



Industria y Comercio

S U P E R I N T E N D E N C I A

Delegatura de propiedad Industrial

División de Nuevas Creaciones

PCT
SOLICITUD

PATENTE DE INVENCION

05-75396

21 **EXPEDIENTE No.**

54 **TÍTULO** Ciclo de Potencia y sistema para
aprovechar puentes de calor de temperatura
Moderada y Baja

51 **CLASIFICACIÓN INTERNACIONAL** FOIK 25/06

71 **SOLICITANTE** Kalex, Snc

DOMICILIO Belmont, California, USA

74 **APODERADO** Dilce Elena Rodríguez P' Alemán

22 **BOGOTÁ, D. C.,** Agosto 1/05

FORMULARIO ÚNICO DE SOLICITUD DE PATENTE
PCT
ENTRADA EN FASE NACIONAL

1) SOLICITUD DE			
☒ Patente de invención		☐ Patente de Modelo de Utilidad	
☐ Capítulo I		☒ Capítulo II	
2) SOLICITANTE (71)	Nombre: KALEX, INC		IDENTIFICACIÓN C C ☐ NIT ☒ C E ☐ OTRO ☐ Cual _____ NUMERO _____
	Dirección: 2630 Carlmont Drive, Belmont, CA 94002 Estados Unidos Nacionalidad o domicilio: Belmont, CA, Estados Unidos Lugar de constitución: California, Estados Unidos <i>ver folio 25</i>		
	Teléfono	Fax	
	E Mail		
3) REPRESENTANTE O APODERADO	Nombre: DILIA MARÍA RODRÍGUEZ D ALEMAN		IDENTIFICACIÓN C C ☒ NIT ☐ C E ☐ OTRO ☐ NÚMERO 41 654 882 TP 20824 CSJ
	Dirección: Carrera 11 N° 86-53 Piso 6 Bogotá D C Teléfono: 6181088 Fax: 6350824 E Mail: info@clarkemodet.com.co		
4) INVENTOR (ES) (72)	Nombre: 1 KALINA, Alexander, I Dirección: 1 105 Glengarry Way, Hillsborough, CA 94010-7313, Estados Unidos Nacionalidad o Domicilio: Estadounidense		
5) PCT (86) Solicitud Internacional No: PCT/US2004/003025 Fecha: FEB 3, 2004 Publicación Internacional No: Wo2004/070173 A1 Fecha: Agosto 19, 2004			
6) Título (54) CICLO DE POTENCIA Y SISTEMA PARA APROVECHAR FUENTES DE CALOR DE TEMPERATURA MODERADA Y BAJA			
7) Clasificación Internacional: F01K 25/06			
8) PRIORIDAD	33) País de Origen	(32) Fecha	(31) Número de Solicitud
	SI ☒ NO ☐	Estados Unidos	Febrero 3, 2003
	Estados Unidos	Sept. 22, 2003	10/669,134
9) Comprobante de pago N° _____ Fecha _____			
Instrucciones para el diligenciamiento del presente formulario Ver reverso de esta pagina			

10)

ANEXOS

- ☒ Comprobante de pago de la tasa de presentación de la solicitud
- ☐ Comprobante de pago por reivindicación de prioridad
- ☐ Documento que acredita la existencia y representación legal cuando el solicitante sea persona Jurídica
- ☐ Poderes, si fuera el caso
- ☐ Documento de cesión del inventor al solicitante o a su causante
- ☐ Declaraciones
- ☒ Copia de la solicitud Internacional (Resumen descripción, reivindicación, Dibujos)
- ☒ Traducción de la solicitud Internacional al castellano (Resumen, descripción reivindicación, Dibujos)
- ☒ Copia del examen preliminar efectuado por la IPEA
- ☐ De ser el caso copia del contrato de acceso
- ☐ De ser el caso documento que acredita la licencia o autorización de uso de conocimientos tradicionales de las comunidades indígenas
- ☐ De ser el caso certificado de depósito del material biológico
- ☐ Arte final 12 x 12 y 6 x 6 cm
- ☐ De ser el caso información sobre otras solicitudes de patente o títulos obtenidos en el extranjero por el mismo titular o su causante relacionados parcial o totalmente con la invención de esta solicitud
- ☒ Otros
 - 1 Reporte internacional de búsqueda
 - 2 Solicitud PCT
 - 3 Notificación pago de tasas
 - 4 PCT Capítulo II
 - 5 Notificación de la transmisión del reporte de búsqueda
 - 6 Solicitud europea 652 368 A1
 - 7 Solicitud Europea 472020 A1
 - 8 Solicitud US2003/0167769 A1
 - 9 Solicitud US4,982,568
 - 10 Solicitud US4,548 043
 - 11 Solicitud US2004/0055302 A1
 - 12 Solicitud US2004/0050048 A1

2

11) FIGURA CARACTERÍSTICA

12) Solicitud concesión de la patente,

NOMBRE DILIA RODRÍGUEZ D ALEMAN

FIRMA

C C 41 654 882 de Bogota TP 20824 CSJ

Instrucciones para el diligenciamiento del presente formulario Ver reverso de esta pagina

142

SUPERINDUSTRIA Y COMERCIO
Radica-ion 85875396 80000000 Folios 242
Fecha (MM): 2005-08-01 16 57:29
Tramite 011 PCT-PATENT 379 FASE NPTI 411 PRESENTAC
Dependencia 2828 DIVISION DE NUEVAS CREACIONES

SUPERINTENDENCIA DE INDUSTRIA Y COMERCIO

NIT 800176089-2

RECIBO OFICIAL DE CAJA 05 - 57,167
FECHA AGOSTO 1 DE 2005

***** CONSIGNACION *****

DEPOSITANTE	TIPO PAGO	BANCO	CUENTA	No PAGO	FECHA PGO	Vr PAGO
CLARKE RODET Y CO	COLOMBCONSIGNACION	BANCO POPULAR	050-00110-6	35422048	01/08/2005	3,365,000 00

***** CONCEPTO *****

CANT	RENTISTICO	CONCEPTO	TOTAL CONCEPTO
1	50005-01-01 SOLICITUDES	1 TRAMITES DE SOL DE PATENTE DE IN	443,000 00
		TOTAL	\$ 443,000 00

SON CUATROCIENTOS CUARENTA Y TRES MIL PESOS

RESPONSABLE _____

RECIBO DE CAJA APLICADO AL EXPEDIENTE No _____

(19) World Intellectual Property
Organization
International Bureau



(43) International Publication Date
19 August 2004 (19.08.2004)

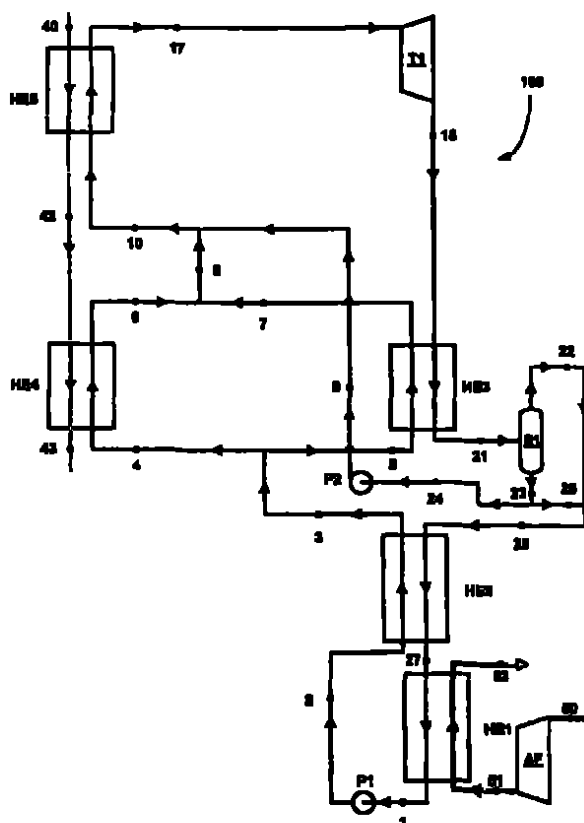
PCT

(10) International Publication Number
WO 2004/070173 A1

- (51) International Patent Classification⁷ F01K 25/06 (74) Agent STROZIER, Robert, W P.O. Box 429 Bellaire, TX 77402-0429 (US)
- (21) International Application Number PCT/US2004/003025 (81) Designated States (unless otherwise indicated, for every kind of national protection available) AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW
- (22) International Filing Date 3 February 2004 (03.02.2004)
- (25) Filing Language English
- (26) Publication Language English
- (30) Priority Data
10/357 328 3 February 2003 (03.02.2003) US
10/669 134 23 September 2003 (23.09.2003) US
- (71) Applicant (for all designated States except US) KALEX, INC. [US/US] 2630 Carlmont Drive Belmont, CA 94002 (US)
- (72) Inventor, and
(75) Inventor/Applicant (for US only) KALINA, Alexander, I [US/US] 105 Glangary Way Hillsborough, CA 94010-7313 (US)
- (84) Designated States (unless otherwise indicated, for every kind of regional protection available) ARIPO (BW, GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW) Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM) European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PT, RO, SE, SI, SK, TR) OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG)

(Continued on next page)

(54) Title POWER CYCLE AND SYSTEM FOR UTILIZING MODERATE AND LOW TEMPERATURE HEAT SOURCES



(57) Abstract A new thermodynamic cycle is disclosed for converting energy from a low temperature stream external source into useable energy using a working fluid comprising of a mixture of a low boiling component and a higher boiling component and including a higher pressure circuit and a lower pressure circuit. The cycle is designed to improve the efficiency of the energy extraction process by recirculating a portion of a liquid stream prior to further cooling. The new thermodynamic processes and systems for accomplishing these improved efficiencies are especially well-suited for streams from low temperature geothermal sources.

WO 2004/070173 A1



Published

- with international search report
- before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments

For two letter codes and other abbreviations refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

PCT PATENT SPECIFICATION

TITLE **POWER CYCLE AND SYSTEM FOR UTILIZING MODERATE AND LOW TEMPERATURE HEAT SOURCES**

INVENTOR **Alexander I. Kalina**

ASSIGNEE **KALEX, INC**

RELATED APPLICATIONS

[0001] This application is a Continuation-in-Part of United States Patent Application Serial No. 10/669,134, filed 23 September 2003 which is a Continuation-in-Part of United States Patent Application Serial No. 10/357,328 filed 3 February 2003

BACKGROUND OF THE INVENTION

1 Field of the Invention

[0002] The present invention relates to a system and method for the utilization of heat sources with moderate to low initial temperature, such as geothermal waste heat sources or other similar sources

[0003] More particularly, the present invention relates to a system and method for the utilization of heat sources with moderate to low initial temperature, such as geothermal waste heat sources or other similar sources involving a multi-staged heating process and at least one separation step to enrich the working fluid which is eventually fully vaporized for energy extraction

2 Description of the Related Art

[0004] In the prior art, US patent number 4982568, a working fluid is a mixture of at least two components with different boiling temperatures. The high pressure at which this working fluid vaporizes and the pressure of the spent working fluid (after expansion in a turbine) at which the working fluid condenses are chosen in such a way that at the initial temperature of condensation is higher than the initial temperature of boiling. Therefore, it is possible that the initial boiling of the working fluid is achieved by recuperation of heat released in the process of the condensation of the spent working fluid. But in a case where the initial temperature of the heat source used is moderate or low, the range of temperatures of the heat source is narrow, and therefore, the possible range of such recuperative boiling-condensation is significantly reduced and the efficiency of the system described in the prior art diminishes.

[0005] Thus, there is a need in the art for a new thermodynamic cycle and a system based thereon for enhanced energy utilization and conversion.

+
7

-2-

SUMMARY OF THE INVENTION

[0006] The present invention provides a method for extracting thermal energy from low to moderate temperatures source streams including the step of transforming thermal energy from a fully vaporized boiling stream into a usable energy form to produce a lower pressure, spent stream. The fully vaporized boiling stream is formed by transferring thermal energy from an external heat source stream to a boiling stream to form the fully vaporized boiling stream and a cooled external heat source stream. The method also includes the steps of transferring thermal energy from the spent stream to a first portion of a heated higher pressure, basic working fluid stream to form a partially condensed spent stream and a first pre-heated, higher pressure, basic working fluid stream and transferring thermal energy from the cooled external heat source stream to a second portion of the heated higher pressure, basic working fluid stream to form a second pre-heated, higher pressure, basic working fluid stream and a spent external heat source stream. The method also includes the steps of combining the first and second pre-heated, higher pressure basic working fluid streams to form a combined pre-heated, higher pressure basic working fluid stream and separating the partially condensed spent stream into a separated vapor stream and a separated liquid stream. The method also includes the steps of pressurizing a first portion of the separated liquid stream to a pressure equal to a pressure of the combined pre-heated, higher pressure basic working fluid stream to form a pressurized liquid stream and combining the pressurized liquid stream with the combined pre-heated, higher pressure basic working fluid stream to form the boiling stream.

The method also includes the steps of combining a second portion of the separated liquid stream with the separated vapor stream to form a lower pressure, basic working fluid stream and transferring thermal energy from the lower pressure, basic working fluid stream to a higher pressure, basic working fluid stream to form the heated, higher pressure, basic working fluid stream and a cooled, lower pressure, basic working fluid stream. The method also includes the steps of transferring thermal energy from the cooled, lower pressure, basic working fluid stream to an external coolant stream to form a spent coolant stream and a fully condensed, lower pressure, basic working fluid stream, and pressurizing the fully condensed, lower pressure, basic working fluid stream to the higher pressure, basic working fluid stream.

[0007] In a more efficient implementation of the present invention, the method provides the additional steps of separating the boiling stream into a vapor stream and a liquid stream, combining a portion of the liquid stream with the vapor stream and passing it through a small

heater exchanger in contact with the external heat source stream to insure complete vaporization and superheating of the boiling stream. A second portion of the liquid stream is depressurized to a pressure equal to a pressure of the spent stream.

[0008] In a more yet more efficient implementation of the present invention, the method provides in addition to the additional steps described in paragraph 0006, the steps of separating the depressurized second portion of the liquid stream of paragraph 0006 into a vapor stream and a liquid stream, where the vapor stream is combined with the pressurized liquid stream having the parameters of the point 9 and repressurized before being combined with the stream having the parameters of the point 8. While the liquid stream is depressurized to a pressure equal to a pressure of the spent stream having the parameters of the point 18.

[0009] The present invention also provides a two cycle thermodynamic method where a first boiling composition is heated, vaporized, expanded in a turbine to extract a quantity of more useable energy such as electric energy and condensed and a recirculating composition is heated, partially vaporized, expanded in the same turbine to extract a quantity of more useable energy such as electric energy and condensed, where the two cycle improve an overall efficiency of the energy conversion system.

[0010] The present invention provides a systems as set forth in Figures 1A-D and 2 adapted to implement the methods of this invention.

DESCRIPTION OF THE DRAWINGS

[0011] 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.

[0012] Figure 1A depicts a schematic of a preferred thermodynamic cycle of this invention,

[0013] Figure 1B depicts a schematic of another preferred thermodynamic cycle of this invention, [0014] Figure 1C depicts a schematic of another preferred thermodynamic cycle of this invention,

[0015] Figure 1D depicts a schematic of another preferred thermodynamic cycle of this invention, and

[0016] Figure 2 depicts a schematic of another preferred thermodynamic cycle of this invention.

DETAILED DESCRIPTION OF THE INVENTION

[0017] The inventors have found that a novel thermodynamical cycle (system and process) can

be implemented using a working fluid including a mixture of at least two components. The preferred working fluid being a water-ammonia mixture, though other mixtures, such as mixtures of hydrocarbons and/or freons can be used with practically the same results. The systems and methods of this invention are more efficient for converting heat from relatively low temperature fluid such as geothermal source fluids into a useful form of energy. The systems use a multi-component basic working fluid to extract energy from one or more (at least one) geothermal source streams in one or more (at least one) heat exchangers or heat exchange zones. The heat exchanged basic working fluid then transfers its gained thermal energy to a turbine (or other system for extracting thermal energy from a vapor stream and converting the thermal energy into mechanical and/or electrical energy) and the turbine converts the gained thermal energy into mechanical energy and/or electrical energy. The systems also include pumps to increase the pressure of the streams at certain points in the systems and a heat exchangers which bring the basic working fluid in heat exchange relationships with a cool stream. One novel feature of the systems and methods of this invention, and one of the features that increases the efficiency of the systems, is the result of using a split two circuit design having a higher pressure circuit and a lower pressure circuit and where a stream comprising spent liquid separated for spent vapor from the higher pressure circuit is combined with a stream comprising the spent lower pressure stream at the pressure of the spent lower pressure stream prior to condensation to form the initial fully condensed liquid stream and where the combined stream is leaner than the initial fully condensed liquid stream. The present system is well suited for small and medium sized power units such as 3 to 5 Mega Watt power facilities.

[0018] The working fluid used in the systems of this inventions preferably is a multi-component fluid that comprises a lower boiling point component fluid – the low-boiling component – and a higher boiling point component – the high-boiling component. Preferred working fluids include an ammonia-water mixture, a mixture of two or more hydrocarbons, a mixture of two or more freon, a mixture of hydrocarbons and freon, or the like. In general, the fluid can comprise mixtures of any number of compounds with favorable thermodynamic characteristics and solubility. In a particularly preferred embodiment, the fluid comprises a mixture of water and ammonia.

[0019] It should be recognized by an ordinary artisan that at those point in the systems of this invention where a stream is split into two or more sub-streams, the valves that effect such

-5-

stream splitting are well known in the art and can be manually adjustable or are dynamically adjustable so that the splitting achieves the desired improvement in efficiency

[0020] Referring now to Figure 1A, a preferred embodiment of a system of this invention, generally 100, is shown. The system 100 is described in terms of its operation using streams, conditions at points in the system, and equipment. A fully condensed working fluid stream at a temperature close to ambient having parameters as at a point 1, enters a feed pump P1, where it is pumped to an elevated pressure, and obtains parameters as at a point 2. The composition of the working fluid stream having the parameters of the point 2 will be hereafter referred to as a "basic composition" or "basic solution." The working fluid stream having the parameters of the point 2, then passes through a recuperative pre-heater or heat exchanger HE2, where it is heated in counter flow by a returning stream of the basic solution as described below, and obtains parameters as at a point 3. The state of the basic working solution at the point 3 corresponds to a state of saturated, or slightly sub-cooled liquid.

[0021] Thereafter, the stream of basic solution having the parameters of the point 3 is divided into two sub-streams having parameters as at points 4 and 5, respectively. The sub-stream having the parameters of the point 4, then passes through a heat exchanger HE4, where it is heated and partially vaporized by a stream of a heat source fluid (e.g., geothermal brine stream) having parameters as at a point 42 as described below, and obtains parameters as at a point 6. While, the stream of basic solution having the parameters of the point 5 passes through a heat exchanger HE3, where it is heated and partially vaporized by a condensing stream having parameters as at a point 20 in a condensing process 20-21 also described below and obtains parameters as at a point 7. Thereafter, the sub-streams having parameters as at points 6 and 7 are combined, forming a combined stream having parameters as at a point 8. The stream of basic solution having the parameters of the point 8 is then combined with a stream of a recirculating solution having parameters as at a point 29 as described below, and forms a stream of a boiling solution having parameters as at a point 10. The stream having the parameters of the point 29 is in a state of sub-cooled liquid, and, therefore, as a result of the mixing of the streams having the parameters of the points 8 and 29, a substantial absorption of vapor occurs, and the temperature rises substantially. Thus, a temperature of the stream having the parameters of the point 10 is usually significantly higher than that of the stream having the parameters of the point 8. The composition of the stream having the parameters of the point 10 is referred to herein as a "boiling solution."

[0022] The stream of boiling solution having the parameters of the point 10, then passes through a heat exchanger HE5, where it is heated and vaporized by the stream of the heat source fluid having parameters as at a point 41. The vaporized stream exiting the heat exchanger HE5 now has parameters as at a point 11. The stream having the parameters of the point 11 then enters into a gravity separator S2, where it is separated into a vapor stream having parameters as at a point 13 and a liquid stream having parameters as at a point 12. The liquid stream having the parameters of the point 12 is then divided into two sub-streams having parameters as at points 14 and 15, respectively. The sub-stream having the parameters of the point 14 usually represents a very small portion of the total liquid stream, and is combined with the vapor stream having the parameters of the point 13 as described below, forming a stream of working solution with parameters as at a point 16. The stream of working solution having the parameters of the point 16, then passes through a heat exchanger HE6 (a small heat exchanger sometimes called a vapor drier to insure that the state of the stream exiting the heat exchanger is a superheated vapor), where it is further heated by the stream of the heat source fluid having parameters as at a point 40, to form a fully vaporized and slightly superheated stream having parameters as at a point 17. Thereafter, the stream of working solution having the parameters of the point 17 passes through a turbine T1, where it is expanded, producing useful power (conversion of thermal energy into mechanical and electrical energy) to form a stream having parameters as at a point 18.

[0023] The recirculating liquid having the parameters of the point 15 as described above passes through a throttle valve TV1, where its pressure is reduced to an intermediate pressure to form a stream having parameters as at a point 19. As a result of throttling, the parameters of the stream at the point 19 correspond to a state of a vapor-liquid mixture. The stream having the parameters of the point 19, then enters into a gravity separator S3, where it is separated into a vapor stream having parameters as at the point 30, and a liquid stream having parameters as at a point 31. The liquid stream having the parameters of the point 31 passes through a second throttle valve TV2, where its pressure is further reduced to a pressure to form a stream having parameters as at a point 32, where the pressure of the stream having the parameters of the point 32 is equal to a pressure of the stream having the parameters of the point 18 as described above. Thereafter, the stream having the parameter of the point 32 and the stream having the parameters of the point 18 are combined forming a stream of a condensing solution having the parameters of the point 20. The stream having parameters of

-7-

the point 20 passes through the heat exchanger HE3, in counter flow to the stream having the parameters of the point 5, in a cooling process 5-7. After passing through the heat exchanger HE3, the stream having the parameters of the point 20 is partially condensed, releasing heat for the heating process 20-21 described above and obtains parameters as at a point 21.

[0024] The stream having the parameters of the point 21 then enters into a gravity separator S1, where it is separated into a vapor stream having parameters as at a point 22 and a liquid stream having parameters as at a point 23. The liquid stream having the parameters of the point 23 is in turn divided into two sub-streams having parameters as at points 25 and 24, respectively. The liquid sub-stream having the parameters of the point 25 is then combined with the vapor stream having the parameters of the point 22, forming a stream of the basic solution having parameters as at a point 26.

[0025] The liquid sub-stream having parameters of the point 24 enters a circulating pump P2, where its pressure is increased to a pressure equal to a pressure in gravity separator S3, i.e., equal to a pressure of the vapor stream having the parameters of the point 30 described above, and obtains parameters as at point 9. The liquid stream having the parameters of the point 9 is in a state of a sub-cooled liquid. The liquid stream having the parameters of point 9 is then combined with the vapor stream having the parameters of the point 30 described above. A pressure of the streams having the parameters of the points 9 and 30 is chosen in such a way that the sub-cooled liquid having the parameters of the point 9 fully absorbs all of the vapor stream having the parameters of the point 30, forming a liquid stream having parameters as at point 28. The liquid stream having the parameters of the point 28 is in a state of saturated or sub-cooled liquid. Thereafter, the stream having the parameters of the point 28 enters into a circulating pump P3, where its pressure is increased to a pressure equal to a pressure of the stream having the parameters of the point 8, and obtains parameters of the point 29 described above. The stream having the parameters of the point 29 is then combined with the stream of basic solution having the parameters of the point 8, forming the stream of the boiling solution having the parameters of the point 10 described above.

[0026] The stream of basic solution having the parameters of the point 26 enters into the heat exchanger HE2, where it partially condenses releasing heat for a heating process 2-3 described above, and obtains parameters as at a point 27. Thereafter the stream of basic solution having the parameters of the point 27 enters into a condenser HE1, where its is cooled and fully condensed by an air or water stream having parameters as at point 51.

-8-

described below, and obtains parameters of the point 1

[0027] An air (or water) stream having parameters as at a point 50 enters an air fan AF (or compressor in the case of water) to produce an air stream having parameters as at a point 51, which forces the air stream having the parameters of the point 51 into the heat exchanger HE1, where it cools the stream of basic working fluid in a cooling process 27-1, and obtains parameters as at point 52

[0028] The stream of heat source fluid with the parameters of the point 40 passes through the heat exchanger HE6, where it provides heat from a heating process 6-17, and obtains the parameters of the point 41. The stream of heat source fluid having the parameters of the point 41 passes through the heat exchanger HE5, where it provides heat for a heating process 10-11, and obtains the parameters of the point 42. The stream of heat source fluid having the parameters of the point 42 enters into the heat exchanger HE4, where it provides heat for a heating process 4-6 and obtains parameters as at point 43

[0029] In the previous variants of the systems of this invention, the recirculating stream having parameters as at the point 29 was mixed with the stream of basic solution having parameters as at the point 8. As a result of this mixing, a temperature of the combined stream having parameters as at the point 10 was substantially higher than a temperature of the streams having parameters as at the points 8 and 29

[0030] Referring now to Figure 1D, another embodiment of the system of this invention, generally 100, is shown to include an additional heat exchanger HE7, i.e., the heat exchanger HE5 is split into two heat exchangers HE5' and HE7 designed to reduce the temperature difference between the stream, having the parameters as at the point 10 and the streams having the parameters as at the points 8 and 29

[0031] In the new embodiment, the stream with parameters as at the point 8 is sent into the heat exchanger HE7 where it is heated and further vaporized by a heat source stream, such as a geothermal fluid stream, having the parameters as at a point 44 producing the heat source stream having parameters as at the point 42 in a counter flow heat exchange process 44-42 and a stream having parameters as at a point 34. Only then is the steam having the parameters as at the point 34 mixed with a recirculating stream having the parameters as at the point 29 (as described above) forming a combined stream having parameters as at the point 10. A temperature at of the stream having the parameters as at the point 34 is chosen in such a way that the temperature of the stream having the parameters as at the point 10 is equal or very

close to the temperature of the stream having the parameters as at the point 34. As a result, the irreversibility of mixing a stream of basic solution and a stream of recirculating solution is drastically reduced. The resulting stream having the parameters as at the point 10 passes through the heat exchanger HE5' where it is heated and vaporized in a counter flow process 41-44 by the heat source stream such as a geothermal fluid stream having the parameters as at the point 41.

[0032] This embodiment can also include a sub-streams having parameter as at points 14, as described above, which usually represents a very small portion of the total liquid stream, and is combined with the vapor stream having the parameters of the point 13 (not shown) as described below, to form the stream of working solution with parameters as at the point 16. Additionally, this embodiment can also include the AF unit and associated streams as described above.

[0033] The advantages of the arrangement of streams shown in the present embodiment include at least the following. a temperature difference in the heat exchanger HE7 (which is, in essence, the low temperature portion of the heat exchanger HE5 in the previous variants), are substantially increased and therefore the size of the heat exchanger HE7 is reduced, while the heat exchanger HE5' of this embodiment works in absolutely the same way as the high temperature portion of the heat exchanger HE5 of the previous variants. The efficiency of the system of this embodiment is not affected at all.

[0034] This embodiment of the method of mixing a recirculating stream with a stream of basic solution can be applied to all variants described above. One experienced in the art can easily apply this method without further explanation.

[0035] An example of calculated parameters for the points described above are given in Table 1 for the embodiment shown in Figure 1A.

