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(54) **POWER SYSTEMS AND METHODS
IMPLEMENTING AND USING SAME**

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(57) **ABSTRACT**

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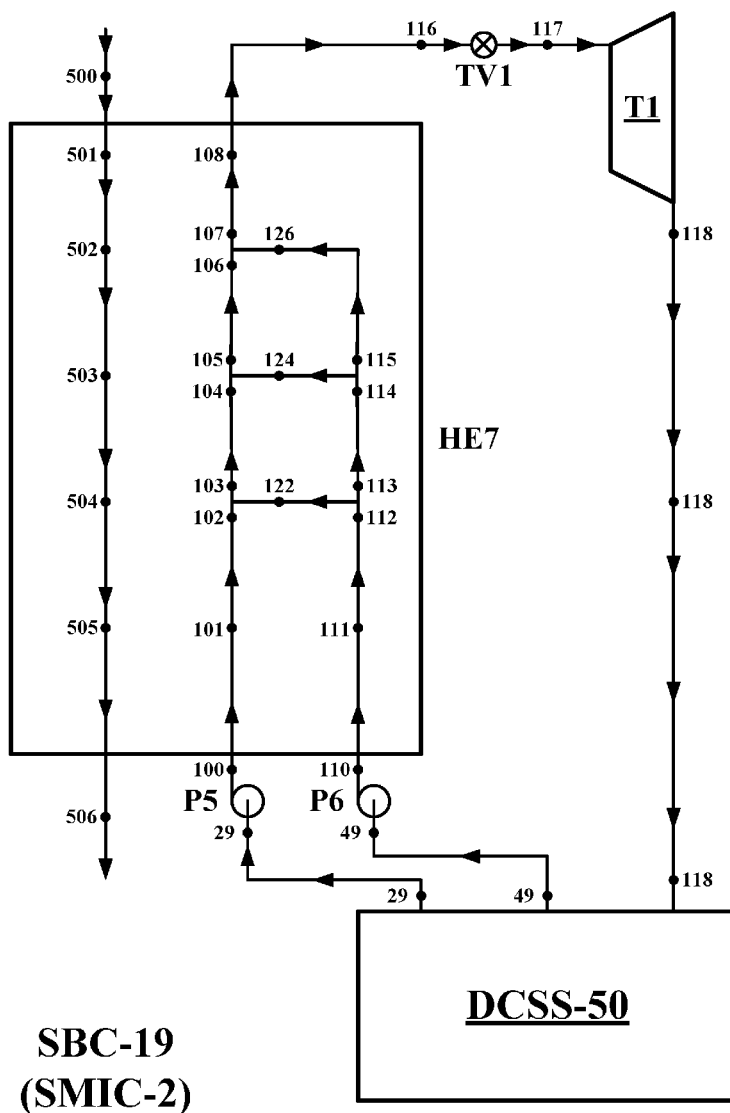
Power systems and methods including a vaporization subsystem (VPSS), an energy conversion subsystem (ECSS), and a distillation condensation subsystem (DCSS), where the DCSS produces a fully condensed, lean working solution stream (LWSS) and a fully condensed, rich working solution stream (RWSS) from a multiple component working fluid using an external coolant stream, the VPSS vaporizes and superheats the LWSS and RWSS in a multi-stage vaporization process such that each LWSS remains in a state of subcooled liquid prior to being mixed with the RWSS or one or more intermediate solution streams to maximize heat extraction from an external heat source stream to form a combined working solution stream (CWSS) and converting a portion of the heat in the CWSS into a useable form of energy in the ECSS.

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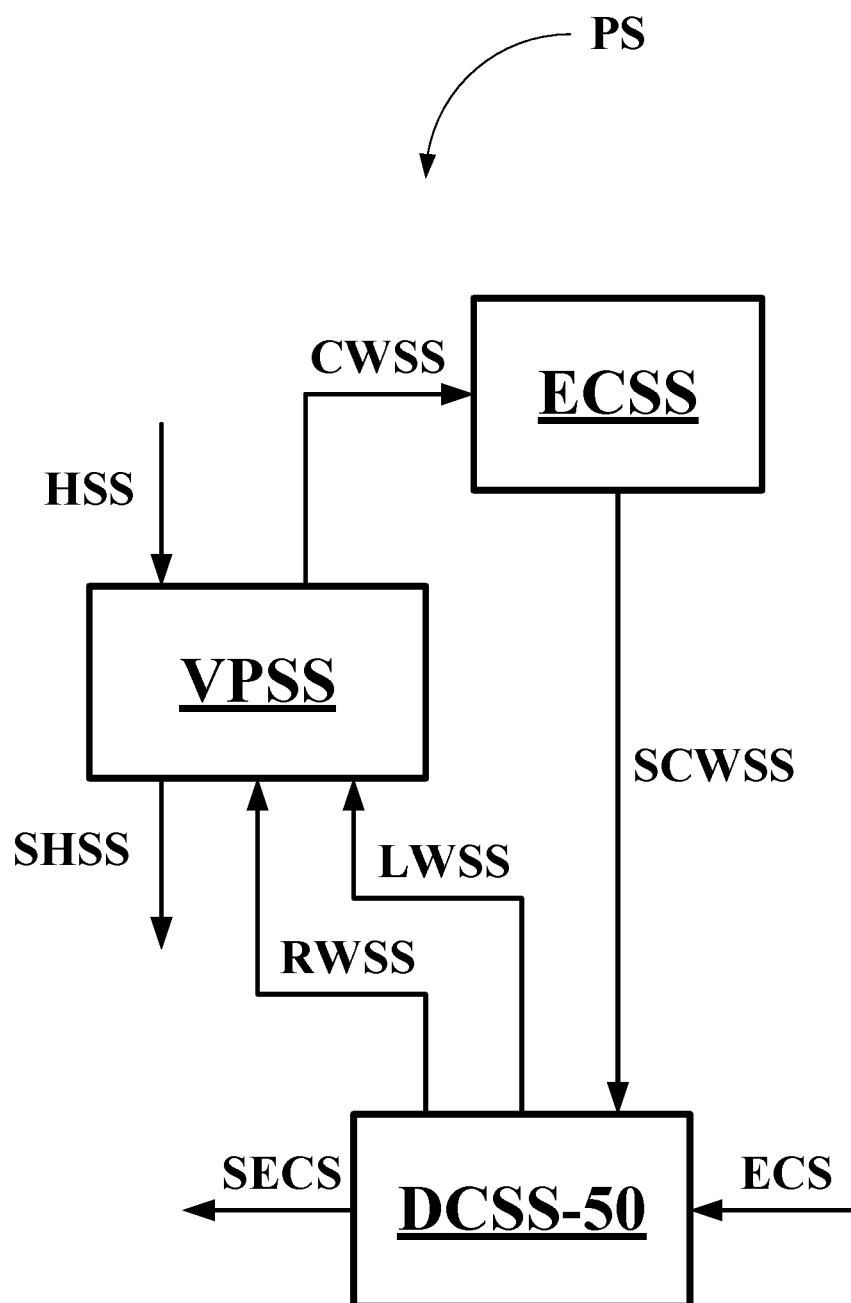


FIG. 1

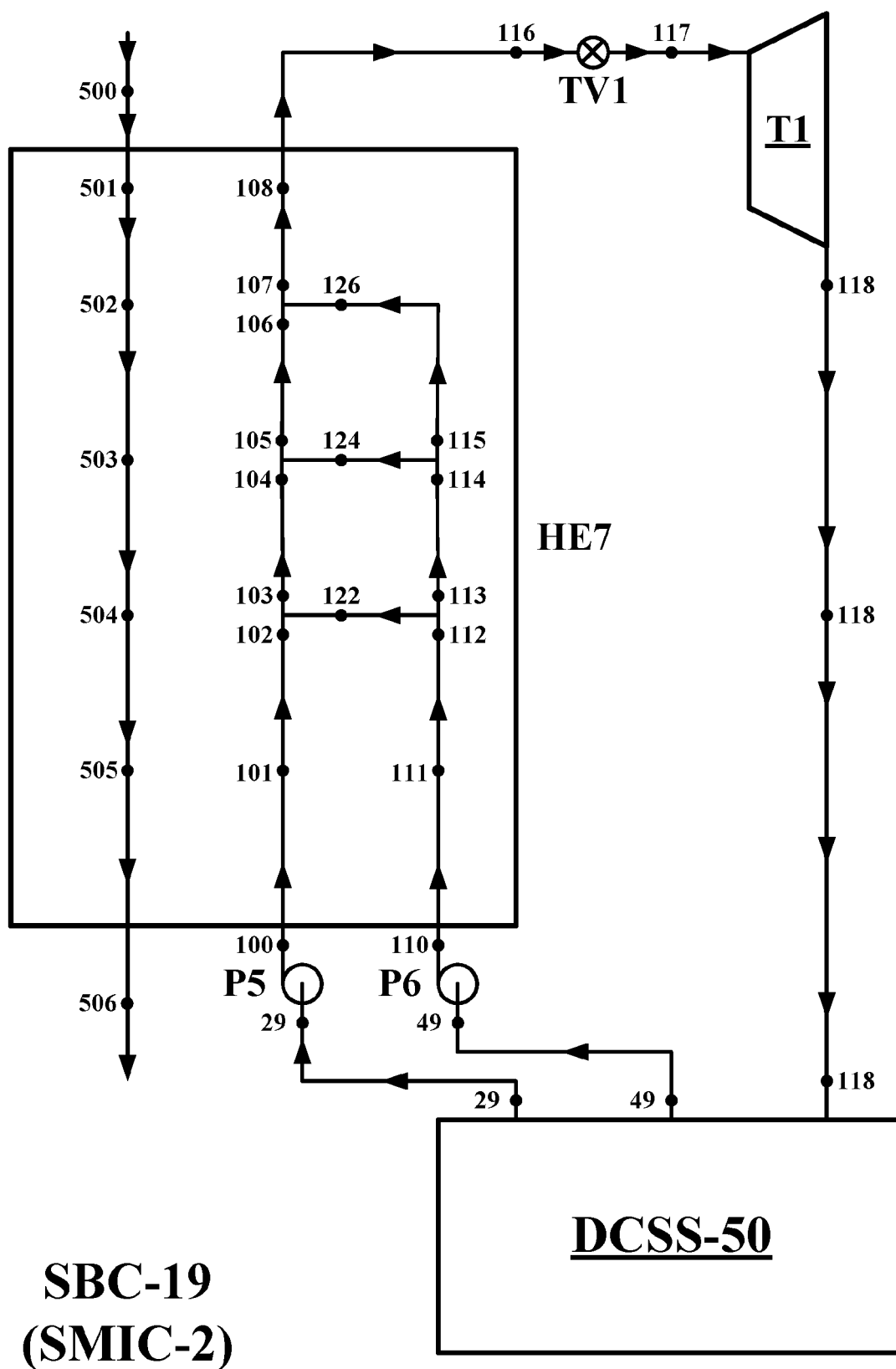
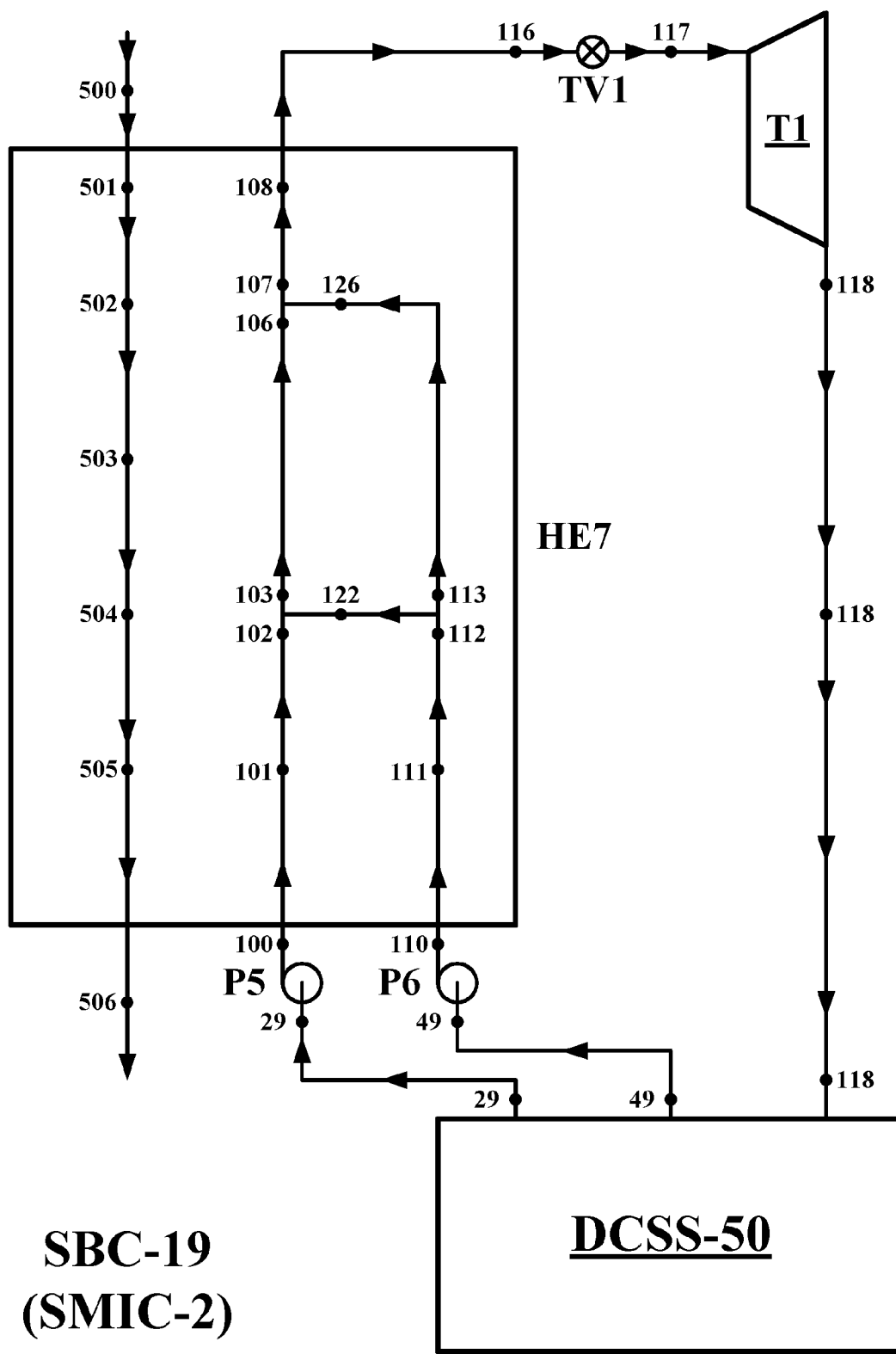


