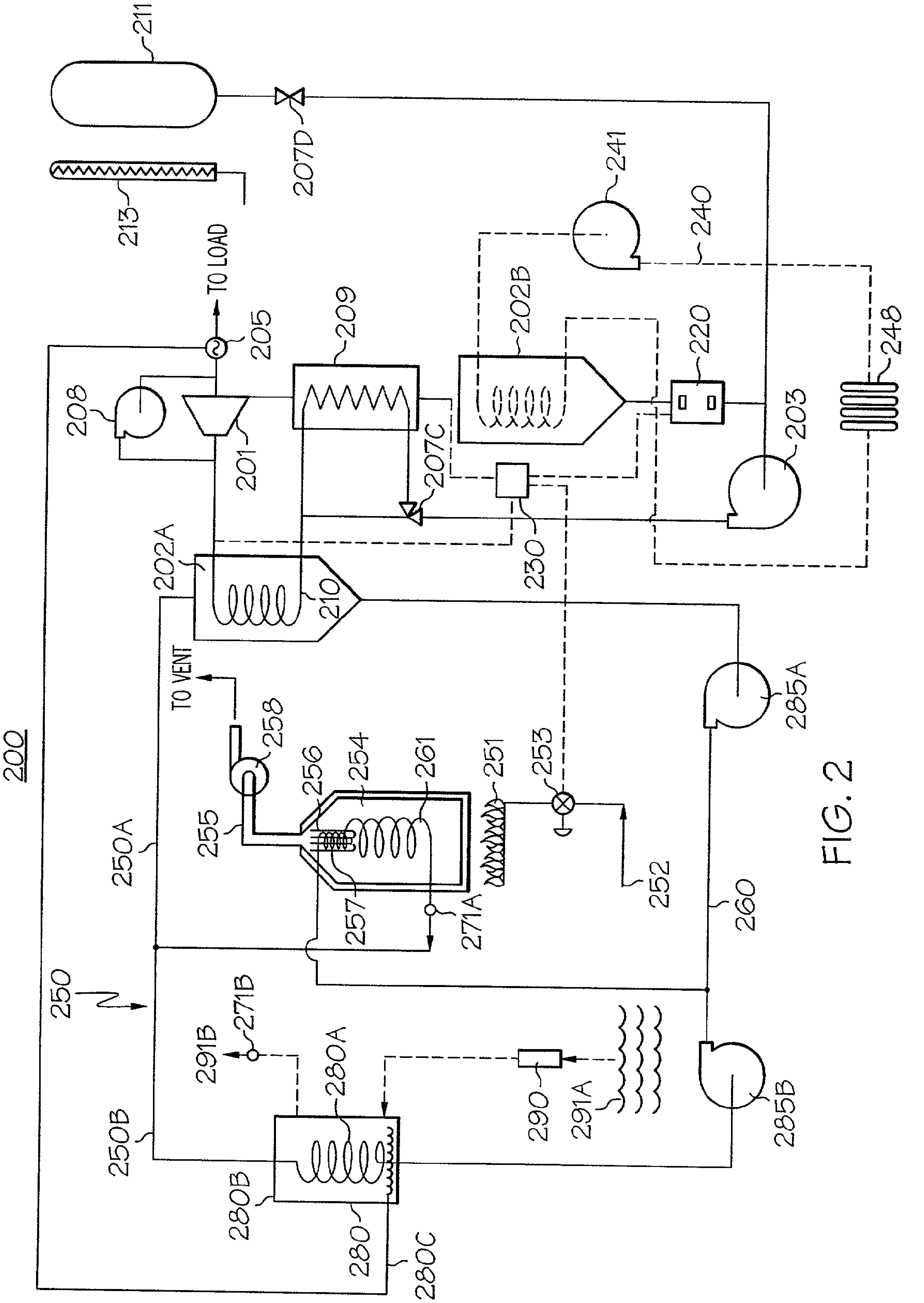

100
TO LOAD
101
102
103
104
105
107A
107B
107C
107D
107E
107F
108
109
110
111
113
120
130
140
141
148
151
152
153
155
156
157
158
180
191A
191B

FIG. 1



200
211
213
207D
TO LOAD
205
208
201
209
202B
241
240
220
248
203
207C
230
202A
210
TO VENT
258
256
254
261
251
253
255
250A
257
271A
252
260
285A
250
271B
291B
280A
290
291A
285B
250B
280B
280
280C