TABLE 1
Parameter of Points in the Embodiment of Figure 1A

Point No	Concentration X	Temperature T (°F)	Pressure P (psia)	Enthalpy h (btu/lb)	Entropy S(btu/lb°F)	Weight (g/g1)
Parameters of Working Fluid Streams						
1	0.975	73.5	133.4091	37.8369	0.09067	1.0
2	0.975	75.0186	520.0	40.1124	0.09145	1.0
3	0.975	165.0	508.2780	147.9816	0.27769	1.0

-10-

Point No	Concentration X	Temperature T (°F)	Pressure P (psia)	Enthalpy h (btu/lb)	Entropy S(btu/lb°F)	Weight (g/g1)
4	0 975	165 0	508 2780	147 9816	0 27769	0 6010
5	0 975	165 0	508 2780	147 9816	0 27769	0 3990
6	0 975	208 0	498 5	579 1307	0 96196	0 6010
7	0 975	208 0	498 5	579 1307	0 96196	0 3990
8	0 975	208 0	498 5	579 1307	0 96196	1 0
9	0 40874	170 2394	220 0	45 8581	0 21737	0 3880
10	0 81773	231 1316	498 5	433 8631	0 76290	1 40575
11	0 81773	300 0	490 0	640 0316	1 04815	1 40757
12	0 35855	300 0	490 0	200 2510	0 43550	0 1950
13	0 89168	300 0	490 0	710 8612	1 14682	1 21075
14	0 35855	300 0	490 0	200 2510	0 43550	0 1655
15	0 35855	300 0	490 0	200 2510	0 43550	0 17845
16	0 8845	300 0	490 0	703 9808	1 13724	1 2272
17	0 8845	306 0	488 5	718 3184	1 15637	1 2273
18	0 8845	213 3496	139 5	642 4511	1 17954	1 2273
19	0 35855	249 1433	220 0	200 2510	0 44140	0 17845
20	0 81671	214 6540	139 5	584 8515	1 08437	1 3880
21	0 81671	170 0	137 5	460 9041	0 89583	1 3880
22	0 97746	170 0	137 5	624 6175	1 16325	0.99567
23	0.40874	170 0	137 5	45 4163	0 21715	0 39233
24	0 40874	170 0	137 5	45 4163	0 21715	0 3880
25	0 40874	170 0	137 5	45 4163	0 21715	0 00433
26	0 975	170 0	137 5	622 1123	1 15916	1 0
27	0 975	93 9659	135 5	514 2431	0 97796	1 0
28	0 43013	195 9556	220 0	74 5165	0 26271	0 40575
29	0 43013	196 6491	498 5	75 8407	0 26312	0.40575
30	0 89772	249 1433	220 0	700 9614	1 21784	0 01775
31	0 2990	249 1433	220 0	144 9514	0 35565	0 16070

-11-

Point No	Concentration X	Temperature T (°F)	Pressure P (psia)	Enthalpy h (btu/lb)	Entropy S(btu/lb°F)	Weight (g/g1)
32	0.2990	233.8807	139.5	144.9514	0.35718	0.16070
Parameters of Geothermal Source Stream						
40	brine	315.0		283.0		3.90716
41	brine	311.3304		279.3304		3.90716
42	brine	237.4534		2305.1534		3.90716
43	brine	170.0		138.0		3.90716
Parameters of Air Cooling Stream						
50	air	51.7	14.7	122.3092		91.647
51	air	51.9341	14.72	122.3653		91.647
52	air	73.5463	14.7	127.5636		91.647

[0036] In the system described above, the liquid produced in separator S1 eventually passes through heat exchanger HE5 and is partially vaporized. However, the composition of this liquid is only slightly richer than the composition of the liquid separated from the boiling solution in separator S2. In general, the richer the composition of the liquid added to the basic solution as compared to the composition of the liquid added to the spent working solution (point 18), the more efficient the system. In the proposed system, the bulk of liquid from separator S2, having parameter as point 15 is throttled to an intermediate pressure, and then divided into vapor and liquid in separator S3. As a result, the liquid stream having the parameters of the point 32 which is mixed with the spent working solution stream having the parameters of the point 18, is leaner than the liquid separated from the boiling solution in separator S2. In addition, the recirculating liquid which is separated in separator S1 is mixed with the vapor stream from separator S3, and, therefore, is enriched. As a result, the liquid stream having the parameters of the point 29, which is added to the stream of basic solution having the parameters of the point 10, is richer than the liquid stream produced from separator S1.

[0037] If the system is simplified, and the liquid stream from the separator S2 having parameters of the point 15 is throttled in one step to a pressure equal to the pressure of the stream having the parameters of the point 18, then the system requires less equipment, but its efficiency is slightly reduced. This simplified, but preferred variant of the system of this

-12-

invention is shown in Figure 1B, where the separator S3 and the throttle valve TV2 have been removed along with the streams having the parameters of the points 30, 31 and 32. The operation of such a variant of this system of Figure 1A does not require further separate description because all of the remaining features are fully described in conjunction with the detailed description of system and process of Figure 1A.

[0038] If the quantity of liquid from separator S1 is reduced to such a degree that the composition of the boiling solution stream having the parameters of the point 10 becomes equal to the composition of the working solution which passes through the turbine T1, then the separator S2 can be eliminated along with the throttle valve TV1. Therefore, the heat exchanger HE6 also becomes unnecessary, and is also eliminated because in this implementation there is no risk of liquid droplets being present in the boiling stream due to the absence of the separator S2. This even more simplified variant of the system of this invention is presented in Figure 1C. Its efficiency is yet again lower than the efficiency of the previous variant described in Figure 1B, but it is still more efficient than the system described in the prior art.

[0039] The choice in between the three variants of the system of this invention is dictated by economic conditions of operations. One experienced in the art can easily compare the cost of additional equipment, the value of additional power output given by increased efficiency and make an informed decision as to the exact variant chosen.

[0040] A summary of efficiency and performance of these three variants of this invention and the system described in the prior art are presented in Table 2.

TABLE 2
Performance Summary

	Systems of This Invention			Prior Art
	Variant 1	Variant 2	Variant 3	
Heat Input (Btu)	566 5385	565 5725	564 2810	487 5263
Specific Brine Flow (lb/lb)	3 960716	3 9005	3 89159	3 36225
Heat Rejection (Btu)	476 4062	476 4062	476 4062	414 0260
Turbine Enthalpy Drop (Btu)	93 1119	91 7562	90 2988	75 376
Turbine Work (Btu)	90 7841	89 4623	88 0413	73 4828
Pump Work (Btu)	2 9842	2 5812	2 4240	1 867
Air Fan Work (Btu)	5 1414	5 1414	5 1414	3 5888
Net Work (Btu)	82 6785	81 7397	80 4759	68 027

Net Thermal Efficiency (%)	14 595	14 453	14 262	13 954
Second Law efficiency (%)	54 23	53 703	52 995	51 85

[0041] It is apparent from the simulated data in Table 2 that all three variants of this invention show improvements in net values net work improvements of 21.54%, 20.16% and 18.30%, respectively; and net thermal and second law efficiency improvements of 4.59%, 3.58% and 2.21%, respectively

Improved Variant

[0042] In yet another preferred embodiment of the system of this invention designed for the utilization of heat source with moderate to low initial temperature, such as geothermal, waste heat and similar sources, an improved configuration is described below

[0043] In a previous variant a system was described which provided substantial improvements over the prior art United States Patent No. 4,982,568 and this variant represents a further improvement in efficiency

[0044] Referring now to Figure 2, another preferred embodiment of the system of this invention, generally 200, is shown to include a fully condensed working fluid stream 202 at a temperature close to ambient having parameters as at a point 1, which corresponds to a state of saturated liquid, enters into a feed or first pump, P1. The stream 202 having parameters as at the point 1 is pumped to an elevated pressure obtaining a stream 204 having parameters as at a point 2. Thereafter, the stream 204 having the parameters as at the point 2 is mixed with a stream 206 of liquid having parameters as at a point 39, as described below, forming a stream 208 having parameters as at a point 64. The composition of the stream 206 having the parameters as at the point 39 is leaner than the composition of the stream 204 having the parameters as at the point 2 (i.e., the stream 206 has a lower concentration of the low-boiling component than does the stream 204). Obviously, the composition of the stream 208 having the parameters as at the point 64 is leaner than the composition of the stream 204 having parameters as at the point 2, but richer (having a higher concentration of the low-boiling component) than the stream having the parameters as at the point 39.

[0045] Thereafter the stream 208 with the parameters as at the point 64 passes through a second heat exchanger HE2, where it is heated in counter-flow with a first stream 210 having parameters as at a point 26 in a first heat exchange process 26-27, as described below, to form a stream 212 having parameters as at a point 33, corresponding to a state of saturated or

-14-

slightly sub-cooled liquid and a partially condensed stream 214 having parameters as at a point 27. Thereafter, the stream 212 having the parameters as at the point 33 is divided into two sub-streams 216 and 218, having parameters as at points 3 and 34, respectively. The stream 218 with the parameters as at the point 34 then passes through a second throttle valve, TV2, where its pressure is reduced, to form a lower pressure stream 220 having parameters as at a point 35. The stream 220 with the parameters as at the point 35, a mixed stream of vapor and liquid, and is sent into a first gravity separator, S1, where it is separated into a vapor stream 222 having parameters as at a point 28, and a liquid stream 224 having parameters as at a point 38. The liquid stream 224 having the parameters as at the point 38 enters into a second pump, P2, where it is pumped to a pressure equal to a pressure of the stream 204 having the parameters as at the point 2, forming the stream 206 having the parameters as at the point 39. Thereafter, the stream 206 with parameters as at the point 39 is mixed with the stream 204 having the parameters as at the point 2, as described above.

[0046] The stream 216 having a composition represented by the parameters as at the point 3 will have a composition referred to herein as a first boiling composition. Obviously, the compositions of the streams 208, 212, 218, and 220 having the parameters of the points 64, 33, 34 and 35, respectively, are the same composition as the stream 216 having the parameters as at the point 3. The composition of the streams 202 and 204 having the parameters as at the points 1 and 2, respectively, will have the composition referred to as a basic composition. The composition of the streams 210 and 214 having the parameters as at the points 26 and 27, respectively as described below, is the same the composition of the streams 202 and 204 having the parameters as at the points 1 and 2.

[0047] The stream 216 having the first boiling composition and the parameters as at the point 3, is divided into three sub-streams 226, 228, and 230 having parameters as at points 4, 5 and 62, respectively. The sub-stream 226 having the parameters as at the point 4 passes through a fourth heat exchanger HE4, where it is heated, boiled and partially vaporized to form a first partially vaporized stream 232 having parameters as at a point 6 in counter-flow with a stream 234 of a heat source fluid having entering parameters as at a point 43 and leaving parameters as at a point 45, where the stream 234 is a geothermal fluid in the case of a geothermal installation. The sub-stream 228 having the parameters as at the point 5 passes through a third heat exchanger HE3, where it is heated, boils and is partially vaporized to form a second partially vaporized stream 236 having parameters as at a point 7, in counter-flow with a

-15-

returning condensing stream 238 having parameters as at a point 20 to form a partially condensed stream 240 having parameters as at a point 21, as described below. The sub-stream 230 having the parameters as at the point 62 passes through a fifth heat exchanger HE5 where it is heated, boiled and partially vaporized to form a third partially vaporized stream 242 having parameters as at a point 63 in counter-flow by a condensing stream 244 having parameters as at a point 60 to form a fully condensed stream 246 having parameters as at a point 61, as described below.

[0048] Thereafter, the streams 232, 236, and 242 having the parameters as at the points 6, 7, and 63, respectively, are combined forming a combined stream 248 having parameters as at a point 8. The fully condensed stream 246 having the parameters as at the point 61 enters into a circulating or a fourth pump P4, where it is pumped to a pressure equal to a pressure of the stream 248 as at the point 8, as described above, to form a higher pressure fully condensed stream 250 having parameters as at a point 65. Thereafter, the stream 250 having the parameters as at the point 65 is combined with the stream 248 having the parameters as at the point 8, forming a second combined stream 252 having parameters as at a point 9. It is obvious that the composition of the streams 226, 228, 252, 236, 230, 242 and 248 having the parameters as at the points 4, 5, 6, 7, 62, 63 and 8, respectively, are the same as the composition of the stream 216 having the parameters as at the point 3, i.e., the first boiling composition. Because the composition of the streams 244, 246 and 250 having parameters as at the points 60, 61 and 65 is leaner than the first boiling composition, the composition of the combined stream 252 having the parameters as at the point 9 is leaner than the first boiling composition. The composition of the streams 244, 246 and 250 having parameters as at the points 60, 61 and 65 is referred to herein as a recirculating composition, while the composition of the combined stream 252 having the parameters as at the point 9 is referred to herein as a second boiling composition.

[0049] The second combined stream 252 having the second boiling composition and the other parameters as at the point 9 passes through a sixth heat exchanger HE6, where it is further boiled and vaporized to form a further vaporized stream 254 having parameters as at a point 11, in counter-flow by the stream 234 of the heat source fluid having entering parameters as at a point 41 and leaving parameters as at a point 43. Thereafter, the further vaporized stream 254 having the second boiling composition and the other parameters as at the point 11 enters into a second gravity separator S2, where it is separated into a second vapor stream 256

-16-

having parameters as at a point 67, and a second liquid stream 258 having parameters as at a point 68. The second liquid stream 258 having the as at the point 68 may be separated into two sub-streams 260 and 262 having parameters as at points 15 and 69, respectively, in some preferred embodiment of this variant a flow rate of the stream 262 having the parameter as at the point 69 will be is equal to zero. The stream 262 having the parameters as at the point 69, if present, is combined with the second vapor stream 256 having the parameters as at the point 67, forming a third combined stream 264 having parameters as at a point 16, the composition of which will hereafter be referred to as a working composition.

[0050] The stream 264 having the working composition and the other parameters as at the point 16 passes through a seventh heat exchanger HE7, where it is heated and fully vaporized, and slightly superheated to form a fully vaporized stream 266 having parameters as at a point 17, in counter-flow by the stream 234 of the heat source fluid having entering parameters as at a point 40 and leaving parameters as at a point 41. The fully vaporized stream 266 having the working composition and the other parameters as at the point 17, then passes through a turbine T1, where it expands, producing work, and forming a spent stream 268 having the working composition and other parameters as at a point 18.

[0051] The second liquid stream 260 having the parameters as at the point 15, as described above, passes through a first throttle valve TV1, where its pressure is reduced to a pressure equal to the pressure of the stream 222 having the parameters as at the point 28, as described above, to form a lower pressure stream 270 having parameters as at a point 19. Then, the stream 270 having the parameters as at the point 19 enters a third gravity separator S3, where it is separated into a third vapor stream 272 having parameters as at a point 30 and a third liquid stream 274 having parameters as at a point 31. Thereafter, the third liquid stream 274 having the parameters as at the point 31 passes through a third throttle valve TV3, where its pressure is reduced to a pressure equal to a pressure of the spent stream 268 having the parameters as at the point 18, as described above, to form a lower pressure stream 276 having parameters as at a point 32. The stream 276 having the parameters as at the point 32 is then combined with the spent stream 268 having parameters as at the point 18, forming the [third combined] stream 238 having parameters as at the point 20.

[0052] The stream 238 having parameters as at the point 20 passes through the third heat exchanger HE3, where it partially condenses, providing heat for a heat exchange process 5-7, as described above, forming the stream 240 having the parameters as at the point 21. The

-17-

stream 240 having the parameters as at the point 21 enters into a fourth gravity separator S4, where it is separated into a fourth vapor stream 280 having parameters as at a point 22, and a fourth liquid stream 282 having parameters as at a point 23. Then, the fourth liquid stream 282 having parameters as at a point 23 is divided into two liquid sub-streams 284 and 286, having parameters as at points 24 and 25, respectively. The liquid sub-stream 286 having the parameters as at the point 25 is combined with the fourth vapor stream 280 having parameters as at the point 22, forming the stream 210 having the basic composition and the other parameters as at the point 26.

[0053] The liquid sub-stream 284 having the parameters as at the point 24 enters into a circulating or third pump P3, where it is pumped to a pressure equal to a pressure of the streams 222 and 272 having the parameters as at points 28 and 30, as described above, forming a higher pressure stream 288 having parameters as at a point 29. Thereafter, the streams 222, 272, and 288 having the parameters as at points 28, 29, and 30 are combined together forming the stream 244 having the circulating composition and the other parameters as at the point 60. The stream 244 having the parameters as at the point 60, passes through the third heat exchanger HE3, where it is fully condensed, providing heat for a process 62-63, to form the stream 246 having the parameters as at the point 61, as previously described. Again, the liquid stream 246 having the parameters as at the point 61 is pumped by the circulating or fourth pump P4, to form the higher pressure stream 250 having the parameters as at the point 65, which is then mixed with the stream 248 having the first boiling composition and the other parameters as at the point 8, forming the combined stream 252 having the second boiling composition and the other parameters as at the point 9, as described above.

[0054] The stream 210 having the basic composition and other parameters as at the point 26 passes through the second heat exchanger HE2, where it partially condenses, providing heat for a heat-exchange process 64-33, as described above, forming the partially condensed stream 214 having parameters as at the point 27. Then, the stream 214 having parameters as at the point 27 passes through a first condenser-heat exchanger HE1, where it is cooled by a coolant stream 290 having initial parameter as at a point 50 and final parameters as at a point 51 (water or air), to form the fully condensed stream 202 having parameters as at the point 1.

[0055] As in the other variants of the system of this invention, the embodiments described

-18-

above are also is closed.

[0056] As with the previous embodiment of system of this invention that the latest variant improves upon, the working process of the system of this invention is composed of two cycles. The first cycle is a cycle of the first boiling composition, which is heated and vaporized and then expands in the turbine, and then fully condenses in the first heat exchanger HE1, a condenser. The second cycle is a cycle of the recirculating composition, which only partially boils, producing vapor, this vapor also passes through the turbine, and mostly or completely condenses in the third heat exchanger HE3 (a recuperative boiler/condenser). The richer the composition of the liquid stream 284 having the parameters as at the point 24 is, the liquid produced in the recuperative boiler/condenser HE3, the larger the portion of this stream that can be subsequently vaporized, thus increasing the efficiency of the overall process.

[0057] In the previous variants, the liquid stream having the initial parameters as at the point 24 was pumped to an intermediate pressure, enriched by mixing with a vapor stream having the parameters as at the point 30, and then added to a stream of the first boiling composition. In the present variant of the system of this invention, the condensed liquid having the parameters as at the point 24 is pumped and then enriched, not only by the stream of vapor having the parameters as at the point 30, but also with a much larger stream of vapor having parameters as at the point 28. As a result, the streams 244, 246 and 250 having the recirculating composition and the other parameters as at the points 60, 61 and 65, respectively, are enriched significantly more than in the previous designs or variants. The additional enriching with the vapor stream 222 having the parameters as at the point 28 is produced by better utilization of heat released in the process of condensation of the basic composition.

[0058] As a result of this better utilization of heat release in the condensation process, the latter variant of the system of this invention has an overall efficiency of 3% to 5% higher than the previous variants of the system of this invention. A sample of the heat and performance balances of this latter variant of the system of this invention are tabulated in Tables 3-5, and the parameters of all points described above and designated in Figure 2 are tabulated in Table 6.

TABLE 3
Simulated Heat Balance Data

-19-

Property	Energy kW	Energy Btu/lb
Heat In	84,926 44	546 57 Btu/lb
Heat Rejected	70,606 87	454 42 Btu/lb
Turbine enthalpy drops	14,912 74	95 98
Gross Generator Power	14,220 04	91 52
Process Pumps (-3 82)	-653 04	-4 20
Cycle Output	13,567 00	87 32
Other Pumps and Fans (-4 87)	-813 26	-5 23
Net Output	12,753 74	82 08
Gross Generator Power	14,220 04	91 52
Cycle Output	13,567 00	87 32
Net Output	12,573 74	82 08

TABLE 4
Simulated Efficiency Data

Property	Percentage %
Net thermal efficiency	15 02
Second Law Limit	26 91
Second Law Efficiency	55 80

TABLE 5
Simulated Specific Consumption Data

Property	Heat Btu/lb
Specific Brine Consumption	154 55
Specific Power Output	6 47

OVERALL HEAT BALANCE (Btu/lb)

Heat In is equal to Brine plus pumps = $546.57 + 3.82 = 550.39$

Heat Out is equal to turbine plus condenser = $95.98 + 454.42 = 550.39$

TABLE 6
Simulated Specific Consumption Data

Pt.	X lb/lb	T °F	P psia	H Btu/lb	S Btu/lb-R	G Rel. G/G=1	Phase	Wetness lb/lb
WORKING FLUID								
1	0.9299	73.27	126.766	22.3023	0.08415	1.06803	Mix	1
2	0.9298	74.67	498.675	24.4996	0.09502	1.06903	Liq	-93.23°F ^a
3	0.9250	165.00	478.675	130.1713	0.26958	1.00000	Mix	1
4	0.9250	165.00	478.675	130.1713	0.26958	0.45691	Mix	1
5	0.9250	165.00	478.675	130.1713	0.26958	0.41981	Mix	1
6	0.9250	213.11	477.675	527.0695	0.89377	0.45691	Mix	0.1624
7	0.9250	207.99	477.675	515.2115	0.81618	0.41981	Mix	0.1769
8	0.9250	209.22	477.675	515.8261	0.97100	1.00000	Mix	0.1761
9	0.8254	213.11	477.675	396.6378	0.71018	1.34291	Mix	0.4228
11	0.8254	303.50	476.675	666.9563	1.08645	1.34287	Mix	0.1022
15	0.3433	303.50	476.675	205.2395	0.00000	0.13718	Mix	0
16	0.8803	303.50	476.675	719.3763	1.15990	1.20569	Vap	0°F ^a
17	0.9903	306.00	475.175	721.3333	1.16278	1.20569	Vap	2.7°F ^a
18	0.8803	211.57	131.766	641.7309	1.19377	1.20569	Mix	0.0624
19	0.3433	259.31	235.449	205.2395	0.44562	0.13718	Mix	0.912
20	0.8249	212.99	131.766	596.1109	1.10762	1.33080	Mix	0.1457
21	0.8249	170.00	130.766	474.6254	0.92207	1.33090	Mix	0.2613
22	0.9757	170.00	130.766	626.2892	1.17133	0.99303	Mix	0
23	0.3986	170.00	130.766	45.9319	0.21750	0.34778	Mix	1
24	0.3986	170.00	130.766	45.9319	0.21150	0.26277	Mix	1
25	0.3986	170.00	130.766	45.9319	0.21750	0.09501	Mix	1
26	0.9298	170.00	130.766	580.0959	1.09541	1.06803	Mix	0.0796
27	0.9298	99.23	128.766	441.1110	0.91316	1.06903	Mix	0.2106
28	0.9997	113.13	235.449	560.4625	0.99869	0.06803	Mix	0
29	0.3986	170.34	235.449	46.5386	0.21185	0.26277	Liq	-44.74°F ^a
30	0.8851	259.31	235.449	110.8870	1.22271	0.01207	Mix	0
31	0.2910	259.31	235.449	156.4614	0.37066	0.12511	Mix	1
32	0.2910	225.92	131.766	156.4614	0.37300	0.12511	Mix	0.9453
33	0.9250	165.00	478.675	130.1713	0.26958	1.50538	Mix	1

Pt.	X lb/lb	T °F	P psia	H Btu/lb	S Btu/lb-R	G Rel G/G=1	Phase	Wetness lb/lb
34	0 9250	165 00	478 675	130 1713	0 26958	0 50538	Mix	1
35	0 9250	113 13	235 449	130 1713	0 27648	0 50539	Mix	0 8654
38	0 9134	113 13	235 449	63 2351	0 16414	0 43735	Mix	1
39	0 9134	114 48	498 675	65 0826	0 16514	0 43735	Liq	-55 04°F*
60	0 5350	199 51	235 449	171 8993	0 41197	0 34287	Mix	0 8295
61	0 5350	170 00	234 449	47 5498	0 21963	0 34287	Mix	1
62	0 9250	165 00	478 675	130 1713	0 26959	0 12328	Mix	1
63	0 9250	193 51	477 675	476 0256	0 81670	0 12328	Mix	0 2323
64	0 9250	96 39	498 675	36 2899	0 10896	1 50539	Liq	-81 99°F*
65	0 5350	170 97	477 675	49 0179	0 21944	0 34287	Liq	-61 41°F*
67	0 9603	303 50	476 675	719 3763	1 15990	1 20569	Mix	0
68	0 3433	303 50	476 675	205 2395	0 44092	0 13718	Mix	1
69	0 3433	303 50	476 675	205 2395	0 00000	0 00000	Mix	0
HEAT SOURCE								
40	BRINE	315 00	0 000	287 1318	0 00000	3 71523	Liq	
41	BRINE	314 37	0 000	286 4967	0 00000	3 71523	Liq	
43	BRINE	219 11	0 000	198 8263	0 00000	3 71523	Liq	
45	BRINE	170 00	0 000	140 0149	0 00000	3 71523	Liq	
COOLANT								
50	AIR	51 70	14 693	122 3092	1 62806	67 5974	Vap	511.4°F*
51	AIR	79 65	14 673	129,0316	1 64095	67 5974	Vap	539 3°F*
52	AIR	79 95	14 693	129 1036	1 64099	67 5974	Vap	539 6°F*

* Temperature of Stream at the indicated point

[0059] All references cited herein are incorporated by reference. While this invention has been described fully and completely, it should be understood that, within the scope of the appended claims, the invention may be practiced otherwise than as specifically described. 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.