FIG. 2A



**SBC-19
(SMIC-2)
Variant 1**

FIG. 2B

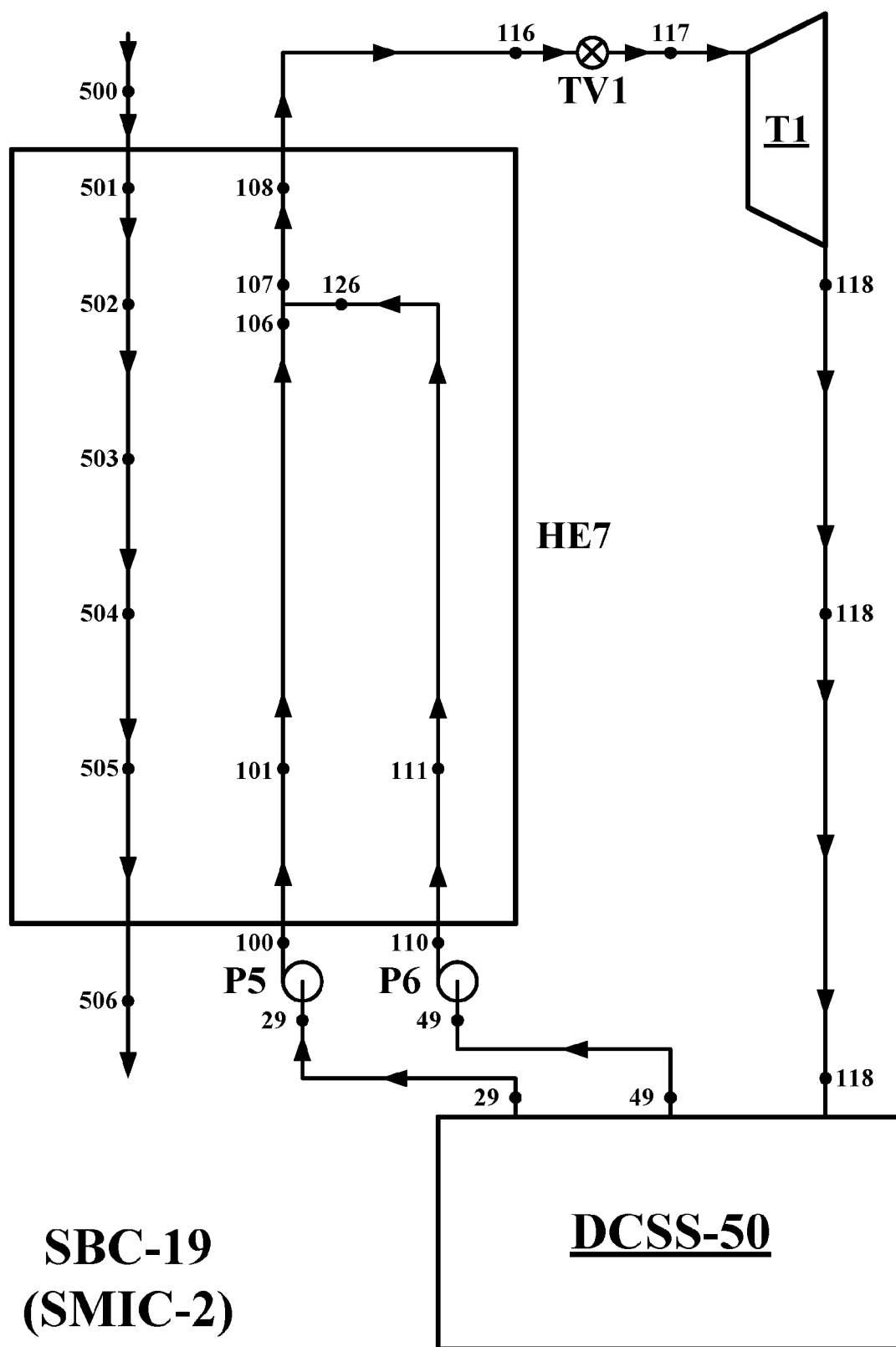


FIG. 2C

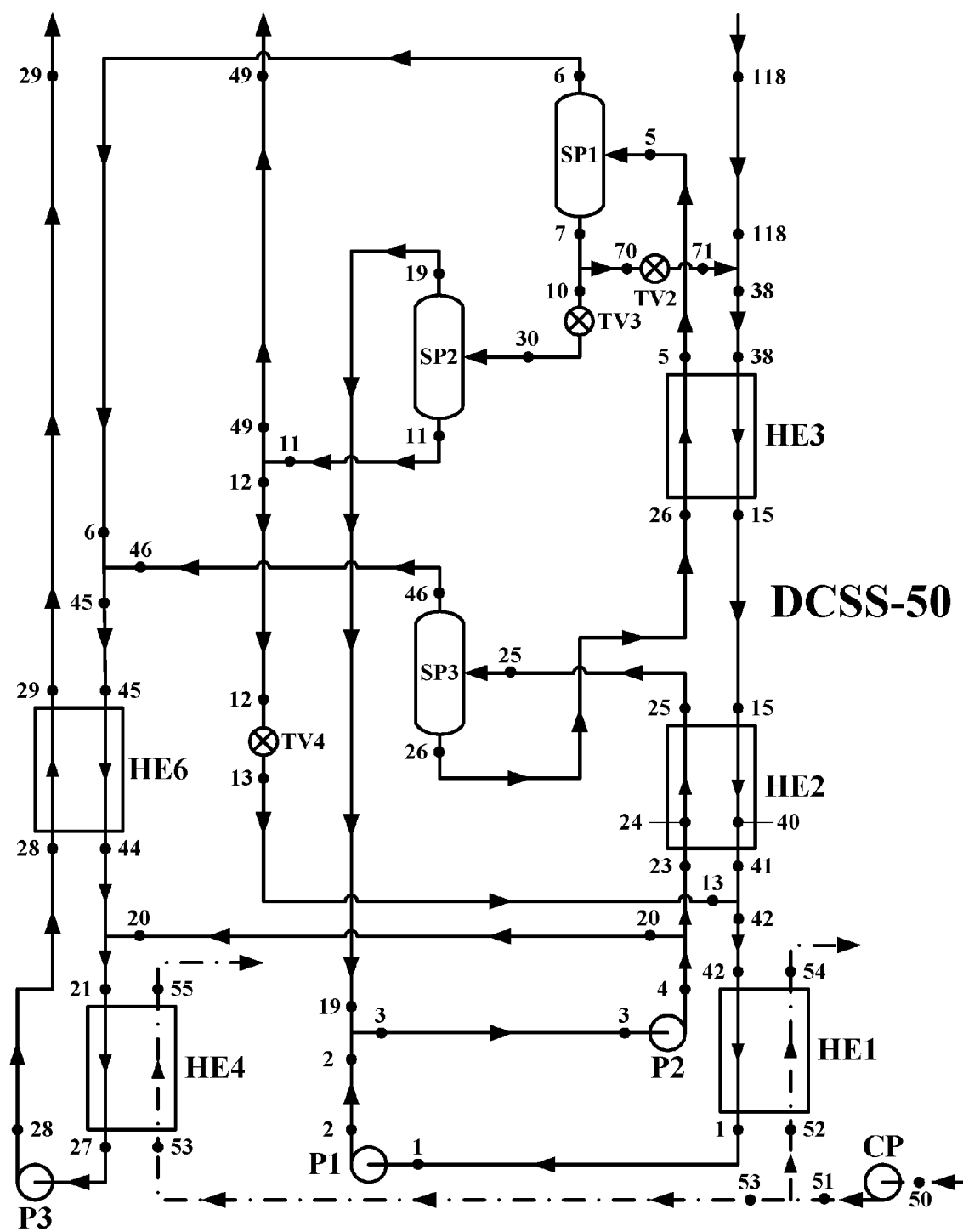


FIG. 3

POWER SYSTEMS AND METHODS IMPLEMENTING AND USING SAME

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] Embodiments of the present invention relate to systems and methods, designated SBC-19 with DCSS-50, intended for the generation of power utilizing heat from heat sources that have a wide range of temperatures such as exhausts from a gas turbine, or other similar exhaust gas heat sources, or alternately, industrial waste heat sources.

[0003] More particularly, embodiments of the present invention relate to systems and methods, designated SBC-19 with DCSS-50, intended for the generation of power utilizing heat from heat sources that have a wide range of temperatures such as exhausts from a gas turbine, or other similar exhaust gas heat sources, or alternately, industrial waste heat sources, where the system includes a vaporization subsystem, an energy extraction subsystem, and a distillation condensation subsystem (DCSS-50).

[0004] 2. Description of the Related Art

[0005] When utilizing such sources it is crucial to make maximum utilization of the heat available; i.e., to cool the heat source down to the greatest degree possible and make use of the heat thus obtained.

[0006] To this end, in the prior art, bottoming cycles utilizing the exhaust from gas turbines use dual and even triple pressure Rankine cycle systems, with two or three turbines respectively. In such systems, the high temperature portion of the heat from the heat source stream is used for high pressure boiling (utilized in a high pressure turbine), the mid-temperature portion of the heat is used at moderate pressures (in a mid-pressure turbine,) and the low-temperature portion of the heat is used at low pressure (in a low pressure turbine).