FIG. 2

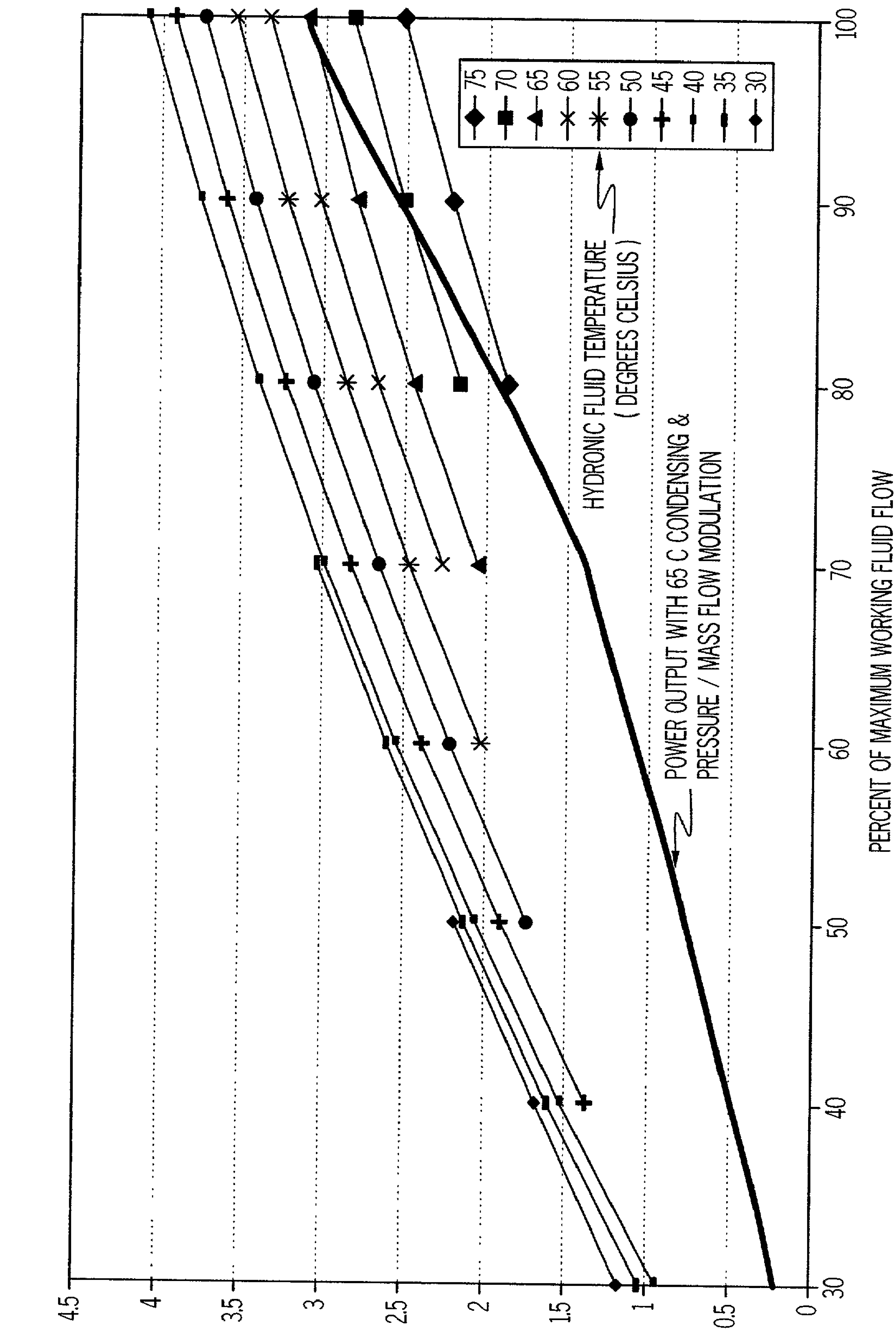

NET ELECTRICAL POWER OUTPUT (kWe)
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
30
40
50
60
70
80
90
100
PERCENT OF MAXIMUM WORKING FLUID FLOW
75
70
65
60
55
50
45
40
35
30
HYDRONIC FLUID TEMPERATURE (DEGREES CELSIUS)
POWER OUTPUT WITH 65 C CONDENSING & PRESSURE / MASS FLOW MODULATION

FIG. 3

ORGANIC RANKINE CYCLE MICRO COMBINED HEAT AND POWER SYSTEM

BACKGROUND OF THE INVENTION

[0001] The present invention generally relates to improvements in operability of a Rankine cycle cogeneration system using an organic working fluid, and more particularly to the integration of one or more components into such a system to increase flexibility in system start-up, output heat-to-power ratio and hot water production.

[0002] The concept of cogeneration, or combined heat and power (CHP), has been known for some time as a way to improve overall efficiency in energy production systems. With a typical CHP system, heat (usually in the form of hot air or water) and electricity are the two forms of energy that are generated. In such a system, the heat produced from a combustion process can drive an electric generator, as well as heat up water, often turning it into steam for dwelling or process heat. Traditionally, CHP systems have been large, centrally-operated facilities under the control of the state or a large utility company, sized to provide energy for many thousands of users. If the region being served by the CHP has as part of its infrastructure adequate heat transporting capability, the centrally-generated heat and electric power model of the large CHP system can, within limits, function reasonably efficiently and reliably. In the absence of adequate heat transport capability, however, while the region's electric power needs would continue to be met by the central generating station, the heat needs would need to be fulfilled separately and remotely from the electricity production, often near or within the building housing the end-user. This latter configuration typically includes the presence of one or more boilers that could generate hot water or steam to provide most or all of the localized building heating requirements. While either configuration works well for its intended purpose, inefficiencies arise. In the former system, much of the heat generated at the central generating station is, after being transported over long distances, unavailable for remote use. In the latter system, the lack of CHP capability necessitates the consumption of additional energy at the remote location to satisfy heat requirements.

[0003] Recent trends in the deregulation of energy production and distribution have made viable the concept of distributed generation. With distributed generation, the large, central generating station is supplemented with, or replaced by numerous smaller autonomous or semi-autonomous units. These changes have led to the development of smaller CHP systems, called micro-CHP, which are distinguished from traditional CHP by the size of the system. By way of contrast, the electric output of a generating station-sized CHP could be in the tens, hundreds or thousands of megawatts (MW), where the electric output of a micro-CHP is fairly small, in the low kW_e or even sub-kW_e range. The inclusion of a distributed system into dwellings that already have fluid-carrying pipes for heat transport is especially promising, as little or no disturbance of the existing building structure to insert new piping is required. Similarly, a micro-CHP system's inherent multifunction capability can reduce structural redundancy. Accordingly, the market for localized heat generation capability in Europe and the United Kingdom (UK), as well as certain parts of the United States, dictates that a single unit for residential and small commercial sites provide heat for both space heat (SH), such as a hydronic system with radiator, and domestic hot water (DHW), such as a shower head or faucet in a sink or bathtub, via demand (instantaneous) or storage systems.

[0004] As with all energy production devices that rely on non-renewable sources, such as natural gas, coal or oil, a more efficient system consumes lower quantities of fuel to generate the same energy output as its less efficient counterpart. A key factor in keeping micro-CHP system efficiency high over a wide range of operating conditions is how much thermal output is required at the heat source, such as a natural gas burner. Unfortunately, the nature of micro-CHP system operation, where both electric power and heat are generated from the same combustion process often under a fixed heat to power (Q/P) ratio, is such that when thermal output is reduced to minimize fuel consumption, the electric power production often drops even more quickly. As such, these systems cannot operate efficiently when climatic changes and user energy-consumption habits deviate significantly, over the course of a day or the year, from the rated Q/P. With a fixed Q/P heat-led system, because the electric power output follows heat production, a significant turndown in thermal load results in a concomitant loss in electric output, and because maximizing system efficiency is typically a corollary to maximizing electric output, such part power operation severely limits the benefits associated with cogeneration systems.

[0005] What is needed is a micro-CHP system that can operate at high efficiencies regardless of the Q/P requirements. The present inventors have recognized that with modulation, the system continues to operate over a longer period of time such that its duty cycle is relatively large and that the variable heat output need not encroach on maximizing electrical output. They have further recognized that by modulating the system, Q/P is improved at all conditions, especially at part power conditions. They have also recognized that a modulation approach that varies the mass flow of the working fluid to match the heat load while simultaneously varying the fuel flow to the heat source in order to keep the inlet temperature of the working fluid heated by the heat source at a constant temperature results in a thermal output that can be closely tailored to a user's needs while keeping electrical power output at a maximum. They have moreover recognized that the inclusion of various system componentry, such as recuperators and accumulators, can improve the efficiency of modulating a system by the aforementioned approach. They have additionally recognized that in countries where emission requirements are stringent, modulating can lower burner output at certain system operating conditions more effectively than by cycling the system such that fuel consumption to achieve the same amount of energy output is reduced.

BRIEF SUMMARY OF THE INVENTION

[0006] These needs are met by the present invention, where a new micro-CHP system is described. According to a first aspect of the present invention, a cogeneration system is disclosed. The system includes a heat source, a working fluid circuit and at least one energy conversion circuit operatively responsive to the working fluid circuit such that upon operation of the cogeneration system, the energy conversion circuit is configured to provide useable energy. In the present context, the term "useable energy" includes that which a user can put to practical use, rather than waste or incidental energy. This is consistent with the concept of cogeneration, which is frequently considered to be the thermodynamically sequential production of two or more useful forms of energy from a single primary energy source. The most notable examples of useable energy arising out of the operation of a cogeneration system are electricity (preferably alternating current electricity, derived from the mechanical turning of a generator), and heat in the form of SH and DHW. The working fluid circuit is made up of conduit, an expander, condenser, pump and recuperator. The conduit is configured to transport an organic working fluid, where at least a portion of the conduit is disposed adjacent the heat source such that during heat source operation, the heat transferred to the conduit is sufficient to superheat the organic working fluid disposed in that part of the conduit. The organic working fluid passing through the expander remains superheated after expansion, while the condenser is in fluid communication with the expander to extract some of the heat still extant in the working fluid after the expansion process. The pump is configured to circulate the organic working fluid through at least the conduit, expander and condenser. The recuperator is coupled to the conduit and is configured to increase the temperature of the organic working fluid entering the portion of the conduit disposed adjacent the heat source.