-22-

CLAIMS

I claim

- 1 A method for implementing a thermodynamic cycle comprising the steps of
transforming thermal energy from a fully vaporized boiling stream into a usable energy form to produce a lower pressure, spent stream,
transferring thermal energy from an external heat source stream to a boiling stream to form the fully vaporized boiling stream and a cooled external heat source stream,
transferring thermal energy from the spent stream to a first portion of a heated higher pressure, basic working fluid stream to form a partially condensed spent stream and a first pre-heated, higher pressure, basic working fluid stream,
transferring thermal energy from the cooled external heat source stream to a second portion of the heated higher pressure, basic working fluid stream to form a second pre-heated, higher pressure, basic working fluid stream and a spent external heat source stream,
combining the first and second pre-heated, higher pressure basic working fluid streams to form a combined pre-heated, higher pressure basic working fluid stream,
separating the partially condensed spent stream into a separated vapor stream and a separated liquid stream,
pressurizing a first portion of the separated liquid stream to a pressure equal to a pressure of the combined pre-heated, higher pressure basic working fluid stream to form a pressurized liquid stream,
combining the pressurized liquid stream with the combined pre-heated, higher pressure basic working fluid stream to form the boiling stream,
combining a second portion of the separated liquid stream with the separated vapor stream to form a lower pressure, basic working fluid stream,
transferring thermal energy from the lower pressure, basic working fluid stream to a higher pressure, basic working fluid stream to form the heated, higher pressure, basic working fluid stream and a cooled, lower pressure, basic working fluid stream,
transferring thermal energy from the cooled, lower pressure, basic working fluid stream to an external coolant stream to form a spent coolant stream and a fully condensed, lower pressure, basic working fluid stream, and
pressurizing the fully condensed, lower pressure, basic working fluid stream to the

-23-

higher pressure, basic working fluid stream

2 The method of claim 1, wherein the external heat source stream is a geothermal stream

3 A method for implementing a thermodynamic cycle comprising the steps of transforming thermal energy from a fully vaporized basic working fluid stream into a usable energy form to produce a lower pressure, spent stream,

combining the spent stream with a depressurized liquid stream to form a lower pressure mixed stream,

transferring thermal energy from the lower pressure mixed stream to a first portion of a pre heated higher pressure, basic working fluid stream to form a cooled mixed lower pressure stream and a first heated, higher pressure, basic working fluid stream,

separating the cooled mixed lower pressure stream into a separated lower pressure vapor stream and a separated lower pressure liquid stream,

mixing a first portion of the separated liquid stream with the separated vapor stream to form a second mixed lower pressure stream,

transferring thermal energy from the second mixed lower pressure stream to a higher pressure, basic working fluid stream to form a pre-heated higher pressure, basic working fluid stream and a cooled second mixed lower pressure stream,

condensing the cooled second mixed lower pressure stream with an external cooling stream to form a fully condensed lower pressure basic working fluid stream,

pressuring the fully condensed lower pressure basic working fluid stream to form a higher pressure basic working fluid stream,

transferring thermal energy from a thrice cooled external heat source stream to a second portion of the pre-heated higher pressure basic working fluid stream to form a second heated higher pressure basic working fluid stream and a spent external heat source stream,

combining the first and second heated higher pressure, basic working fluid streams to form a combined heated, higher pressure, basic working fluid stream,

transferring thermal energy from a twice cooled external heat source stream to the combined heated, higher pressure basic working fluid streams to form a hotter higher pressure basic working fluid stream and the thrice cooled external heat source stream,

-24-

combining a higher pressure separated vapor stream with the hotter higher pressure basic working fluid stream to form a mixed higher pressure stream,

transferring thermal energy from a once cooled external heat source stream to the mixed higher pressure stream to form the twice cooled external stream and a partially vaporized higher pressure stream,

separating the partially vaporized higher pressure stream into a second separated vapor higher pressure stream and a second separated higher pressure liquid stream,

transferring thermal energy from an external heat source stream to the second separated vapor higher pressure stream to form the once cooled external heat source stream and the fully vaporized basic working fluid,

reducing the pressure of the second separated higher pressure liquid stream to form a reduced pressure mixed stream,

separating the reduced pressure mixed stream into the first separated vapor stream and a first reduced pressure separated liquid stream, and

reducing the pressure of the reduced pressure separated liquid stream into the lower pressure liquid stream

4 The method of claim 3, wherein the external heat source stream is a geothermal stream

5 A method for implementing a two cycle thermodynamic system comprising the steps of

combining the first compositional stream with a second compositional stream having a recirculating composition to form a combined stream,

heating the combined stream to form a mixed combine stream with an external heat source stream,

separating the mixed combined stream into a vapor combined stream and a liquid stream,

fully vaporizing the vapor combined stream to form a fully vaporized stream with the external heat source stream,

expanding and transforming thermal energy from the fully vaporized stream into a usable energy form to produce a spent stream,

-25-

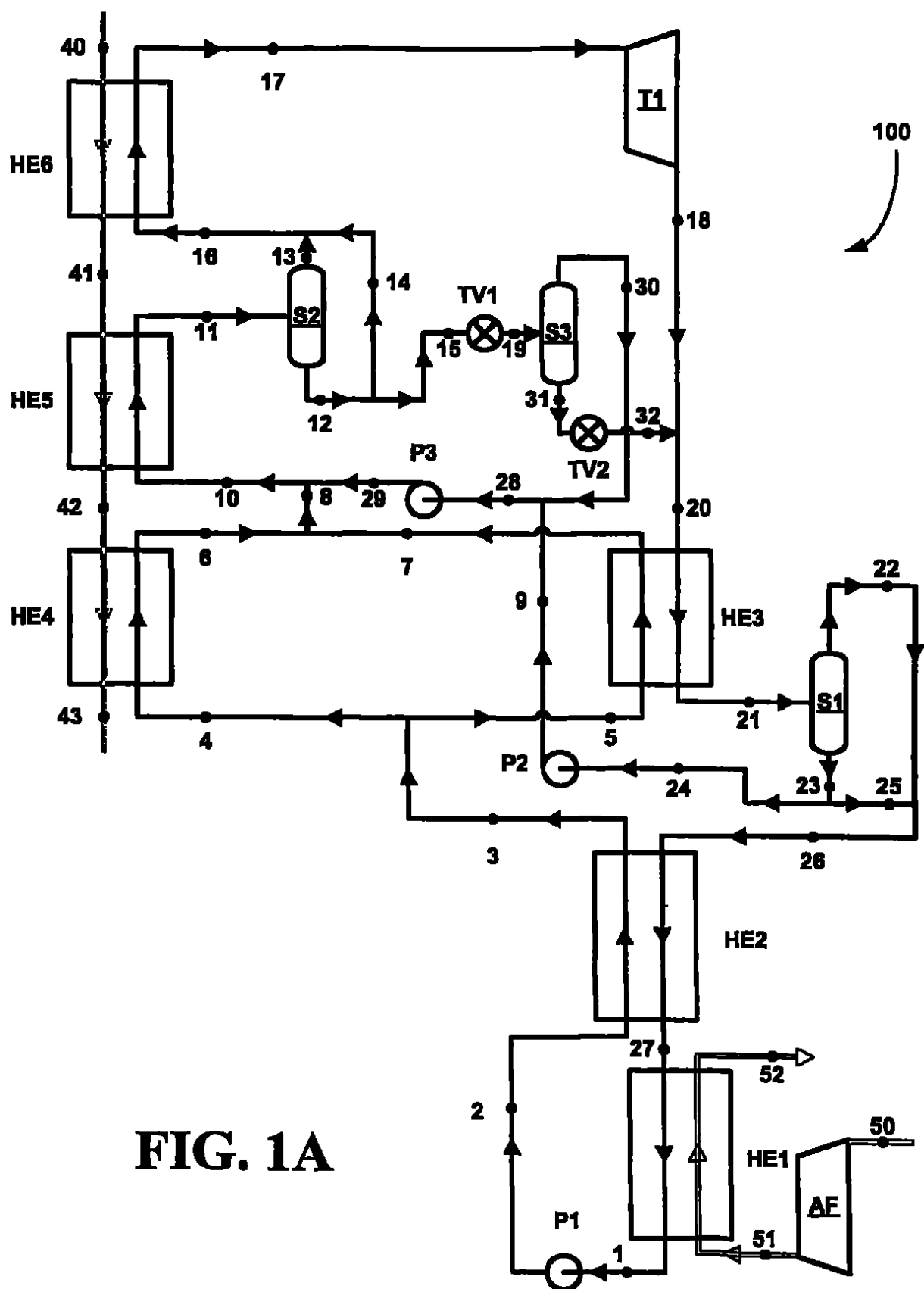
cooling and separating the spent stream into a first compositional precursor stream and a second compositional precursor stream,

condensing the first compositional precursor stream,

forming the first compositional stream from the first compositional precursor stream and an enriched stream having a lower concentration of a low-boiling component, and

forming the second compositional stream from the second compositional precursor stream and two lean vapor stream having a higher concentration of the low-boiling component

6 The method of claim 5, wherein the external heat source stream is a geothermal stream



32

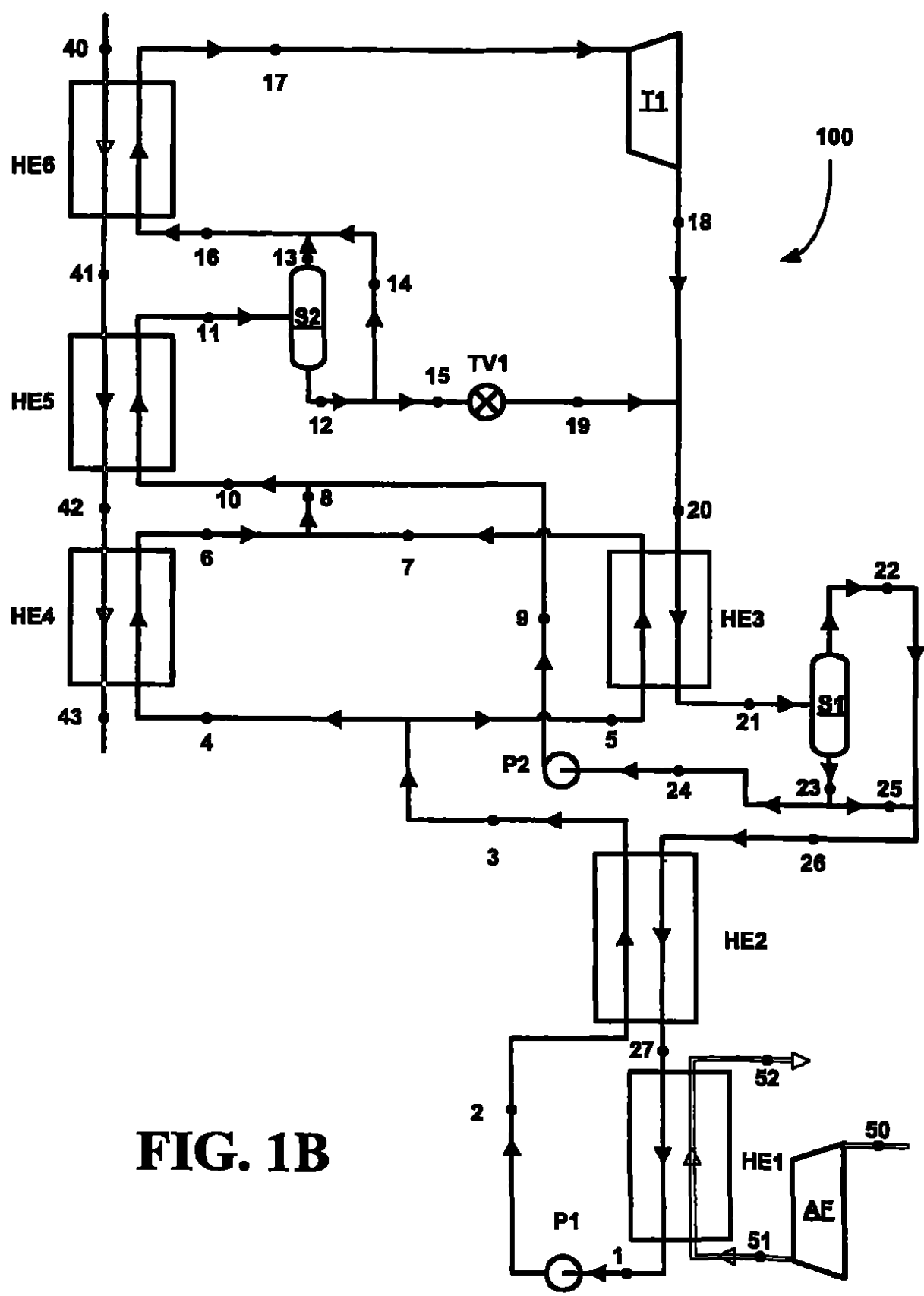


FIG. 1B

32

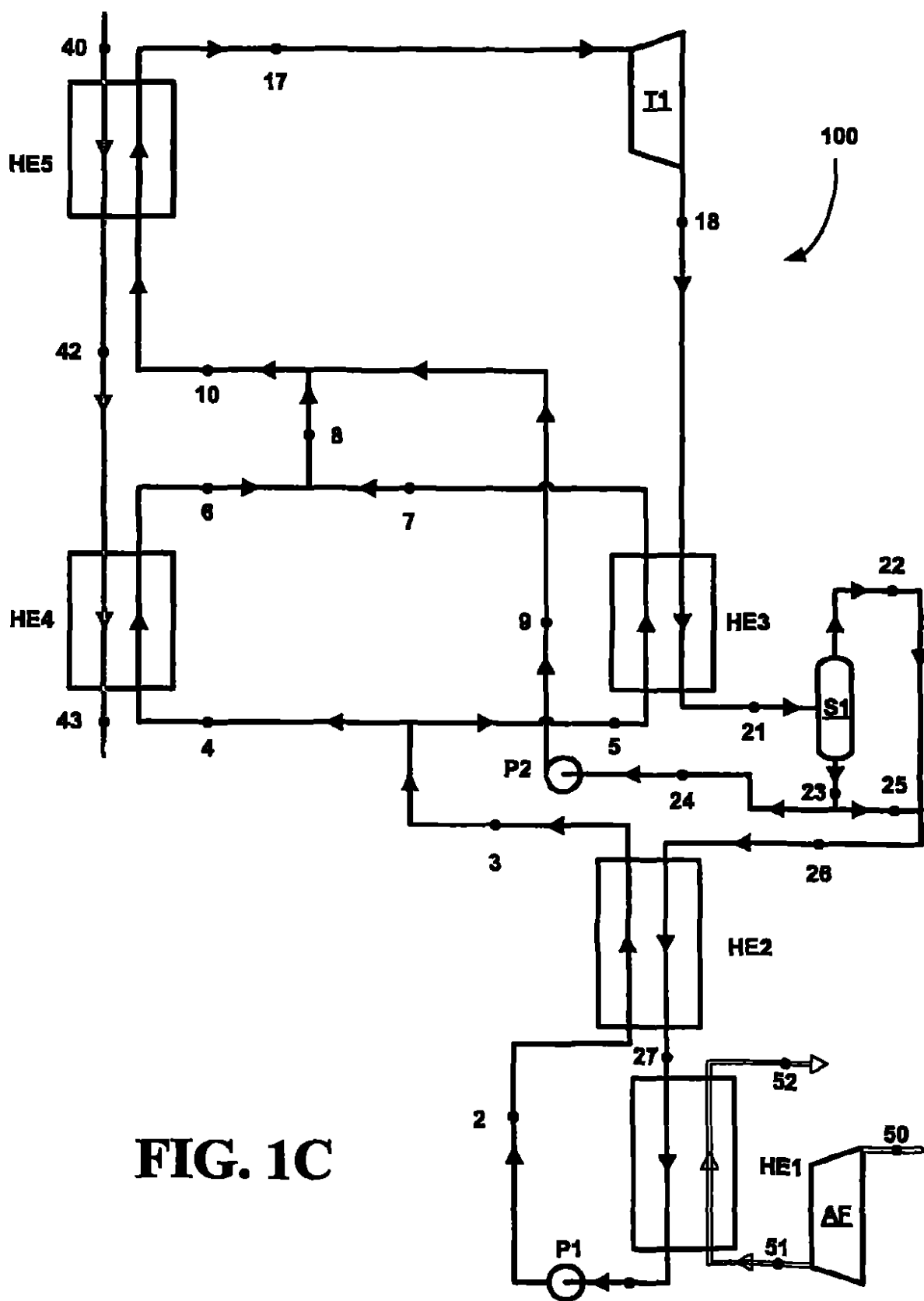


FIG. 1C

34
34

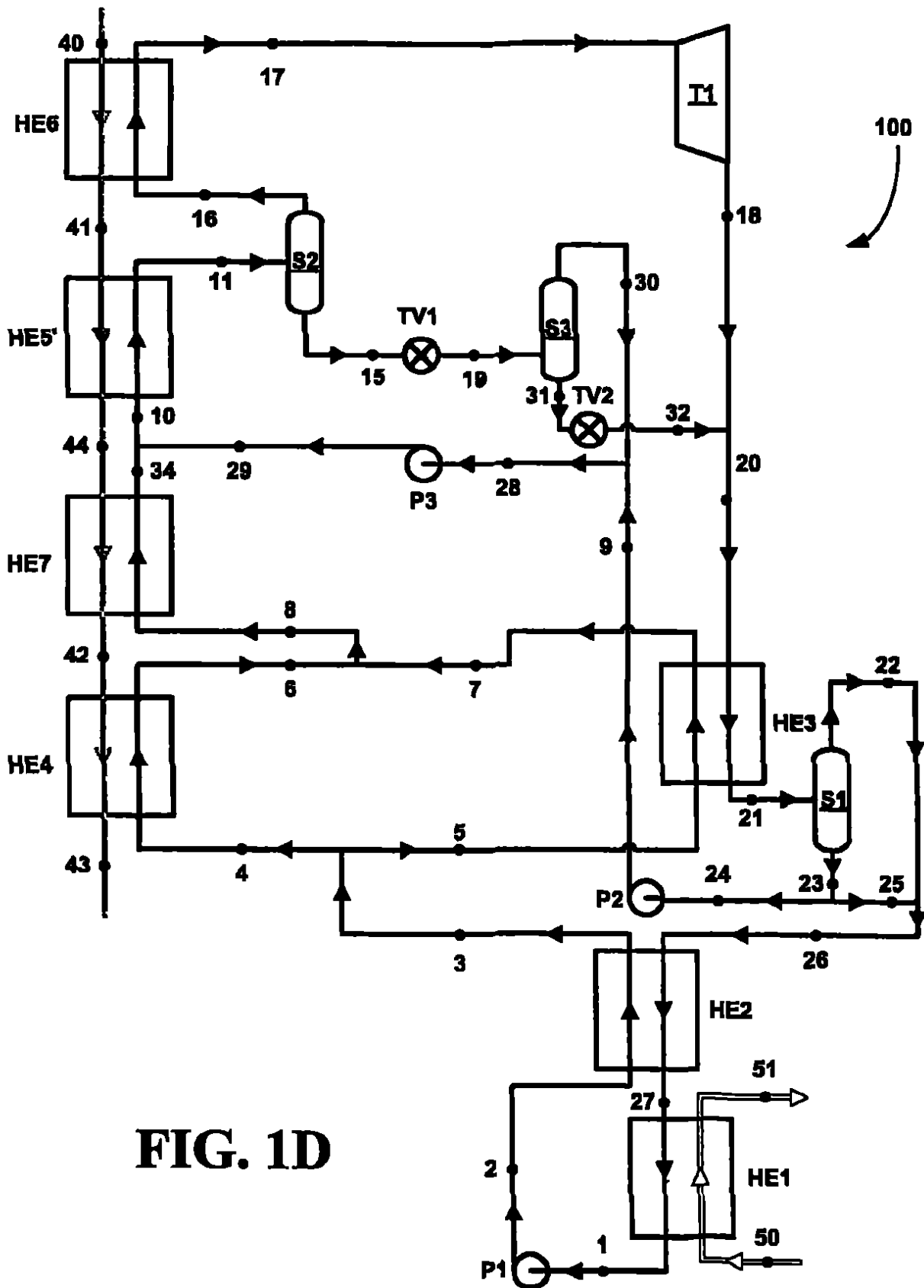
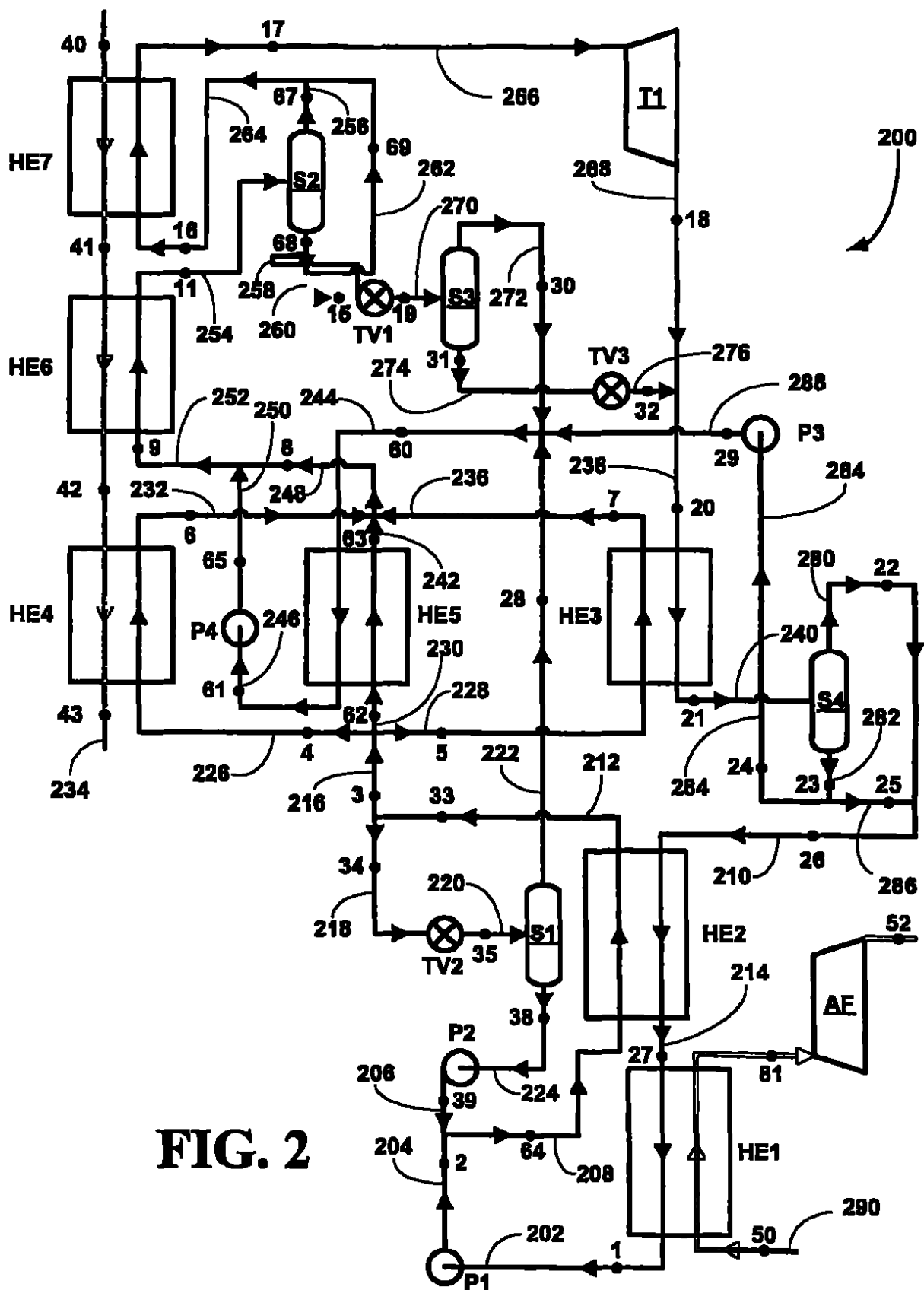


FIG. 1D

**FIG. 2**

WO 2004/070173

PTC/US2004/003025

Título CICLO DE POTENCIA Y SISTEMA PARA APROVECHAR FUENTES DE CALOR DE TEMPERATURA MODERADA Y BAJA

Resumen de WO2004070173

Se divulga un nuevo ciclo termodinámico para convertir energía a partir de una corriente de baja temperatura, de una fuente externa, en energía aprovechable usando un fluido de trabajo que consiste de una mezcla de un componente con bajo punto de ebullición y un componente de alto punto de ebullición y que incluye un circuito de alta presión y un circuito de baja presión. El ciclo es diseñado para mejorar la eficiencia del proceso de extracción de energía mediante la recirculación de una porción de la corriente de líquido antes de un enfriamiento adicional. El nuevo proceso termodinámico y los sistemas para lograr estas mejoras de eficiencia son especialmente adecuados para corrientes provenientes de fuentes geotérmicas de baja temperatura.

ESPECIFICACIÓN DE PATENTE PCT

TÍTULO CICLO DE POTENCIA Y SISTEMA PARA APROVECHAR FUENTES DE CALOR DE TEMPERATURA MODERADA Y BAJA

INVENTOR Alexander I. Kalina

ASIGNADA KALEX, INC

SOLICITUDES RELACIONADAS

[0001] Esta solicitud es una Continuación-en-Parte de la Solicitud de Patente de los Estados de Unidos Senal No 10/669,134, archivada el 23 de Septiembre de 2003 la cual es una Continuación-en-Parte de la Solicitud de Patente de los Estados de Unidos Senal No 10/357,328 archivada el 3 de Febrero de 2003

ANTECEDENTES DE LA INVENCION

1 Campo de la Invención

[0002] La presente invención describe un sistema y un método para el aprovechamiento de fuentes de calor con temperatura inicial moderada a baja, tales como fuentes de calor residual de origen geotérmico u otras fuentes similares

[0003] De forma más particular, la presente invención describe un sistema y un método para el aprovechamiento de fuentes de calor con temperatura inicial moderada a baja, tales como fuentes de calor residual de origen geotérmico u otras fuentes similares que implican un proceso de calentamiento multi-etapas y al menos un paso de separación para enriquecer el fluido de trabajo el cual eventualmente se evapora completamente para la extracción de energía

2 Descripción del estado del Arte

[0004] Dentro de los antecedentes, patente numero 4982568 de los Estados Unidos, un fluido de trabajo es una mezcla de al menos dos componentes con temperaturas de ebullición diferentes La alta presión a la cual este fluido de trabajo se evapora y la

presión del fluido de trabajo agotado (después de la expansión en la turbina) en la cual el fluido de trabajo se condensa son seleccionadas de forma que la temperatura inicial de condensación es mayor que la temperatura inicial de ebullición. Por lo tanto, es posible que la temperatura inicial de ebullición se alcance mediante la recuperación del calor liberado en el proceso de condensación del fluido de trabajo agotado. Pero en un caso donde la temperatura inicial de la fuente de calor usada es moderada o baja, el intervalo de temperaturas de la fuente de calor es estrecho, y por lo tanto, el intervalo de estas para la recuperación ebullición-condensación se reduce significativamente y la eficiencia de los sistemas descritos en los antecedentes disminuye.

[0005] De esta forma, existe una necesidad dentro del arte por un nuevo ciclo y un sistema basado en este para aumentar el aprovechamiento y conversión de energía.

RESUMEN DE LA INVENCION

[0006] La presente invención proporciona un método para extraer energía térmica a partir de corrientes fuentes de calor con temperaturas baja a moderada que incluye el paso de transformación de energía térmica de una corriente de ebullición totalmente evaporada en una forma de energía aprovechable para producir una corriente agotada, de presión mas baja. La corriente de ebullición totalmente evaporada se forma por la transferencia de energía térmica desde una corriente externa fuente de calor a una corriente de ebullición para formar la corriente de ebullición totalmente evaporada y una corriente externa fuente de calor enfriada. El método también incluye los pasos de transferencia de energía térmica de la corriente agotada a una primera porción de una corriente de fluido de trabajo básico, de mayor presión, calentada, para formar una

corriente agotada parcialmente condensada y una primera corriente de fluido de trabajo básico pre-calentada, de mayor presión, y transferencia de energía térmica desde la corriente externa fuente de calor enfriada a una segunda porción de corriente de fluido de trabajo básico, de mayor presión, calentada, para formar una segunda corriente de fluido de trabajo básico pre-calentada, de mayor presión, y una corriente externa fuente de calor agotada. El método también incluye los pasos de combinación de la primera y segunda corrientes de fluido de trabajo básico pre-calentadas, de mayor presión para formar una corriente de fluido de trabajo básico pre-calentada combinada, de mayor presión y separación de la corriente agotada parcialmente condensada en una corriente de vapor separada y una corriente de líquido separada. El método también incluye los pasos de presurización de una primera porción de la corriente de líquido separada hasta una presión igual a la presión de la corriente de fluido de trabajo básico precalentada combinada, de mayor presión, para formar una corriente de líquido presurizada y combinación de la corriente de líquido presurizada con la corriente de fluido de trabajo básico pre-calentada combinada, de mayor presión para formar la corriente de ebullición.

El método también incluye los pasos de combinación de una segunda porción de la corriente de líquido separada con la corriente de vapor separada para formar la corriente de fluido de trabajo básico de menor presión, y transferencia de energía térmica de la corriente de fluido de trabajo básico de menor presión, a una corriente de fluido de trabajo básico de mayor presión, para formar la corriente de fluido de trabajo básico, de mayor presión, calentada y una corriente de fluido de trabajo básico, de menor presión, enfriada. El método también incluye los pasos de transferencia de

energía térmica de la corriente de fluido de trabajo básico, de menor presión, enfriada, a una corriente externa de enfriamiento para formar una corriente de enfriamiento agotada y una corriente de fluido de trabajo básico, de menor presión, totalmente condensada, y presurización de la corriente de fluido de trabajo básico totalmente condensada, de menor presión, hasta la corriente de fluido de trabajo básico, de mayor presión

[0007] En una implementación más eficiente de la presente invención, el método proporciona los pasos adicionales de separación de la corriente de ebullición en una corriente de vapor y una corriente de líquido, combinación de una porción de la corriente de líquido con la corriente de vapor y su paso a través de un intercambiador de calor pequeño en contacto con la corriente externa fuente de calor para asegurar una evaporación completa y el sobrecalentamiento de la corriente de ebullición. Una segunda porción de la corriente de líquido se despresuriza hasta una presión igual a la presión de la corriente agotada.