[0007] Thus, there is a need in the art for power systems that utilize a single pressure turbine energy extraction system that maximizes heat utilization of heat from heat sources that have a wide range of temperatures such as exhausts from a gas turbine, or other similar exhaust gas heat sources, or alternately, industrial waste heat sources.

SUMMARY OF THE INVENTION

[0008] Embodiments of this invention provide a power system (PS) including a vaporization subsystem (VPSS), an energy conversion subsystem (ECSS), and a distillation condensation subsystem (DCSS-50), where the system utilizes a multiple component working fluid, the DCSS-50 produces a fully condensed lean working solution stream and a fully condensed working solution stream from the working fluid using an external coolant stream, and the VPSS vaporizes and superheats the two working solution streams in a multi-stage vaporization process such that each lean stream remains in a state of subcooled liquid prior to being mixed with the rich working solution stream or intermediate solution stream to maximize heat extraction from an external heat source stream and converting a portion of the heat in a combined working solution stream exiting the VPSS in the ECSS.

[0009] Embodiments of this invention provide a method including transferring heat from an external heat source stream to a fully condensed lean working solution stream and a fully condensed working solution stream derived from

a multiple component working fluid in a multi-stage vaporization process such that each lean stream remains in a state of subcooled liquid prior to being mixed with the rich working solution stream or one or more intermediate solution streams to maximize heat extraction from an external heat source stream in a vaporization subsystem (VPSS) to form a fully vaporized and superheated combined working solution stream, converting a portion of heat in a fully vaporized and superheated combined working solution stream in the ECSS into a useable form of energy (mechanical and/or electrical), and condensing a spent combined working solution stream in a distillation condensation subsystem (DCSS-50) using an external coolant stream to form a lean working solution stream and a rich working solution stream.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] The invention can be better understood with reference to the following detailed description together with the appended illustrative drawings in which like elements are numbered the same:

[0011] FIG. 1 depicts a general embodiment of a system of this invention including a vaporization subsystem (VPSS), an energy conversion subsystem (ECSS), and a distillation condensation subsystem (DCSS-50).

[0012] FIG. 2A depicts a specific embodiment of a system of this invention.

[0013] FIG. 2B depicts another specific embodiment of a system of this invention.

[0014] FIG. 2C depicts another specific embodiment of a system of this invention.

[0015] FIG. 3 depicts an embodiment of the distillation condensation subsystem (DCSS-50).

DEFINITIONS USED IN THE INVENTION

[0016] The term “substantially” means that the property is within 95% of its desired value. In other embodiments, “substantially” means that the property is within 97.5% of its desired value. In other embodiments, “substantially” means that the property is within 99% of its desired value. In other embodiments, “substantially” means that the property is within 99.9% of its desired value. For example, the term “substantially complete” as it relates to a coating, means that the coating is at least 95% complete. In other embodiments, the term “substantially complete” as it relates to a coating, means that the coating is at least 97.5% complete. In other embodiments, the term “substantially complete” as it relates to a coating, means that the coating is at least 99% complete. In other embodiments, the term “substantially complete” as it relates to a coating, means that the coating is at least 99.9% complete.

[0017] The term “substantially” means that a value is within about $\pm 5\%$ of the indicated value. In certain embodiments, the value is within about $\pm 2.5\%$ of the indicated value. In certain embodiments, the value is within about $\pm 1\%$ of the indicated value. In certain embodiments, the value is within about $\pm 0.5\%$ of the indicated value. In certain embodiments, the value is within about $\pm 0.1\%$ of the indicated value. In certain embodiments, the value is within about $\pm 0.01\%$ of the indicated value.

[0018] The term “about” means that the value is within about $\pm 10\%$ of the indicated value. In certain embodiments, the value is within about $\pm 5\%$ of the indicated value. In

certain embodiments, the value is within about $\pm 2.5\%$ of the indicated value. In certain embodiments, the value is within about $\pm 1\%$ of the indicated value. In certain embodiments, the value is within about $\pm 0.5\%$ of the indicated value. The term “about” means that the property is within about $\pm 10\%$ of the indicated value. In certain embodiments, the property is within about $\pm 5\%$ of the indicated value. In certain embodiments, the property is within about $\pm 2.5\%$ of the indicated value. In certain embodiments, the property is within about $\pm 1\%$ of the indicated value. In certain embodiments, the property is within about $\pm 0.5\%$ of the indicated value.

[0019] The term “mixture” means that two or more components have been mixed together to form a mixture before use.

[0020] The term “combination” means that two or more components are used separately and the final composition includes a combination of material made from single components.

DETAILED DESCRIPTION OF THE INVENTION

[0021] The inventor has found that systems and corresponding methods can be constructed that permit maximization of generation of power utilizing heat from heat sources that have a wide range of temperatures such as exhausts from a gas turbine, or other similar exhaust gas heat sources, or alternately, industrial waste heat sources. In the present systems, a multiple component, variable composition working fluid is used and the maximum possible utilization of the heat source is attained by using a multi-stage vaporization process for the working fluid, with different compositions of working fluid at each stage.

[0022] Embodiments of this invention relate to systems for power generation including a distillation condensation subsystem (DCSS-50), where a spent combined working solution stream CWFS is fully condensed in a multi-stage distillation and condensation process using variable composition streams derived from the CWFS and an external coolant stream CS to produce a fully condensed rich working solution stream RWFS and a fully condensed lean working solution stream LWFS and a spent CS. The systems further includes a vaporization subsystem (VPSS), where heat from an external heat source stream HSS is used to heat, fully vaporize and superheat the RWFS and the LWFS in a multi-stage vaporization process such that each lean working solution stream remains in a state of supercooled liquid prior to being mixed with the rich working solution stream or one or more intermediate solution streams to maximize heat transfer from the HSS to produce a fully vaporized and superheated CWFS and a spent HSS. The systems further includes an energy conversion subsystem (ECSS), where a portion of heat associated with the CWFS is converted into a useable form of energy producing a spent CWFS which is forwarded to the DCSS-50 closing the system. All of the streams used in the systems are derived from a single multi-component fluid.

[0023] In certain embodiments, the VPSS includes a single heat exchange unit having two working solution tubes and at least one combining valve, where (a) the combining valve combines a heated lean working solution stream in a state of subcooled liquid and a vaporized rich working solution stream under conditions where the lean working solution stream is fully absorbed by the vaporized rich

working solution stream producing a vaporized combined working solution stream, (b) once formed, the vaporized combined working solution stream is superheated to form the fully vaporized and superheated, combined working solution stream, and (c) all heat is derived from the external heat source stream, the ECSS comprises a single pressure turbine, and the DCSS-50 comprising at least two throttle control valves, three heat exchanges units, two condensers, three pumps, and three separators.

[0024] In other embodiments of the invention, the VPSS comprises a single heat exchange unit having two working solution tubes and two combining valves and one dividing valve, where (a) the dividing valve divides a heated lean working solution stream into a heated first lean working solution substream and a heated second lean working solution substream, (b) a first combining valve combines the heated second lean working solution substream in a state of subcooled liquid and a partially vaporized rich working solution stream under conditions where the heated second lean working solution substream is fully absorbed by the partially vaporized rich working solution stream producing a partially vaporized intermediate solution stream, (c) a second combining valve combines a further heated first lean working solution substream in a state of subcooled liquid and a vaporized intermediate solution stream under conditions where the further heated first lean working solution substream is fully absorbed by the vaporized intermediate solution stream producing a vaporized combined working solution stream, (d) once formed, the vaporized combined working solution stream is superheated to form the fully vaporized and superheated, combined working solution stream, and (e) all heat is derived from the external heat source stream, the ECSS comprises a single pressure turbine, and the DCSS-50 comprising three throttle control valves, three heat exchanges units, two condensers, three pumps, and three separators.

[0025] In other embodiments of the invention, the VPSS comprises a single heat exchange unit having two working solution tubes and three combining valves and two dividing valves, where (a) a first dividing valve divides a heated lean working solution stream into a heated first lean working solution substream and a heated second lean working solution substream, (b) a first combining valve combines the heated second lean working solution substream in a state of subcooled liquid and a partially vaporized rich working solution stream under conditions where the second heated lean working solution substream is fully absorbed by the partially vaporized rich working solution stream producing a partially vaporized first intermediate solution stream, (c) a second dividing valve divides a further heated lean first working solution substream into a further heated third lean working solution substream and a further heated fourth lean working solution substream, (d) a second combining valve combines a further heated third lean working solution substream and a heated partially vaporized first intermediate solution stream under conditions where the yet further heated third lean working solution substream is fully absorbed by the heated partially vaporized first intermediate solution stream producing a partially vaporized second intermediate solution stream, (f) a third combining valve combines a yet further heated fourth lean working solution substream and a vaporized second intermediate solution stream under conditions where the yet further heated fourth lean working solution substream is fully absorbed by the

vaporized second intermediate solution stream producing a vaporized combined working solution stream, (g) once formed, the vaporized combined working solution stream is superheated to form the fully vaporized and superheated, combined working solution stream, and (h) all heat is derived from the external heat source stream, the ECSS comprises a single pressure turbine, and the DCSS-50 comprising three throttle control valves, three heat exchanges units, two condensers, three pumps, and three separators.

[0026] In other embodiments of the invention, the single multi-component working fluid comprises at least one lower boiling point component and at least one higher boiling point component. In other embodiments, the single multi-component fluid is selected from the group consisting of a ammonia-water mixture, a mixture of two or more hydrocarbons, a mixture of two or more freon, a mixture of hydrocarbons and freons, and mixtures thereof. In other embodiments, the single multi-component fluid comprises a mixture of compounds having favorable thermodynamic characteristics and solubilities. In other embodiments, the single multi-component fluid comprises a mixture of water and ammonia.

[0027] Embodiments of this invention relate to methods include condensing a spent combined working solution stream in a distillation condensation subsystem in a multi-stage distillation and condensation process using variable composition streams derived from the spent combined working solution stream and an external coolant stream producing a fully condensed, intermediate pressure, rich working solution stream and a fully condensed, intermediate pressure, lean working solution stream and a spent external coolant stream. The methods also include concurrently pressurizing the fully condensed, intermediate pressure, rich working solution stream and the fully condensed, intermediate pressure, lean working solution stream in separate feed pumps producing a fully condensed, higher pressure, rich working solution stream and a fully condensed, higher pressure, lean working solution stream. The methods also include transferring heat from an external heat source stream in a vaporization subsystem in a multi-stage vaporization process such that each higher pressure, lean working solution stream remains in a state of subcooled liquid prior to being mixed with the rich working solution stream or one or more intermediate solution streams derived from the rich working solution stream and the lean working solution stream or one or more lean working solution substreams to maximize heat transfer from the external heat source stream producing a fully vaporized and superheated, higher pressure, combined working solution stream and a spent external heat source stream. The methods also include converting a portion of heat in a fully vaporized and superheated, higher pressure, combined working solution stream in an energy extraction subsystem to a useable form of energy (mechanical and/or electrical) producing the spent combined working solution stream. All of the streams used in the methods are derived from a single multi-component fluid comprises at least one lower boiling point component and at least one higher boiling point component selected from the group consisting of a ammonia-water mixture, a mixture of two or more hydrocarbons, a mixture of two or more freon, a mixture of hydrocarbons and freons, and mixtures thereof.

[0028] Embodiments of this invention relate to methods including concurrently forwarding: (a) a fully condensed, rich working solution stream into a fifth pump producing a

higher pressure, fully condensed, rich working solution stream and (b) a fully condensed, lean working solution stream into a sixth pump producing a higher pressure, fully condensed, lean working solution stream. The methods include vaporizing and superheating the higher pressure, fully condensed, rich working solution stream and the higher pressure, fully condensed, lean working solution stream in a vaporization subsystem in a multi-stage vaporization process using heat from an initial external heat source stream so that the higher pressure, fully condensed, lean working solution stream or a plurality of higher pressure, lean working solution substreams is/are in a state of subcooled liquid prior to mixing and being fully absorbed by a vapor component of a vaporized, higher pressure, rich working solution stream or a plurality of vaporized, higher pressure, intermediate solution streams derived from the higher pressure, rich working solution stream and the higher pressure, lean working solution stream producing a fully vaporized and superheated, combined working solution stream and a spent external heat source stream. The methods include converting a portion of heat in the fully vaporized and superheated, combined working solution stream in an energy extraction subsystem to a useable form of energy comprising mechanical and/or electrical energy producing a spent combined working solution stream. The methods include condensing the spent combined working solution stream in a multi-stage distillation and condensation process in a distillation condensation subsystem using variable composition streams derived from the spent combined working solution stream and an initial external coolant stream to produce the fully condensed, rich working solution stream, the fully condensed, lean working solution stream, and a spent external coolant stream. All of the streams using in the methods are derived from a single multi-component fluid.