[0007] The thermodynamic properties of some organic working fluids are ideally suited to the temperature and pressure regimes encountered in micro-CHP operation. Of particular interest is that such fluids remain superheated even after giving up a significant portion of their energy in the expansion process. This is in contrast to other working fluids, such as water, that typically condense to a saturated condition after expansion. Furthermore, the use of organic working fluid rather than water is important where shipping and even some end uses could subject portions of the system to freezing temperatures (below 32° Fahrenheit, 0° Celsius). With a water-filled system, damage and inoperability could ensue after prolonged exposure to sub-freezing temperatures, whereas an organic working fluid-based system would be impervious to temperature extremes encountered by dwellings and related buildings incorporating such a system. In addition, by using an organic working fluid rather than water, corrosion issues germane to water in the presence of oxygen are avoided. The organic working fluid is preferably either a halocarbon refrigerant or a naturally-occurring hydrocarbon. Examples of the former include the refrigerant known as R-245fa, while examples of the latter include some of the alkanes, such as isopentane. Another advantage associated with organic working fluids is that their high vapor density and heat transfer properties in the superheated state ensure that maximum heat and power can be extracted from the fluid without having to resort to a large expander. To handle the expansion loads of the superheated organic working fluid, the expander is preferably a scroll expander.

[0008] Optionally, the energy conversion circuit comprises a generator coupled to the expander to produce electricity and a circulating fluid medium in thermal communication with the condenser such that at least a portion of the heat given up by the organic working fluid in the condenser provides increased thermal content to the circulating fluid medium. In the present context, the term "thermal communication" is meant to broadly cover all instances of thermal interchange brought about as a result of coupling between system components, whereas the more narrow "heat exchange communication" is meant to cover the more specific relationship between direct, adjacent heat exchange components designed specifically for that purpose.

[0009] The recuperator preferably includes a first heat exchange passage disposed between the expander and the condenser and a second heat exchange passage disposed between the pump and the portion of the conduit adjacent the heat source. In the present context, a component in a fluid circuit is "between" other components in the same circuit when the fluid in the circuit can flow through the between component on its way from one to the other of the surrounding components. A recuperator bypass valve can be included so that, with proper control, the amount of fluid flowing through the recuperator can be varied, allowing concomitant variation in Q/P. Preferably, the circulating fluid medium is configured to transport either or both an SH fluid, such as water or forced air, or DHW. Preferably, the heat source is a burner in thermal communication with an evaporator such that heat provided by the burner causes the organic working fluid that flows through the conduit in the evaporator to become superheated. Also, the burner can be disposed within a container (of which the evaporator may form an integral part) which may include an exhaust duct to carry away combustion products (primarily exhaust gas), an exhaust fan to further facilitate such product removal, as well as an exhaust gas heat exchanger disposed adjacent (preferably within) the exhaust duct so that residual heat present in the exhaust gas can be used for supplemental heating in other parts of the cogeneration system. The exhaust gas heat exchanger can further include an exhaust gas recirculation device to further improve heat transfer from the exhaust gas.

[0010] Additionally, an accumulator responsive to pressure differences within the working fluid circuit can be included. Under a first operating condition, the accumulator adds excess working fluid to the working fluid circuit, and under a second operating condition, the accumulator removes excess working fluid from the working fluid circuit. The accumulator is preferably disposed intermediate the condenser and the pump, and is situated at a higher elevation relative to the pump to promote the gravity flow of the additional working fluid from the accumulator to the pump during the first operating condition. In addition, a warming device can be thermally coupled to the accumulator such that during at least a portion of the time the cogeneration system is not in operation, the accumulator is maintained at a higher temperature than the remainder of the working fluid circuit. A valve configured to selectively fluidly isolate the accumulator from the remainder of the working fluid circuit can also be included. When open, this valve allows the accumulator to be charged before starting so that during system warm-up, the accumulator can return the extra charge to the system.

[0011] The cogeneration system can be configured such that the organic working fluid is directly-fired or indirectly-fired. In the former configuration, the relationship between the burner and the organic working fluid-carrying evaporator is such that the flame from the combustion process in the burner directly impinges on either the conduit carrying the fluid or a container (alternately referred to as a combustion chamber) that houses at least a portion of the organic working fluid-carrying conduit such that the portion of the conduit where the organic working fluid becomes superheated is considered the evaporator. In the latter configuration, the flame from the combustion process in the burner gives up a portion of its heat to conduit making up a secondary circuit, which in turn conveys a heat exchange fluid to an interloop heat exchanger. The indirectly-fired system is advantageous in terms of system flexibility, due in part to its ability to minimize temperature excursions in the evaporator, and maintainability, as heat-sensitive components (such as the conduit used to carry the working fluid) are not directly exposed to the combustion process in the case of a burner for a heat source. The directly-fired system is advantageous in terms of system cost and simplicity.

[0012] According to another aspect of the present invention, a cogeneration system including a heat source, a working fluid circuit and at least one energy conversion circuit is disclosed. The working fluid circuit is made up of conduit, an expander, condenser, pump and accumulator. As with the previously-described aspect, the conduit is configured to transport an organic working fluid, where at least a portion of the conduit is disposed adjacent the heat source such that during heat source operation, the heat transferred to the conduit is sufficient to superheat the organic working fluid disposed in that part of the conduit. Also as before, the organic working fluid passing through the expander remains superheated after expansion, while the condenser is in fluid communication with the expander to extract some of the heat remaining in the working fluid after the expansion process. Similarly, the pump is configured to circulate the organic working fluid through at least the conduit, expander and condenser. The accumulator is responsive to pressure differences within the working fluid circuit, and is configured to add excess working fluid to the working fluid circuit during a first operating condition while removing excess working fluid from the working fluid circuit under a second operating condition. The accumulator is preferably disposed intermediate the condenser and the pump, and is situated at a higher elevation relative to the pump to promote the gravity flow of the additional working fluid to the pump during the first operating condition. In addition, a warming device can be thermally coupled to the accumulator such that during at least a portion of the time the cogeneration system is not in operation, the accumulator is maintained at a higher temperature than the remainder of the working fluid circuit. A valve configured to selectively fluidly isolate the accumulator from the remainder of the working fluid circuit can also be included. When open, this valve allows the accumulator to be charged before starting so that during system warm-up, the accumulator can return the extra charge to the system.

[0013] According to yet another aspect of the present invention, a Rankine cycle cogeneration system is disclosed. The cogeneration system includes a heat source, a working fluid circuit and at least one energy conversion circuit operatively responsive to the working fluid circuit such that upon operation of the cogeneration system, the energy conversion circuit is configured to provide useable energy. The working fluid circuit includes conduit configured to transport an organic working fluid, an expander in fluid communication with the conduit, a condenser in fluid communication with the expander, a pump to circulate the organic working fluid, a recuperator coupled to the conduit and configured to increase the temperature of the organic working fluid entering prior to the working fluid encountering the heat source, and an accumulator intermediate the condenser and the pump. As with the previous aspect of the invention, at least a portion of the conduit is disposed adjacent the heat source such that, during operation of the heat source, the organic working fluid passing through that portion of the conduit is heated to a superheated state, and remains in such state after passing through the expander. Also as previously discussed, the accumulator is preferably responsive to pressure differences within the working fluid circuit such that under a first operating condition, the accumulator adds excess working fluid to the working fluid circuit, and under a second operating condition, the accumulator removes excess working fluid from the working fluid circuit. The accumulator is preferably situated at a higher elevation relative to the condenser to promote the gravity flow of the excess working fluid resident in the accumulator to the condenser during the first operating condition.