[0008] En una implementación aún más eficiente de la presente invención, el método proporciona en adición a los pasos adicionales descritos en el párrafo 0006, los pasos de separación de la segunda porción despresurizada de la corriente de líquido del párrafo 0006 en una corriente de vapor y una corriente de líquido, donde la corriente de vapor se combina con la corriente de líquido presurizada que tiene los parámetros del punto 9 y se presuriza nuevamente antes de ser combinada con la corriente que tiene los parámetros del punto 8. Mientras que la corriente de líquido se despresuriza hasta

una presión igual a la presión de una corriente agotada que tiene los parámetros del punto 18

[0009] La presente invención también proporciona un método termodinámico de dos ciclos donde una primera composición de ebullición se calienta, se evapora, se expande en una turbina para extraer una cantidad de energía más aprovechable tal como energía eléctrica y se condensa y una composición recirculante se calienta, se evapora parcialmente, se expande en la misma turbina para extraer una cantidad de energía más aprovechable tal como energía eléctrica y se condensa, en donde los dos ciclos mejoran la eficiencia total del sistema de conversión de energía

[0010] La presente invención proporciona sistemas según lo dispuesto en las Figuras 1A-D y 2 adaptados para implementar los métodos de esta invención

DESCRIPCIÓN DE LAS FIGURAS

[0011] La invención se puede entender mejor si se hace referencia a la siguiente descripción detallada junto con las figuras ilustrativas adicionales en las cuales se numeran igual como elementos

[0012] La figura 1A representa un diagrama esquemático de un ciclo termodinámico preferido de esta invención,

[0013] La Figura 1B representa un diagrama esquemático de otro ciclo termodinámico preferido de esta invención,

[0014] La Figura 1C representa un diagrama esquemático de otro ciclo termodinámico prefendo de esta invención,

[0015] La Figura 1D representa un diagrama esquemático de otro ciclo termodinámico prefendo de esta invención,

[0016] La Figura 2 representa un diagrama esquemático de otro ciclo termodinámico prefendo de esta invención

DESCRIPCIÓN DETALLADA DE LA INVENCION

[0017] Los inventores han encontrado que un ciclo termodinámico novedoso (sistema y proceso) puede ser implementado usando un fluido de trabajo que incluye una mezcla de al menos dos componentes. El fluido de trabajo prefendo es una mezcla amoniaco-agua, aunque otras mezclas, tales como mezclas de hidrocarburos y/o freones puede ser usada con prácticamente los mismos resultados. Los sistemas y los métodos de esta invención son más eficientes para la conversión de calor a partir de fluidos con temperaturas relativamente bajas tales como fluidos de fuentes geotérmicas en una forma aprovechable de energía. Los sistemas usan un fluido de trabajo básico multi-componente para extraer la energía de una o más (al menos una) de las corrientes de fuente geotérmica en uno o más (al menos uno) intercambiadores de calor o zonas de intercambio de calor. El fluido de trabajo básico que intercambié calor entonces transfiere la energía térmica ganada a un turbina (u otro sistema para la extracción de energía térmica a partir de una corriente de vapor y que convierte la energía térmica en

energía mecánica y/o eléctrica) y la turbina convierte la energía térmica ganada en energía mecánica y/o eléctrica. Los sistemas también incluyen bombas para incrementar la presión de las corrientes en ciertos puntos en los sistemas y los intercambiadores de calor que conducen el fluido de trabajo básico hacia una relación de intercambio de calor con la corriente fría. Una característica novedosa de los sistemas y métodos de esta invención, y una de las características que incrementa la eficiencia de los sistemas, es el resultado de usar un diseño de circuito dividido en dos que tiene un circuito de alta presión y un circuito de baja presión y donde una corriente que contiene líquido agotado separado del vapor agotado desde el circuito de alta presión se combina con una corriente que contiene la corriente de baja presión agotada a la presión de la corriente de baja presión agotada antes de la condensación de la corriente de líquido completamente condensada y donde la corriente combinada es menos densa que la corriente inicial de líquido completamente condensada. El presente sistema es adecuado para unidades de potencia designadas como pequeñas o medianas tales como instalaciones de potencia de 3 a 5 Mega Vatios.

[0018] El fluido de trabajo usado en los sistemas de las presentes invenciones es preferiblemente un fluido multi-componente que contiene un componente fluido de menor punto de ebullición – el componente de baja-ebullición – y un componente de punto de ebullición mas alto – el componente de alta-ebullición. Fluidos de trabajo preferidos incluyen una mezcla de amoníaco-agua, una mezcla de dos o más hidrocarburos, una mezcla de dos o más freones, una mezcla de hidrocarburos y freón, o aquellas similares. En general, el líquido puede contener mezclas de cualquier número de compuestos con características termodinámicas y solubilidad favorables. En

una forma de ejecución particularmente preferida, el fluido contiene una mezcla de agua y amoníaco

[0019] Debe ser reconocido por una persona con la experiencia convencional que en los sistemas señalados de esta invención una corriente fue dividida en dos o más sub-corrientes, las válvulas que efectúan dicha división de la corriente son bien conocidas en el arte y pueden ser ajustadas manualmente o son ajustadas de forma dinámica de modo que la división permita alcanzar la mejora en eficiencia deseada

[0020] Refinándose ahora a la Figura 1A, se muestra un modo de ejecución prefendo de un sistema de esta invención, generalmente 100. El sistema 100 se describe en términos de las corrientes de operación usadas, de las condiciones en los puntos dentro el sistema y del equipo. Una corriente de fluido de trabajo completamente condensada a una temperatura cercana a la ambiente que tiene parámetros como los del punto 1, entra a una bomba de alimentación P1, donde se bombea a una presión elevada, y obtiene parámetros como los del punto 2. La composición de la corriente del fluido de trabajo que tiene los parámetros del punto 2 será referenda de aquí en adelante como una "composición básica" o "solución básica". La corriente de fluido de trabajo que tiene los parámetros del punto 2, entonces pasa a través de un precalentador o de un intercambiador de calor recuperativo HE2, donde se calienta en contra flujo mediante una corriente que retorna de la solución básica como se describe más adelante, y obtiene parámetros como los del punto 3. El estado de la solución de trabajo básica en el punto 3 corresponde a un estado de líquido saturado, o levemente sub-enfriado.

[0021] Después de esto, la corriente de la solución básica que tiene los parámetros del punto 3 se divide en dos sub-corrientes que tienen parámetros como los de los puntos 4 y 5, respectivamente. La sub-corriente que tiene los parámetros del punto 4, entonces pasa a través de un intercambiador de calor HE4, donde se calienta y se evapora parcialmente por una corriente de un fluido fuente de calor (e.g., de la corriente de salmuera geotérmica) que tiene parámetros como los del punto 42 según lo descrito más adelante, y obtiene parámetros como los del punto 6. Mientras que, la corriente de la solución básica que tiene los parámetros del punto 5 pasa a través de un intercambiador de calor HE3, donde se calienta y se evapora parcialmente mediante una corriente de condensación que tiene parámetros como los del punto 20 en un proceso de condensación 20-21 que también se describe más adelante y obtiene parámetros como los del punto 7. Después de esto, las sub-corrientes que tienen parámetros como los de los puntos 6 y 7 se combinan, formando una corriente combinada que tiene parámetros como los del punto 8. La corriente de solución básica que tiene los parámetros del punto 8 entonces se combina con una corriente de una solución recirculante que tiene parámetros como los del punto 29 según lo descrito más adelante, y forma una corriente de una solución de ebullición que tiene parámetros como los del punto 10. La corriente que tiene los parámetros del punto 29 está en un estado de líquido sub-enfriado, y, por lo tanto, como resultado de la mezcla de las corrientes que tienen los parámetros de los puntos 8 y 29, ocurre una absorción substancial del vapor, y la temperatura se eleva substancialmente. De esta forma, una temperatura de la corriente que tiene los parámetros del punto 10 es generalmente significativamente más alta que la de la corriente que tiene los parámetros del punto 8.

La composición de la corriente que tiene los parámetros del punto 10 se refiere aquí como "solución de ebullición"

[0022] La corriente de la solución de ebullición que tiene los parámetros del punto 10, entonces pasa a través de un intercambiador de calor HE5, donde se calienta y se evapora por la corriente de fluido fuente de calor que tiene parámetros como los del punto 41. La corriente evaporada que sale del intercambiador de calor HE5 ahora tiene parámetros como los del punto 11. La corriente que tiene los parámetros del punto 11 entra entonces en un separador por gravedad S2, donde se separa en una corriente de vapor que tiene parámetros como los del punto 13 y una corriente de líquido que tiene parámetros como los del punto 12. La corriente de líquido que tiene los parámetros del punto 12 entonces se divide en dos sub-corrientes que tienen parámetros como los de los puntos 14 y 15, respectivamente. La sub-corriente que tiene los parámetros del punto 14 representa generalmente una porción muy pequeña de la corriente de líquido total, y se combina con la corriente del vapor que tiene los parámetros del punto 13 según lo descrito más adelante, formando una corriente de solución de trabajo con parámetros como los del punto 16. La corriente de la solución de trabajo que tiene los parámetros del punto 16, entonces pasa a través de un intercambiador de calor HE6 (un intercambiador de calor pequeño algunas veces llamado un secador de vapor para asegurar que el estado de la corriente que sale del intercambiador de calor sea de un vapor sobrecalentado), donde se calienta aun más por la corriente del fluido fuente de calor que tiene parámetros como los del punto 40, para formar una corriente completamente evaporada y levemente sobrecalentada que tiene parámetros como los del punto 17. Después de esto, la corriente de la solución de trabajo que tiene los

parámetros del punto 17 pasa a través de una turbina T1, donde se expande, produciendo potencia aprovechable (conversión de la energía térmica en energía mecánica y eléctrica) para formar una corriente que tiene parámetros como los del punto 18

[0023] El líquido recirculante que tiene los parámetros del punto 15 según lo descrito anteriormente pasa a través de una válvula reguladora TV1, donde su presión se reduce a una presión intermedia para formar una corriente que tiene parámetros como los del punto 19. Como resultado de la regulación, los parámetros de la corriente en el punto 19 corresponden al estado de una mezcla vapor-líquido. La corriente que tiene los parámetros del punto 19, entonces entra en un separador por gravedad S3, donde se separa en una corriente de vapor que tiene parámetros como los del punto 30, y una corriente de líquido que tiene parámetros como los del punto 31. La corriente de líquido que tiene los parámetros del punto 31 pasa a través de una segunda válvula reguladora TV2, donde su presión se reduce aún más hasta formar una corriente que tiene parámetros como los del punto 32, donde la presión de la corriente que tiene los parámetros del punto 32 es igual a la presión de la corriente que tiene los parámetros del punto 18 según lo descrito anteriormente. Después de esto, la corriente que tiene los parámetros del punto 32 y la corriente que tiene los parámetros del punto 18 se combinan formando una corriente de una solución de condensación que tiene los parámetros del punto 20. La corriente que tiene parámetros del punto 20 pasa a través de un intercambiador de calor HE3, en contra flujo a la corriente que tiene los parámetros del punto 5, en un proceso de enfriamiento 5-7. Después de pasar a través del intercambiador de calor HE3, la corriente que tiene los parámetros del punto 20 se

condensa parcialmente, liberando el calor para el proceso de calentamiento 20-21 descrito anteriormente y obtiene parámetros como los del punto 21

[0024] La corriente que tiene los parámetros del punto 21 entonces entra en un separador por gravedad S1, donde se separa en una corriente de vapor que tiene parámetros como los del punto 22 y una corriente de líquido que tiene parámetros como los del punto 23. A su vez la corriente de líquido que tiene los parámetros del punto 23 se divide en dos sub-corrientes que tienen parámetros como los de los puntos 25 y 24, respectivamente. La sub-corriente de líquido que tiene los parámetros del punto 25 se combina entonces con la corriente de vapor que tiene los parámetros del punto 22, formando una corriente de la solución básica que tiene parámetros como los del punto 26

[0025] La sub-corriente de líquido que tiene los parámetros del punto 24 entra en una bomba de circulación P2, donde su presión se incrementa a una presión igual a una presión en el separador por gravedad S3, es decir, igual a una presión de la corriente del vapor que tiene los parámetros del punto 30 descrito anteriormente, y obtiene parámetros como los del punto 9. La corriente de líquido que tiene los parámetros del punto 9 está en un estado de líquido sub-enfriado. La corriente de líquido que tiene los parámetros del punto 9 entonces se combina con la corriente del vapor que tiene los parámetros del punto 30 descrito anteriormente. Se elige una presión de las corrientes que tienen los parámetros de los puntos 9 y 30 de forma tal que el líquido sub-enfriado que tenga los parámetros del punto 9 absorba completamente toda la corriente del vapor que tiene los parámetros del punto 30, formando una corriente de líquido que

tiene parámetros como los del punto 28. La corriente de líquido que tiene los parámetros del punto 28 está en un estado de líquido saturado o sub-enfriado. Después de esto, la corriente que tiene los parámetros del punto 28 entra en una bomba de circulación P3, donde su presión se incrementa a una presión igual a la presión de la corriente que tiene los parámetros del punto 8, y obtiene los parámetros del punto 29 descrito anteriormente. La corriente que tiene los parámetros del punto 29 se combina entonces con la corriente de la solución básica que tiene los parámetros del punto 8, formando la corriente de la solución e ebullición que tiene los parámetros del punto 10 descrito anteriormente.

[0026] La corriente de la solución básica que tiene los parámetros del punto 26 entra en el intercambiador de calor HE2, donde se condensa parcialmente liberando calor para un proceso de calentamiento 2-3 descrito anteriormente, y obtiene parámetros como los del punto 27. Después de esto, la corriente de solución básica que tiene los parámetros del punto 27 entra en un condensador HE1, donde se enfría y se condensa completamente mediante una corriente de aire o de agua que tiene parámetros como los del punto 51 descrito más adelante, y obtiene los parámetros del punto 1.

[0027] Una corriente del aire (o agua) que tiene parámetros como los del punto 50 entra en un ventilador de aire AF (o compresor en el caso de agua) para producir una corriente de aire que tiene parámetros como los del punto 51, que hace entrar a la corriente de aire que tiene los parámetros del punto 51 en el intercambiador de calor HE1, donde enfría la corriente de fluido de trabajo básico en un proceso de enfriamiento 27-1, y obtiene parámetros como los del punto 52.

52

[0028] La corriente de fluido fuente de calor con los parámetros del punto 40 pasa a través del intercambiador de calor HE6, donde proporciona calor para un proceso de calentamiento 6-17, y obtiene los parámetros del punto 41. La corriente fluido fuente de calor que tiene los parámetros del punto 41 pasa a través del intercambiador de calor HE5, donde proporciona el calor para un proceso de calentamiento 10-11, y obtiene los parámetros del punto 42. La corriente de fluido fuente de calor que tiene los parámetros del punto 42 entra en el intercambiador de calor HE4, donde proporciona el calor para un proceso de calentamiento 4-6 y obtiene parámetros como los del punto 43.

[0029] En las variantes anteriores de los sistemas de esta invención, la corriente recirculante que tenía parámetros como los del punto 29 fue mezclada con la corriente de solución básica que tenía parámetros como los del punto 8. Como resultado de esta mezcla, una temperatura de la corriente combinada que tiene parámetros como los del punto 10 fue substancialmente más alta que una temperatura de las corrientes que tienen parámetros como los de los puntos 8 y 29.

[0030] Refinándose ahora a la Figura 1D, otro modo de ejecución del sistema de esta invención, generalmente 100, se demuestra para incluir un intercambiador de calor adicional HE7, es decir, el intercambiador de calor HE5 está dividido en dos intercambiadores de calor HE5' y HE7, diseñados para reducir la diferencia de la temperatura entre la corriente que tiene los parámetros como los del punto 10 y las corrientes que tienen los parámetros como los de los puntos 8 y 29.

[0031] En el nuevo modo de ejecución, la corriente con parámetros como los del punto 8 se envía dentro del intercambiador de calor HE7 donde se calienta y posteriormente se evapora por una corriente fuente de calor, tal como una corriente de fluido geotérmico, que tiene los parámetros como los del punto 44, lo que produce la corriente fuente de calor que tiene parámetros como los del punto 42 en un proceso de intercambio de calor en contra flujo 44-42 y una corriente que tiene parámetros como los del punto 34. Solo entonces se mezcla la corriente que tiene los parámetros como los del punto 34 con una corriente de recirculación que tiene parámetros como los del punto 29 (según lo descrito anteriormente) lo que forma una corriente combinada que tiene parámetros como los del punto 10. Se selecciona una temperatura en la corriente que tiene los parámetros como los del punto 34, de tal manera que la temperatura de la corriente que tiene los parámetros como los del punto 10 sea igual o muy cercana a la temperatura de la corriente que tiene los parámetros como los del punto 34. Como consecuencia, la irreversibilidad de mezclar una corriente de solución básica y una corriente de solución recirculante se reduce drásticamente. La corriente resultante que tiene los parámetros como los del punto 10 pasa a través del intercambiador de calor HE5' donde se calienta y se evapora en un proceso en contra flujo 41-44 por la corriente fuente de calor, tal como una corriente de fluido geotérmico que tiene los parámetros como los del punto 41.

[0032] Este modo de ejecución también puede incluir unas sub-corrientes que tienen parámetros como los del punto 14, según lo descrito anteriormente, lo cual representa generalmente una porción muy pequeña de la corriente de líquido total, y se combina con la corriente de vapor que tiene los parámetros del punto 13 (no mostradas) según lo

descrito más adelante, para formar la corriente de la solución de trabajo con parámetros como los del punto 16. Adicionalmente, este modo de ejecución también puede incluir la unidad AF y las corrientes asociadas según lo descrito anteriormente.

[0033] Las ventajas del arreglo de corrientes mostradas en el presente modo de ejecución incluyen por lo menos las siguientes: una diferencia de temperatura en el intercambiador de calor HE7 (que es, esencialmente, la porción de baja temperatura del intercambiador de calor HE5 en las variantes anteriores) se aumenta substancialmente y por lo tanto el tamaño del intercambiador de calor HE7 se reduce, mientras que el intercambiador de calor HE5' de este modo de ejecución trabaja exactamente de la misma manera que la porción de alta temperatura del intercambiador de calor HE5 de las variantes anteriores. La eficacia del sistema de este modo de ejecución no se afecta en absoluto.

[0034] Este modo de ejecución del método de mezclar una corriente recirculante con una corriente de la solución básica se puede aplicar a todas las variantes descritas anteriormente. Una persona con experiencia en el arte puede aplicar fácilmente este método sin una explicación adicional.

[0035] Un ejemplo de los parámetros calculados para los puntos descritos anteriormente se da en la tabla 1 para el modo de ejecución mostrado en la Figura 1A.

53

TABLA 1

Parámetros de Puntos en el Modo de Ejecución de la Figura 1A

Punto No	Concentración X	Temperatura T(°F)	Presión P(psla)	Entalpía h(btu/lb)	Entropía S(btu/lb°F)	Peso (g/g1)
Parámetro de Corrientes de Fluido de Trabajo						
1	0 975	73 5	133 4091	37 8389	0 09067	1 0
2	0 975	75 0186	520 0	40 1124	0 09145	1 0
3	0 975	165 0	508 2780	147 9816	0 27769	1 0
4	0 975	165 0	508 2780	147 9816	0 27769	0 6010
5	0 975	165 0	508 2780	147 9816	0 27769	0 3990
6	0 975	208 0	498 5	579 1307	0 96196	0 6010
7	0 975	208 0	498 5	579 1307	0 96196	0 3990
8	0 975	208 0	498 5	579 1307	0 96196	1 0
9	0 40874	170 2394	220 0	45 8581	0 21737	0 3880
10	0 81773	231 1316	498 5	433 8631	0 7629	1 40575
11	0 81773	300 0	490 0	640 0316	1 04815	1 40757
12	0 35855	300 0	490 0	200 2510	0 4355	0 195
13	0 89168	300 0	490 0	710 8612	1 14682	1 21075
14	0 35855	300 0	490 0	200 2510	0 43550	0 1655
15	0 35855	300 0	490 0	200 2510	0 43550	0 17845
16	0 8845	300 0	490 0	703 9808	1 13721	1 2272
17	0 8845	306 0	488 5	718 3184	1 15637	1 2273
18	0 8845	213 3496	139 5	642 4511	1 17954	1 2273
19	0 35855	249 1433	220 0	200 2510	0 44140	0 17845

54

Punto No	Concentración X	Temperatura T(°F)	Presión P(psla)	Entalpia h(btu/lb)	Entropia S(btu/lb°F)	Peso (g/g1)
20	0 81671	214 6540	139 5	584 8515	1 08437	1 3880
21	0 81671	170 0	137 5	460 9041	0 89573	1 3880
22	0 97746	170 0	137 5	624 6175	1 16325	0 99567
23	0 40874	170 0	137 5	45 4163	0 21715	0 39233
24	0 40874	170 0	137 5	45 4163	0 21715	0 3880
25	0 40874	170 0	137 5	45 4163	0 21715	0 00433
26	0 975	170 0	137 5	622 1123	1 15916	1 0
27	0 975	93 9659	137 5	514 2431	0 97796	1 0
28	0 43013	195 9556	220 0	74 5165	0 26271	0 40575
29	0 43013	196 6491	498 5	75 8407	0 26312	0 40575
30	0 89772	249 1433	220 0	700 9614	1 21784	0 01775
31	0 2990	249 1433	220 0	144 9514	0 35565	0 16070
32	0 2990	233 8807	139 5	144 9514	0 35718	0 16070
Parámetro de Corriente de Fuente Geotérmica						
40	Salmuera	315 0		283 0		3 90716
41	Salmuera	311 3304		279 3304		3 90716
42	Salmuera	237 4536		2305 1534		3 90716
43	Salmuera	170 0		138 0		3 90716
Parámetros de Corriente de Aire de Enfriamiento						
50	Aire	51 7	14 7	122 3092		91 647
51	Aire	51 9341	14 72	122 6353		91 647
52	Aire	73 5463	14 7	127 5636		91 647

[0036] En el sistema descrito anteriormente, el líquido producido en el separador S1 eventualmente pasa a través del intercambiador de calor HE5 y se evapora parcialmente. Sin embargo, la composición de este líquido es solamente un poco más rica que la composición del líquido separado de la solución de ebullición en el separador S2. En general, cuanto más rica sea la composición del líquido adicionado a la solución básica con respecto a la composición del líquido adicionado a la solución de trabajo agotada (punto 18), el sistema será más eficiente. En el sistema propuesto, el volumen de líquido del separador S2, que tiene parámetros como los del punto 15, se regula a una presión intermedia, y después se divide en vapor y líquido en el separador S3. Como consecuencia, la corriente de líquido que tiene los parámetros del punto 32 que se mezcla con la corriente solución de trabajo agotada que tiene los parámetros del punto 18, es menos densa que el líquido separado de la solución de ebullición en el separador S2. Además, el líquido recirculante que se separa en el separador S1 se mezcla con la corriente de vapor del separador S3, y, por lo tanto, se enriquece. Como consecuencia, la corriente de líquido que tiene los parámetros del punto 29, que se adiciona a la corriente de la solución básica que tiene los parámetros del punto 10, es más rica que la corriente de líquido producida del separador S1.

[0037] Si se simplifica el sistema, y la corriente de líquido del separador S2 que tiene parámetros del punto 15 se regula en un paso hasta una presión igual a la presión de la corriente que tiene los parámetros del punto 18, por lo tanto el sistema requiere menos equipo, pero su eficiencia se reduce levemente. Esta variante simplificada, pero preferida del sistema de esta invención se muestra en la Figura 1B, donde el separador S3 y la válvula reguladora TV2 han sido retiradas junto con las corrientes que tienen los

parámetros de los puntos 30, 31 y 32. La operación de tal variante de este sistema de la **Figura 1A** no requiere una descripción más amplia de forma individual porque todas las características restantes se describen completamente junto con la descripción detallada del sistema y el proceso de la **Figura 1A**.

[0038] Si la cantidad de líquido del separador **S1** se reduce a tal grado que la composición de la corriente de la solución de ebullición que tiene los parámetros del punto **10** llega a ser igual a la composición de la solución de trabajo que pasa a través de la turbina **T1**, entonces el separador **S2** se puede eliminar junto con la válvula reguladora **TV1**. Por lo tanto, el intercambiador de calor **HE6** también hace innecesario, y también se elimina porque en esta forma de implementación no hay riesgo de que gotas líquidas estén presentes en la corriente de ebullición debido a la ausencia del separador **S2**. Esta variante aún más simplificada del sistema de esta invención se presenta en **Figura 1C**. Su eficiencia es de nuevo aún más baja que la eficiencia de la variante anterior descrita en la **Figura 1B**, sin embargo, sigue siendo más eficiente que el sistema descrito en el arte anterior.

[0039] La selección entre las tres variantes del sistema de esta invención se determina por las condiciones económicas de las operaciones. Una persona con experiencia en el arte puede comparar fácilmente el costo del equipo adicional, el valor de la potencia adicional producida gracias al incremento de eficiencia y tomar una decisión justificada con relación a la variante exacta elegida.

[0040] Un resumen de la eficiencia y el funcionamiento de las tres variantes de esta invención y del sistema descrito en el arte anterior se presentan en la tabla 2

TABLA 2
Resumen de Desempeño

	Sistemas de Esta Invención			Arte anterior
	Vanante 1	Vanante 2	Vanante 3	
Entrada de Calor (Btu)	566 5385	565 5725	564 281	487 5263
Flujo Específico de Salmuera (lb/lb)	3 960716	3 9005	3 89159	3 36225
Disipación de Calor (Btu)	476 4062	476 4062	476 4062	414 026
Calda de Entalpía en Turbina (Btu)	93 1119	91 7582	90 2988	75 376
Trabajo de Turbina (Btu)	90 7841	89 4823	88 0413	73 4824
Trabajo de Bomba (Btu)	2 9842	2 5812	2 424	1 867
Trabajo de Ventilador de Aire (Btu)	5 1414	5 1414	5 1414	3 5888
Trabajo Neto (Btu)	82 6785	81 7397	80 4759	68 027
Eficiencia Térmica Neta (%)	14 595	14 453	14 262	13 954
Eficiencia de Segunda Ley (%)	54 23	53 703	52 995	51 85

[0041] Es evidente de los datos simulados en la Tabla 2 que las tres variantes de esta invención demuestran mejoras en los valores netos mejoras en el trabajo neto de 21 54%, 20 16% y 18 30%, respectivamente, y mejoras en las eficiencias netas térmicas y de segunda ley de 4 59%, 3 58% y 2 21%, respectivamente

Variante mejorada

[0042] Incluso en otro modo de ejecución prefenda del sistema de esta invención diseñada para el aprovechamiento de una fuente de calor con temperatura inicial

moderada a baja, tal como fuentes geotérmicas, fuentes de calor residual y similares, una configuración mejorada se describe a continuación

[0043] En una variante anterior se describió un sistema que proporcionó mejoras substanciales sobre la patente No 4,982, 568 de Estados Unidos del arte anterior y esta variante representa otra mejora en eficiencia

[0044] Refinándose ahora a la Figura 2, otra forma de ejecución preferida del sistema de esta invención, generalmente 200, se muestra para incluir una corriente de fluido de trabajo completamente condensada 202 a una temperatura cercana a la ambiente que tienen parámetros como los del punto 1, que corresponde a un estado de líquido saturado, entra en un alimento o en una primera bomba, P1. La corriente 202 que tiene parámetros como los del punto 1 se bombea a una presión elevada obteniendo una corriente 204 que tiene parámetros como los del punto 2. Después de esto, la corriente 204 que tiene los parámetros como los del punto 2 se mezcla con una corriente 206 de líquido que tiene parámetros como los del punto 39, según lo descrito más adelante, formando una corriente 208 que tiene parámetros como los del punto 64. La composición de la corriente 206 que tiene los parámetros como los del punto 39 es menos densa que la composición de la corriente 204 que tiene los parámetros como los del punto 2 (es decir, la corriente 206 tiene una concentración más baja del componente de bajo punto de ebullición que la corriente 204). Obviamente, la composición de la corriente 208 que tiene los parámetros como los del punto 64 es menos densa que la composición de la corriente 204 que tiene parámetros como los del punto 2, pero más

nca (teniendo una concentración más alta del componente de bajo punto de ebullición) que la corriente que tiene los parámetros como los del punto 39

[0045] Después de esto, la corriente 208 con los parámetros como los del punto 64 pasa a través de un segundo intercambiador de calor HE2, donde se calienta en contra flujo mediante una primera corriente 210 que tiene parámetros como los del punto 26 en un primer proceso de intercambio de calor 26-27, según lo descrito más adelante, para formar una corriente 212 que tiene parámetros como los del punto 33, lo que corresponde a un estado de líquido saturado o levemente sub-enfriado y una corriente parcialmente condensada 214 que tiene parámetros como los del punto 27. Después de esto, la corriente 212 que tiene los parámetros como los del punto 33 se divide en dos sub-corrientes 216 y 218, que tienen parámetros como los de los puntos 3 y 34, respectivamente. La corriente 218 con los parámetros como los del punto 34 entonces pasa a través de una segunda válvula reguladora, TV2, donde se reduce su presión, para formar una corriente 220 de menor presión que tiene parámetros como los del punto 35. La corriente 220 con los parámetros como los del punto 35, una corriente que mezcla vapor y líquido, se envía dentro de un primer separador por gravedad, S1, donde se separa en una corriente 222 de vapor que tiene parámetros como los del punto 28, y una corriente de líquido 224 que tiene parámetros como los del punto 38. La corriente de líquido 224 que tiene los parámetros como los del punto 38 entra en una segunda bomba, P2, donde se bombea a una presión igual a una presión de la corriente 204 que tiene los parámetros como los del punto 2, formando la corriente 206 que tiene los parámetros como los del punto 39. Después de esto, la corriente 206 con

parámetros como los del punto 39 se mezcla con la corriente 204 que tiene los parámetros como los del punto 2, según lo descrito anteriormente

[0046] La corriente 216 que tiene una composición representada por los parámetros como los del punto 3 tendrá una composición definida aquí como primera composición de ebullición. Obviamente, las composiciones de las corrientes 208, 212, 218 y 220 que tienen los parámetros de los puntos 64, 33, 34 y 35, respectivamente, son la misma composición de la corriente 216 que tiene los parámetros como los del punto 3. La composición de las corrientes 202 y 204 que tienen los parámetros como los de los puntos 1 y 2, respectivamente, tendrá la composición definida como una composición básica. La composición de las corrientes 210 y 214 que tienen los parámetros como los de los puntos 26 y 27, respectivamente según lo descrito más adelante, es igual a la composición de las corrientes 202 y 204 que tienen los parámetros como los de los puntos 1 y 2.