[0029] In certain embodiments of the invention, the multi-stage vaporization process includes concurrently heating: (a) the higher pressure, fully condensed, rich working solution stream and (b) the higher pressure, fully condensed, lean working solution stream with heat from a first cooled external heat source stream in a lower portion of the vaporization subsystem producing the spent external heat source stream, a vaporized, higher pressure, rich working solution stream, and a heated, higher pressure, lean working solution stream, which corresponds to a state of subcooled liquid. The multi-stage vaporization process also includes combining the vaporized, higher pressure, rich working solution stream and the heated, higher pressure, lean working solution stream in the vaporization subsystem under conditions so that the heated, higher pressure, lean working solution stream is fully absorbed by a vapor content of the vaporized, higher pressure, rich working solution stream producing a vaporized, combined working solution stream. The multi-stage vaporization process also includes heating the vaporized, combined working solution stream with heat from the initial heat source stream in an upper portion of the vaporization subsystem producing the fully vaporized and superheated, combined working solution stream and the first cooled external heat source stream.

[0030] In other embodiments of the invention, the multi-stage distillation and condensation process includes concurrently heating: (a) the higher pressure, fully condensed, rich working solution stream and (b) the higher pressure, fully condensed lean working solution stream with heat from a second cooled external heat source stream producing the

spent external heat source stream, a partially vaporized, higher pressure, rich working solution stream, and a heated, higher pressure, lean working solution stream, which corresponds to a state of subcooled liquid. The multi-stage vaporization process also includes dividing the heated, higher pressure, lean working solution stream into a heated, higher pressure, first lean working solution substream and a heated, higher pressure, second lean working solution substream, where both of the heated, higher pressure, lean working solution substreams correspond to states of subcooled liquid. The multi-stage vaporization process also includes combining the partially vaporized, higher pressure, rich working solution stream and the heated, higher pressure, first lean working solution substream in the vaporization subsystem under conditions so that the heated, higher pressure, first lean working solution stream is fully absorbed by a vapor content of the partially vaporized, higher pressure, rich working solution stream producing a higher pressure, first intermediate solution stream. The multi-stage vaporization process also includes currently heating: (a) the higher pressure, first intermediate solution stream and the heated, higher pressure, second lean working solution substream with heat from a first cooled external heat source stream producing the second external heat source stream, a partially vaporized, higher pressure, first intermediate solution stream, and a further heated, higher pressure, second lean working solution substream, which corresponds to a state of subcooled liquid. The multi-stage vaporization process also includes combining the partially vaporized, higher pressure, first intermediate solution stream and the further heated, higher pressure, second lean working solution substream in the vaporization subsystem under conditions so that the further heated, higher pressure, second lean working solution substream is fully absorbed by a vapor content of the partially vaporized, higher pressure, first intermediate solution stream producing the vaporized, combined working solution stream. The multi-stage vaporization process also includes heating the vaporized, combined working solution stream with heat from the initial heat source stream in an upper portion of the vaporization subsystem producing the fully vaporized and superheated, combined working solution stream and the first cooled external heat source stream.

[0031] In other embodiments of the invention, the multi-stage distillation and condensation process includes currently heating (a) the higher pressure, fully condensed, rich working solution stream and (b) the higher pressure, fully condensed, lean working solution stream with heat from a third cooled external heat source stream producing the spent external heat source stream, a partially vaporized, higher pressure, rich working solution stream, and a heated, higher pressure, lean working solution stream, which corresponds to a state of subcooled liquid. The multi-stage vaporization process also includes dividing the heated, higher pressure, lean working solution stream into a heated, higher pressure, first lean working solution substream and a heated, higher pressure, second lean working solution substream, where both of the heated, lean working solution substreams correspond to states of subcooled liquid. The multi-stage vaporization process also includes combining the partially vaporized, higher pressure, rich working solution stream and the heated, higher pressure, first lean working solution substream in the vaporization subsystem under conditions so that the heated, higher pressure, first lean working solution substream is fully absorbed by a vapor content of the

partially vaporized, higher pressure, rich working solution stream producing a higher pressure, first intermediate solution stream. The multi-stage vaporization process also includes currently heating: (a) the higher pressure, first intermediate solution stream and the heated, higher pressure, second lean working solution substream with heat from a second cooled external heat source stream producing the third external heat source stream, a partially vaporized, higher pressure, first intermediate solution stream, and a further heated, higher pressure, second lean working solution stream, which corresponds to a state of subcooled liquid. The multi-stage vaporization process also includes dividing the further heated, higher pressure, second lean working solution substream into a further heated, higher pressure, third lean working solution substream and a further heated, higher pressure, fourth lean working solution substream, where both of the further heated, higher pressure, lean working solution substream correspond to a state of subcooled liquid. The multi-stage vaporization process also includes combining the partially vaporized, higher pressure, first intermediate solution stream and the further heated, higher pressure, third lean working solution substream in the vaporization subsystem under conditions so that the further heated, higher pressure, third lean working solution substream is fully absorbed by a vapor content of the partially vaporized, higher pressure, first intermediate solution stream producing a higher pressure, second intermediate solution stream. The multi-stage vaporization process also includes currently heating: (a) the higher pressure, second intermediate solution stream and the further heated, higher pressure, fourth lean working solution substream with heat from a first cooled external heat source stream producing the second external heat source stream, a vaporized, higher pressure, second intermediate solution stream, and a yet further heated, higher pressure, fourth lean working solution stream, which corresponds to a state of subcooled liquid. The multi-stage vaporization process also includes combining the vaporized, higher pressure, second intermediate solution stream and the yet further heated, higher pressure, fourth lean working solution substream in the vaporization subsystem under conditions so that the yet further heated, higher pressure, fourth lean working solution substream is fully absorbed by a vapor content of the vaporized, higher pressure, second intermediate solution stream producing the vaporized combined working solution stream. The multi-stage vaporization process also includes heating the vaporized combined working solution stream with heat from the initial heat source stream in an upper portion of the vaporization subsystem producing the fully vaporized and superheated, combined working solution stream and the first cooled external heat source stream.

[0032] In other embodiments of the invention, the multi-stage distillation and condensation process includes if the spent combined working solution stream (S118) is in a state of slightly superheated vapor, combining the spent combined working solution stream (S118) and a second pressure adjusted, first lean substream (S71) producing a saturated vapor intermediate solution stream (S38). The multi-stage vaporization process also includes transferring heat from either the spent combined working solution stream (S118) or the saturated vapor intermediate solution stream (S38) in a third heat exchange unit (HE3) in counterflow to a liquid third lean stream (S26) producing either a partially condensed, spent combined working solution stream (S15) or a

partially condensed, intermediate solution stream (S15) corresponding to a state of a liquid-vapor mixture and a heated third lean stream (S5) corresponding to a state of a liquid-vapor mixture. The multi-stage vaporization process also includes transferring heat from either the partially condensed, spent combined working solution stream (S15) or the partially condensed, intermediate solution stream (S15) in a second heat exchange unit (HE2) in counterflow to a second higher pressure, rich basic solution substream (S23) producing a cooled and partially condensed, spent combined working solution stream (S41) or a cooled and partially condensed, intermediate solution stream (S41) corresponding to a state of a vapor-liquid mixture and a partially vaporized, second higher pressure, rich basic solution substream (S25) corresponding to a state of a vapor-liquid mixture. The multi-stage vaporization process also includes combining either the cooled and partially condensed, spent combined working solution stream (S41) or the cooled and partially condensed, intermediate solution stream (S41) and a pressure adjusted lean working solution substream (S13) producing a lean basic solution stream (S42), where a composition of the lean basic solution stream (S42) is substantially leaner than a composition of the intermediate solution streams and a composition of the combined working solution streams. The multi-stage vaporization process also includes condensing the lean basic solution stream (S42) in a condenser or first exchange unit or heat exchanger (HE1) in counterflow to a first higher pressure external coolant substream (S52) producing a fully condensed lean basic solution stream (S1) and a spent external coolant substream (S54). The multi-stage vaporization process also includes pressurizing the fully condensed lean basic solution stream (S1) in a feed or first pump (P1) producing an intermediate pressure lean basic solution stream (S2) corresponding to a state of subcooled liquid. The multi-stage vaporization process also includes combining the intermediate pressure lean basic solution stream (S2) and a vapor second rich stream (S19) corresponding to a state of saturated vapor producing an intermediate pressure, rich basic solution stream (S3) corresponding to a state of saturated liquid, where the intermediate pressure lean basic solution stream (S2) fully absorbs the vapor second rich stream (S19) and a composition of the intermediate pressure, rich basic solution stream (S3) is richer than a composition of the lean basic solution streams. The multi-stage vaporization process also includes pressurizing the intermediate pressure, rich basic solution stream (S3) in a circulating or second pump (P2) producing a higher pressure, rich basic solution stream (S4) corresponding to a state of subcooled liquid. The multi-stage vaporization process also includes dividing the higher pressure, rich basic solution stream (S4) into a first higher pressure, rich basic solution substream (S20) and the second higher pressure, rich basic solution substream (S23). The multi-stage vaporization process also includes separating the partially vaporized, second higher pressure, rich basic solution substream (S25) in a third gravity separator (SP3) producing the liquid third lean stream (S26) and a vapor third rich stream (S46), where a composition of the third lean stream (S26) is leaner than a composition of the rich basic solution substreams. The multi-stage vaporization process also includes separating the heated third lean stream (S5) in a first gravity separator (SP1) producing a saturated vapor first rich stream (S6) and a saturated liquid first lean stream (S7). The multi-stage vaporization process also

includes if the spent combined working solution stream is in a state of slightly superheated vapor, dividing the saturated liquid first lean stream (S7) into a first saturated liquid first lean substream (S70) and a second saturated liquid first lean substream (S10) and pressure adjusting the second saturated liquid first lean substream (S70) in a second throttle-valve (TV2) producing the second pressure adjusted, first lean substream (S71). The multi-stage vaporization process also includes pressure adjusting the first saturated liquid first lean substream (S10) or the saturated liquid first lean stream (S7) in a third throttle valve (TV3) producing an intermediate pressure first lean substream (S30) or an intermediate pressure saturated first lean stream (S30) corresponding to a state of a liquid-vapor mixture. The multi-stage vaporization process also includes separating the intermediate pressure first lean substream (S30) or the intermediate pressure saturated first lean stream (S30) in a second gravity separator (SP2) producing the saturated vapor rich stream (S19) and a saturated liquid, intermediate pressure, lean working solution stream (S11). The multi-stage vaporization process also includes dividing the saturated liquid, intermediate pressure, lean working solution stream (S11) into a saturated liquid, intermediate pressure, lean working solution substream (S12) and the saturated liquid lean, intermediate pressure, working solution stream (S49). The multi-stage vaporization process also includes pressure adjusting the saturated liquid, intermediate pressure, lean working solution substream (S12) in a fourth throttle valve (TV4) producing the pressure adjusted lean working solution substream (S13). The multi-stage vaporization process also includes combining the saturated vapor first rich stream (S6) and the vapor third rich stream (S46) producing a combined vapor rich stream (S45). The multi-stage vaporization process also includes transferring heat from the combined vapor rich stream (S45) in a sixth heat exchange unit or heat exchanger (HE6) in counterflow to an intermediate pressure rich working solution stream (S28) producing a cooled and partially condensed, combined rich stream (S44) corresponding to a state of a vapor-liquid mixture and a heated intermediate pressure rich working solution stream (S29). The multi-stage vaporization process also includes combining the cooled and partially condensed, combined rich stream (S44) and the first higher pressure rich basic solution substream (S20) producing a rich working solution stream (S21) corresponding to a state of a liquid-vapor mixture. The multi-stage vaporization process also includes condensing the rich working solution stream (S21) in a condenser or fourth heat exchange unit or heat exchanger (HE4) in counterflow to a second higher pressure coolant substream (S53) producing a spent coolant substream (S55) and a condensed rich working solution stream (S27) corresponding to a state of saturated liquid. The multi-stage vaporization process also includes pressurizing the condensed rich working solution stream (S27) in a booster or third pump (P3) producing the intermediate pressure rich working solution stream (S28) corresponding to a state of subcooled liquid.