[0014] According to still another aspect of the present invention, a Rankine cycle cogeneration system is disclosed. The system includes an organic working fluid, an evaporator made up of a burner and conduit adjacently spaced relative to the burner, a substantially closed-loop working fluid circuit in thermal communication with the burner, and at least one energy conversion circuit. Heat generated during burner operation is sufficient to superheat the organic working fluid disposed in the adjacent conduit. The closed-loop working fluid circuit includes an expander that in operation maintains the organic working fluid in a superheated state after expansion in the expander, a condenser in fluid communication with the expander, a pump configured to circulate the organic working fluid, a recuperator configured to increase the temperature of the organic working fluid entering the evaporator, and an accumulator fluidly responsive to pressure differences within the working fluid. The accumulator adds excess working fluid to the working fluid circuit under a first operating condition (such as during system start-up), and removes excess working fluid from the working fluid circuit under a second operating condition (such as during steady state operation). The energy conversion circuit includes a generator coupled to the expander to produce electricity, and a circulating fluid medium in thermal communication with the condenser such that at least a portion of the heat given up by the organic working fluid in the condenser provides increased thermal content to the circulating fluid medium. The circulating fluid medium is preferably an SH or DHW circuit, including conduit, one or more pumps and related valving, control and heat exchange equipment.

[0015] According to another aspect of the present invention, a dwelling configured to provide at least a portion of the heat and power needs of occupants therein is disclosed. The dwelling (which can be, for example, a house, apartment or commercial, industrial or office building) includes walls, a roof situated above the walls, at least one ingress/egress (such as a door) to facilitate passage into and out of the dwelling, and a cogeneration system in heat and power communication with at least one room formed within the dwelling. The cogeneration system includes, at a minimum, a heat source, a working fluid circuit and at least one energy conversion circuit. Optionally, the dwelling further comprises a controller (such as a thermostat) that is signally connected to a measuring sensor, such as an outdoor temperature sensing device. The sensed outdoor temperature can form the basis for the controller to set a desired hydronic fluid temperature. In addition, the controller can be responsive to occupant input. In addition, an accumulator (if present) is configured to be responsive to pressure differences within the working fluid circuit in a manner similar to that discussed in the preceding aspect of the invention.

[0016] According to yet another aspect of the present invention, a micro combined heat and power system is disclosed. The micro combined heat and power system includes an electric production subsystem and a heat production subsystem. The electric production subsystem includes an organic working fluid, a burner for superheating the organic working fluid, a scroll expander configured to receive and expand the organic working fluid such that the organic working fluid remains in a superheated state, a generator operatively coupled to the scroll expander to produce electricity, a condenser in fluid communication with the scroll expander, a pump to circulate the organic working fluid through the electricity generating loop, a recuperator in thermal communication with the expander, and an accumulator intermediate the condenser and the pump. The heat production subsystem comprises a circulating fluid medium in thermal communication with the condenser.

[0017] According to still another aspect of the present invention, a method of producing heat and electrical power from a cogeneration device is disclosed. A first working fluid circuit with conduit, expander, condenser, pump and recuperator, and an energy conversion circuit (both circuits of which are similar to that discussed in the first aspect) are used in the present method to achieve cogeneration. Steps in the method include providing a heat source, configuring the first circuit to transport an organic working fluid past the heat source, superheating the organic working fluid that flows adjacent the heat source, and expanding the superheated organic working fluid to generate electricity. The organic working fluid in the first circuit is maintained in a superheated state at least until the organic working fluid enters a recuperator, whereupon it exchanges at least a portion of its excess heat with organic working fluid that has already passed through the condenser, exchanging at least a portion of excess heat from the organic working fluid that has passed through the recuperator in a condenser with a circulating fluid medium. The organic working fluid is returned via the recuperator such that after picking up additional heat therein, it passes adjacent the heat source. Optionally, the circulating fluid medium is configured to transport an SH fluid, such as water or forced air. Similarly, the circulating fluid medium can be configured to transport DHW.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

[0018] The following detailed description of the preferred embodiments of the present invention can be best understood when read in conjunction with the following drawings, where like structure is indicated with like reference numerals and in which:

[0019] **FIG. 1** shows a schematic diagram of a directly-fired cogeneration system according to an embodiment of the present invention having a connection to both SH and DHW capability;

[0020] **FIG. 2** shows a schematic diagram of an indirectly-fired cogeneration system configuration with connections to separate SH and DHW capability; and

[0021] **FIG. 3** shows that electrical output is maximized when a cogeneration system is modulated according variable heat loads as compared to that of maintaining a constant heat load.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0022] Referring initially to **FIG. 1, a** micro-CHP system **100** capable of providing electric current and heated fluid is shown. The system **100** includes a working fluid circuit and an energy conversion circuit. The working fluid circuit includes an expander **101**, a condenser **102**, a pump **103** and an evaporator **104**. These four components define the major components that together approximate an ideal Rankine cycle system. That is, the evaporator **104** acts as a constant pressure heat addition, the expander **101** allows efficient, nearly isentropic expansion of the working fluid, the condenser **102** acts to reject heat at a constant pressure, and the pump **103** provides efficient, nearly isentropic compression. The evaporator **104** can be a stand-alone device, or part of a larger heat source. In such a configuration, the heat (shown in the figure being produced by a combustion process where a fuel, such as natural gas, is transported via gas line **152** past gas valve **153** to a burner **151**) in the evaporator **104** is transferred to an organic working fluid being transported through conduit **110** (alternately referred to as piping). In the present micro-CHP system **100**, the energy produced by the expansion of the organic working fluid is converted to electricity and heat as the two useable forms of energy. An exhaust gas recirculation (EGR) device **156** functions in conjunction with the exhaust duct **155** as part of exhaust gas heat exchanger **157**. The hot exhaust gas stream is directed axially through the EGR device **156** and heat exchanger **157**. The primary benefit of the EGR device **156** is that levels of harmful gaseous by-products (such as NO_x) can be reduced. An optional fan **158** to pull away heat source byproducts is shown downstream of the heat source as an induced-draft fan, although it could also be a forced-draft fan if located upstream relative to the burner **151** and its ancillary componentry.