[0047] La corriente 216 que tiene la primera composición de ebullición con los parámetros como los del punto 3, se divide en tres sub-corrientes 226, 228, y 230 que tienen parámetros como los de los puntos 4, 5 y 62, respectivamente. La sub-corriente 226 que tiene los parámetros como los del punto 4 pasa a través de un cuarto intercambiador de calor HE4, donde se calienta, ebulle y se evapora parcialmente para formar una primera corriente parcialmente evaporada 232 que tiene parámetros como en un punto 6, en contra flujo mediante una corriente 234 de un fluido fuente de calor que tiene parámetros de entrada como los del punto 43 y parámetros de salida como los del punto 45, donde la corriente 234 es un fluido geotérmico en el caso de una

instalación geotérmica La sub-comente 228 que tiene los parámetros como los del punto 5 pasa a través de un tercer intercambiador de calor HE3, donde se calienta, ebulle y se evapora parcialmente para formar una segunda comente parcialmente evaporada 236 que tiene parámetros como los del punto 7, en contra flujo mediante una comente de condensación que retorna 238 que tiene parámetros como los del punto 20 para formar una comente parcialmente condensada 240 que tiene parámetros como los del punto 21, según lo descrito más adelante La sub-comente 230 que tiene los parámetros como los del punto 62 pasa a través de un quinto intercambiador de calor HE5 donde se calienta, ebulle y se evapora parcialmente para formar una tercera comente parcialmente evaporada 242 que tiene parámetros como los del punto 63 en contra flujo mediante una comente de condensación 244 que tiene parámetros como los del punto 60 para formar una comente completamente condensada 246 que tiene parámetros como los del punto 61, según lo descrito más adelante

[0048] Después de esto, las comentes 232, 236, y 242 que tienen los parámetros como en los puntos 6, 7, y 63, respectivamente, se combinan formando una comente combinada 248 que tiene parámetros como los del punto 8 La comente completamente condensada 246 que tiene los parámetros como los del punto 61 entra en una circulación o una cuarta bomba P4, donde se bombea a una presión igual a la presión de la comente 248 igual al punto 8, según lo descrito anteriormente, para formar una comente completamente condensada de mayor presión 250 que tiene parámetros como los del punto 65 Después de esto, la comente 250 que tiene los parámetros como los del punto 65 se combina con la comente 248 que tiene los parámetros como los del punto 8, formando una segunda comente combinada 252 que tiene parámetros como

los del punto 9 Es obvio que la composición de las corrientes 226, 228, 252, 236, 230, 242 y 248 que tienen los parámetros como los de los puntos 4, 5, 6, 7, 62, 63 y 8, respectivamente, es igual a la composición de la corriente 216 que tiene los parámetros como los del punto 3, es decir, la primera composición de ebullición Como la composición de las corrientes 244, 246 y 250 que tienen parámetros como en los puntos 60, 61 y 65 es menos densa que la primera composición de ebullición, la composición de la corriente combinada 252 que tiene los parámetros como los del punto 9 es menos densa que la primera composición de ebullición La composición de las corrientes 244, 246 y 250 que tienen parámetros como los de los puntos 60, 61 y 65 se refiere aquí como composición recirculante, mientras que la composición de la corriente combinada 252 que tiene los parámetros como los del punto 9 se refiere aquí como una segunda composición de ebullición

[0049] La segunda corriente combinada 252 que contiene la segunda composición de ebullición y los otros parámetros como los del punto 9 pasa a través de un sexto intercambiador de calor HE6, donde los procesos de ebullición y evaporación se intensifican para formar una corriente evaporada más a fondo 254 que tiene parámetros como los del punto 11, en contra flujo mediante una corriente 234 de fluido fuente de calor que tiene al entrar parámetros como los del punto 41 y al salir parámetros como los del punto 43 Después de esto, la corriente sobre evaporada 254 que tiene la segunda composición de ebullición y los otros parámetros como los del punto 11 entra en un segundo separador por gravedad S2, donde se separa en una segunda corriente de vapor 256 que tiene parámetros como en un punto 67, y una segunda corriente de líquido 258 que tiene parámetros como los del punto 68 La segunda corriente de

líquido 258 que tiene los parámetros como los del punto 68 se puede separar en dos sub-corrientes 260 y 262 que tienen parámetros como los de los puntos 15 y 69, respectivamente, en una cierta forma de ejecución preferida de esta variante un velocidad de flujo de la corriente 262 que tiene los parámetros como del punto 69 será igual a cero. La corriente 262 que tiene los parámetros como los del punto 69, si está presente, se combina con la segunda corriente de vapor 256 que tiene los parámetros como los del punto 67, formando una tercera corriente combinada 264 que tiene parámetros como los del punto 16, la composición del cual de aquí en adelante será referida como composición de trabajo.

[0050] La corriente 264 que tiene la composición de trabajo y los otros parámetros como los del punto 16 pasa a través de un séptimo intercambiador de calor HE7, donde se calienta y se evapora completamente, y se sobrecalienta para formar una corriente completamente evaporada 266 que tiene parámetros como los del punto 17, en contra flujo mediante la corriente 234 del fluido fuente de calor que tiene al entrar parámetros como los del punto 40 y al salir parámetros como los del punto 41. La corriente completamente evaporada 266 que tiene la composición de trabajo y los otros parámetros como los del punto 17, pasa entonces a través de una turbina T1, donde se expande, produciendo trabajo, y formando una corriente agotada 268 que tiene la composición de trabajo y otros parámetros como los del punto 18.

[0051] La segunda corriente de líquido 260 que tiene los parámetros como los del punto 15, según lo descrito anteriormente, pasa a través de una primera válvula reguladora TV1, donde su presión se reduce a una presión igual a la presión de la

corriente 222 que tiene los parámetros como los del punto 28, según lo descrito anteriormente, para formar una corriente de menor presión 270 que tiene parámetros como los del punto 19. Entonces, la corriente 270 que tiene los parámetros como los del punto 19 entra en un tercer separador por gravedad S3, donde se separa en una tercera corriente de vapor 272 que tiene parámetros como los del punto 30 y una tercera corriente de líquido 274 que tiene parámetros como los del punto 31. Después de esto, la tercera corriente de líquido 274 que tiene los parámetros como los del punto 31 pasa a través de una tercera válvula reguladora TV3, donde su presión se reduce hasta una presión igual a la presión de la corriente agotada 268 que tiene los parámetros como los del punto 18, según lo descrito anteriormente, para formar una corriente de menor presión 276 que tiene parámetros como los del punto 32. La corriente 276 que tiene los parámetros como los del punto 32 se combina entonces con la corriente agotada 268 que tiene parámetros como en el punto 18, formando la corriente [la tercera combinada] 238 que tiene parámetros como los del punto 20.

[0052] La corriente 238 que tiene parámetros como los del punto 20 pasa a través del tercer intercambiador de calor HE3, donde se condensa parcialmente, proporcionando el calor para un proceso de intercambio de calor 5-7, según lo descrito anteriormente, formando la corriente 240 que tiene los parámetros como los del punto 21. La corriente 240 que tiene los parámetros como los del punto 21 entra en un cuarto separador por gravedad S4, donde se separa en una cuarta corriente de vapor 280 que tiene parámetros como los del punto 22, y una cuarta corriente de líquido 282 que tiene parámetros como los del punto 23. Entonces, la cuarta corriente de líquido 282 que tiene parámetros como los del punto 23 se divide en dos sub-corrientes de líquido 284 y

286, que tienen parámetros como los de los puntos 24 y 25, respectivamente. La sub-corriente de líquido 286 que tiene los parámetros como los del punto 25 se combina con la cuarta corriente de vapor 280 del vapor que tiene parámetros como los del punto 22, formando la corriente 210 que tienen la composición básica y los otros parámetros como los del punto 26.

[0053] La sub-corriente de líquido 284 que tiene los parámetros como los del punto 24 entra en una circulación o en una tercera bomba P3, donde se bombea a una presión igual a una presión de las corrientes 222 y 272 que tienen los parámetros como en los puntos 28 y 30, según lo descrito anteriormente, formando una corriente de mayor presión 288 que tiene parámetros como los del punto 29. Después de esto, las corrientes 222, 272, y 288 que tienen los parámetros como los de los puntos 28, 29, y 30 se combinan formando la corriente 244 que tiene la composición de circulación y los otros parámetros como los del punto 60. La corriente 244 que tiene los parámetros como los del punto 60, pasa a través del tercer intercambiador de calor HE3, donde se condensa completamente, proporcionando el calor para un proceso 62-63, para formar la corriente 246 que tiene los parámetros como los del punto 61, según lo descrito previamente. Una vez más la corriente de líquido 246 que tiene los parámetros como los del punto 61 se bombea por la circulación o la cuarta bomba P4, para formar la corriente de mayor presión 250 que tiene los parámetros como los del punto 65, que entonces se mezcla con la corriente 248 que tiene la primera composición de ebullición y los otros parámetros como los del punto 8, formando la corriente combinada 252 que tiene la segunda composición de ebullición y los otros parámetros como los del punto 9, según lo descrito anteriormente.

[0054] La corriente 210 que tiene la composición básica y otros parámetros como los del punto 26 pasa a través del segundo intercambiador de calor HE2, donde se condensa parcialmente, proporcionando el calor para el proceso de intercambio de calor 64-33, según lo descrito anteriormente, formando la corriente parcialmente condensada 214 que tiene parámetros como los del punto 27. Entonces, la corriente 214 que tiene parámetros como los del punto 27 pasa a través de un primer intercambiador de calor – condensador HE1, donde se enfría mediante una corriente de enfriamiento 290 que tiene parámetros iniciales como los del punto 50 y parámetros finales como los del punto 51 (agua o aire), para formar la corriente completamente condensada 202 que tiene parámetros como en el punto 1.

[0055] Como en las otras variantes del sistema de esta invención, los modos de ejecución descritos anteriormente son también divulgados.

[0056] Como con los modos de ejecución previos del sistema de esta invención, donde la última variante introduce mejoras sobre la anterior, el proceso de trabajo del sistema de esta invención se compone de dos ciclos. El primer ciclo es un ciclo de la primera composición de ebullición, la cual se calienta y se evapora y después se expande en la turbina, y después se condensa completamente en el primer intercambiador de calor HE1 (un condensador). El segundo ciclo es un ciclo de la composición recirculante, la cual ebulle solo parcialmente, produciendo vapor, este vapor también pasa a través de la turbina, y se condensa mayoritariamente o totalmente en el tercer intercambiador de calor HE3 (una caldera/condensador recuperativo). Cuanto más rica es la composición de la

corriente de líquido 284 que tiene los parámetros como los del punto 24 (es decir, el líquido producido en la caldera/condensador recuperativo HE3), será mayor la porción de esta corriente que puede ser evaporada posteriormente, aumentando de esta forma la eficiencia total del proceso

[0057] En las variantes anteriores, la corriente de líquido que tenía los parámetros iniciales como los del punto 24 fue bombeada a una presión intermedia, enriquecida mediante la mezcla con una corriente de vapor que tenía los parámetros como los del punto 30, y después adicionada a una corriente de la primera composición de ebullición. En la presente variante del sistema de esta invención, el líquido condensado que tiene los parámetros como los del punto 24 se bombea y después se enriquece, no solamente por la corriente de vapor que tiene los parámetros como los del punto 30, sino también con una corriente mucho más grande de vapor que tiene parámetros como los del punto 28. Como consecuencia, las corrientes 244, 246 y 250 que tienen la composición recirculante y los otros parámetros como en los de los puntos 60, 61 y 65, respectivamente, se enriquecen considerablemente más que en los diseños o las variantes anteriores. El enriquecimiento adicional con la corriente de vapor 222 que tiene los parámetros como los del punto 28 se produce gracias a un mejor aprovechamiento del calor liberado en el proceso de condensación de la composición básica.

[0058] Como resultado de un mejor aprovechamiento del calor liberado en el proceso de condensación, la última variante del sistema de esta invención tiene una mayor eficiencia total, entre el 3% y el 5%, que las variantes anteriores del sistema de esta

invención Una muestra de los balances de calor y desempeño de esta última variante del sistema de esta invención se tabula en tablas 3-5, y los parámetros de todos los puntos descritos anteriormente y señalados en la figura 2 se tabulan en la tabla 6

TABLA 3

Datos Simulados de Balance de Calor

Propiedad	Energía kW	Energía Btu/lb
Entrada de Calor	84,926 44	546 57
Calor Disipado	70,606 87	454 42
Caldas de Entalpía en la Turbina	14,912 74	95 98
Potencia Bruta del Generador	14,220 04	91 52
Bombas de Proceso (-3 82)	-653 04	-4 20
Producción del Ciclo	13,567 00	87 32
Otras Bombas y Ventiladores (-4 87)	-813 26	-5 23
Producción Neta	12,753 74	82 08
Potencia Bruta del Generador	14,220 04	91 52
Producción del Ciclo	13,567 00	87 32
Producción Neta	12,573 74	82 08

TABLA 4

Datos Simulados de Eficiencia

Propiedad	Porcentaje %
Eficiencia Térmica Neta	15 02
Límite de la Segunda Ley	26 91
Eficiencia de la Segunda Ley	55 80

TABLA 5

Datos Simulados de Consumo Específico

Propiedad	Calor Btu/Lb
Consumo Específico de Salmuera	154 55
Producción Específica de Potencia	6 47

BALANCE DE CALOR TOTAL (Btu/lb)

Entrada de Calor es igual a salmuera más bombas = 546 57 + 3 82 = 550 39

Salida de Calor es igual a turbina más condensador = 95 98 + 454 42 = 550 39

TABLA 6

Datos Simulados de Consumo Específico

Pt	X lb/lb	T °F	P psia	H Btu/Lb	S Btu/lb-R	G Rel G/G-1	Fase	Humedad lb/lb
FLUIDO DE TRABAJO								
1	0 9299	73 27	128 766	22 3023	0 08415	1 06803	Mez	1
2	0 9298	74 67	498 675	24 4996	0 09502	1 06903	Liq	-93 23°F ^a
3	0 9250	165 00	478 675	130 1713	0 26958	1 00000	Mez	1
4	0 9250	165 00	478 675	130 1713	0 26958	0 45691	Mez	1
5	0 9250	165 00	478 675	130 1713	0 26958	0 41981	Mez	1
6	0 9250	213 11	477 675	527 0895	0 89377	0 45691	Mez	0 1624
7	0 9250	207 99	477 675	515 2115	1 81618	0 41981	Mez	0 1769
8	0 9250	209 22	477 675	515 8261	1 97100	1 00000	Mez	0 1761
9	0 8254	213 11	477 675	396 8378	0 71018	1 34291	Mez	0 4228
11	0 8254	303 50	476 675	666 9563	1 08645	1 34287	Mez	0 1022
15	0 3433	303 50	476 675	205 2395	0 00000	0 13718	Mez	0
16	0 8803	303 50	476 675	719 3763	1 15990	1 20569	Vap	0°F ^a
17	0 9903	306 00	475 175	721 3333	1 16278	1 20569	Vap	2 7°F ^a
18	0 8803	211 57	131 766	641 7309	1 19377	1 20569	Mez	0 0624
19	0 3433	259 31	235 449	205 2395	0 44562	0 13718	Mez	0 912
20	0 8249	212 99	131 766	596 1109	1 10762	1 33080	Mez	0 1457
21	0 8249	170 00	130 766	474 6254	0 92207	1 33090	Mez	0 2613
22	0 9757	170 00	130 766	626 2892	1 17133	0 99303	Mez	0
23	0 3986	170 00	130 766	45 9319	0 21750	0 34778	Mez	1
24	0 3986	170 00	130 766	45 9319	0 21150	0 26277	Mez	1
25	0 3986	170 00	130 766	45 9319	0 21750	0 09501	Mez	1
26	0 9298	170 00	130 766	580 0959	1 09541	1 06803	Mez	0 0796
27	0 9298	99 23	128 766	441 1110	0 91316	1 06903	Mez	0 2106
28	0 9997	113 13	235 449	560 4625	0 99869	0 06803	Mez	0
29	0 3986	170 34	235 449	46 5386	0 21185	0 26277	Liq	-44 74°F ^a
30	0 8851	259 31	235 449	110 8870	1 22271	0 01207	Mez	0

70

Pl	X lb/lb	T °F	P psia	H Btu/Lb	S Btu/lb-R	G Rel G/G-1	Fase	Humedad lb/lb
31	0 2910	259 31	235 449	156 4614	0 37086	0 12511	Mez	1
32	0 2910	225 92	131 766	156 4614	0 37300	0 12511	Mez	0 9453
33	0 9250	165 00	478 675	130 1713	0 26958	1 50538	Mez	1
34	0 9250	165 00	478 675	130 1713	0 26958	0 50538	Mez	1
35	0 9250	113 13	235 449	130 1713	0 27648	0 50538	Mez	0 8854
38	0 9134	113 13	235 449	63 2351	0 16414	0 43735	Mez	1
39	0 9134	114 48	498 675	65 0826	0 16514	0 43735	Liq	-55 04 °F*
60	0 5350	199 51	235 449	171 8993	0 41197	0 34287	Mez	0 8295
61	0 5350	170 00	234 449	47 5498	0 21963	0 34287	Mez	1
62	0 9250	165 00	478 675	130 1713	0 26959	0 12328	Mez	1
63	0 9250	193 51	477 675	476 0256	0 81670	0 12328	Mez	0 2323
64	0 9250	96 39	498 675	36 2899	0 10896	1 50539	Liq	-81 99°F*
65	0 5350	170 97	477 675	49 0179	0 21944	0 34287	Liq	-61 41°F*
67	0 9603	303 50	476 675	719 3763	1 15990	1 20569	Mez	0
68	0 3433	303 50	476 675	205 2395	0 44092	0 13718	Mez	1
69	0 3433	303 50	476 675	205 2395	0 00000	0 00000	Mez	0
FUENTE DE CALOR								
40	SALMUERA	315 00	0 000	287 1318	0	3 71523	Liq	
41	SALMUERA	314 37	0 000	286 4967	0	3 71523	Liq	
43	SALMUERA	219 11	0 000	198 8263	0	3 71523	Liq	
45	SALMUERA	170 00	0 000	140 0149	0	3 71523	Liq	
REFRIGERANTE								
50	AIRE	51 70	14 693	122 3092	1 62806	67 5974	Vap	511 4°F*
51	AIRE	79 65	14 673	129 0316	1 64095	67 5974	Vap	539 3°F*
52	AIRE	79 95	14 693	129 1036	1 64099	67 5974	Vap	539 6°F*

* Temperatura de la Corriente en el punto indicado

[0059] Todas las referencias citadas aquí son incorporadas mediante referencia. No obstante esta invención se ha descrito completa y totalmente, se debe entender que, dentro del alcance de las reivindicaciones adjuntas, la invención se puede poner en práctica de otras maneras diferentes a las descritas de forma específica. Aunque la invención se ha divulgado con referencia a sus modos de ejecución preferidos, a partir

REIVINDICACIONES

1 Un método para la implementación de un ciclo termodinámico que consta de los pasos de

transformación de energía térmica de una corriente de ebullición completamente evaporada en una forma de energía aprovechable para producir una corriente agotada, de menor presión,

transferencia de energía térmica desde una corriente externa fuente de calor a una corriente de ebullición para formar la corriente de ebullición completamente evaporada y una corriente externa fuente de calor enfriada,

transferencia de energía térmica desde la corriente agotada a una primera porción de corriente de fluido de trabajo básico, de mayor presión, calentada, para formar una corriente agotada parcialmente condensada y una primera corriente de fluido de trabajo básico pre-calentada, de mayor presión,

transferencia de energía térmica desde la corriente externa fuente de calor enfriada a una segunda porción de corriente de fluido de trabajo básico, de mayor presión, calentada, para formar una segunda corriente de fluido de trabajo básico pre-calentada, de mayor presión, y una corriente externa fuente de calor agotada,

combinación de la primera y segunda corrientes de fluido de trabajo básico precalentadas, de mayor presión para formar una corriente de fluido de trabajo básico precalentada combinada, de mayor presión,

separación de la corriente agotada parcialmente condensada en una corriente de vapor separada y una corriente de líquido separada,

presurización de una primera porción de la corriente de líquido separada hasta una presión igual a la presión de la corriente de fluido de trabajo básico precalentada combinada, de mayor presión, para formar una corriente de líquido presurizada,

combinación de la corriente de líquido presurizada con la corriente de fluido de trabajo básico combinada precalentada, de mayor presión para formar la corriente de ebullición,

combinación de una segunda porción de la corriente de líquido separada con la corriente de vapor separada para formar la corriente de fluido de trabajo básico de menor presión,

transferencia de energía térmica de la corriente de fluido de trabajo básico de menor presión, a una corriente de fluido de trabajo básico de mayor presión, para formar la corriente de fluido de trabajo básico, de mayor presión, calentada y una corriente de fluido de trabajo básico, de menor presión, enfriada,

transferencia de energía térmica de la corriente de fluido de trabajo básico, de menor presión, enfriada, a una corriente externa de enfriamiento para formar una corriente de enfriamiento agotada y una corriente de fluido de trabajo básico, de menor presión, totalmente condensada,

presurización de la corriente de fluido de trabajo básico totalmente condensada, de menor presión, hasta la corriente de fluido de trabajo básico, de mayor presión

2 El método de la reivindicación 1, en donde la corriente externa fuente de calor es una corriente geotérmica

3 Un método para la implementación de un ciclo termodinámico que consta de los pasos de

de la lectura de esta descripción aquellas personas con experiencia en el arte pueden estimar cambios y modificaciones que se pueden llevar a cabo y que no se separan del alcance y del espíritu de la invención según lo descrito anteriormente y de lo reivindicado a continuación

transformación de energía térmica de una corriente de fluido de trabajo básico completamente evaporada en una forma de energía aprovechable para producir una corriente agotada, de menor presión,

combinación de la corriente agotada con una corriente de líquido despresunzado para formar una corriente mezclada de menor presión,

transferencia de energía térmica de una corriente mezclada de menor presión a una primera porción de una corriente de fluido de trabajo básico, de mayor presión, pre-calentada, para formar una corriente mezclada enfriada de menor presión y una primera corriente de fluido de trabajo básico calentada, de mayor presión,

separación de la corriente mezclada enfriada de menor presión en una corriente de vapor de menor presión separada y una corriente de líquido de menor presión separada,

mezcla de una primera porción de la corriente líquido separado con la corriente de vapor separado para formar una segunda corriente mezclada de menor presión,

transferencia de energía térmica desde la segunda corriente mezclada de menor presión a una corriente de fluido de trabajo básico, de mayor presión, para formar una corriente de fluido de trabajo básico pre-calentada, de mayor presión, y una segunda corriente mezclada de menor presión enfriada,

condensación de la segunda corriente mezclada de menor presión enfriada con un corriente de enfriamiento externa para formar una corriente de fluido de trabajo de menor presión completamente condensada,

presunzación de la corriente de fluido de trabajo de menor presión completamente condensada para formar una corriente de fluido de trabajo de mayor presión,

transferencia de la energía térmica desde una corriente externa fuente de calor tres veces enfriada a una segunda porción de la corriente de fluido de trabajo básico de mayor presión pre-calentada para formar una segunda corriente de fluido de trabajo básico de mayor presión calentada y una corriente externa fuente de calor agotada,

combinación de la primera y segunda corrientes de fluido de trabajo básico, de mayor presión, calentadas, para formar una corriente combinada calentada de fluido de trabajo básico, de mayor presión,

transferencia de la energía térmica desde una corriente externa fuente de calor dos veces enfriada a la corriente combinada calentada de fluido de trabajo básico, de mayor presión para formar una corriente de fluido de trabajo básico, de mayor presión, más caliente y una corriente externa fuente de calor tres veces enfriada,

combinación de una corriente de vapor de mayor presión separada con la corriente de fluido de trabajo básico, de mayor presión, más caliente para formar una corriente mezclada de mayor presión,

transferencia de energía térmica desde una corriente fuente de calor enfriada una vez a la corriente mezclada de mayor presión para formar una corriente externa dos veces enfriada y una corriente de mayor presión parcialmente evaporada,

separación de la corriente de mayor presión parcialmente evaporada en una segunda corriente de vapor de mayor presión separada y una segunda corriente de líquido de mayor presión separada,

transferencia de la energía térmica desde una corriente externa fuente de calor a la segunda corriente de vapor de mayor presión separada para formar la corriente externa fuente de calor enfriada una vez y el fluido de trabajo básico completamente evaporado

reducción de la presión de la segunda corriente de líquido de mayor presión separada para formar una corriente mezclada de presión reducida,

separación de la corriente mezclada de presión reducida en la primera corriente de vapor separada y una primera corriente de líquido de presión reducida separada, y

reducción de la presión de la corriente de líquido de presión reducida separada produciendo una corriente líquida de menor presión

4 El método de la reivindicación 3, en donde la corriente externa fuente de calor es una corriente geotérmica

5 Un método para la implementación de un ciclo termodinámico que consta de los pasos de

combinación de la primera corriente compositiva con una segunda corriente compositiva que tienen una composición recirculante para formar una corriente combinada,

calentamiento de la corriente combinada para formar una corriente combinada mezclada combinada con una corriente externa fuente de calor;

separación de la corriente combinada mezclada en una corriente de vapor combinada y una corriente de líquido,

evaporación completa de la corriente de vapor combinada para formar una corriente de vapor completamente evaporada con la corriente externa fuente de calor,

expansión y transformación de la energía térmica de la corriente de vapor completamente evaporada a una forma de energía aprovechable para producir una corriente agotada,

enfriamiento y separación de la corriente agotada en una primera corriente precursora compositiva una segunda corriente precursora compositiva,

condensación de la primera corriente precursora compositiva,

formación de la primera corriente compositiva a partir de la primera corriente precursora compositiva y una corriente enriquecida que tiene una menor concentración de un componente de baja ebullición, y

formación de la segunda corriente compositiva a partir de la segunda corriente precursora compositiva y de la corriente menos densa de vapor dos que tienen una concentración más alta del componente de baja ebullición