[0033] In certain embodiments of this invention, the methods further comprise pressurizing an initial external coolant stream (S50) in a circulating pump (CP) producing a higher pressure external coolant stream (S51), and dividing the higher pressure external coolant stream (S51) into a first higher pressure external coolant substream (S52) and a second higher pressure external coolant substream (S53).

[0034] In other embodiments of this invention, the streams comprise a multi-component working fluid. In other embodiments of this invention, the single multi-component working fluid at least one lower boiling point component and at least one higher boiling point component. In other embodiments of this invention, the single multi-component fluid is selected from the group consisting of an ammonia-water mixture, a mixture of two or more hydrocarbons, a mixture of two or more freon, a mixture of hydrocarbons and freons, and mixtures thereof. In other embodiments of this invention, the single multi-component fluid comprises a mixture of water and ammonia.

Suitable Reagents and Equipment

[0035] The working fluid used in the systems of this invention are multi-component fluids comprising a lower boiling point component and a higher boiling point component. Suitable multi-components fluids include, without limitation, ammonia-water mixtures, mixtures of two or more hydrocarbons, mixtures of two or more freon, mixtures of hydrocarbons and freons, or mixtures thereof. In general, the fluid may comprise mixtures of any number of compounds with favorable thermodynamic characteristics and solubility. In certain embodiments, the multi-component fluid comprises a mixture of water and ammonia.

[0036] It should be recognized by an ordinary artisan that at those points in the systems of this invention were a stream is split into two or more sub-streams, dividing valves that affect such stream splitting are well known in the art and may be manually adjustable or dynamically adjustable so that the splitting achieves the desired stream flow rates and system efficiencies. Similarly, when stream are combined, combining valve that affect combining are also well known in the art and may be manually adjustable or dynamically adjustable so that the splitting achieves the desired stream flow rates and system efficiencies. The combining and dividing value may also include flow controllers and sensors for determining stream parameters including, without limitation, temperature, pressure, composition, boiling point, etc.

DETAILED DESCRIPTION OF THE DRAWINGS OF THE INVENTION

General System

[0037] Referring now to FIG. 1, a general embodiment of a power system of this invention, generally PS, designated SBC-19, is shown to include a vaporization subsystem (VPSS), an energy conversion subsystem (ECSS), and a distillation condensation subsystem (DCSS-50). A fully condensed rich working solution stream RWFS and a fully condensed lean working solution stream LWSS are produced in the DCSS-50 and forwarded to the VPSS. Heat from a heat source stream HSS is used to heat and fully vaporize the RWFS and the LWFS producing a fully vaporized combined working solution stream CWSS and a spent heat source stream SHSS. The CWSS then is forwarded to the ECSS, where a portion of heat associated with the CWSS is converted into a useable form of energy producing a spent working fluid stream SCWSS. The SCWSS is then forwarded to the DCSS-50, where the SCWFS is distilled and condensed using an external coolant stream (ECS) producing the RWFS and the LWFS and a spent external coolant

stream (SECS), which are then forwarded separately to the VPSS, closing the system. All of the streams are derived from a single multi-component fluid. In the DCSS-50, a multi-stage distillation and condensation process is used to form the RWSS and the LWSS and the SECS using variable composition streams derived from the SCWSS and the ECS. In the VPSS, a multi-stage vaporization process is used to fully vaporize and superheat the RWSS and LWSS to form the CWSS so that each lean working solution stream remains in a state of subcooled liquid prior to being mixed with the RWSS or one or more intermediate solution streams derived from the RWSS and all or portions of the LWSS to maximize heat transfer from the HSS producing a fully vaporized and superheated CWFS and the SHSS.

Specific Embodiment of Complete System

[0038] Referring now to FIG. 2, an intermediate pressure rich working solution stream S29 having parameters as at a point 29 and an intermediate pressure lean working solution stream S49 having parameters as at a point 49 exit the distillation condensation sub system (DCSS-50). The intermediate pressure rich working solution stream S29 has a higher concentration of a low-boiling component of a multi-component working fluid, while the intermediate pressure lean working solution stream S49 has a lower concentration of the low-boiling component of the multi-component fluid.

[0039] The streams S29 and S49 are now sent into two feed pumps P5 and P6, respectively, where their pressure is increased producing a higher pressure rich working solution stream S100 having parameters as at a point 100 and a higher pressure lean working solution stream S110 having parameters as at a point 110. For optimized operation, temperatures of the rich working solution stream S100 and the lean working solution stream S110 must be equal or substantially equal. Both streams S100 and S110 correspond to a state of subcooled liquid.

[0040] The streams S100 and S110 now enter into a heat recovery vapor generator (HRVG) also referred to herein as a seventh heat exchange unit or exchanger HE7. The rich working solution stream S100 and the lean working solution stream S110 flow through their own pipes into the HRVG/HE7, and are not mixed together, but become mixed in stages prior to exiting the HRVG/HE7.

[0041] Inside the HRVG/HE7, the rich working solution stream S100 and the lean working solution stream S110 are heated in counterflow with an initial heat source stream S500 having parameters as at a point 500 in a multi-stage heat exchange process 500-501-502-503-504-505-506 producing a spent heat source stream S506 having parameters as at a point 506 as described below and a fully vaporized and superheated combined working solution stream S116 having parameters as at a point 116.

[0042] At first, in a low-temperature portion 505-506 of the heat exchange process 500-501-502-503-504-505-506, heat from a fifth cooled heat source stream S505 having parameters as at parameters as at a point 505 is used to heat the streams S100 and S110 up to a temperature producing a heated rich working solution stream S101 having parameters as at a point 101 and a heated lean working solution stream S111 having parameters as at a point 111. A temperature of the heated rich working solution stream S101 corresponds to its boiling point, while a temperature of the lean working solution stream S111 is the same, but still corresponds to a state of subcooled liquid.

[0043] Thereafter, in another portion **504-505** of the multi-stage heat exchange process **500-501-502-503-504-505-506**, heat from a fourth cooled heat source stream **S504** having parameters as at parameters as at a point **504** is used to heat the heated streams **S101** and **S111** producing a further heated rich working solution stream **S102** having parameters as at a point **102** and a further heated lean working solution stream **S112** having parameters as at a point **112**. The further heated rich working solution stream **S102** is now boiling and is partially vaporized and corresponds to a state of a vapor-liquid mixture, while the further heated lean working solution stream **S112** still corresponds to a state of subcooled liquid.

[0044] The stream **S112** is now divided into two substreams **S113** and **S122** having parameters as at points **113** and **122**, respectively. Note that pressures of the stream **S112** and the substreams **S113** and **S122** are slightly higher than a pressure of the stream **S102**.

[0045] The substream **S122** is now mixed with the stream **S102** producing a first intermediate solution stream **S103** having parameters as at a point **103** corresponding to a state of a vapor-liquid mixture.

[0046] As a result of this mixing, a substantial portion of the vapor in the stream **S102** is absorbed by the substream **S122**, which is in a state of subcooled liquid. As a result, a temperature of the first intermediate solution stream **S103** is increased and becomes equal to a temperature of the substream **S113**. Temperatures of the stream **S112** and substreams **S113** and **S122**, as well as a flow rate of the substream **S122**, are selected in such a way so as to make a temperature of the stream **S103** equal to the temperatures of the stream **S112** and the substream **S113**.

[0047] Now, in another portion **503-504** of the multi-stage heat exchange process **500-501-502-503-504-505-506**, heat from a third cooled heat source stream **S503** having parameters as at parameters as at a point **503** is used to heat the first intermediate solution stream **S103** and the lean working solution substream **S113** producing a heated first intermediate solution stream **S104** having parameters as at a point **104** and a heated lean working solution substream **S114** having parameters as at a point **114**. The stream **S104** is partially vaporized, while the substream **S114** is heated to a temperature that is higher than a temperature of the stream **S104**. The substream **S114** continues to remain in a state of subcooled liquid.

[0048] Thereafter heated lean working solution substream **S114** is then divided into two substreams **S115** and **S124** having parameters as at points **115** and **124**, respectively.

[0049] The heated lean working solution substream **S124** (corresponding to a state of subcooled lean liquid) is now mixed with the heated first intermediate solution stream **S104** (corresponding to a state of a vapor-liquid mixture) producing a second intermediate solution stream **S105** having parameters as at a point **105**, corresponding to a state of a vapor-liquid mixture with a concentration and is leaner than the first intermediate solution stream **S104**.

[0050] As before, as a result of this mixing, a substantial portion of the vapor in the first intermediate solution stream **S104** is absorbed by the heated lean working solution substream **S124**, which is in a state of subcooled liquid. As a result, a temperature of the second intermediate solution stream **S105** is increased and becomes equal to a temperature at the heat lean working solution substream **S115**.

[0051] In another portion **502-503** of the multi-stage heat exchange process **500-501-502-503-504-505-506**, heat from a second cooled heat source stream **S502** having parameters as at parameters as at a point **502** is used to heat the second intermediate solution stream **S105** and the lean working solution substream **S115** producing a heated second intermediate solution stream **S106** having parameters as at a point **106** and a further heated lean working solution substream **S126** having parameters as at a point **126**. This heating causes the stream **S105** to be further partially vaporized forming the stream **S106**. A temperature the substream **S126** is higher than a temperature the stream **S106**, but as before, due to the lean composition of the substream **126**, it remains in a state of subcooled liquid.

[0052] At this point, the further heated lean working solution substream **S126** and the heated second intermediate solution stream **S106** are combined, forming a combined working solution stream **S107** having parameters as at a point **107**, corresponding to a state of a liquid-vapor mixture.

[0053] Once more, as a result of this mixing, a substantial portion of the vapor in the heat second intermediate solution stream **S106** is absorbed by the further heated lean working solution stream **S126**, which is in a state of subcooled liquid. As a result, a temperature of the combined working solution stream **S107** is increased and becomes equal to a temperature the further heated lean working solution stream **S126**.

[0054] A total flow rate the combined working solution stream **S107** is equal a sum of flow rates of the rich working solution stream **S100** and the lean working solution stream **S110** as described below. A composition of the combined working solution stream **S107** is referred to as the combined working solution composition.

[0055] Now, in another portion **501-502** of the multi-stage heat exchange process **500-501-502-503-504-505-506**, heat from a first cooled heat source stream **S501** having parameters as at a point **501** is used to heat the combined working solution stream **S107**, which fully vaporizes producing a fully vaporized combined working solution stream **S108** having parameters as at a point **108**, corresponding to a state of saturated vapor.

[0056] Thereafter, in another portion **500-501** of the multi-stage heat exchange process **500-501-502-503-504-505-506**, heat from the initial heat source stream **S500** is used to heat the fully vaporized combined working solution stream **S108**, which is superheated producing a superheated, fully vaporized combined working solution stream **S116** having parameters as at a point **116**, corresponding to a state of superheated vapor.

[0057] This multi-stage process **500-501-502-503-504-505-506** of heat transfer means that the boiling process begins at point **101**, capturing the low-temperature heat of the heat source and cooling the heat source to a temperature as at the point **506**. The boiling temperature of the stream **S101** is much lower than the boiling point of the working solution would be, had it not been divided into lean and rich streams. Thus, if the working fluid had not been so divided, much less heat could have been absorbed by the divided lean and rich streams from the heat source stream or transferred from the heat source stream to the divided lean and rich streams.