[0023] The energy conversion circuit takes the increased energy imparted to the working fluid in the working fluid circuit and converts it into useable form. The electrical form of the useable energy comes from a generator **105** (preferably induction type) that is coupled to expander **101**. The hot fluid form of the useable energy comes from a circulating fluid medium **140** (shown preferably as a combined SH and DHW loop) thermally coupled to condenser **102**. Hydronic fluid flowing through circulating fluid medium **140** is circulated with a conventional pump **141**, and can be supplied as space heat via radiator **148** or related device. As an example, hydronic fluid could exit the condenser **102** at about 112° F. (50° C.) and return to it as low as 86° F. (30° C.). The nature of the heat exchange process is preferably through either heat exchangers **180** (shown notionally for the DHW loop, but equally applicable to the SH loop), or through a conventional hot water storage tank (for a DHW loop). Isolation of either the SH or DHW loop within circulating fluid medium **140** is accomplished through valves **107**E and **107**F. It will be appreciated by those of ordinary skill in the art that while the embodiments depicted in the figures show DHW and SH heat exchangers in parallel (and in some circumstances being supplied from the same heat exchange device, shown later), it is within the spirit of the present disclosure that series or sequential heat exchange configurations could be used. It will also be appreciated that the heat exchanger **180** depicted in **FIG. 1** could be in the form of the aforementioned hot water storage tank, where the hot fluid circulating through circulating fluid medium **140** gives up at least a portion of its heat to incoming domestic cold water coming from water supply **191**A, which is typically from a municipal water source, well or the like. Once heated in the tank, the domestic water can then be routed to remote DHW locations, such as a shower, bath or hot water faucet, through DHW outlet **191**B.

[**0024**] The organic working fluid (such as naturally-occurring hydrocarbons or halocarbon refrigerants, not shown) circulates through the working fluid circuit loop defined by the fluidly-connected expander **101**, condenser **102**, pump **103**, evaporator **104**, and conduit **110**. The embodiment of the micro-CHP system **100** shown in **FIG. 1** is operated as a directly-fired system, where the fluid that passes adjacent the heat source is also the working fluid passing through the expander **101**. The condenser extracts excess heat from the organic working fluid after the fluid has been expanded such that circulating fluid loops hooked up to the condenser can absorb and transfer the heat to remote locations. While the expander **101** can be any type, it is preferable that it be a scroll device. For example, the scroll expander **101** can be based on a conventional single scroll device, as is known in the art. A scroll device exhibits numerous advantages over other positive-displacement systems. For example, since they are made in very high production volume in dedicated modern facilities, its cost is inherently low. Furthermore, the modification to an existing production line to convert from making scroll compressors to making scroll expanders is considerably simpler than to modify an existing reciprocating compressor production line, as the changes to valves and actuation are minimized. Additionally, by operating with very few moving parts, it can go long durations between service or component failure. Moreover, when operating in expansion mode, once the fixed volume of working fluid is captured, the nature of the working fluid-containing chamber is such that the volume of the chamber is always expanding. This also promotes long component life as it avoids the possibility of trapping and attempting to compress (such as upon a return stroke) a working fluid that could, under certain pressure and temperature regimes, include an incompressible liquid phase condensate. An optional oil pump **108** may be used to provide lubricant to the scroll.

[**0025**] An optional level indicator switch **120** is placed at the discharge of condenser **102**, while controller **130** is used to regulate system operation. Sensors connected to controller **130** measure key parameters, such as fluid level information taken from the level indicator switch **120**, and organic working fluid temperatures at various points within the organic working fluid circuit. Through appropriate program logic, it can be used to vary pump speed, gas flow rate and evaporator output temperature, as well as to open and close valves.

[**0026**] Referring next to **FIG. 3, a** comparison between two ways to mimic the modulation of a boiler to achieve maximum system efficiency is shown. In many conventional boiler applications, where the set point of the system **100** is determined by a single parameter, such as an outdoor temperature, controller **130** (not presently shown) can be used to provide primary control input to the evaporator **104** (not presently shown). By operating the evaporator in a variable-capacity mode, where the gas valve **153** on the burner **151** (neither of which are presently shown) can be modulated, the SH or DHW portions of the circulating fluid medium can be maintained at the desired set point. Such modulation permits quasi-steady state system operation that is responsive to heat needs that are keyed to a specified hydronic supply temperature set point, which is preferably the hydronic temperature coming off the condenser **102** (not presently shown). For example, the ambient outdoor temperature is measured and sets the desired hydronic supply temperature. A single measuring point is used, preferably positioned on the North side of the building (in the Northern hemisphere), to avoid the influence of direct sunlight on cold days. A linear variation of the hydronic set point is used, so that on very cold days the hydronic set point is at or near its maximum setting (shown in the figure as 75° C.), while on warm days the set point is at or near its minimum (shown in the figure as 25° C.). The hydronic pump **141** (not presently shown) operates continuously so there is always a flow through the system.

[**0027**] Similarly, for the micro-CHP, a single measurement of outdoor ambient temperature can be used to establish the hydronic supply set point temperature. The working fluid mass flow is then controlled by the controller to maintain the actual supply temperature at this set point. Either an inverter drive or a separate input on the pump **103** would be sufficient to adjust the displacement of the pump **103** at constant motor speed to vary flow rate. The gas valve **153** is modulated to maintain the desired set point for the evaporator **104** outlet temperature of the working fluid into the expander **101**. Properties of the working fluid, as well as of optional fluids, such as lubricants, may dictate maximum operating temperatures of the fluid coming out of the evaporator **104**. For example, if the working fluid is the refrigerant known as R-245fa, the temperature set point at the evaporator **104** exit is about 310° F. (154° C.).

[**0028**] By operating the system such that the temperature of the working fluid at the evaporator **104** outlet is at or near its maximum value, good overall system efficiency results, regardless of system load. This can include very low thermal loads; for example, if the thermal load falls much below about 30 to 40% of full load, it is appropriate to shutdown the system and cease making both heat and power. Since the hydronic pump is kept running at all times, even at a low flow rate, the controller **130** can continuously monitor the error signal between the hydronic actual and set point values. When this error is large enough, (i.e., the actual temperature is below the set point by a preselected value) the controller **130** can start the system for another on-cycle. As the system **100** operates it may find that even at the minimum system mass flow, the actual supply temperature begins to exceed the set point. When this occurs, the system **100** is again shut down. Under this approach, the system **100** will operate for as many hours as possible during the colder heating season by running just often enough to maintain the hydronic supply temperature at the right value for the nominal heating load. When the system **100** operates at less than the maximum hydronic supply temperature, more power is generated than at the maximum temperature, so the controller **130** automatically and passively maximizes the electric power, which can be produced. Thus, as shown in the figure, the net electrical output goes up (at the same working fluid mass flow rate) as hydronic fluid supply temperature requirements goes down, while variations in working fluid flow rate and can be used in conjunction to vary electric output under a given thermal load. This inherent flexibility promotes overall energy (electrical and heat) system efficiency.

[0029] Referring again to **FIG. 1**, the generator **105** is preferably an asynchronous device, thereby promoting simple, low-cost operation of the system **100**, and reducing reliance on complex generator speed controls and related grid interconnections. An asynchronous generator always supplies maximum possible power without controls, as its torque requirement increases rapidly when generator **105** exceeds system frequency. The generator **105** can be designed to provide commercial frequency power, for example, 50 or 60 Hz, while staying within close approximation (often 150 or fewer revolutions per minute (rpm)) of synchronous speed (3000 or 3600 rpm). Block valve **107**A and bypass valve **107**B are situated in the organic working fluid flow path defined by conduit **110**. These valves respond to a signal in controller **130** that would indicate if no load (such as a grid outage) were on the system, or if a high Q/P were desired, thus allowing the superheated vapor to bypass the expander, thereby transferring a majority of the excess heat to the heat exchange loop in the condenser **102** (for high Q/P operation), as well as additionally avoiding overspeed of expander **101**.