6 El método de la reivindicación 5, en donde la corriente externa fuente de calor es una corriente geotérmica

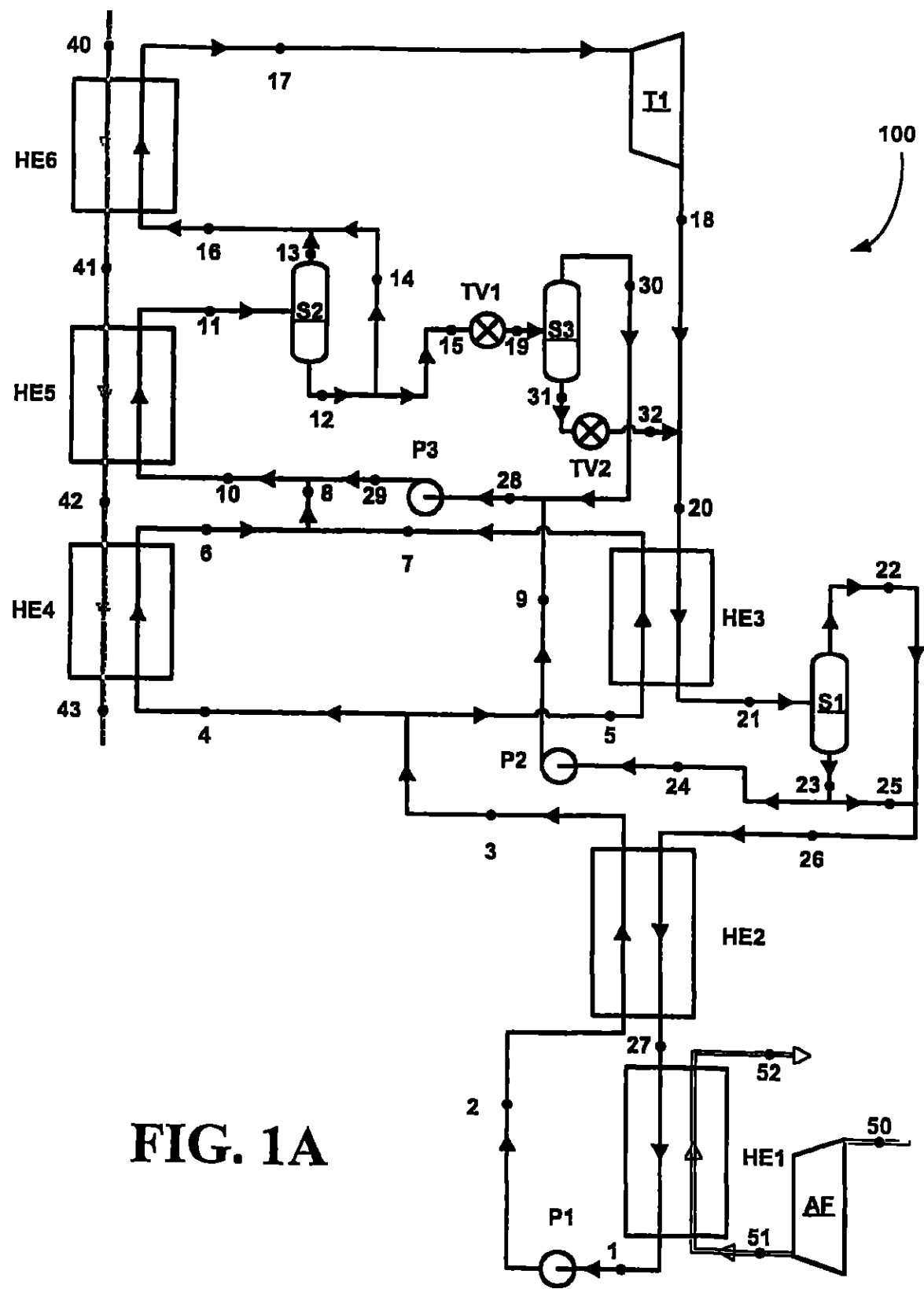
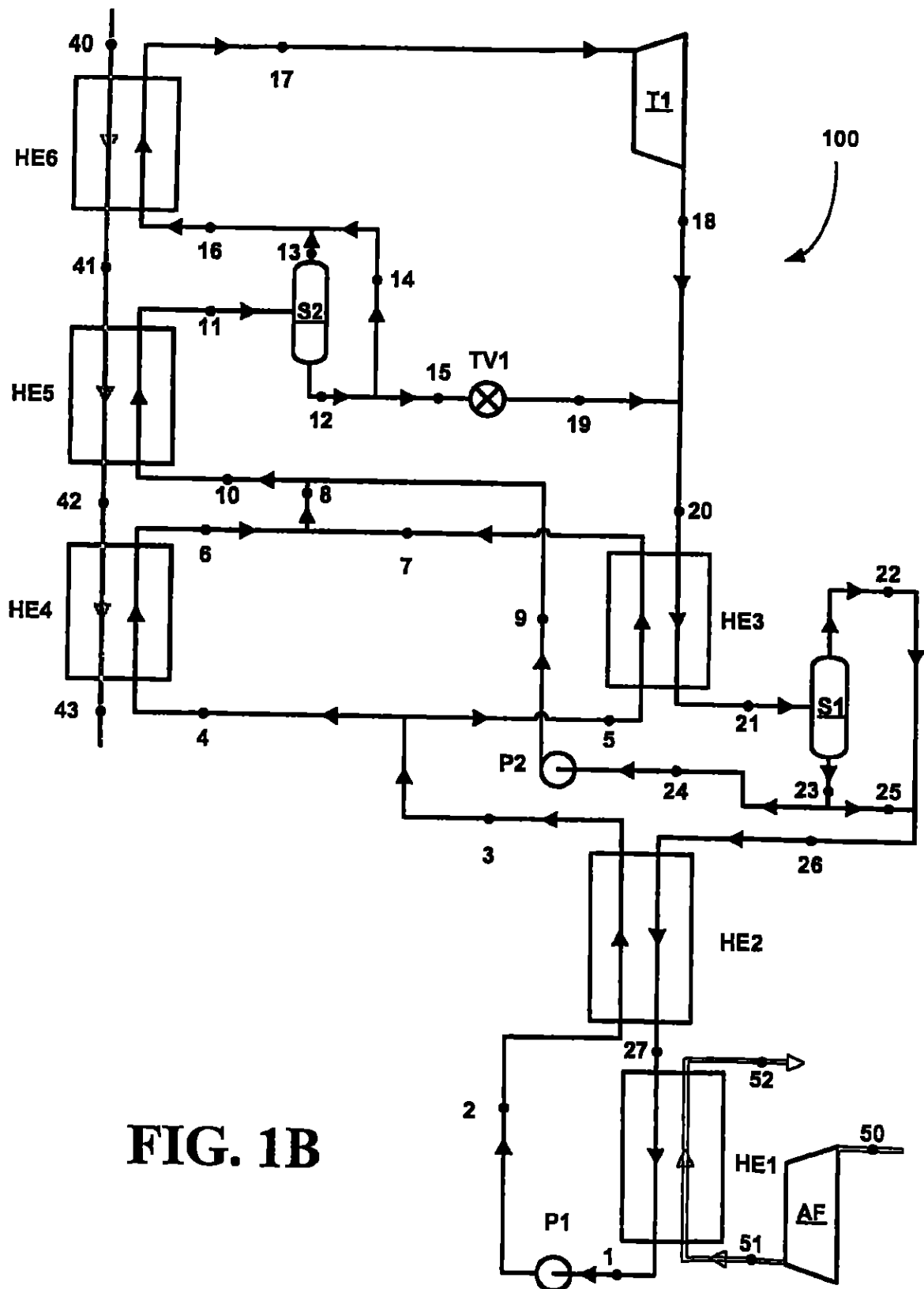


FIG. 1A

**FIG. 1B**

80

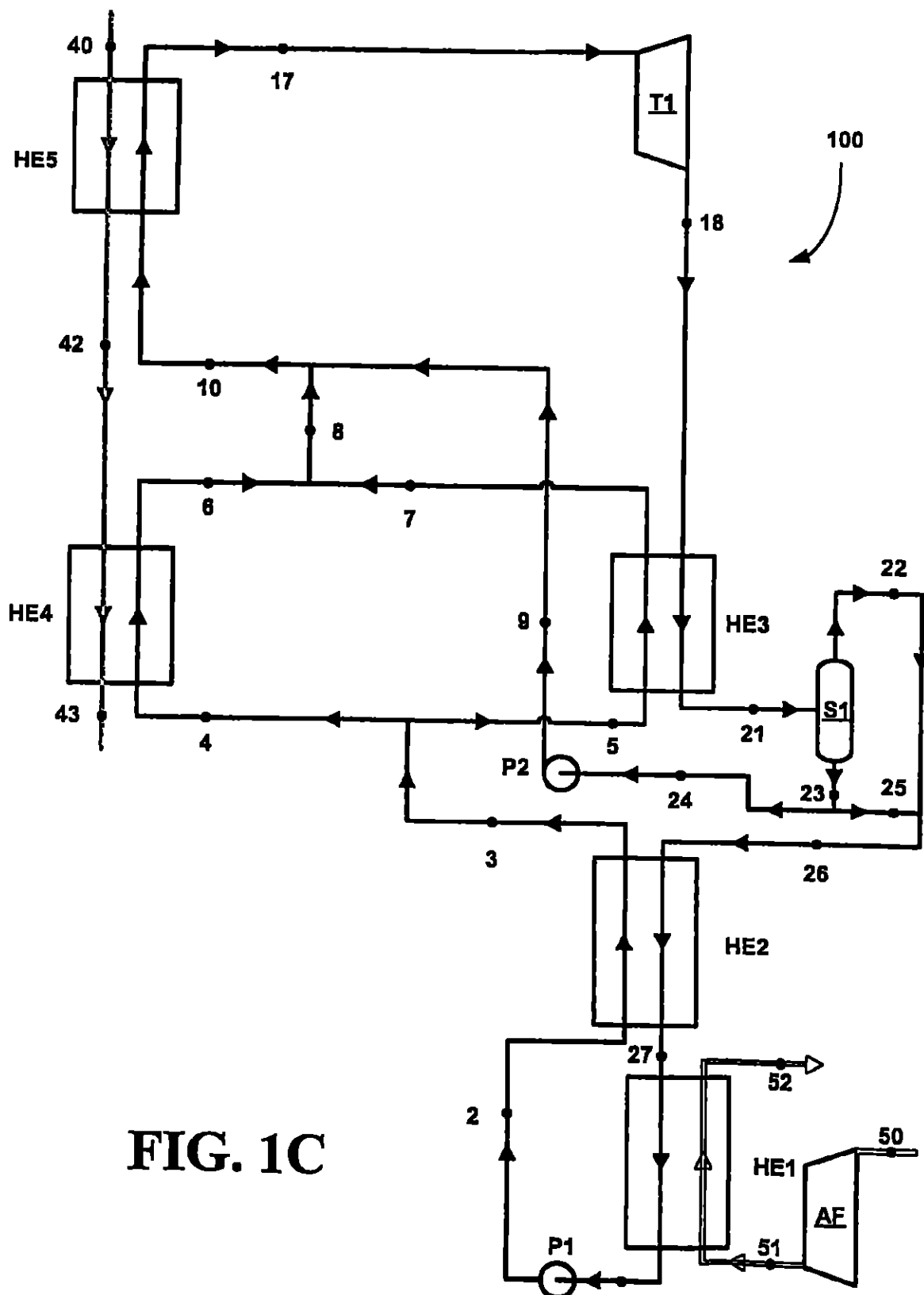


FIG. 1C

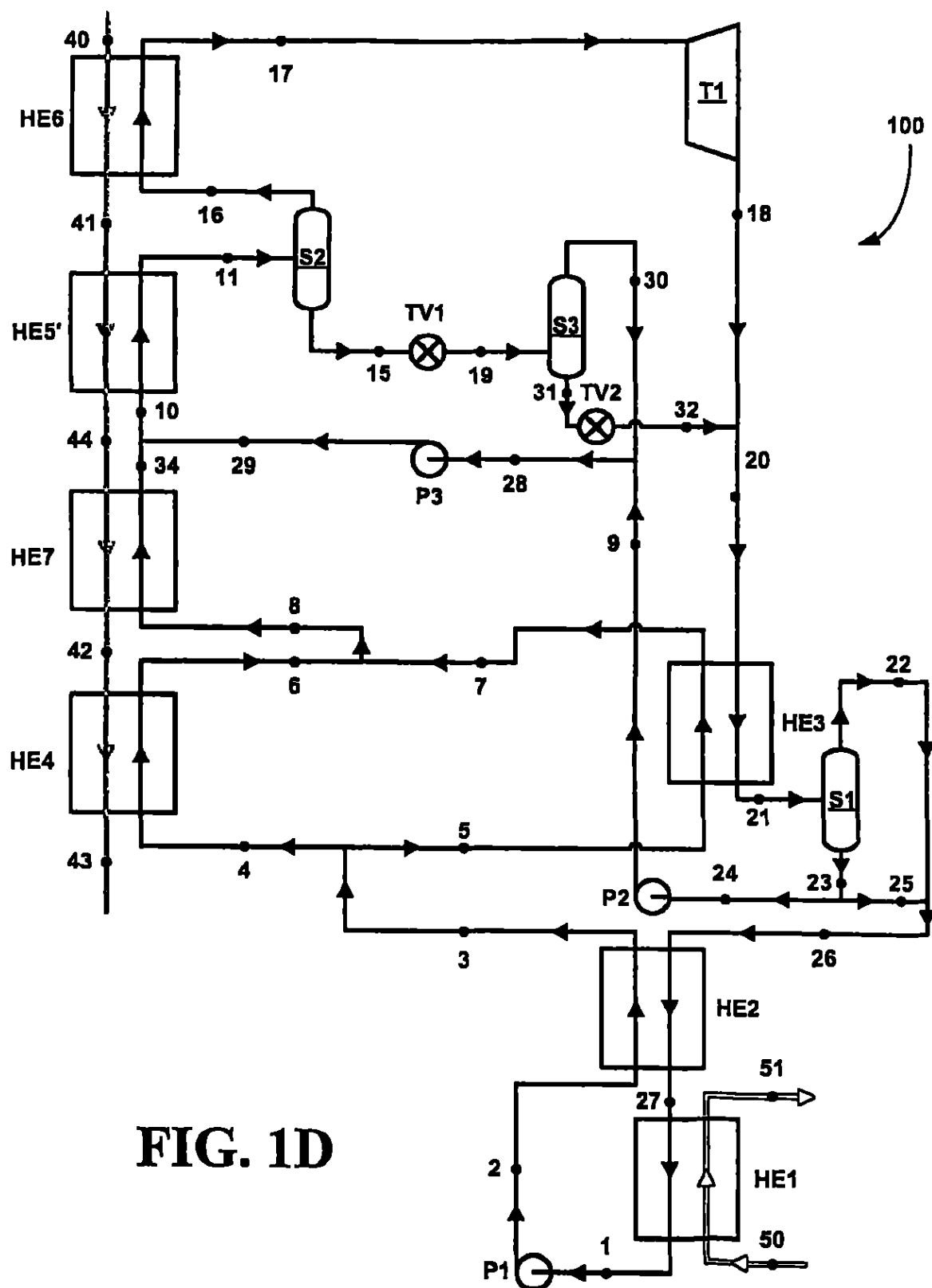


FIG. 1D

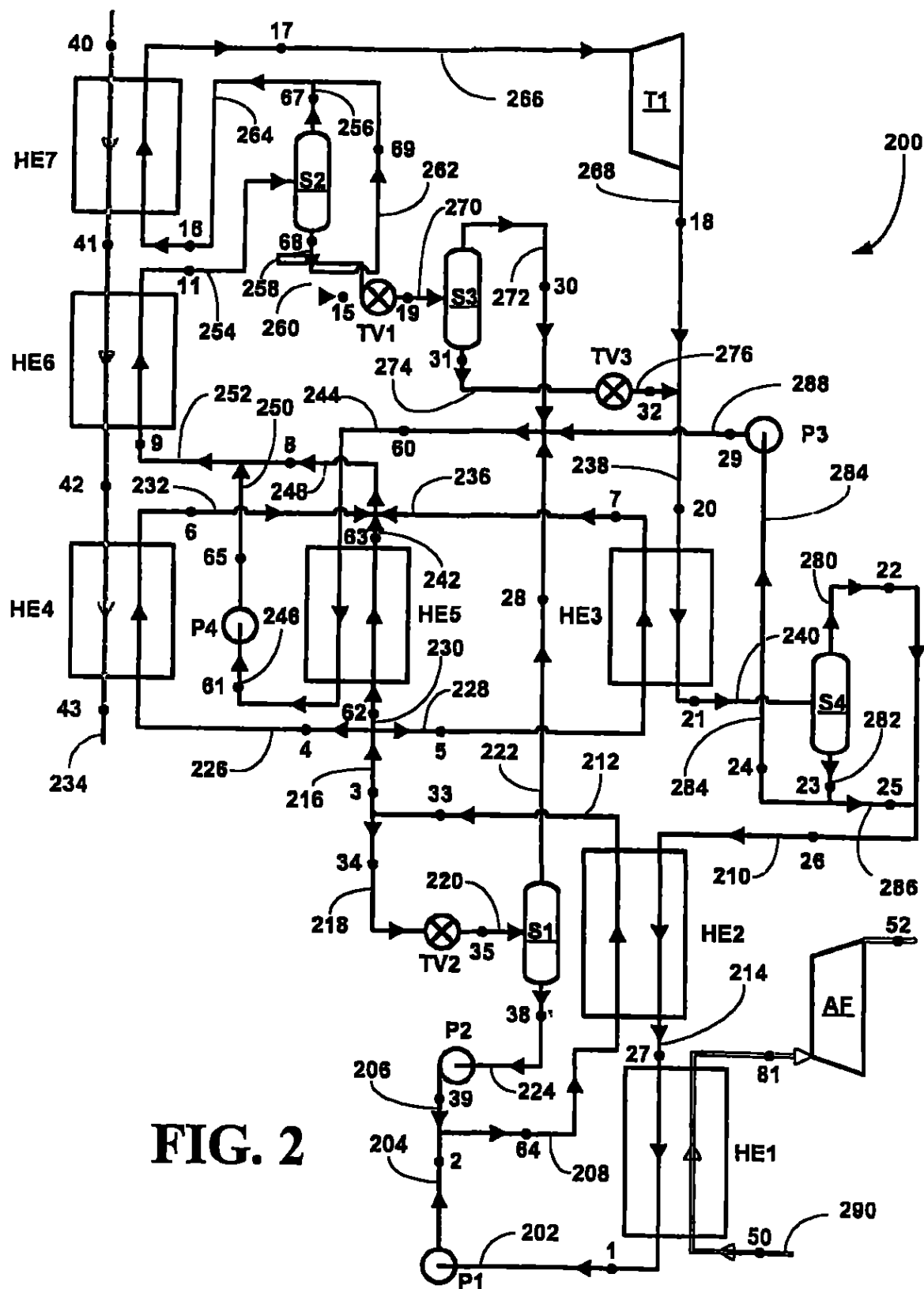


FIG. 2

PATENT COOPERATION TREATY

From the
INTERNATIONAL PRELIMINARY EXAMINING AUTHORITYTo:
ROBERT W. STROZIER
P.O. BOX 429
BELLAIRE, TX 77402-0429

PCT

NOTIFICATION OF TRANSMITTAL OF
INTERNATIONAL PRELIMINARY
EXAMINATION REPORT

(PCT Rule 71.1)

Date of Mailing
(day/month/year)

01 NOV 2004

Applicant's or agent's file reference

02019/04PCT

IMPORTANT NOTIFICATION

International application No.

PCT/US04/03025

International filing date (day/month/year)

03 February 2004 (03.02.2004)

Priority date (day/month/year)

03 February 2003 (03.02.2003)

Applicant

KALEX, LLC.

1. The applicant is hereby notified that this International Preliminary Examining Authority transmits herewith the international preliminary examination report and its annexes, if any, established on the international application.
2. A copy of the report and its annexes, if any, is being transmitted to the International Bureau for communication to all the elected Offices.
3. Where required by any of the elected Offices, the International Bureau will prepare an English translation of the report (but not of any annexes) and will transmit such translation to those Offices.
4. REMINDER

The applicant must enter the national phase before each elected Office by performing certain acts (filing translations and paying national fees) within 30 months from the priority date (or later in some Offices) (Article 39(1)) (see also the reminder sent by the International Bureau with Form PCT/IB/301).

Where a translation of the international application must be furnished to an elected Office, that translation must contain a translation of any annexes to the international preliminary examination report. It is the applicant's responsibility to prepare and furnish such translation directly to each elected Office concerned.

For further details on the applicable time limits and requirements of the elected Offices, see Volume II of the PCT Applicant's Guide.

Name and mailing address of the IPEA/US

Mail Stop PCT, Attn: IPEA/US
Commissioner for Patents
P.O. Box 1490
Alexandria, Virginia 22313-1490
Facsimile No. (703) 305-3230

Authorized officer

Hong M. Nguyen

Telephone No. (703) 305-0861

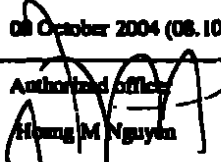
Form PCT/IPBA/416 (July 1992)

PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference 02019/04PCT	FOR FURTHER ACTION See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)	
International application No. PCT/US04/03025	International filing date (day/month/year) 03 February 2004 (03.02.2004)	Priority date (day/month/year) 03 February 2003 (03.02.2003)
International Patent Classification (IPC) or national classification and IPC IPC(7) F01K 25/06 and US Cl. 60/649, 651, 671		
Applicant KALEX, LLC.		
1 This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36. 2 This REPORT consists of a total of <u>3</u> sheets, including this cover sheet ☐ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT) These annexes consist of a total of <u> </u> sheets. 3 This report contains indications relating to the following items: I ☒ Basis of the report II ☐ Priority III ☐ Non-establishment of report with regard to novelty inventive step and industrial applicability IV ☐ Lack of unity of invention V ☒ Reasoned statement under Article 35(2) with regard to novelty inventive step or industrial applicability citations and explanations supporting such statement VI ☐ Certain documents cited VII ☐ Certain defects in the international application VIII ☐ Certain observations on the international application		
Date of submission of the demand 29 July 2004 (29.07.2004)	Date of completion of this report 08 October 2004 (08.10.2004)	
Name and mailing address of the IPEA/US Mail Stop PCT Attn: IPEA/US Commissioner for Patents P.O. Box 1450 Alexandria, Virginia 22313 1450 Facsimile No. (703) 305-3230	Authorized officer  Hong M. Nguyen Telephone No. (703) 305-0861	

Form PCT/IPEA/409 (cover sheet)(July 1998)

85

L. Basis of the report

1 With regard to the elements of the international application: *

- ☒ the international application as originally filed
- ☒ the description.
pages 1-21 as originally filed
pages NONE filed with the demand
pages NONE filed with the letter of _____
- ☒ the claims
pages 22-25 as originally filed
pages NONE as amended (together with any statement) under Article 19
pages NONE filed with the demand
pages NONE filed with the letter of _____
- ☒ the drawings
pages 1-5 as originally filed
pages NONE filed with the demand
pages NONE filed with the letter of _____
- ☐ the sequence listing part of the description.
pages NONE as originally filed
pages NONE filed with the demand
pages NONE filed with the letter of _____

2 With regard to the language, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed unless otherwise indicated under this item.
These elements were available or furnished to this Authority in the following language _____ which is:

- ☐ the language of a translation furnished for the purposes of international search (under Rule 23 1(b))
- ☐ the language of publication of the international application (under Rule 48 3(b))
- ☐ the language of the translation furnished for the purposes of international preliminary examination (under Rules 55 2 and/or 55 3)

3 With regard to any nucleotide and/or amino acid sequence disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing.

- ☐ contained in the international application in printed form.
- ☐ filed together with the international application in computer readable form.
- ☐ furnished subsequently to this Authority in written form.
- ☐ furnished subsequently to this Authority in computer readable form.
- ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
- ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4 ☒ The amendments have resulted in the cancellation of

- ☒ the description, pages NONE
- ☒ the claims Now NONE
- ☒ the drawings sheets/fig NONE

5 ☐ This report has been established as if (some of) the amendments had not been made since they have been considered to go beyond the disclosure as filed, as indicated in the Supplemental Box (Rule 70 2(c)) **

* Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17)

** Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No
PCT/US04/03025

86

V Reasoned statement under Rule 66.2(a)(II) with regard to novelty, inventive step or industrial applicability, citations and explanations supporting such statement

1 STATEMENT

Novelty (N)	Claims 1-6	YES
	Claims NONE	NO
Inventive Step (IS)	Claims 1-6	YES
	Claims NONE	NO
Industrial Applicability (IA)	Claims 1-6	YES
	Claims NONE	NO

2 CITATIONS AND EXPLANATIONS

Claims 1-6 meet the criteria set out in PCT Article 33(2)-(3) because the prior art does not teach or fairly suggest a method for implementing a thermodynamic cycle comprising many steps of separating streams, heat exchanging, and combining streams in the specific manner as claimed.

Claims 1-6 meet the criteria set out in PCT Article 33(4) and thus have industrial applicability because the subject matter claimed can be made or used in industry

NEW CITATIONS

INTERNATIONAL SEARCH REPORT

International Application No.
PCT/US2004/003025A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 F01K25/06

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 F01K F03G

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the International search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication where appropriate of the relevant passages	Relevant to claim No.
A	EP 0 652 368 A (EXERGY INC) 10 May 1995 (1995-05-10) page 3, line 55 -page 8, line 3 abstract, figures	1-6
A	US 4 548 043 A (KALINA ALEXANDER I) 22 October 1985 (1985-10-22) column 1, line 4 -column 2, line 60 abstract, figures 1-4	1-6
A	EP 0 472 020 A (KALINA ALEXANDER IFAEVICH) 26 February 1992 (1992-02-26) page 1, line 37 -page 6, line 26 abstract, figure	1,2,5,6
P,A	US 2003/167769 A1 (BHARATHAN DESIKAN ET AL) 11 September 2003 (2003-09-11) abstract, figures 1,4	1,2,5,6
-/--		

☒ Further documents are listed in the continuation of box C.☒ Patent family members are listed in annex.

Special categories of cited documents

- A document defining the general state of the art which is not considered to be of particular relevance
- E earlier document but published on or after the international filing date
- L document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- O document referring to an oral disclosure, use, exhibition or other means
- P document published prior to the international filing date but later than the priority date claimed

- T later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- X document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- Y document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
- A document member of the same patent family

Date of the actual completion of the international search

28 June 2004

Date of mailing of the international search report

02/07/2004

Name and mailing address of the ISA

European Patent Office P.B. 6818 Paterlingen 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-8040, Tx. 81 851 spe nl
Fax: (+31-70) 340-8018

Authorized officer

Zerf, G

INTERNATI NAL SEARCH REPORT

International Application No.
PCT/US2004/003025

88

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4 982 568 A (KALINA ALEXANDER I) 8 January 1991 (1991-01-08) cited in the application column 3, line 36 -column 12, line 7 abstract, figures	3,4
E	US 2004/055302 A1 (KALINA ALEXANDER I) 25 March 2004 (2004-03-25) the whole document	1-6
E	US 2004/050048 A1 (KALINA ALEXANDER I) 18 March 2004 (2004-03-18) the whole document	1-6

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No.