[0058] In the same manner, the further stages of vaporization, controlled by the mixing of working solution streams inside the HRVG/HE7, allow for the capture of the

mid-temperature and last the high temperature portions of the heat of the heat source stream.

[0059] Returning to the system, the superheated, fully vaporized combined working solution stream S116 is now sent into an admission throttle-valve TV1, where its pressure may be slightly reduced (in order to make sure the inlet pressure to the turbine remains stable) producing a pressure adjusted superheated, fully vaporized combined working solution stream S117 having parameters as at a point 117, corresponding to a state of superheated vapor.

[0060] The pressure adjusted superheated, fully vaporized combined working solution stream S117 is now sent into a turbine Ti, where it is expanded, producing useable work (mechanical and/or electrical) producing a spent combined working solution stream S118 having parameters as at a point 118. In most cases, the parameters of the stream S118 will correspond to a state of slightly superheated vapor. However, it is possible that the parameters the stream S118 will correspond instead to a state of saturated vapor.

[0061] Looking back now to the heat source stream, the initial heat source stream S500 having the parameters as at the point 500, enters into the system and into the HRVG/HE7, where it provides heat for a heat exchange process 108-116, as described above, producing the first cooled heat source stream S501 having the parameters as at the point 501. The first cooled heat source stream S501 now provides heat for a heat exchange process 107-108, as described above, producing the second cooled heat source stream S502 having the parameters as at point 502. The second cooled heat source stream S502 now provides heat for heat source processes 105-106 and 115-126, as described above, producing the third cooled heat source stream S503 having the parameters as at the point 503. The third cooled heat source stream S503 now provides heat for heat exchanges processes 103-104 and 113-114, as described above, producing the fourth cooled heat source stream S504 having the parameters as at point 504. The fourth cooled heat source stream S504 now provides heat for heat exchange processes 101-102 and 111-112, as described above, producing the fifth cooled heat source stream S505 having the parameters as at point 505. The fifth cooled heat source stream S505 now provides heat for heat exchange processes 100-101 and 110-111, as described above, producing the spent heat source stream S506 having the parameters as at the point 506, exiting the HRVG/HE7 and the system.

[0062] The spent combined working solution stream S118 must now be condensed and re-divided into the rich working solution stream S29 and the lean working solution stream S49. In order to do this, a distillation condensation sub system (DCSS-50) is employed.

Specific Embodiment of DCSS-50

[0063] Referring now to FIG. 3, the DCSS-50 is shown operates as follows.

[0064] The spent combined working solution stream S118 corresponding to a state of saturated or slightly superheated vapor, enters into the DCSS-50. If the combined working solution stream S118 is in a state of slightly superheated vapor, it is now mixed with a pressure adjusted second SP1 lean substream S71 having parameters as at a point 71, as described below, producing a saturated vapor intermediate solution stream S38 having parameters as at a point 38. If on the other hand, the combined working solution stream S118 is in a state of saturated vapor, then the pressure adjusted

second SP1 lean substream S71 has a flow rate of zero and the parameters of the intermediate solution stream S38 are the same as the parameters of the combined working solution stream S118.

[0065] Either the saturated vapor intermediate solution stream S38 or the combined working solution stream S118 is now sent into a third heat exchange unit or exchanger HE3, where it is cooled and partially condensed in counterflow in a heat exchange process 26-5 or 38-15 with a liquid SP3 lean stream S26 having parameters as at a point 26 producing a cooled and partially condensed intermediate solution stream S15 having parameters as at a point 15 corresponding to a state of a liquid-vapor mixture and a heated and partially vaporized SP3 lean stream S5 having parameters as at a point 5 corresponding to a state of a liquid-vapor mixture.

[0066] The cooled and partially condensed intermediate solution stream S15 is now sent into a second heat exchange unit or heat exchanger HE2, where it is further cooled in counterflow with a second higher pressure rich basic solution substream S23 having parameters as at a point 23 in a heat exchange process 15-40-41 or 23-24-25 producing a further cooled and partially condensed intermediate solution stream S41 having parameters as at a point 41 corresponding to a state of a vapor-liquid mixture and a heated higher pressure rich basic solution substream S25 having parameters as at a point 25 as described below.

[0067] The further cooled and partially condensed intermediate solution stream S41 is then mixed with a pressure adjusted SP2 lean working solution substream S13 having parameters as at point 13, as described below, producing a lean basic solution stream S42 having parameters as at a point 42. A composition of the lean basic solution stream S42 is substantially leaner than a composition of the intermediate solution streams S38, S15, S40, and S41 and the combined working solution stream S118. The leaning of the intermediate solution stream S41 to produce the lean basic solution stream S42 allows for a full condensation of the lean basic solution stream S42 at a low pressure using an external coolant stream as described below.

[0068] The lean basic solution stream S42 is now sent into a condenser or first exchange unit or heat exchanger HE1, where it is fully condensed in counterflow with a first higher pressure external coolant substream S52 having parameters as at a point 52 in a heat exchange process 42-1 or 52-54 producing by a fully condensed lean basic solution stream S1 having parameters as at a point 1 and a spent external coolant substream S54 having parameters as at a point 54 as described below.

[0069] The fully condensed lean basic solution stream S1 is now pumped to an intermediate pressure by a feed or first pump P1 producing an intermediate pressure lean basic solution stream S2 having parameters as at a point 2 corresponding to a state of subcooled liquid.

[0070] The intermediate pressure lean basic solution stream S2 is now mixed with a vapor SP2 rich stream S19 having parameters as at a point 19 corresponding to a state of rich saturated vapor as described below producing a rich basic solution stream S3 having parameters as at a point 3 corresponding to a state of saturated liquid.

[0071] The intermediate pressure lean basic solution stream S2 corresponding to a state of subcooled liquid fully absorbs the vapor SP2 rich stream S19 producing the rich basic solution stream S3. Therefore, a composition of the

rich basic solution stream S3 is richer than the composition of the lean basic solution streams S42, S1, and S2.

[0072] The rich basic solution stream S3 is now sent into a circulating or second pump P2, where its pressure is increased producing a higher pressure rich basic solution stream S4 having parameters as at point 4 corresponding to a state of subcooled liquid.

[0073] The higher pressure rich basic solution stream S4 is now divided into a first higher pressure rich basic solution substream S20 and the second higher pressure rich basic solution substream S23 having parameters as at points 20 and 23, respectively.

[0074] The second higher pressure rich basic solution substream S23 is now sent into the second heat exchanger HE2 in the heat exchange process 15-40-41 or 23-24-25 as described above. In the second heat exchanger HE2, the second higher pressure rich basic solution substream S23 reaches its boiling point temperature producing a boiling second higher pressure rich basic solution substream S24 as at a point 24, which also corresponds to a temperature of the condensing intermediate solution stream S40 having parameters as at a point 40, and then as it flows through the remainder of the second heat exchanger HE2, the second higher pressure rich basic solution substream S23 is partially vaporized producing a partially vaporize, higher pressure rich basic solution substream S25 having parameters as at a point 25 corresponding to a state of a vapor-liquid mixture.

[0075] The partially vaporized, higher pressure rich basic solution substream S25 is now sent into a third gravity separator SP3, where it separated into the saturated liquid SP3 lean stream S26 having the parameters as at the point 26 and a saturated vapor SP3 rich stream S46 having parameters as at a point 46. Note, that a composition of the SP3 lean stream S26 is leaner than a composition of the rich basic solution substream S25.

[0076] The saturated liquid SP3 lean stream S26 is now sent into the third heat exchanger HE3, where it is heated and partially vaporized in counterflow with the intermediate solution stream S38 in the heat exchange process 38-15 or 26-5 as described above producing the heated SP3 lean stream S5 having the parameters as at the point 5, corresponding to a state of a liquid-vapor mixture.

[0077] The heated SP3 lean stream S5 is now sent into a first gravity separator SP1, where it is separated into a saturated vapor SP1 rich stream S6 having parameters as at a point 6, and a saturated liquid SP1 lean stream S7 having parameters as at a point 7.

[0078] The saturated liquid SP1 lean stream S7 is now divided into a saturated liquid first SP1 lean substream S10 having parameters as at a point 10 and a saturated liquid second SP1 lean substream S70 having parameters as at a point 70, if needed as described above.

[0079] The saturated liquid second SP1 lean substream S70 is now sent through a second throttle-valve TV2, where its pressure is reduced to a pressure equal to the pressure of the combined working solution stream S118 producing the pressure adjusted second SP1 lean substream S71 having the parameters as at the point 71, before being mixed with the combined working solution stream S118, forming the intermediate solution stream S38, as described above.

[0080] Meanwhile, the saturated liquid first SP1 lean substream S10 is sent through a third throttle valve TV3, where its pressure is reduced to an intermediate pressure producing an intermediate pressure first SP1 lean substream

S30 having parameters as at a point 30, corresponding to a state of a liquid-vapor mixture.

[0081] The intermediate pressure first SP1 lean substream S30 is now sent into a second gravity separator SP2, where it is separated into the saturated vapor SP2 rich stream S19 having the parameters as at the point 19 as described above and a saturated liquid lean working solution stream S11 having parameters as at a point 11. A composition of the stream S11 is the same as a composition of the intermediate pressure lean working solution stream S49 in the main system as described above and referred to as the lean working solution.

[0082] Meanwhile, the saturated vapor SP1 rich stream S6 exiting the first gravity separator SP1 is combined with the vapor SP3 rich stream S46 as described above producing a combined vapor rich stream S45 having parameters as at a point 45.

[0083] The combined vapor rich stream S45 is now sent into a sixth heat exchange unit or heat exchanger HE6, where it is cooled and partially condensed in counterflow with an intermediate pressure rich working solution stream S28 having parameters as at a point 28 in a heat exchange process 45-44 or 28-29 producing a cooled and partially condensed, combined rich stream S44 having parameters as at a point 44, corresponding to a state of a vapor-liquid mixture.

[0084] The cooled and partially condensed, combined rich stream S44 is now mixed with the first higher pressure rich basic solution substream S20 as described above producing a rich working solution stream S21 having parameters as at a point 21 corresponding to a state of a liquid-vapor mixture. The rich working solution stream S21 has a composition that is the same as the composition of the intermediate pressure rich working solution stream S29 in the main system as described above and referred to as the rich working solution.

[0085] The rich working solution stream S21 is now sent into a condenser or fourth heat exchange unit or heat exchanger HE4, where it is fully condensed in counterflow with a second higher pressure coolant substream S53 having parameters as at a point 53 in a heat exchange process 53-55 or 21-27 producing a spent coolant substream S55 having a parameter as a point 55 and a condensed rich working solution stream S27 having parameters as at a point 27 corresponding to a state of saturated liquid.

[0086] The condensed rich working solution stream S27 is now pumped by a booster or third pump P3 to an increased pressure producing the intermediate pressure rich working solution stream S28 having the parameters as at the point 28 corresponding to a state of subcooled liquid.

[0087] The intermediate pressure rich working solution stream S28 is then sent into the sixth heat exchanger HE6, where it provides heat for the heat exchange process 45-44 or 28-29 as described above producing the heated rich working solution S29 having the parameters as at the point 29, corresponding to a state of a subcooled liquid, prior to exiting the DCSS-50 and returning to the main system.

[0088] Meanwhile, the lean working solution stream S11 exiting the second gravity separator SP2 is divided into the lean working solution stream S49 having the parameters as at the point 49 and a lean working solution substream S12 having parameters as at a point 12.

[0089] The intermediate pressure lean working solution stream S49 is then sent out of the DCSS-50 and back into the main system as described above. A temperature at lean

working solution stream S49 determines a desired temperature of the intermediate pressure rich working solution stream S29 as described above. The two temperatures should be equal or substantially equal, so as to allow the temperatures of the rich working solution stream S100 and the lean working solution stream S110 of the main system to be equal or substantially equal or as close to equal as possible.