[0030] A recuperator **109** is placed between expander **101** and condenser **102** in order to selectively extract additional heat from the working fluid once the fluid has been expanded. To achieve Q/P that varies depending on the heat and electric loads, the burner **151** is capable of modulation, while the condenser **102** is simultaneously responsive to fluctuating thermal content in the working fluid and capable of transferring enough heat for hydronic SH needs (as well as DHW needs). The recuperator **109** is central to providing a balance between these often diverging requirements. To meet the heat requirement of the circulating fluid medium, varying amounts of working fluid can be diverted around the recuperator to feed the condensed working fluid directly into evaporator **104**. Bypass valve **107**C can be a three-way modulating valve to effect such diversion. For example, if the hydronic fluid requirements of the circulating fluid medium are substantial (such as on a very cold day), the bypass valve **107**C can be set to largely or entirely bypass the secondary loop in recuperator **109** to enable maximum heat transfer to condenser **102**. Alternately, if the heat load on the system **100** is reduced (such as on a relatively mild day), then bypass valve **107**C can be set to permit a significant portion of the working fluid leaving condenser **102** to pass through the secondary loop of recuperator **109** to absorb some of the heat from the just-expanded working fluid, thereby reducing heat input requirements from burner **151** to the working fluid entering the evaporator **104**. One of the basic approaches to controlling the temperature at the evaporator outlet is to vary the mass flow out of the expander. By way of example, when the working fluid is R-245fa, the outlet temperature can be fixed, or set, to about 310° F. (154° C.). By selecting a corresponding pump capacity and speed to control the mass flow of working fluid into the evaporator, coupled with the ability of the expander to accept a concomitant amount of vapor flow, the evaporator outlet pressure tends to be typically between 380 and 400 psia (2.62 MPa and 2.76 MPa, respectively), with a preferred pressure of 392 psia (2.70 MPa) at full load. The outlet temperature of 310° F. (154° C.) leaves about 30° F. (17° C.) of superheat above the saturation temperature for the fluid, thereby simplifying the control system and its ability to adjust the burner firing rate to maintain the set outlet temperature. Then, as the thermal output capacity to meet lower loads is reduced, which could be due to cool or warm weather, the pump flow and the pressure changes accordingly to a lesser value. In an alternative approach, the same superheat temperature (30° F., 17° C.) can be maintained, while allowing the evaporator outlet temperature to fluctuate. Of the two approaches, it is preferable to run the evaporator outlet at a constant 310° F. (154° C.) from an efficiency stand point and for simplicity of the controller, as calculating the proper superheat temperature requires measuring, in some way, the evaporator outlet pressure. Because the constant temperature mode results in a higher efficiency and the expander is robust enough for constant temperature operation, it is the preferred mode of operation for the system **100**.

[0031] An accumulator **111** is connected intermediate condenser **102** and pump **103**. Insofar as the term "intermediate" is construed in the present context to describe the positioning of the accumulator **111** relative to condenser **102** and pump **103** more broadly than the aforementioned "between" (which was used to describe the relation between the expander **101**, recuperator **109** and condenser **102**), such use is meant to cover the connection of the intermediate component (the accumulator **111**) to its upstream and downstream component neighbors (the condenser **102** and pump **103**, respectively) to enable (although not necessitate) fluid communication between two or more of the components at any given time. A warming device **113** can be placed adjacent the accumulator **111** to keep the working fluid inside slightly warmer than the remaining circuit during periods of system inoperation. Heat for the warming device **113** can be, for example, from an electric (resistive) supply. Accumulator **111** can be isolated from the remainder of the organic working fluid circuit by accumulator isolation accumulator isolation valve **107**D, and is situated vertically above at least the pump **103** such that fluid flowing from accumulator **111** can be gravity-fed to the inlet of pump **103**. The accumulator **111** acts as a working fluid storage device in that during periods of low fluid flow rates (such as during system startup), it can provide an additional charge of fluid into the working fluid circuit to minimize, among other things, cavitation of pump **103**. Once the system has reached its normal operating condition, excess fluid in the working fluid circuit can return to the accumulator **111**, which being slightly cooler than the remainder of the organic working fluid circuit will allow the excess fluid to condense inside. The accumulator **111** serves as a source of additional working fluid during startup when liquid working fluid typically accumulates in the crankcase of expander **101** and potentially in the recuperator **109**. The additional working fluid from the accumulator **111** insures sufficient liquid working fluid to avoid or minimize cavitation of pump **103**. The warming device **113** can be used if necessary to provide the pressure needed to force the liquid working fluid out of the accumulator **111** and into the working fluid circuit. Once the system has reached its normal operating condition, any liquid working fluid in the crankcase of expander **101** and (if applicable) recuperator **109** will vaporize and return to the working fluid circuit. If the warming device **113** is turned off, the normal pressure and temperature of the working fluid will exceed that of the accumulator **111**, causing excess working fluid to be forced back into the accumulator **111**.

[**0032**] The return of the liquid to the accumulator **111** lowers the liquid level in the condenser **102**. This allows the condenser **102** to operate more efficiently. Without the accumulator **111**, a working fluid charge that is sufficient to prevent cavitation of pump **103** during startup may result in a flooded condenser **102** during normal operation. This excess liquid in the condenser **102** will result in higher condensing pressures and reduced efficiency and performance. Accumulator isolation valve **107**D serves to control the passage of liquid working fluid into and out of accumulator **111**. Accumulator isolation valve **107**D would be opened when the system is off to allow the liquid working fluid to enter the active working fluid circuit. At startup, accumulator isolation valve **107**D would be closed to prevent return of the working fluid liquid back into the accumulator **111** until the system **100** was fully warmed up and the liquid working fluid had been driven out of the crankcase of expander **101** and (if applicable) from recuperator **109**. Accumulator isolation valve **107**D would then be opened to allow the working fluid liquid to return to accumulator **111**.

[**0033**] Other means of controlling the flow of liquid working fluid into and out of accumulator **111** are also possible. In one embodiment, warming device **113** could be energized to raise the temperature and pressure in the accumulator **111** above that of the working fluid during startup. The accumulator **111** would thus remain full of vapor only until the warming device **113** was turned off and the accumulator **111** began to cool off. Alternatively, a check valve with an orifice could replace accumulator isolation valve **107**D. The check valve could allow the liquid to quickly transfer from the accumulator **111** while the system is off. During startup, the check valve would restrict flow back into the accumulator **111** except as metered through the orifice.

[**0034**] Referring next to **FIG. 2**, an indirectly-fired cogeneration system **200** is shown. A second loop **250** in cogeneration system **200** includes two parallel sub-loops **250**A, **250**B, while a first loop, which includes an expander **201** coupled to generator **205**, condenser **202**B, pump **203**, recuperator **209**, conduit **210** and accumulator **211** with warming device **213**, is configured similarly to, although not necessarily identical to, the system shown in **FIG. 1**. The most significant difference of the first loop over the system of **FIG. 1** is that the evaporator **104** of the former system is now replaced with an interloop heat exchanger **202**A, thus acting as a heat source for the first loop. Controller **230** is similar to that of the previously described system, but now with enlarged functionality to additionally control some or all of the operations of the second loop **250**. It will be appreciated that circulating fluid medium **240** is, while notionally depicting only an SH component that includes a pump **241** and radiator **248**, is understood to be similar to that of **FIG. 1**. Also as before, valve **207**C can be used to bypass the recuperator **209** in order to achieve variable Q/P, while pump **208** is used to circulate oil or related lubricant through the expander.