PCT/US2004/003025

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 0652368 A	10-05-1995	US 5440882 A	15-08-1995
		AT 161074 T	15-12-1997
		CN 1110762 A ,B	25-10-1995
		DE 69407261 D1	22-01-1998
		DE 69407261 T2	23-04-1998
		DK 652368 T3	09-02-1998
		EP 0652368 A1	10-05-1995
		ES 2111258 T3	01-03-1998
		GR 3026220 T3	29-05-1998
		IT 1276054 B1	24-10-1997
		JP 7208117 A	08-08-1995
		NZ 264705 A	21-12-1995
		RU 2123606 C1	20-12-1998
US 4548043 A	22-10-1985	AU 578961 B2	10-11-1988
		AU 4518685 A	01-05-1986
		BR 8504116 A	17-06-1986
		CA 1216433 A1	13-01-1987
		CN 85106253 A ,B	10-04-1986
		DE 3567059 D1	02-02-1989
		EP 0180295 A1	07-05-1986
		ES 8608624 A1	01-12-1986
		IL 75859 A	18-01-1990
		IN 165121 A1	19-08-1989
		JP 1674446 C	26-06-1992
		JP 3036129 B	30-05-1991
		JP 61104108 A	22-05-1986
		KR 9209138 B1	13-10-1992
		MX 159176 A	27-04-1989
		PT 80873 A ,B	01-08-1985
		ZA 8505491 A	26-03-1986
EP 0472020 A	26-02-1992	US 5029444 A	09-07-1991
		AT 126566 T	15-09-1995
		CN 1059014 A ,B	26-02-1992
		DE 69112155 D1	21-09-1995
		DE 69112155 T2	04-01-1996
		DK 472020 T3	27-12-1995
		EP 0472020 A1	26-02-1992
		ES 2078396 T3	16-12-1995
		GR 3017789 T3	31-01-1996
		JP 2716606 B2	18-02-1998
		JP 6026441 A	01-02-1994
		MX 9100666 A1	01-04-1992
		NZ 239143 A	23-12-1993
US 2003167769 A1	11-09-2003	NONE	
US 4982568 A	08-01-1991	IT 1240752 B	17-12-1993
		JP 2245405 A	01-10-1990
		JP 2962751 B2	12-10-1999
		NZ 232060 A	26-07-1991
US 2004055302 A1	25-03-2004	WO 2004027325 A2	01-04-2004
US 2004050048 A1	18-03-2004	NONE	

PCT REQUEST

1/4

02019/04PCT

Original (for SUBMISSION) printed on 03 02 2004 08:14 22 PM

0	For receiving Office use only	
0 1	International Application No	
0-2	International Filing Date	
0-3	Name of receiving Office and "PCT International Application"	
0-4	Form PCT/RO/101 PCT Request	
0-4 1	Prepared using	PCT-EASY Version 2 92 (updated 01 11 2003)
0-5	Petition The undersigned requests that the present international application be processed according to the Patent Cooperation Treaty	
0-6	Receiving Office (specified by the applicant)	United States Patent and Trademark Office (USPTO) (RO/US)
0-7	Applicant's or agent's file reference	02019/04PCT
I	Title of invention	POWER CYCLE AND SYSTEM FOR UTILIZING MODERATE AND LOW TEMPERATURE HEAT SOURCES
II	Applicant	
II-1	This person is	applicant only
II-2	Applicant for	all designated States except US
II-4	Name	KALEX, INC
II-5	Address	2630 Carlmont Drive Belmont, CA 94002 United States of America
II-6	State of nationality	US
II 7	State of residence	US
II-8	Telephone No	650 343 8089
II-9	Facsimile No.	650-595-1792
III-1	Applicant and/or inventor	
III 1 1	This person is:	applicant and inventor
III 1-2	Applicant for	US only
III 1-4	Name (LAST First)	KALINA, Alexander, I
III 1-5	Address	105 Glengarry Way Hillsborough CA 94010-7313 United States of America
III 1-6	State of nationality	US
III 1 7	State of residence	US
III 1-8	Telephone No	650 343 8089
III 1-9	Facsimile No	650 343 6069

IV 1	Agent or common representative or address for correspondence The person identified below is hereby/has been appointed to act on behalf of the applicant(s) before the competent International Authorities as	agent
IV 1.1	Name (LAST First)	STROZIER Robert, W
IV 1.2	Address.	P O Box 429 Bellaire, TX 77402-0429 United States of America
IV 1.3	Telephone No.	713-977-7000
IV 1.4	Facsimile No.	713-977-7011
IV 1.5	e-mail	rwstroz@flash.net
IV 1.5	Agent's registration No	34024
V	Designation of States	
V-1	Regional Patent (other kinds of protection or treatment, if any are specified between parentheses after the designation(s) concerned)	AP: BW GH GM KE LS MW MZ SD SL SZ TZ UG ZM ZW and any other State which is a Contracting State of the Harare Protocol and of the PCT EA: AM AZ BY KG KZ MD RU TJ TM and any other State which is a Contracting State of the Eurasian Patent Convention and of the PCT EP: AT BE BG CH&LI CY CZ DE DK EE ES FI FR GB GR HU IE IT LU MC NL PT RO SE SI SK TR and any other State which is a Contracting State of the European Patent Convention and of the PCT OA: BF BJ CF CG CI CM GA GN GQ GW ML MR NE SN TD TG and any other State which is a member State of OAPI and a Contracting State of the PCT
V-2	National Patent (other kinds of protection or treatment, if any are specified between parentheses after the designation(s) concerned)	AE AG AL AM AT AU AZ BA BB BG BR BW BY BZ CA CH&LI CN CO CR CU CZ DE DK DM DZ EC EE EG ES FI GB GD GE GH GM HR HU ID IL IN IS JP KE KG KP KR KZ LC LK LR LS LT LU LV MA MD MG MK MN MW MX MZ NA NI NO NZ OM PG PH PL PT RO RU SC SD SE SG SK SL SY TJ TM TN TR TT TZ UA UG US UZ VC VN YU ZA ZM ZW

C/2

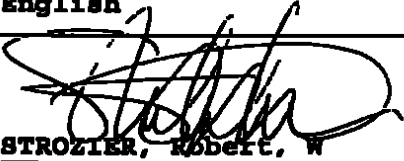
V-5	Precautionary Designation Statement In addition to the designations made under items V-1, V-2 and V-3, the applicant also makes under Rule 4.9(b) all designations which would be permitted under the PCT except any designation(s) of the State(s) indicated under item V-6 below. The applicant declares that those additional designations are subject to confirmation and that any designation which is not confirmed before the expiration of 15 months from the priority date is to be regarded as withdrawn by the applicant at the expiration of that time limit.		
V-6	Exclusion(s) from precautionary designations	NONE	
VI-1	Priority claim of earlier national application		
VI-1-1	Filing date	03 February 2003 (03 02 2003)	
VI-1-2	Number	10/357,328	
VI-1-3	Country	US	
VI-2	Priority claim of earlier national application		
VI-2-1	Filing date	23 September 2003 (23 09 2003)	
VI-2-2	Number	10/669,134	
VI-2-3	Country	US	
VI-3	Priority document request The receiving Office is requested to prepare and transmit to the International Bureau a certified copy of the earlier application(s) identified above as item(s):	VI-1, VI-2	
VII-1	International Searching Authority Chosen	European Patent Office (EPO) (ISA/EP)	
VIII	Declarations	Number of declarations	
VIII-1	Declaration as to the identity of the inventor	-	
VIII-2	Declaration as to the applicant's entitlement, as at the international filing date, to apply for and be granted a patent	-	
VIII-3	Declaration as to the applicant's entitlement, as at the international filing date, to claim the priority of the earlier application	-	
VIII-4	Declaration of inventorship (only for the purposes of the designation of the United States of America)	-	
VIII-5	Declaration as to non-prejudicial disclosures or exceptions to lack of novelty	-	

PCT REQUEST

4/4

02019/04PCT

Original (for SUBMISSION) printed on 03.02.2004 06 14.22 PM

IX	Check list	number of sheets	electronic file(s) attached
IX 1	Request (including declaration sheets)	4	-
IX-2	Description	21	-
IX-3	Claims	4	-
IX-4	Abstract	1	EZABST00 TXT
IX-5	Drawings	5	-
IX-7	TOTAL	35	
	Accompanying items	paper document(s) attached	electronic file(s) attached
IX-8	Fee calculation sheet	✓	-
IX-17	PCT-EASY diskette	-	Diskette
IX 19	Figure of the drawings which should accompany the abstract	2	
IX-20	Language of filing of the international application	English	
X-1	Signature of applicant, agent or common representative		2/5/04
X-1 1	Name (LAST First)	STROZIER, ROBERT, W	3 Feb 2004

FOR RECEIVING OFFICE USE ONLY

10-1	Date of actual receipt of the purported international application	
10-2	Drawings	
10-2-1	Received	
10-2-2	Not received	
10-3	Corrected date of actual receipt due to later but timely received papers or drawings completing the purported international application	
10-4	Date of timely receipt of the required corrections under PCT Article 11(2)	
10-5	International Searching Authority	ISA/EP
10-6	Transmittal of search copy delayed until search fee is paid	

FOR INTERNATIONAL BUREAU USE ONLY

11 1	Date of receipt of the record copy by the International Bureau	
------	--	--

PCT (ANNEX FEE CALCULATION SHEET)

1/2

02019/04PCT

Original (for SUBMISSION) printed on 03.02.2004 05:14:22 PM

(This sheet is not part of and does not count as a sheet of the international application)

0	For receiving Office use only	
0-1	International Application No.	
0-2	Date stamp of the receiving Office	
0-4	Form PCT/ROH101 (Annex) PCT Fee Calculation Sheet Prepared using	PCT-EASY Version 2.92 (updated 01.11.2003)
0-6	Applicant's or agent's file reference	02019/04PCT
2	Applicant	KALEX, INC, et al
12	Calculation of prescribed fees	fee amount/multiplier Total amounts (USD)
12-1	Transmittal fee T	⇒ 240
12-2-1	Search fee S	⇒ 1,119
12-2-2	International search to be carried out by	EP
12-3	International fee	
	Basic fee (first 30 sheets) b1	476
12-4	Remaining sheets	5
12-5	Additional amount (X)	12
12-6	Total additional amount b2	60
12-7	b1 + b2 = B	536
12-8	Designation fees	
	Number of designations contained in international application	100
12-9	Number of designation fees payable (maximum 5)	5
12-10	Amount of designation fee (X)	104
12-11	Total designation fees D	520
12-12	PCT-EASY fee reduction R	-148
12-13	Total international fee (B+D-R) I	⇒ 908
12-14	Fee for priority document	
	Number of priority documents requested	2
12-15	Fee per document (X)	20
12-16	Total priority document fee P	⇒ 40
12-17	TOTAL FEES PAYABLE (T+S+I+P)	⇒ 2,307
12-18	Mode of payment	cheque

Dear Sir/Madam
I can let you
get PCT-SAFE
to function
I know fees are
wrong ~~PA~~

VALIDATION LOG AND REMARKS

95

13-2-7	Validation messages Contents	Yellow! The power of attorney or a copy of the general power of attorney will need to be furnished unless all applicants sign the request form
--------	---------------------------------	--

96

Original (for SUBMISSION) printed on 03/02/2004 08:14:22 PM

PCT-EASY INFORMATION SHEET

(For applicant use only DO NOT submit this sheet with the international application)

VALIDATION LOG

	Contents
Yellow!	The power of attorney or a copy of the general power of attorney will need to be furnished unless all applicants sign the request form.

Before submitting the International Application, please carefully verify that:

- the information contained on printed Request form is correct,
- Box X of the Request form has been signed
- all elements of the international application as indicated in Boxes VII and IX of the Request form have been attached and
- the diskette containing the PCT-EASY zip file of the International Application has been enclosed and has been clearly labeled "PCT-EASY" with the applicant's or agent's file reference and the first applicant's name.

ATTENTION

DO NOT modify any indications on the Request form printout. The electronic version of the PCT-EASY application has been locked. If an error or an omission is discovered at this time, you must reopen the stored form for submission, perform necessary amendments and immediately resubmit the form. Finally, a NEW submission diskette must be created manually by resending the corrected stored form to the diskette. The previously created printout and submission diskette must be destroyed in order to prevent the possibility of erroneously sending it to the RO.

A new thermodynamic cycle is disclosed for converting energy from a low temperature stream external source into useable energy using a working fluid comprising of a mixture of a low boiling component and a higher boiling component and including a higher pressure circuit and a lower pressure circuit. The cycle is designed to improve the efficiency of the energy extraction process by recirculating a portion of a liquid stream prior to further cooling. The new thermodynamic processes and systems for accomplishing these improved efficiencies are especially well suited for streams from low temperature geothermal sources.

97

PCT PATENT SPECIFICATION

9x

TITLE **POWER CYCLE AND SYSTEM FOR UTILIZING MODERATE AND LOW TEMPERATURE HEAT SOURCES**

INVENTOR **Alexander I Kalina**

ASSIGNEE **KALEX INC**

RELATED APPLICATIONS

[0001] This application is a Continuation-in-Part of United States Patent Application Serial No 10/669 134 filed 23 September 2003 which is a Continuation in-Part of United States Patent Application Serial No 10/357,328 filed 3 February 2003

BACKGROUND OF THE INVENTION

1 Field of the Invention

[0002] The present invention relates to a system and method for the utilization of heat sources with moderate to low initial temperature, such as geothermal waste heat sources or other similar sources.

[0003] More particularly the present invention relates to a system and method for the utilization of heat sources with moderate to low initial temperature, such as geothermal waste heat sources or other similar sources involving a multi-staged heating process and at least one separation step to enrich the working fluid which is eventually fully vaporized for energy extraction

2 Description of the Related Art

[0004] In the prior art US patent number 4982568 a working fluid is a mixture of at least two components with different boiling temperatures. The high pressure at which this working fluid vaporizes and the pressure of the spent working fluid (after expansion in a turbine) at which the working fluid condenses are chosen in such a way that at the initial temperature of condensation is higher than the initial temperature of boiling. Therefore it is possible that the initial boiling of the working fluid is achieved by recuperation of heat released in the process of the condensation of the spent working fluid. But in a case where the initial temperature of the heat source used is moderate or low the range of temperatures of the heat source is narrow and therefore the possible range of such recuperative boiling-condensation is significantly reduced and the efficiency of the system described in the prior art diminishes.

[0005] Thus there is a need in the art for a new thermodynamic cycle and a system based thereon for enhanced energy utilization and conversion.

SUMMARY OF THE INVENTION

[0006] The present invention provides a method for extracting thermal energy from low to moderate temperatures source streams including the step of transforming thermal energy from a fully vaporized boiling stream into a usable energy form to produce a lower pressure, spent stream. The fully vaporized boiling stream is formed by transferring thermal energy from an external heat source stream to a boiling stream to form the fully vaporized boiling stream and a cooled external heat source stream. The method also includes the steps of transferring thermal energy from the spent stream to a first portion of a heated higher pressure basic working fluid stream to form a partially condensed spent stream and a first pre-heated higher pressure, basic working fluid stream and transferring thermal energy from the cooled external heat source stream to a second portion of the heated higher pressure, basic working fluid stream to form a second pre-heated, higher pressure, basic working fluid stream and a spent external heat source stream. The method also includes the steps of combining the first and second pre-heated, higher pressure basic working fluid streams to form a combined pre-heated, higher pressure basic working fluid stream and separating the partially condensed spent stream into a separated vapor stream and a separated liquid stream. The method also includes the steps of pressurizing a first portion of the separated liquid stream to a pressure equal to a pressure of the combined pre-heated higher pressure basic working fluid stream to form a pressurized liquid stream and combining the pressurized liquid stream with the combined pre-heated higher pressure basic working fluid stream to form the boiling stream.

The method also includes the steps of combining a second portion of the separated liquid stream with the separated vapor stream to form a lower pressure basic working fluid stream and transferring thermal energy from the lower pressure, basic working fluid stream to a higher pressure, basic working fluid stream to form the heated, higher pressure, basic working fluid stream and a cooled lower pressure basic working fluid stream. The method also includes the steps of transferring thermal energy from the cooled lower pressure, basic working fluid stream to an external coolant stream to form a spent coolant stream and a fully condensed lower pressure, basic working fluid stream and pressurizing the fully condensed lower pressure, basic working fluid stream to the higher pressure basic working fluid stream.

[0007] In a more efficient implementation of the present invention the method provides the additional steps of separating the boiling stream into a vapor stream and a liquid stream combining a portion of the liquid stream with the vapor stream and passing it through a small

heater exchanger in contact with the external heat source stream to insure complete vaporization and superheating of the boiling stream. A second portion of the liquid stream is depressurized to a pressure equal to a pressure of the spent stream.

[0008] In a more yet more efficient implementation of the present invention, the method provides in addition to the additional steps described in paragraph 0006, the steps of separating the depressurized second portion of the liquid stream of paragraph 0006 into a vapor stream and a liquid stream, where the vapor stream is combined with the pressurized liquid stream having the parameters of the point 9 and repressurized before being combined with the stream having the parameters of the point 8. While the liquid stream is depressurized to a pressure equal to a pressure of the spent stream having the parameters of the point 18.

[0009] The present invention also provides a two cycle thermodynamic method where a first boiling composition is heated, vaporized, expanded in a turbine to extract a quantity of more useable energy such as electric energy and condensed, and a recirculating composition is heated, partially vaporized, expanded in the same turbine to extract a quantity of more useable energy such as electric energy and condensed, where the two cycle improve an overall efficiency of the energy conversion system.

[0010] The present invention provides a systems as set forth in Figures 1A-D and 2 adapted to implement the methods of this invention.

DESCRIPTION OF THE DRAWINGS

[0011] 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.

[0012] Figure 1A depicts a schematic of a preferred thermodynamic cycle of this invention.

[0013] Figure 1B depicts a schematic of another preferred thermodynamic cycle of this invention. [0014] Figure 1C depicts a schematic of another preferred thermodynamic cycle of this invention.

[0015] Figure 1D depicts a schematic of another preferred thermodynamic cycle of this invention and

[0016] Figure 2 depicts a schematic of another preferred thermodynamic cycle of this invention.

DETAILED DESCRIPTION OF THE INVENTION

[0017] The inventors have found that a novel thermodynamical cycle (system and process) can

be implemented using a working fluid including a mixture of at least two components. The preferred working fluid being a water ammonia mixture though other mixtures such as mixtures of hydrocarbons and/or freons can be used with practically the same results. The systems and methods of this invention are more efficient for converting heat from relatively low temperature fluid such as geothermal source fluids into a useful form of energy. The systems use a multi-component basic working fluid to extract energy from one or more (at least one) geothermal source streams in one or more (at least one) heat exchangers or heat exchange zones. The heat exchanged basic working fluid then transfers its gained thermal energy to a turbine (or other system for extracting thermal energy from a vapor stream and converting the thermal energy into mechanical and/or electrical energy) and the turbine converts the gained thermal energy into mechanical energy and/or electrical energy. The systems also include pumps to increase the pressure of the streams at certain points in the systems and a heat exchangers which bring the basic working fluid in heat exchange relationships with a cool stream. One novel feature of the systems and methods of this invention, and one of the features that increases the efficiency of the systems, is the result of using a split two circuit design having a higher pressure circuit and a lower pressure circuit and where a stream comprising spent liquid separated for spent vapor from the higher pressure circuit is combined with a stream comprising the spent lower pressure stream at the pressure of the spent lower pressure stream prior to condensation to form the initial fully condensed liquid stream and where the combined stream is leaner than the initial fully condensed liquid stream. The present system is well suited for small and medium sized power units such as 3 to 5 Mega Watt power facilities.

[0018] The working fluid used in the systems of this inventions preferably is a multi-component fluid that comprises a lower boiling point component fluid – the low-boiling component – and a higher boiling point component – the high boiling component. Preferred working fluids include an ammonia water mixture, a mixture of two or more hydrocarbons a mixture of two or more freon a mixture of hydrocarbons and freon or the like. In general, the fluid can comprise mixtures of any number of compounds with favorable thermodynamic characteristics and solubility. In a particularly preferred embodiment the fluid comprises a mixture of water and ammonia.

[0019] It should be recognized by an ordinary artisan that at those point in the systems of this invention where a stream is split into two or more sub-streams the valves that effect such

stream splitting are well known in the art and can be manually adjustable or are dynamically adjustable so that the splitting achieves the desired improvement in efficiency

[0020] Referring now to Figure 1A a preferred embodiment of a system of this invention generally 100 is shown. The system 100 is described in terms of its operation using streams, conditions at points in the system and equipment. A fully condensed working fluid stream at a temperature close to ambient having parameters as at a point 1 enters a feed pump P1 where it is pumped to an elevated pressure, and obtains parameters as at a point 2. The composition of the working fluid stream having the parameters of the point 2 will be hereafter referred to as a "basic composition" or "basic solution." The working fluid stream having the parameters of the point 2 then passes through a recuperative pre-heater or heat exchanger HE2 where it is heated in counter flow by a returning stream of the basic solution as described below and obtains parameters as at a point 3. The state of the basic working solution at the point 3 corresponds to a state of saturated, or slightly sub-cooled liquid.

[0021] Thereafter, the stream of basic solution having the parameters of the point 3 is divided into two sub-streams having parameters as at points 4 and 5, respectively. The sub-stream having the parameters of the point 4 then passes through a heat exchanger HE4, where it is heated and partially vaporized by a stream of a heat source fluid (e.g., geothermal brine stream) having parameters as at a point 42 as described below, and obtains parameters as at a point 6. While, the stream of basic solution having the parameters of the point 5 passes through a heat exchanger HE3, where it is heated and partially vaporized by a condensing stream having parameters as at a point 20 in a condensing process 20-21 also described below and obtains parameters as at a point 7. Thereafter the sub-streams having parameters as at points 6 and 7 are combined forming a combined stream having parameters as at a point 8. The stream of basic solution having the parameters of the point 8 is then combined with a stream of a recirculating solution having parameters as at a point 29 as described below and forms a stream of a boiling solution having parameters as at a point 10. The stream having the parameters of the point 29 is in a state of sub-cooled liquid, and, therefore as a result of the mixing of the streams having the parameters of the points 8 and 29 a substantial absorption of vapor occurs and the temperature rises substantially. Thus a temperature of the stream having the parameters of the point 10 is usually significantly higher than that of the stream having the parameters of the point 8. The composition of the stream having the parameters of the point 10 is referred to herein as a "boiling solution."

[0022] The stream of boiling solution having the parameters of the point 10 then passes through a heat exchanger HE5 where it is heated and vaporized by the stream of the heat source fluid having parameters as at a point 41. The vaporized stream exiting the heat exchanger HE5 now has parameters as at a point 11. The stream having the parameters of the point 11 then enters into a gravity separator S2 where it is separated into a vapor stream having parameters as at a point 13 and a liquid stream having parameters as at a point 12. The liquid stream having the parameters of the point 12 is then divided into two sub-streams having parameters as at points 14 and 15 respectively. The sub-stream having the parameters of the point 14 usually represents a very small portion of the total liquid stream and is combined with the vapor stream having the parameters of the point 13 as described below forming a stream of working solution with parameters as at a point 16. The stream of working solution having the parameters of the point 16 then passes through a heat exchanger HE6 (a small heat exchanger sometimes called a vapor drier to insure that the state of the stream exiting the heat exchanger is a superheated vapor), where it is further heated by the stream of the heat source fluid having parameters as at a point 40, to form a fully vaporized and slightly superheated stream having parameters as at a point 17. Thereafter the stream of working solution having the parameters of the point 17 passes through a turbine T1, where it is expanded, producing useful power (conversion of thermal energy into mechanical and electrical energy) to form a stream having parameters as at a point 18.

[0023] The recirculating liquid having the parameters of the point 15 as described above passes through a throttle valve TV1 where its pressure is reduced to an intermediate pressure to form a stream having parameters as at a point 19. As a result of throttling, the parameters of the stream at the point 19 correspond to a state of a vapor-liquid mixture. The stream having the parameters of the point 19 then enters into a gravity separator S3 where it is separated into a vapor stream having parameters as at the point 30 and a liquid stream having parameters as at a point 31. The liquid stream having the parameters of the point 31 passes through a second throttle valve TV2 where its pressure is further reduced to a pressure to form a stream having parameters as at a point 32 where the pressure of the stream having the parameters of the point 32 is equal to a pressure of the stream having the parameters of the point 18 as described above. Thereafter the stream having the parameter of the point 32 and the stream having the parameters of the point 18 are combined forming a stream of a condensing solution having the parameters of the point 20. The stream having parameters of

the point 20 passes through the heat exchanger HE3 in counter flow to the stream having the parameters of the point 5 in a cooling process 5-7. After passing through the heat exchanger HE3 the stream having the parameters of the point 20 is partially condensed, releasing heat for the heating process 20-21 described above and obtains parameters as at a point 21.

[0024] The stream having the parameters of the point 21 then enters into a gravity separator S1, where it is separated into a vapor stream having parameters as at a point 22 and a liquid stream having parameters as at a point 23. The liquid stream having the parameters of the point 23 is in turn divided into two sub-streams having parameters as at points 25 and 24 respectively. The liquid sub-stream having the parameters of the point 25 is then combined with the vapor stream having the parameters of the point 22, forming a stream of the basic solution having parameters as at a point 26.

[0025] The liquid sub-stream having parameters of the point 24 enters a circulating pump P2 where its pressure is increased to a pressure equal to a pressure in gravity separator S3, i.e., equal to a pressure of the vapor stream having the parameters of the point 30 described above, and obtains parameters as at point 9. The liquid stream having the parameters of the point 9 is in a state of a sub-cooled liquid. The liquid stream having the parameters of point 9 is then combined with the vapor stream having the parameters of the point 30 described above. A pressure of the streams having the parameters of the points 9 and 30 is chosen in such a way that the sub-cooled liquid having the parameters of the point 9 fully absorbs all of the vapor stream having the parameters of the point 30, forming a liquid stream having parameters as at point 28. The liquid stream having the parameters of the point 28 is in a state of saturated or sub-cooled liquid. Thereafter, the stream having the parameters of the point 28 enters into a circulating pump P3 where its pressure is increased to a pressure equal to a pressure of the stream having the parameters of the point 8, and obtains parameters of the point 29 described above. The stream having the parameters of the point 29 is then combined with the stream of basic solution having the parameters of the point 8, forming the stream of the boiling solution having the parameters of the point 10 described above.

[0026] The stream of basic solution having the parameters of the point 26 enters into the heat exchanger HE2 where it partially condenses, releasing heat for a heating process 2-3 described above and obtains parameters as at a point 27. Thereafter the stream of basic solution having the parameters of the point 27 enters into a condenser HE1 where it is cooled and fully condensed by an air or water stream having parameters as at point 51.

described below and obtains parameters of the point 1

[0027] An air (or water) stream having parameters as at a point 50 enters an air fan AF (or compressor in the case of water) to produce an air stream having parameters as at a point 51 which forces the air stream having the parameters of the point 51 into the heat exchanger HE1 where it cools the stream of basic working fluid in a cooling process 27-1 and obtains parameters as at point 52

[0028] The stream of heat source fluid with the parameters of the point 40 passes through the heat exchanger HE6 where it provides heat from a heating process 6-17, and obtains the parameters of the point 41. The stream of heat source fluid having the parameters of the point 41 passes through the heat exchanger HE5, where it provides heat for a heating process 10-11, and obtains the parameters of the point 42. The stream of heat source fluid having the parameters of the point 42 enters into the heat exchanger HE4, where it provides heat for a heating process 4-6 and obtains parameters as at point 43

[0029] In the previous variants of the systems of this invention, the recirculating stream having parameters as at the point 29 was mixed with the stream of basic solution having parameters as at the point 8. As a result of this mixing, a temperature of the combined stream having parameters as at the point 10 was substantially higher than a temperature of the streams having parameters as at the points 8 and 29

[0030] Referring now to Figure 1D, another embodiment of the system of this invention, generally 100, is shown to include an additional heat exchanger HE7, i.e., the heat exchanger HE5 is split into two heat exchangers HE5' and HE7 designed to reduce the temperature difference between the stream having the parameters as at the point 10 and the streams having the parameters as at the points 8 and 29

[0031] In the new embodiment the stream with parameters as at the point 8 is sent into the heat exchanger HE7 where it is heated and further vaporized by a heat source stream such as a geothermal fluid stream having the parameters as at a point 44 producing the heat source stream having parameters as at the point 42 in a counter flow heat exchange process 44-42 and a stream having parameters as at a point 34. Only then is the steam having the parameters as at the point 34 mixed with a recirculating stream having the parameters as at the point 29 (as described above) forming a combined stream having parameters as at the point 10. A temperature at of the stream having the parameters as at the point 34 is chosen in such a way that the temperature of the stream having the parameters as at the point 10 is equal or very

close to the temperature of the stream having the parameters as at the point 34. As a result the irreversibility of mixing a stream of basic solution and a stream of recirculating solution is drastically reduced. The resulting stream having the parameters as at the point 10 passes through the heat exchanger HES' where it is heated and vaporized in a counter flow process 41-44 by the heat source stream such as a geothermal fluid stream having the parameters as at the point 41.