[0090] Meanwhile, the lean working solution substream S12 is sent through a fourth throttle-valve TV4, where its pressure is reduced to a pressure equal to a pressure of the intermediate solution stream S41 producing the pressure adjusted lean working solution substream S13 having parameters as at the point 13. The pressure adjusted lean working solution substream S13 is now mixed with the intermediate solution stream S41 producing the lean basic solution stream S42 as described above.

[0091] Meanwhile, looking at the initial external coolant stream S50 having the parameter as at the point 50 comprising cooling water, is pumped by a circulating pump CP to increase a pressure of the coolant producing a higher pressure external coolant stream S51 having the parameter as at the point 51. The higher pressure coolant stream S51 is then divided into the first higher pressure coolant substream S52 and the second higher pressure coolant substream S53 having parameters as at points 52 and 53.

[0092] The first higher pressure coolant substream S52 is then sent into the first heat exchanger HE1, cooling and fully condensing the lean basic solution stream S42 in the heat exchange process 42-1 or 52-54 as described above producing a spent coolant stream S54 before exiting the system.

[0093] Meanwhile, the second higher pressure coolant substream S53 is sent into the fourth heat exchanger HE4, cooling and fully condensing the rich working solution stream S27 in the heat exchange process 21-27 or 53-55 as described above producing the spent coolant stream S55 having parameters as at the point 55 before exiting the system.

[0094] Note that compositions of the lean basic solution streams S42, S1 and S2 are leaner than the composition of the spent combined working solution stream S118, the combined working solution composition. This leaning of these streams allows a pressure of the lean basic solution stream S1 (and correspondingly the spent combined working solution stream S118) to be substantially lower than it would be if the spent combined working solution stream S118 were to be condensed directly. This means a lower back pressure on the turbine T1 and thus an increased power output from the main system.

Streams	Compositions
S118	combined working solution
S38, S15, S40 & S41	intermediate solution
S42, S1 & S2	lean basic solution
S26 & S5	SP3 lean
S7, S10, S30, S70 & S71	SP1 lean
S11, S12, S13 & S49	lean working solution
S6	SP1 rich
S19	SP2 rich
S46	SP3 rich
S45 & S44	combined rich vapor
S3, S4, S20, S23 & S25	rich basic solution
S21, S27, S28 & S29	rich working solution

Computation and Analysis of System

[0095] Computation and analysis of the present system has shown that, if used as a bottoming cycle for a gas turbine (which means that the temperature of the initial heat source stream S500 is quite high), then the present system will be a few percent less efficient than a triple-pressure Rankine cycle system bottoming cycle. The present system will, however, substantially out perform a dual-pressure Rankine cycle system bottoming cycle. However since the present system uses only a single turbine, it will be considerably less expensive in terms of capital cost than either a dual or triple-pressure Rankin cycle system and the cost per delivered kilowatt for the present system should be substantially lower than either a dual or triple-pressure Rankine cycle system bottoming cycle.

[0096] Moreover, the present system out performs both dual and triple-pressure Rankine cycle system bottoming cycles outright in cases, where a temperature of the initial heat source stream S500 is somewhat lower, while maintaining its economic advantage.

[0097] Assuming the use of a full exhaust of a GE 9FB gas turbine as the initial heat source stream S500, a triple-pressure Rankine cycle system bottoming cycle will deliver 155,080 kW. In comparison, the present system, with the same heat source stream, will deliver 151,153 kW. Thus the present system will deliver approximately 97.5% of the output of the Rankine cycle system bottoming cycle system, but using only a single turbine to the Rankine system's three turbines (for an estimated cost that should be roughly half as much or less of the Rankine system's cost.)

[0098] The present system described above has been shown using three stages of mixing inside the HRVG/HE7, however, depending on the parameters (initial temperature and/or the chosen pressure at the turbine inlet) of the heat source stream S500 used, it is possible for the system to operate with only two stages of mixing inside the HRVG/HE7 as shown in FIG. 2B, or even with just a single stage of mixing inside the HRVG/HE7 and shown in FIG. 2C. In FIG. 2B, the streams S114, S115, S124, S104, and S105 are missing. In FIG. 2C, the streams S112, S113, S122, S102, S103, S114, S115, S124, S104, and S105. In both FIG. 2B and FIG. 2C, the exact location of the mixing stages will depend on the initial heat source stream used.

[0099] In all cases, however, it is necessary that the lean working solution stream or streams at the point where it is or they are mixed be in a state of a subcooled saturated liquid. At the same time, the rich working solution streams S100 and S101 and the intermediate streams S103, S104, S105 and S106 must be in a state of a vapor-liquid mixture, or a saturated vapor.

[0100] One experienced in the art can select the correct number of mixing stages inside the HRVG/HE7.

[0101] All references cited herein are incorporated by reference. Although the invention has been disclosed with reference to its preferred embodiments, from reading this description those of skill in the art may appreciate changes and modification that may be made which do not depart from the scope and spirit of the invention as described above and claimed hereafter.

We claim:

1. A system for power generation comprising a distillation condensation subsystem (DCSS-50), where a spent combined working solution stream CWFS is fully condensed in a multi-stage distillation and con-

condensation process using variable composition streams derived from the CWFS and an external coolant stream CS to produce a fully condensed rich working solution stream RWFS and a fully condensed lean working solution stream LWFS and a spent CS,

a vaporization subsystem (VPSS), where heat from an external heat source stream HSS is used to heat, fully vaporize and superheat the RWFS and the LWFS in a multi-stage vaporization process such that each lean working solution stream remains in a state of supercooled liquid prior to being mixed with the rich working solution stream or one or more intermediate solution streams to maximize heat transfer from the HSS to produce a fully vaporized and superheated CWFS and a spent HSS, and

an energy conversion subsystem (ECSS), where a portion of heat associated with the CWFS is converted into a useable form of energy producing a spent CWFS which is forwarded to the DCSS-50 closing the system,

where all of the streams are derived from a single multi-component fluid.

2. The system of claim 1, wherein:

the VPSS comprises a single heat exchange unit having two working solution tubes and at least one combining valve,

where (a) the combining valve combines a heated lean working solution stream in a state of subcooled liquid and a vaporized rich working solution stream under conditions where the lean working solution stream is fully absorbed by the vaporized rich working solution stream producing a vaporized combined working solution stream, (b) once formed, the vaporized combined working solution stream is superheated to form the fully vaporized and superheated, combined working solution stream, and (c) all heat is derived from the external heat source stream,

the ECSS comprises a single pressure turbine, and

the DCSS-50 comprising at least two throttle control valves, three heat exchanges units, two condensers, three pumps, and three separators.

3. The system of claim 1, wherein:

the VPSS comprises a single heat exchange unit having two working solution tubes and two combining valves and one dividing valve,

where (a) the dividing valve divides a heated lean working solution stream into a heated first lean working solution substream and a heated second lean working solution substream, (b) a first combining valve combines the heated second lean working solution substream in a state of subcooled liquid and a partially vaporized rich working solution stream under conditions where the heated second lean working solution substream is fully absorbed by the partially vaporized rich working solution stream producing a partially vaporized intermediate solution stream, (c) a second combining valve combines a further heated first lean working solution substream in a state of subcooled liquid and a vaporized intermediate solution stream under conditions where the further heated first lean working solution substream is fully absorbed by the vaporized intermediate solution stream producing a vaporized combined working solution stream, (d) once formed, the vaporized combined working solution stream is superheated to

form the fully vaporized and superheated, combined working solution stream, and (e) all heat is derived from the external heat source stream,

the ECSS comprises a single pressure turbine, and the DCSS-50 comprising three throttle control valves, three heat exchanges units, two condensers, three pumps, and three separators.

4. The system of claim 1, wherein:

the VPSS comprises a single heat exchange unit having two working solution tubes and three combining valves and two dividing valve,

where (a) a first dividing valve divides a heated lean working solution stream into a heated first lean working solution substream and a heated second lean working solution substream, (b) a first combining valve combines the heated second lean working solution substream in a state of subcooled liquid and a partially vaporized rich working solution stream under conditions where the second heated lean working solution substream is fully absorbed by the partially vaporized rich working solution stream producing a partially vaporized first intermediate solution stream, (c) a second dividing valve divides a further heated lean first working solution substream into a further heated third lean working solution substream and a further heated fourth lean working solution substream, (d) a second combining valve combines a further heated third lean working solution substream and a heated partially vaporized first intermediate solution stream under conditions where the yet further heated third lean working solution substream is fully absorbed by the heated partially vaporized first intermediate solution stream producing a partially vaporized second intermediate solution stream, (f) a third combining valve combines a yet further heated fourth lean working solution substream and a vaporized second intermediate solution stream under conditions where the yet further heated fourth lean working solution substream is fully absorbed by the vaporized second intermediate solution stream producing a vaporized combined working solution stream, (g) once formed, the vaporized combined working solution stream is superheated to form the fully vaporized and superheated, combined working solution stream, and (h) all heat is derived from the external heat source stream,

the ECSS comprises a single pressure turbine, and

the DCSS-50 comprising three throttle control valves, three heat exchanges units, two condensers, three pumps, and three separators.

5. The system of claim 1, wherein the single multi-component working fluid comprises at least one lower boiling point component and at least one higher boiling point component.

6. The system of claim 5, wherein the components comprises a mixture of compounds having favorable thermodynamic characteristics and solubilities.

7. The system of claim 1, wherein the single multi-component fluid is selected from the group consisting of a ammonia-water mixture, a mixture of two or more hydrocarbons, a mixture of two or more freon, a mixture of hydrocarbons and freons, and mixtures thereof.

8. The system of claim 7, wherein the single multi-component fluid comprises a mixture of water and ammonia.

9. The system of claim 6, wherein the single multi-component fluid comprises a mixture of two or more hydrocarbons, a mixture of two or more freon, or a mixture of hydrocarbons and freons.

10. A method comprising:

condensing a spent combined working solution stream in a distillation condensation subsystem in a multi-stage distillation and condensation process using variable composition streams derived from the spent combined working solution stream and an external coolant stream producing a fully condensed, intermediate pressure, rich working solution stream and a fully condensed, intermediate pressure, lean working solution stream and a spent external coolant stream,

concurrently pressurizing the fully condensed, intermediate pressure, rich working solution stream and the fully condensed, intermediate pressure, lean working solution stream in separate feed pumps producing a fully condensed, higher pressure, rich working solution stream and a fully condensed, higher pressure, lean working solution stream,

transferring heat from an external heat source stream in a vaporization subsystem in a multi-stage vaporization process such that each higher pressure, lean working solution stream remains in a state of subcooled liquid prior to being mixed with the rich working solution stream or one or more intermediate solution streams derived from the rich working solution stream and the lean working solution stream or one or more lean working solution substreams to maximize heat transfer from the external heat source stream producing a fully vaporized and superheated, higher pressure, combined working solution stream and a spent external heat source stream, and

converting a portion of heat in a fully vaporized and superheated, higher pressure, combined working solution stream in an energy extraction subsystem to a useable form of energy (mechanical and/or electrical) producing the spent combined working solution stream, where all of the streams are derived from a single multi-component fluid comprises at least one lower boiling point component and at least one higher boiling point component selected from the group consisting of a ammonia-water mixture, a mixture of two or more hydrocarbons, a mixture of two or more freon, a mixture of hydrocarbons and freons, and mixtures thereof.