[**0035**] Heat to the two parallel sub-loops **250**A, **250**B is provided by a burner **251**, which is supplied with fuel by a gas train **252** and variable flow gas valve **253**. Piping **260** (alternately referred to as conduit, and which makes up the parallel sub-loops) passes through a combustion chamber **254**, where the heat from the combustion of fuel at burner **251** is given up to the heat exchange fluid (not shown) that flows through piping **260**. Piping **260** branches out into the first parallel sub-loop **250**A, which transports the heat exchange fluid that has been heated in combustion chamber **254** to interloop heat exchanger **202**A in order to give up the heat to organic working fluid flowing through the first loop, which as previously described, save the presence of the interloop heat exchanger **202**A in place of the evaporator **104**, is similar in construction to the directly-fired cogeneration system **100** shown in **FIG. 1**. Block valves (not shown) could be used to regulate flow between the sub-loops **250**A and **250**B; however, by idling the pump of the inactive sub-loop, significant flow in that sub-loop is prevented without the need for additional valving. The second parallel sub-loop **250**B transports the heat exchange fluid to DHW heat exchanger **280** in order to heat up domestic hot water. One side of DHW heat exchanger **280** (which can be a water storage tank) includes coil **280**A configured to transport the heat exchange fluid, and another side, the shell **280**B, to transport DHW (not shown) from a cold water inlet **291**A, past coil **280**A and to DHW outlet **291**B. As with the system shown in **FIG. 1**, the cold water preferably comes from either a well or a city/municipal water supply. Similarly, temperature sensor **271**B can detect the temperature of the DHW coming out of the DHW heat exchanger **280**. This sensor can also be linked to a controller **230** (discussed in more detail below).

[**0036**] Combustion chamber **254** includes an exhaust duct **255**, an exhaust gas recirculation device **256** with exhaust duct heat exchanger **257**, and fan **258**. Temperature sensor **271**A is placed at the combustion chamber **254** outlet for the second loop **250** to measure the temperature conditions of the heat exchange fluid, in a manner similar to that of temperature sensor **271**B. Second loop pumps **285**A, **285**B are used to circulate heat exchange fluid through the second loop **250**, with pump **285**B circulating heat exchange fluid through DHW heater **280** and pump **285**A circulating heat exchange fluid through interloop heat exchanger **204**. The exhaust duct heat exchanger **257** and an EGR device **256** accept hot exhaust gas from the burner **251** and recirculate it in an internal heat exchange process, thereby lowering the temperature of the exhaust gas that is pulled away and vented to the atmosphere by fan **258**. The heat given up by the exhaust gas in the exhaust gas heat exchanger **257** can be used to provide additional heat to other parts of the system **200**. For example, this additional heat can be used to increase the temperature of the heat exchange fluid flowing in second loop **250**, or to increase the heat content of the organic working fluid in the first loop.

[**0037**] Having described the invention in detail and by reference to preferred embodiments thereof, it will be apparent that modifications and variations are possible without departing from the scope of the invention defined in the appended claims. More specifically, although some aspects of the present invention are identified herein as preferred or particularly advantageous, it is contemplated that the present invention is not necessarily limited to these preferred aspects of the invention.

We claim:

1. A cogeneration system comprising:

a heat source;

a working fluid circuit comprising:

conduit configured to transport an organic working fluid through said working fluid circuit, at least a portion of said conduit disposed adjacent said heat source such that said organic working fluid disposed in said portion of said conduit is superheated during operation of said heat source;

an expander in fluid communication with said conduit such that said organic working fluid received therefrom remains superheated after expansion in said expander;

a condenser in fluid communication with said expander;

a pump configured to circulate said organic working fluid through at least said conduit, expander and condenser; and

a recuperator coupled to said conduit and configured to selectively increase the temperature of said organic working fluid entering said portion of said conduit disposed adjacent said heat source; and

at least one energy conversion circuit operatively responsive to said working fluid circuit such that upon operation of said cogeneration system, said at least one energy conversion circuit is configured to provide useable energy.

2. A cogeneration system according to claim 1, wherein said recuperator comprises:

a first heat exchange passage disposed between said expander and said condenser; and

a second heat exchange passage disposed between said pump and said part of said conduit adjacent said heat source.

3. A cogeneration system according to claim 1, wherein said at least one energy conversion circuit comprises:

a generator coupled to said expander to produce electricity; and

a circulating fluid medium in thermal communication with said condenser such that at least a portion of the heat given up by said organic working fluid in said condenser provides increased thermal content to said circulating fluid medium.

4. A cogeneration system according to claim 3, wherein said expander is a scroll expander.

5. A cogeneration system according to claim 3, wherein said circulating fluid medium is configured to transport a space heating fluid.

6. A cogeneration system according to claim 5, wherein said space heating fluid is water.

7. A cogeneration system according to claim 5, wherein said space heating fluid is forced air.

8. A cogeneration system according to claim 3, wherein said circulating fluid medium is configured to transport domestic hot water.

9. A cogeneration system according to claim 1, wherein said heat source is a burner.

10. A cogeneration system according to claim 1, further comprising an accumulator responsive to pressure differences within said working fluid circuit such that under a first operating condition, said accumulator adds excess working fluid to said working fluid circuit, and under a second operating condition, said accumulator removes excess working fluid from said working fluid circuit.

11. A cogeneration system according to claim 10, wherein said accumulator is intermediate said condenser and said pump.

12. A cogeneration system according to claim 10, wherein said accumulator is situated at a higher elevation relative to said pump to promote the gravity flow of said additional working fluid from said accumulator to said pump during said first operating condition.

13. A cogeneration system according to claim 10, further comprising a warming device thermally coupled to said accumulator such that during at least a portion of the period that said cogeneration system is not in operation, said accumulator is maintained at a higher temperature than the remainder of said working fluid circuit.

14. A cogeneration system according to claim 10, further comprising a valve configured to selectively fluidly isolate said accumulator from the remainder of said working fluid circuit.

15. A cogeneration system comprising:

a heat source;

a working fluid circuit comprising:

conduit configured to transport an organic working fluid through said working fluid circuit, at least a portion of said conduit disposed adjacent said heat source such that said organic working fluid disposed in said portion of said conduit is superheated during operation of said heat source;

an expander in fluid communication with said conduit such that said organic working fluid received therefrom remains superheated after expansion in said expander;

a condenser in fluid communication with said expander;

a pump configured to circulate said organic working fluid through at least said conduit, expander and condenser; and

an accumulator responsive to pressure differences within said working fluid circuit such that under a first operating condition, said accumulator adds excess working fluid to said working fluid circuit, and under a second operating condition, said accumulator removes excess working fluid from said working fluid circuit; and

at least one energy conversion circuit operatively responsive to said working fluid circuit such that upon operation of said cogeneration system, said at least one energy conversion circuit is configured to provide useable energy.