11. A method comprising:

concurrently forwarding: (a) a fully condensed, rich working solution stream into a fifth pump producing a higher pressure, fully condensed, rich working solution stream and (b) a fully condensed, lean working solution stream into a sixth pump producing a higher pressure, fully condensed, lean working solution stream,

vaporizing and superheating the higher pressure, fully condensed, rich working solution stream and the higher pressure, fully condensed, lean working solution stream in a vaporization subsystem in a multi-stage vaporization process using heat from an initial external heat source stream so that the higher pressure, fully condensed, lean working solution stream or a plurality of higher pressure, lean working solution substreams is/are in a state of subcooled liquid prior to mixing and being fully absorbed by a vapor component of a vapor-

ized, higher pressure, rich working solution stream or a plurality of vaporized, higher pressure, intermediate solution streams derived from the higher pressure, rich working solution stream and the higher pressure, lean working solution stream producing a fully vaporized and superheated, combined working solution stream and a spent external heat source stream,

converting a portion of heat in the fully vaporized and superheated, combined working solution stream in an energy extraction subsystem to a useable form of energy comprising mechanical and/or electrical energy producing a spent combined working solution stream, and

condensing the spent combined working solution stream in a multi-stage distillation and condensation process in a distillation condensation subsystem using variable composition streams derived from the spent combined working solution stream and an initial external coolant stream to produce the fully condensed, rich working solution stream, the fully condensed, lean working solution stream, and a spent external coolant stream, where all of the streams are derived from a single multi-component fluid.

12. The method of claim 11, wherein the multi-stage vaporization process comprises the steps of:

concurrently heating: (a) the higher pressure, fully condensed, rich working solution stream and (b) the higher pressure, fully condensed, lean working solution stream with heat from a first cooled external heat source stream in a lower portion of the vaporization subsystem producing the spent external heat source stream, a vaporized, higher pressure, rich working solution stream, and a heated, higher pressure, lean working solution stream, which corresponds to a state of subcooled liquid,

combining the vaporized, higher pressure, rich working solution stream and the heated, higher pressure, lean working solution stream in the vaporization subsystem under conditions so that the heated, higher pressure, lean working solution stream is fully absorbed by a vapor content of the vaporized, higher pressure, rich working solution stream producing a vaporized, combined working solution stream, and

heating the vaporized, combined working solution stream with heat from the initial heat source stream in an upper portion of the vaporization subsystem producing the fully vaporized and superheated, combined working solution stream and the first cooled external heat source stream.

13. The method of claim 11, wherein the multi-stage distillation and condensation process comprises the steps of:

concurrently heating: (a) the higher pressure, fully condensed, rich working solution stream and (b) the higher pressure, fully condensed lean working solution stream with heat from a second cooled external heat source stream producing the spent external heat source stream, a partially vaporized, higher pressure, rich working solution stream, and a heated, higher pressure, lean working solution stream, which corresponds to a state of subcooled liquid,

dividing the heated, higher pressure, lean working solution stream into a heated, higher pressure, first lean working solution substream and a heated, higher pressure, second lean working solution substream, where

- both of the heated, higher pressure, lean working solution substreams correspond to states of subcooled liquid,
- combining the partially vaporized, higher pressure, rich working solution stream and the heated, higher pressure, first lean working solution substream in the vaporization subsystem under conditions so that the heated, higher pressure, first lean working solution stream is fully absorbed by a vapor content of the partially vaporized, higher pressure, rich working solution stream producing a higher pressure, first intermediate solution stream,
- currently heating: (a) the higher pressure, first intermediate solution stream and the heated, higher pressure, second lean working solution substream with heat from a first cooled external heat source stream producing the second external heat source stream, a partially vaporized, higher pressure, first intermediate solution stream, and a further heated, higher pressure, second lean working solution substream, which corresponds to a state of subcooled liquid,
- combining the partially vaporized, higher pressure, first intermediate solution stream and the further heated, higher pressure, second lean working solution substream in the vaporization subsystem under conditions so that the further heated, higher pressure, second lean working solution substream is fully absorbed by a vapor content of the partially vaporized, higher pressure, first intermediate solution stream producing the vaporized, combined working solution stream, and
- heating the vaporized, combined working solution stream with heat from the initial heat source stream in an upper portion of the vaporization subsystem producing the fully vaporized and superheated, combined working solution stream and the first cooled external heat source stream.
- 14.** The method of claim **11**, wherein the multi-stage distillation and condensation process comprises the steps of:
- currently heating: (a) the higher pressure, fully condensed, rich working solution stream and (b) the higher pressure, fully condensed, lean working solution stream with heat from a third cooled external heat source stream producing the spent external heat source stream, a partially vaporized, higher pressure, rich working solution stream, and a heated, higher pressure, lean working solution stream, which corresponds to a state of subcooled liquid,
- dividing the heated, higher pressure, lean working solution stream into a heated, higher pressure, first lean working solution substream and a heated, higher pressure, second lean working solution substream, where both of the heated, lean working solution substreams correspond to states of subcooled liquid,
- combining the partially vaporized, higher pressure, rich working solution stream and the heated, higher pressure, first lean working solution substream in the vaporization subsystem under conditions so that the heated, higher pressure, first lean working solution substream is fully absorbed by a vapor content of the partially vaporized, higher pressure, rich working solution stream producing a higher pressure, first intermediate solution stream,
- currently heating: (a) the higher pressure, first intermediate solution stream and the heated, higher pressure,
- second lean working solution substream with heat from a second cooled external heat source stream producing the third external heat source stream, a partially vaporized, higher pressure, first intermediate solution stream, and a further heated, higher pressure, second lean working solution stream, which corresponds to a state of subcooled liquid,
- dividing the further heated, higher pressure, second lean working solution substream into a further heated, higher pressure, third lean working solution substream and a further heated, higher pressure, fourth lean working solution substream, where both of the further heated, higher pressure, lean working solution substream correspond to a state of subcooled liquid,
- combining the partially vaporized, higher pressure, first intermediate solution stream and the further heated, higher pressure, third lean working solution substream in the vaporization subsystem under conditions so that the further heated, higher pressure, third lean working solution substream is fully absorbed by a vapor content of the partially vaporized, higher pressure, first intermediate solution stream producing a higher pressure, second intermediate solution stream,
- currently heating: (a) the higher pressure, second intermediate solution stream and the further heated, higher pressure, fourth lean working solution substream with heat from a first cooled external heat source stream producing the second external heat source stream, a vaporized, higher pressure, second intermediate solution stream, and a yet further heated, higher pressure, fourth lean working solution stream, which corresponds to a state of subcooled liquid,
- combining the vaporized, higher pressure, second intermediate solution stream and the yet further heated, higher pressure, fourth lean working solution substream in the vaporization subsystem under conditions so that the yet further heated, higher pressure, fourth lean working solution substream is fully absorbed by a vapor content of the vaporized, higher pressure, second intermediate solution stream producing the vaporized combined working solution stream, and
- heating the vaporized combined working solution stream with heat from the initial heat source stream in an upper portion of the vaporization subsystem producing the fully vaporized and superheated, combined working solution stream and the first cooled external heat source stream.
- 15.** The method of claim **11**, wherein the multi-stage distillation and condensation process comprises the steps of:
- if the spent combined working solution stream is in a state of slightly superheated vapor, combining the spent combined working solution stream and a second pressure adjusted, first lean substream producing a saturated vapor intermediate solution stream,
- transferring heat from either the spent combined working solution stream or the saturated vapor intermediate solution stream in a third heat exchange unit (HE3) in counterflow to a liquid third lean stream producing either a partially condensed, spent combined working solution stream or a partially condensed, intermediate solution stream corresponding to a state of a liquid-vapor mixture and a heated third lean stream corresponding to a state of a liquid-vapor mixture,

transferring heat from either the partially condensed, spent combined working solution stream or the partially condensed, intermediate solution stream in a second heat exchange unit (HE2) in counterflow to a second higher pressure, rich basic solution substream producing a cooled and partially condensed, spent combined working solution stream or a cooled and partially condensed, intermediate solution stream corresponding to a state of a vapor-liquid mixture and a partially vaporized, second higher pressure, rich basic solution substream corresponding to a state of a vapor-liquid mixture,

combining either the cooled and partially condensed, spent combined working solution stream or the cooled and partially condensed, intermediate solution stream and a pressure adjusted lean working solution substream producing a lean basic solution stream, where a composition of the lean basic solution stream is substantially leaner than a composition of the intermediate solution streams and a composition of the combined working solution streams,

condensing the lean basic solution stream in a condenser or first exchange unit or heat exchanger (HE1) in counterflow to a first higher pressure external coolant substream producing a fully condensed lean basic solution stream and a spent external coolant substream,

pressurizing the fully condensed lean basic solution stream in a feed or first pump (P1) producing an intermediate pressure lean basic solution stream corresponding to a state of subcooled liquid,

combining the intermediate pressure lean basic solution stream and a vapor second rich stream corresponding to a state of saturated vapor producing an intermediate pressure, rich basic solution stream corresponding to a state of saturated liquid, where the intermediate pressure lean basic solution stream fully absorbs the vapor second rich stream and a composition of the intermediate pressure, rich basic solution stream is richer than a composition of the lean basic solution streams,

pressurizing the intermediate pressure, rich basic solution stream in a circulating or second pump (P2) producing a higher pressure, rich basic solution stream corresponding to a state of subcooled liquid,

dividing the higher pressure, rich basic solution stream into a first higher pressure, rich basic solution substream and the second higher pressure, rich basic solution substream,

separating the partially vaporized, second higher pressure, rich basic solution substream in a third gravity separator (SP3) producing the liquid third lean stream and a vapor third rich stream, where a composition of the third lean stream is leaner than a composition of the rich basic solution substreams,

separating the heated third lean stream in a first gravity separator (SP1) producing a saturated vapor first rich stream and a saturated liquid first lean stream,

if the spent combined working solution stream is in a state of slightly superheated vapor, dividing the saturated liquid first lean stream into a first saturated liquid first lean substream and a second saturated liquid first lean substream and pressure adjusting the second saturated liquid first lean substream in a second throttle-valve (TV2) producing the second pressure adjusted, first lean substream,

pressure adjusting the first saturated liquid first lean substream or the saturated liquid first lean stream in a third throttle valve (TV3) producing an intermediate pressure first lean substream or an intermediate pressure saturated first lean stream corresponding to a state of a liquid-vapor mixture,

separating the intermediate pressure first lean substream or the intermediate pressure saturated first lean stream in a second gravity separator (SP2) producing the saturated vapor rich stream and a saturated liquid, intermediate pressure, lean working solution stream,

dividing the saturated liquid, intermediate pressure, lean working solution stream into a saturated liquid, intermediate pressure, lean working solution substream and the saturated liquid lean, intermediate pressure, working solution stream,

pressure adjusting the saturated liquid, intermediate pressure, lean working solution substream in a fourth throttle valve (TV4) producing the pressure adjusted lean working solution substream,

combining the saturated vapor first rich stream and the vapor third rich stream producing a combined vapor rich stream,

transferring heat from the combined vapor rich stream in a sixth heat exchange unit or heat exchanger (HE6) in counterflow to an intermediate pressure rich working solution stream producing a cooled and partially condensed, combined rich stream corresponding to a state of a vapor-liquid mixture and a heated intermediate pressure rich working solution stream

combining the cooled and partially condensed, combined rich stream and the first higher pressure rich basic solution substream producing a rich working solution stream corresponding to a state of a liquid-vapor mixture,

condensing the rich working solution stream in a condenser or fourth heat exchange unit or heat exchanger (HE4) in counterflow to a second higher pressure coolant substream producing a spent coolant substream and a condensed rich working solution stream corresponding to a state of saturated liquid, and

pressurizing the condensed rich working solution stream in a booster or third pump (P3) producing the intermediate pressure rich working solution stream corresponding to a state of subcooled liquid.

16. The method of claim 15, further comprising:

pressurizing an initial external coolant stream in a circulating pump (CP) producing a higher pressure external coolant stream, and

dividing the higher pressure external coolant stream into a first higher pressure external coolant substream and a second higher pressure external coolant substream.

17. The method of claim 11, wherein the single multi-component working fluid comprises at least one lower boiling point component and at least one higher boiling point component.

18. The method of claim 11, wherein the single multi-component fluid is selected from the group consisting of a ammonia-water mixture, a mixture of two or more hydrocarbons, a mixture of two or more freon, a mixture of hydrocarbons and freons, and mixtures thereof.

19. The method of claim 18, wherein the single multi-component fluid comprises a mixture of water and ammonia.

20. The system of claim **18**, wherein the single multi-component fluid comprises a mixture of two or more hydrocarbons, a mixture of two or more freon, or a mixture of hydrocarbons and freons.

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