16. A cogeneration system according to claim 15, wherein said accumulator is intermediate said condenser and said pump.

17. A cogeneration system according to claim 15, wherein said accumulator is situated at a higher elevation relative to

said pump to promote the gravity flow of said additional working fluid from said accumulator to said pump during said first operating condition.

18. A cogeneration system according to claim 15, further comprising a warming device thermally coupled to said accumulator such that during at least a portion of the period that said cogeneration system is not in operation, said accumulator is maintained at a higher temperature than the remainder of said working fluid circuit.

19. A cogeneration system according to claim 15, further comprising a valve configured to selectively fluidly isolate said accumulator from the remainder of said working fluid circuit.

20. A Rankine cycle cogeneration system comprising:

a heat source;

a working fluid circuit comprising:

conduit configured to transport an organic working fluid through said working fluid circuit, at least a portion of said conduit disposed adjacent said heat source such that said organic working fluid disposed in said portion of said conduit disposed adjacent said heat source is heated during operation of said heat source;

an expander in fluid communication with said conduit such that said organic working fluid received therefrom remains superheated after said expansion in said expander;

a condenser in fluid communication with said expander;

a pump configured to circulate said organic working fluid through at least said conduit, expander and condenser;

a recuperator coupled to said conduit and configured to selectively increase the temperature of said organic working fluid entering said portion of said conduit disposed adjacent said heat source; and

an accumulator intermediate said condenser and said pump; and

at least one energy conversion circuit operatively responsive to said working fluid circuit such that upon operation of said cogeneration system, said at least one energy conversion circuit is configured to provide useable energy.

21. A cogeneration system according to claim 20, wherein said accumulator is responsive to pressure differences within said working fluid circuit such that under a first operating condition, said accumulator adds excess working fluid to said working fluid circuit, and under a second operating condition, said accumulator removes excess working fluid from said working fluid circuit.

22. A cogeneration system according to claim 21, wherein said accumulator is situated at a higher elevation relative to said pump to promote the gravity flow of said excess working fluid from said accumulator to said pump during said first operating condition.

23. A Rankine cycle cogeneration system comprising:

an organic working fluid;

an evaporator capable of superheating said organic working fluid, said evaporator comprising:

a burner; and

conduit adjacently spaced relative to said burner such that during burner operation heat transferred therefrom is sufficient to superheat said organic working fluid disposed in said conduit;

a substantially closed-loop working fluid circuit in thermal communication with said burner, said substantially closed-loop working fluid circuit configured to transport said organic working fluid therethrough, said substantially closed-loop working fluid circuit comprising:

an expander in fluid communication with said conduit such that said organic working fluid received therefrom remains superheated after expansion in said expander;

a condenser in fluid communication with said expander;

a pump configured to circulate said organic working fluid through at least said conduit, expander and condenser;

a recuperator coupled to said conduit and configured to selectively increase the temperature of said organic working fluid entering said evaporator; and

an accumulator fluidly responsive to pressure differences within said working fluid circuit such that under a first operating condition, said accumulator adds excess working fluid to said working fluid circuit, and under a second operating condition, said accumulator removes excess working fluid from said working fluid circuit; and

at least one energy conversion circuit comprising:

a generator coupled to said expander to produce electricity; and

a circulating fluid medium in thermal communication with said condenser such that at least a portion of the heat given up by said organic working fluid in said condenser provides increased thermal content to said circulating fluid medium.

24. A dwelling configured to provide at least a portion of the heat and power needs of occupants therein, said dwelling comprising:

a plurality of walls defining at least one room therebetween;

a roof situated above said plurality of walls;

at least one ingress/egress to facilitate passage into and out of said dwelling; and

a cogeneration system in heat and power communication with said at least one room, said cogeneration system comprising:

a heat source;

a working fluid circuit comprising:

conduit configured to transport an organic working fluid through said working fluid circuit, at least a portion of said conduit disposed adjacent said heat source such that said organic working fluid passing through said portion of said conduit disposed adjacent said heat source is superheated during operation of said heat source;

an expander in fluid communication with said conduit such that said organic working fluid received therefrom remains superheated after expansion in said expander;

a condenser in fluid communication with said expander;

a pump configured to circulate said organic working fluid through at least said conduit, expander and condenser; and

a recuperator coupled to said conduit and configured to selectively increase the temperature of said organic working fluid entering said portion of said conduit disposed adjacent said heat source; and

at least one energy conversion circuit operatively responsive to said working fluid circuit such that upon operation of said cogeneration system, said at least one energy conversion circuit is configured to provide useable energy.

25. A dwelling according to claim 24, further comprising a controller to control at least the flow rate of said organic working fluid.

26. A dwelling according to claim 25, wherein said controller is in signal communication with an outdoor sensor.

27. A dwelling according to claim 25, wherein said controller is responsive to occupant input.

28. A dwelling according to claim 27, wherein said controller responsive to occupant input is a thermostat.

29. A dwelling according to claim 24, further comprising an accumulator responsive to pressure differences within said working fluid circuit such that under a first operating condition, said accumulator adds excess fluid to said working fluid circuit, and under a second operating condition, said accumulator removes excess working fluid from said working fluid circuit.

30. A micro combined heat and power system comprising:

an electric production subsystem comprising:

an organic working fluid;

a burner for superheating said organic working fluid;

a scroll expander configured to receive and expand said organic working fluid in a superheated state;

a generator operatively coupled to said scroll expander to produce electricity;

a condenser disposed in fluid communication with said scroll expander;

a pump to circulate said organic working fluid through said electricity generating loop;

a recuperator in thermal communication with said expander such that during operation of said micro combined heat and power system, said superheated organic working fluid exiting said expander selectively gives up at least a portion of its excess heat to increase the temperature of said organic working fluid entering said burner; and

an accumulator intermediate said condenser and said pump; and

a heat production subsystem comprising an circulating fluid medium in thermal communication with said condenser.

31. A method of producing heat and electrical power from a cogeneration device, the method comprising the steps of:

providing a heat source;

configuring a first circuit to transport an organic working fluid adjacent said heat source;

superheating said organic working fluid;

expanding said superheated organic working fluid to generate electricity;

maintaining said organic working fluid in said superheated state at least until said organic working fluid enters a recuperator;

giving up at least a portion of the excess heat from said superheated organic working fluid in said recuperator;

exchanging at least a portion of the excess heat from said organic working fluid that has passed through said recuperator in a condenser with a circulating fluid medium such that after passing through said condenser, said organic working fluid is no longer in a superheated state;

adding heat to said organic working fluid that is no longer in a superheated state in said recuperator; and

returning said organic working fluid such that it is adjacent said heat source.

32. A method according to claim 31, wherein said circulating fluid medium is configured to transport a space heating fluid.

33. A method according to claim 32, wherein said space heating fluid is water.

34. A method according to claim 31, wherein said space heating fluid is forced air.

35. A method according to claim 31, wherein said circulating fluid medium is configured to transport domestic hot water.

36. A method according to claim 31, further comprising adjusting the flow rate of said organic working fluid through said recuperator in response to a set point condition in said circulating fluid medium.

37. A method according to claim 36, wherein said set point condition is a hydronic fluid temperature in said circulating fluid medium.

* * * * *