[0032] This embodiment can also include a sub stream having parameter as at points 14 as described above, which usually represents a very small portion of the total liquid stream and is combined with the vapor stream having the parameters of the point 13 (not shown) as described below to form the stream of working solution with parameters as at the point 16. Additionally, this embodiment can also include the AF unit and associated streams as described above.

[0033] The advantages of the arrangement of streams shown in the present embodiment include at least the following: a temperature difference in the heat exchanger HE7 (which is, in essence, the low temperature portion of the heat exchanger HES in the previous variants), are substantially increased and therefore the size of the heat exchanger HE7 is reduced while the heat exchanger HES' of this embodiment works in absolutely the same way as the high temperature portion of the heat exchanger HES of the previous variants. The efficiency of the system of this embodiment is not affected at all.

[0034] This embodiment of the method of mixing a recirculating stream with a stream of basic solution can be applied to all variants described above. One experienced in the art can easily apply this method without further explanation.

[0035] An example of calculated parameters for the points described above are given in Table 1 for the embodiment shown in Figure 1A.

TABLE 1
Parameter of Points in the Embodiment of Figure 1A

Point No.	Concentration X	Temperature T (°F)	Pressure P (psia)	Enthalpy h (btu/lb)	Entropy S(btu/lb°F)	Weight (g/g)
Parameters of Working Fluid Streams						
1	0.975	73.5	133.4091	37.8369	0.09067	1.0
2	0.975	75.0186	520.0	40.1124	0.09145	1.0
3	0.975	165.0	508.2780	147.9816	0.27769	1.0

Point No	Concentration X	Temperature T (°F)	Pressure P (psia)	Enthalpy h (btu/lb)	Entropy S (btu/lb°F)	Weight (g/g)
4	0.975	165.0	508.2780	147.9816	0.27769	0.6010
5	0.975	165.0	508.2780	147.9816	0.27769	0.3990
6	0.975	208.0	498.5	579.1307	0.96196	0.6010
7	0.975	208.0	498.5	579.1307	0.96196	0.3990
8	0.975	208.0	498.5	579.1307	0.96196	1.0
9	0.40874	170.2394	220.0	45.8581	0.21737	0.3880
10	0.81773	231.1316	498.5	433.8631	0.76290	1.40575
11	0.81773	300.0	490.0	640.0316	1.04815	1.40757
12	0.35855	300.0	490.0	200.2510	0.43550	0.1950
13	0.89168	300.0	490.0	710.8612	1.14682	1.21075
14	0.35855	300.0	490.0	200.2510	0.43550	0.1655
15	0.35855	300.0	490.0	200.2510	0.43550	0.17845
16	0.8845	300.0	490.0	703.9808	1.13724	1.2272
17	0.8845	306.0	488.5	718.3184	1.15637	1.2273
18	0.8845	213.3496	139.5	642.4511	1.17954	1.2273
19	0.35855	249.1433	220.0	200.2510	0.44140	0.17845
20	0.81671	214.6540	139.5	584.8515	1.08437	1.3880
21	0.81671	170.0	137.5	460.9041	0.89583	1.3880
22	0.97746	170.0	137.5	624.6175	1.16325	0.99567
23	0.40874	170.0	137.5	45.4163	0.21715	0.39233
24	0.40874	170.0	137.5	45.4163	0.21715	0.3880
25	0.40874	170.0	137.5	45.4163	0.21715	0.00433
26	0.975	170.0	137.5	622.1123	1.15916	1.0
27	0.975	93.9659	135.5	514.2431	0.97796	1.0
28	0.43013	195.9556	220.0	74.5165	0.26271	0.40575
29	0.43013	196.6491	498.5	75.8407	0.26312	0.40575
30	0.89772	249.1433	220.0	700.9614	1.21784	0.01775
31	0.2990	249.1433	220.0	144.9514	0.35565	0.16070

Point No	Concentration X	Temperature T (°F)	Pressure P (psia)	Enthalpy h (btu/lb)	Entropy S (btu/lb°F)	Weight (g/g)
32	0.2990	233.8807	139.5	144.9514	0.35718	0.16070
Parameters of Geothermal Source Stream						
40	brine	315.0		283.0		3.90716
41	brine	311.3304		279.3304		3.90716
42	brine	237.4534		2305.1534		3.90716
43	brine	170.0		138.0		3.90716
Parameters of Air Cooling Stream						
50	air	51.7	14.7	122.3092		91.647
51	air	51.9341	14.72	122.3653		91.647
52	air	73.5463	14.7	127.5636		91.647

[0036] In the system described above, the liquid produced in separator S1 eventually passes through heat exchanger HE5 and is partially vaporized. However the composition of this liquid is only slightly richer than the composition of the liquid separated from the boiling solution in separator S2. In general, the richer the composition of the liquid added to the basic solution as compared to the composition of the liquid added to the spent working solution (point 18) the more efficient the system. In the proposed system the bulk of liquid from separator S2 having parameter as point 15 is throttled to an intermediate pressure, and then divided into vapor and liquid in separator S3. As a result, the liquid stream having the parameters of the point 32 which is mixed with the spent working solution stream having the parameters of the point 18 is leaner than the liquid separated from the boiling solution in separator S2. In addition, the recirculating liquid which is separated in separator S1 is mixed with the vapor stream from separator S3 and therefore, is enriched. As a result, the liquid stream having the parameters of the point 29 which is added to the stream of basic solution having the parameters of the point 10 is richer than the liquid stream produced from separator S1.

[0037] If the system is simplified and the liquid stream from the separator S2 having parameters of the point 15 is throttled in one step to a pressure equal to the pressure of the stream having the parameters of the point 18 then the system requires less equipment, but its efficiency is slightly reduced. This simplified but preferred variant of the system of this

invention is shown in Figure 1B where the separator S3 and the throttle valve TV2 have been remove along with the streams having the parameters of the points 30 31 and 32 The operation of such a variant of this system of Figure 1A does not require further separate description because all of the remaining features are fully described in conjunction with the detailed description of system and process of Figure 1A

[0038] If the quantity of liquid from separator S1 is reduced to such a degree that the composition of the boiling solution stream having the parameters of the point 10 becomes equal to the composition of the working solution which passes through the turbine T1 then the separator S2 can be eliminated along with the throttle valve TV1 Therefore the heat exchanger HE6 also becomes unnecessary and is also eliminated because in this implementation there is no risk of liquid droplets being present in the boiling stream due to the absence of the separator S2 This even more simplified variant of the system of this invention is presented in Figure 1C Its efficiency is yet again lower that the efficiency of the previous variant described in Figure 1B, but it is still more efficient than the system described in the prior art.

[0039] The choice in between the three variants of the system of this invention is dictated by economic conditions of operations One experienced in the art can easily compare the cost of additional equipment, the value of additional power output given by increased efficiency and make an informed decision as to the exact variant chosen.

[0040] A summary of efficiency and performance of these three variants of this invention and the system described in the prior art are presented in Table 2

TABLE 2
Performance Summary

	Systems of This Invention			Prior Art
	Variant 1	Variant 2	Variant 3	
Heat Input (Btu)	566 5385	565 5725	564 2810	487 5263
Specific Brine Flow (lb/lb)	3 960716	3 9005	3 89159	3 36225
Heat Rejection (Btu)	476 4062	476 4062	476 4062	414 0260
Turbine Enthalpy Drop (Btu)	93 1119	91 7562	90 2988	75 376
Turbine Work (Btu)	90 7841	89 4623	88 0413	73 4828
Pump Work (Btu)	2 9842	2 5812	2 4240	1 867
Air Fan Work (Btu)	5 1414	5 1414	5 1414	3 5888
Net Work (Btu)	82 6785	81 7397	80 4759	68 027

Net Thermal Efficiency (%)	14.595	14.453	14.262	13.954
Second Law efficiency (%)	54.23	53.703	52.995	51.85

[0041] It is apparent from the simulated data in Table 2 that all three variants of this invention show improvements in net values: net work improvements of 21.54%, 20.16% and 18.30% respectively; and net thermal and second law efficiency improvements of 4.59%, 3.58% and 2.21% respectively.

Improved Variant

[0042] In yet another preferred embodiment of the system of this invention designed for the utilization of heat source with moderate to low initial temperature, such as geothermal waste heat and similar sources, an improved configuration is described below.

[0043] In a previous variant a system was described which provided substantial improvements over the prior art United States Patent No. 4,982,568 and this variant represents a further improvement in efficiency.

[0044] Referring now to Figure 2, another preferred embodiment of the system of this invention, generally 200, is shown to include a fully condensed working fluid stream 202 at a temperature close to ambient having parameters as at a point 1, which corresponds to a state of saturated liquid, enters into a feed or first pump, P1. The stream 202 having parameters as at the point 1 is pumped to an elevated pressure obtaining a stream 204 having parameters as at a point 2. Thereafter, the stream 204 having the parameters as at the point 2 is mixed with a stream 206 of liquid having parameters as at a point 39 as described below forming a stream 208 having parameters as at a point 64. The composition of the stream 206 having the parameters as at the point 39 is leaner than the composition of the stream 204 having the parameters as at the point 2 (i.e. the stream 206 has a lower concentration of the low boiling component than does the stream 204). Obviously the composition of the stream 208 having the parameters as at the point 64 is leaner than the composition of the stream 204 having parameters as at the point 2 but richer (having a higher concentration of the low boiling component) than the stream having the parameters as at the point 39.

[0045] Thereafter the stream 208 with the parameters as at the point 64 passes through a second heat exchanger HE2 where it is heated in counter flow with a first stream 210 having parameters as at a point 26 in a first heat exchange process 26-27 as described below to form a stream 212 having parameters as at a point 33 corresponding to a state of saturated or

slightly sub-cooled liquid and a partially condensed stream 214 having parameters as at a point 27. Thereafter the stream 212 having the parameters as at the point 33 is divided into two sub-streams 216 and 218, having parameters as at points 3 and 34 respectively. The stream 218 with the parameters as at the point 34 then passes through a second throttle valve, TV2 where its pressure is reduced, to form a lower pressure stream 220 having parameters as at a point 35. The stream 220 with the parameters as at the point 35, a mixed stream of vapor and liquid, and is sent into a first gravity separator S1, where it is separated into a vapor stream 222 having parameters as at a point 28, and a liquid stream 224 having parameters as at a point 38. The liquid stream 224 having the parameters as at the point 38 enters into a second pump, P2, where it is pumped to a pressure equal to a pressure of the stream 204 having the parameters as at the point 2, forming the stream 206 having the parameters as at the point 39. Thereafter the stream 206 with parameters as at the point 39 is mixed with the stream 204 having the parameters as at the point 2, as described above.

[0046] The stream 216 having a composition represented by the parameters as at the point 3 will have a composition referred to herein as a first boiling composition. Obviously, the compositions of the streams 208, 212, 218 and 220 having the parameters of the points 64, 33, 34 and 35, respectively, are the same composition as the stream 216 having the parameters as at the point 3. The composition of the streams 202 and 204 having the parameters as at the points 1 and 2, respectively, will have the composition referred to as a basic composition. The composition of the streams 210 and 214 having the parameters as at the points 26 and 27, respectively as described below is the same the composition of the streams 202 and 204 having the parameters as at the points 1 and 2.

[0047] The stream 216 having the first boiling composition and the parameters as at the point 3 is divided into three sub-streams 226, 228 and 230 having parameters as at points 4, 5 and 62 respectively. The sub stream 226 having the parameters as at the point 4 passes through a fourth heat exchanger HE4, where it is heated, boiled and partially vaporized to form a first partially vaporized stream 232 having parameters as at a point 6 in counter-flow with a stream 234 of a heat source fluid having entering parameters as at a point 43 and leaving parameters as at a point 45 where the stream 234 is a geothermal fluid in the case of a geothermal installation. The sub stream 228 having the parameters as at the point 5 passes through a third heat exchanger HE3 where it is heated, boils and is partially vaporized to form a second partially vaporized stream 236 having parameters as at a point 7, in counter flow with a

returning condensing stream 238 having parameters as at a point 20 to form a partially condensed stream 240 having parameters as at a point 21 as described below. The sub stream 230 having the parameters as at the point 62 passes through a fifth heat exchanger HE5 where it is heated, boiled and partially vaporized to form a third partially vaporized stream 242 having parameters as at a point 63 in counter-flow by a condensing stream 244 having parameters as at a point 60 to form a fully condensed stream 246 having parameters as at a point 61 as described below.

[0048] Thereafter, the streams 232, 236, and 242 having the parameters as at the points 6, 7, and 63, respectively are combined forming a combined stream 248 having parameters as at a point 8. The fully condensed stream 246 having the parameters as at the point 61 enters into a circulating or a fourth pump P4, where it is pumped to a pressure equal to a pressure of the stream 248 as at the point 8, as described above, to form a higher pressure fully condensed stream 250 having parameters as at a point 65. Thereafter, the stream 250 having the parameters as at the point 65 is combined with the stream 248 having the parameters as at the point 8, forming a second combined stream 252 having parameters as at a point 9. It is obvious that the composition of the streams 226, 228, 252, 236, 230, 242 and 248 having the parameters as at the points 4, 5, 6, 7, 62, 63 and 8, respectively, are the same as the composition of the stream 216 having the parameters as at the point 3, i.e. the first boiling composition. Because the composition of the streams 244, 246 and 250 having parameters as at the points 60, 61 and 65 is leaner than the first boiling composition, the composition of the combined stream 252 having the parameters as at the point 9 is leaner than the first boiling composition. The composition of the streams 244, 246 and 250 having parameters as at the points 60, 61 and 65 is referred to herein as a recirculating composition while the composition of the combined stream 252 having the parameters as at the point 9 is referred to herein as a second boiling composition.

[0049] The second combined stream 252 having the second boiling composition and the other parameters as at the point 9 passes through a sixth heat exchanger HE6, where it is further boiled and vaporized to form a further vaporized stream 254 having parameters as at a point 11 in counter-flow by the stream 234 of the heat source fluid having entering parameters as at a point 41 and leaving parameters as at a point 43. Thereafter, the further vaporized stream 254 having the second boiling composition and the other parameters as at the point 11 enters into a second gravity separator S2 where it is separated into a second vapor stream 256

having parameters as at a point 67 and a second liquid stream 258 having parameters as at a point 68. The second liquid stream 258 having the as at the point 68 may be separated into two sub streams 260 and 262 having parameters as at points 15 and 69 respectively. In some preferred embodiment of this variant a flow rate of the stream 262 having the parameter as at the point 69 will be equal to zero. The stream 262 having the parameters as at the point 69 if present, is combined with the second vapor stream 256 having the parameters as at the point 67, forming a third combined stream 264 having parameters as at a point 16 the composition of which will hereafter be referred to as a working composition.

[0050] The stream 264 having the working composition and the other parameters as at the point 16 passes through a seventh heat exchanger HE7, where it is heated and fully vaporized, and slightly superheated to form a fully vaporized stream 266 having parameters as at a point 17, in counter-flow by the stream 234 of the heat source fluid having entering parameters as at a point 40 and leaving parameters as at a point 41. The fully vaporized stream 266 having the working composition and the other parameters as at the point 17, then passes through a turbine T1, where it expands, producing work, and forming a spent stream 268 having the working composition and other parameters as at a point 18.

[0051] The second liquid stream 260 having the parameters as at the point 15, as described above, passes through a first throttle valve TV1, where its pressure is reduced to a pressure equal to the pressure of the stream 222 having the parameters as at the point 28, as described above, to form a lower pressure stream 270 having parameters as at a point 19. Then the stream 270 having the parameters as at the point 19 enters a third gravity separator S3 where it is separated into a third vapor stream 272 having parameters as at a point 30 and a third liquid stream 274 having parameters as at a point 31. Thereafter, the third liquid stream 274 having the parameters as at the point 31 passes through a third throttle valve TV3, where its pressure is reduced to a pressure equal to a pressure of the spent stream 268 having the parameters as at the point 18 as described above to form a lower pressure stream 276 having parameters as at a point 32. The stream 276 having the parameters as at the point 32 is then combined with the spent stream 268 having parameters as at the point 18 forming the [third combined] stream 238 having parameters as at the point 20.

[0052] The stream 238 having parameters as at the point 20 passes through the third heat exchanger HE3 where it partially condenses providing heat for a heat exchange process 5-7 as described above forming the stream 240 having the parameters as at the point 21. The

stream 240 having the parameters as at the point 21 enters into a fourth gravity separator S4 where it is separated into a fourth vapor stream 280 having parameters as at a point 22, and a fourth liquid stream 282 having parameters as at a point 23. Then the fourth liquid stream 282 having parameters as at a point 23 is divided into two liquid sub-streams 284 and 286 having parameters as at points 24 and 25, respectively. The liquid sub-stream 286 having the parameters as at the point 25 is combined with the fourth vapor stream 280 having parameters as at the point 22 forming the stream 210 having the basic composition and the other parameters as at the point 26.

[0053] The liquid sub-stream 284 having the parameters as at the point 24 enters into a circulating or third pump P3, where it is pumped to a pressure equal to a pressure of the streams 222 and 272 having the parameters as at points 28 and 30, as described above, forming a higher pressure stream 288 having parameters as at a point 29. Thereafter, the streams 222, 272, and 288 having the parameters as at points 28, 29, and 30 are combined together forming the stream 244 having the circulating composition and the other parameters as at the point 60. The stream 244 having the parameters as at the point 60, passes through the third heat exchanger HE3, where it is fully condensed, providing heat for a process 62-63, to form the stream 246 having the parameters as at the point 61, as previously described. Again, the liquid stream 246 having the parameters as at the point 61 is pumped by the circulating or fourth pump P4, to form the higher pressure stream 250 having the parameters as at the point 65, which is then mixed with the stream 248 having the first boiling composition and the other parameters as at the point 8 forming the combined stream 252 having the second boiling composition and the other parameters as at the point 9, as described above.

[0054] The stream 210 having the basic composition and other parameters as at the point 26 passes through the second heat exchanger HE2, where it partially condenses, providing heat for a heat-exchange process 64-33, as described above, forming the partially condensed stream 214 having parameters as at the point 27. Then the stream 214 having parameters as at the point 27 passes through a first condenser heat exchanger HE1 where it is cooled by a coolant stream 290 having initial parameter as at a point 50 and final parameters as at a point 51 (water or air) to form the fully condensed stream 202 having parameters as at the point 1.

[0055] As in the other variants of the system of this invention the embodiments described

above are also is closed

[0056] As with the previous embodiment of system of this invention that the latest variant improves upon the working process of the system of this invention is composed of two cycles. The first cycle is a cycle of the first boiling composition, which is heated and vaporized and then expands in the turbine, and then fully condenses in the first heat exchanger HE1 a condenser. The second cycle is a cycle of the recirculating composition, which only partially boils, producing vapor, this vapor also passes through the turbine, and mostly or completely condenses in the third heat exchanger HE3 (a recuperative boiler/condenser). The richer the composition of the liquid stream 284 having the parameters as at the point 24 (i.e., the liquid produced in the recuperative boiler/condenser HE3), the larger the portion of this stream that can be subsequently vaporized, thus increasing the efficiency of the overall process.

[0057] In the previous variants, the liquid stream having the initial parameters as at the point 24 was pumped to an intermediate pressure, enriched by mixing with a vapor stream having the parameters as at the point 30, and then added to a stream of the first boiling composition. In the present variant of the system of this invention, the condensed liquid having the parameters as at the point 24 is pumped and then enriched, not only by the stream of vapor having the parameters as at the point 30, but also with a much larger stream of vapor having parameters as at the point 28. As a result, the streams 244, 246 and 250 having the recirculating composition and the other parameters as at the points 60, 61 and 65, respectively are enriched significantly more than in the previous designs or variants. The additional enriching with the vapor stream 222 having the parameters as at the point 28 is produced by better utilization of heat released in the process of condensation of the basic composition.

[0058] As a result of this better utilization of heat release in the condensation process the latter variant of the system of this invention has an overall efficiency of 3% to 5% higher than the previous variants of the system of this invention. A sample of the heat and performance balances of this latter variant of the system of this invention are tabulated in Tables 3-5 and the parameters of all points described above and designated in Figure 2 are tabulated in Table 6.

TABLE 3
Simulated Heat Balance Data

Property	Energy kW	Energy Btu/lb
Heat In	84,926 44	546 57 Btu/lb
Heat Rejected	70,606 87	454 42 Btu/lb
Turbine enthalpy drops	14,912 74	95 98
Gross Generator Power	14 220 04	91 52
Process Pumps (-3 82)	-653 04	-4 20
Cycle Output	13,567 00	87 32
Other Pumps and Fans (-4 87)	-813 26	-5 23
Net Output	12,753 74	82 08
Gross Generator Power	14,220 04	91 52
Cycle Output	13,567 00	87 32
Net Output	12,573 74	82 08

TABLE 4
Simulated Efficiency Data

Property	Percentage %
Net thermal efficiency	15 02
Second Law Limit	26 91
Second Law Efficiency	55 80

TABLE 5
Simulated Specific Consumption Data

Property	Heat Btu/lb
Specific Brine Consumption	154 55
Specific Power Output	6 47

OVERALL HFAT BALANCE (Btu/lb)

Heat In is equal to Brine plus pumps = 546.57 + 3 82 = 550 39

Heat Out is equal to turbine plus condenser = 95 98 + 454 42 = 550 39

TABLE 6
Simulated Specific Consumption Data

Pt	X lb/lb	T °F	P psia	H Btu/lb	S Btu/lb-R	G Rel G/G=1	Phase	Wetness lb/lb
WORKING FLUID								
1	0.9299	73.27	126.766	22.3023	0.08415	1.06803	Mix	1
2	0.9298	74.67	498.675	24.4996	0.09502	1.06903	Liq	-93.23°F
3	0.9250	165.00	478.675	130.1713	0.26958	1.00000	Mix	1
4	0.9250	165.00	478.675	130.1713	0.26958	0.45691	Mix	1
5	0.9250	165.00	478.675	130.1713	0.26958	0.41981	Mix	1
6	0.9250	213.11	477.675	527.0695	0.89377	0.45691	Mix	0.1624
7	0.9250	207.99	477.675	515.2115	0.81618	0.41981	Mix	0.1769
8	0.9250	209.22	477.675	515.8261	0.97100	1.00000	Mix	0.1761
9	0.8254	213.11	477.675	396.6378	0.71018	1.34291	Mix	0.4228
11	0.8254	303.50	476.675	666.9563	1.08645	1.34287	Mix	0.1022
15	0.3433	303.50	476.675	205.2395	0.00000	0.13718	Mix	0
16	0.8803	303.50	476.675	719.3763	1.15990	1.20569	Vap	0°F
17	0.9903	306.00	475.175	721.3333	1.16278	1.20569	Vap	2.7°F
18	0.8803	211.57	131.766	641.7309	1.19377	1.20569	Mix	0.0624
19	0.3433	259.31	235.449	205.2395	0.44562	0.13718	Mix	0.912
20	0.8249	212.99	131.766	596.1109	1.10762	1.33080	Mix	0.1457
21	0.8249	170.00	130.766	474.6254	0.92207	1.33090	Mix	0.2613
22	0.9757	170.00	130.766	626.2892	1.17133	0.99303	Mix	0
23	0.3986	170.00	130.766	45.9319	0.21750	0.34778	Mix	1
24	0.3986	170.00	130.766	45.9319	0.21150	0.26277	Mix	1
25	0.3986	170.00	130.766	45.9319	0.21750	0.09501	Mix	1
26	0.9298	170.00	130.766	580.0959	1.09541	1.06803	Mix	0.0796
27	0.9298	99.23	128.766	441.1110	0.91316	1.06903	Mix	0.2106
28	0.9997	113.13	235.449	560.4625	0.99869	0.06803	Mix	0
29	0.3986	170.34	235.449	46.5386	0.21185	0.26277	Liq	-44.74°F
30	0.8851	259.31	235.449	110.8870	1.22271	0.01207	Mix	0
31	0.2910	259.31	235.449	156.4614	0.37066	0.12511	Mix	1
32	0.2910	225.92	131.766	156.4614	0.37300	0.12511	Mix	0.9453
33	0.9250	165.00	478.675	130.1713	0.26958	1.50538	Mix	1

Pt	\ lb/lb	T °F	P psia	H Btu/lb	S Btu/lb-R	G Rel G/G=1	Phase	Wetness lb/lb
34	0 9250	165 00	478 675	130 1713	0 26958	0 50538	Mix	1
35	0 9250	113 13	235 449	130 1713	0 27648	0 50539	Mix	0 8654
38	0 9134	113 13	235 449	63 2351	0 16414	0 43735	Mix	1
39	0 9134	114 48	498 675	65 0826	0 16514	0 43735	Liq	-55 04°F*
60	0 5350	199 51	235 449	171 8993	0 41197	0 34287	Mix	0 8295
61	0 5350	170 00	234 449	47 5498	0 21963	0 34287	Mix	1
62	0 9250	165 00	478 675	130 1713	0 26959	0 12328	Mix	1
63	0 9250	193 51	477 675	476 0256	0 81670	0 12328	Mix	0 2323
64	0 9250	96 39	498 675	36 2899	0 10896	1 50539	Liq	-81 99°F*
65	0 5350	170 97	477 675	49 0179	0 21944	0 34287	Liq	-61 41°F*
67	0 9603	303 50	476 675	719 3763	1 15990	1 20569	Mix	0
68	0 3433	303 50	476 675	205 2395	0 44092	0 13718	Mix	1
69	0 3433	303 50	476 675	205 2395	0 00000	0 00000	Mix	0
HEAT SOURCE								
40	BRINE	315 00	0 000	287 1318	0 00000	3 71523	Liq	
41	BRINE	314 37	0 000	286 4967	0 00000	3 71523	Liq	
43	BRINE	219 11	0 000	198.8263	0 00000	3 71523	Liq	
45	BRINE	170 00	0 000	140 0149	0 00000	3 71523	Liq	
COOLANT								
50	AIR	51 70	14 693	122 3092	1 62806	67 5974	Vap	511 4°F*
51	AIR	79 65	14 673	129,0316	1 64095	67 5974	Vap	539 3°F*
52	AIR	79 95	14 693	129 1036	1 64099	67 5974	Vap	539 6°F*

* Temperature of Stream at the indicated point

[0059] All references cited herein are incorporated by reference While this invention has been described fully and completely, it should be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described 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

CLAIMS

I claim

1 1 A method for implementing a thermodynamic cycle comprising the steps of
 2 transforming thermal energy from a fully vaporized boiling stream into a usable
 3 energy form to produce a lower pressure spent stream,
 4 transferring thermal energy from an external heat source stream to a boiling stream
 5 to form the fully vaporized boiling stream and a cooled external heat source stream
 6 transferring thermal energy from the spent stream to a first portion of a heated higher
 7 pressure, basic working fluid stream to form a partially condensed spent stream and a first
 8 pre-heated, higher pressure, basic working fluid stream,
 9 transferring thermal energy from the cooled external heat source stream to a second
 10 portion of the heated higher pressure, basic working fluid stream to form a second pre-heated,
 11 higher pressure, basic working fluid stream and a spent external heat source stream
 12 combining the first and second pre-heated, higher pressure basic working fluid
 13 streams to form a combined pre-heated, higher pressure basic working fluid stream
 14 separating the partially condensed spent stream into a separated vapor stream and a
 15 separated liquid stream,
 16 pressurizing a first portion of the separated liquid stream to a pressure equal to a
 17 pressure of the combined pre-heated, higher pressure basic working fluid stream to form a
 18 pressurized liquid stream
 19 combining the pressurized liquid stream with the combined pre-heated higher
 20 pressure basic working fluid stream to form the boiling stream
 21 combining a second portion of the separated liquid stream with the separated vapor
 22 stream to form a lower pressure basic working fluid stream,
 23 transferring thermal energy from the lower pressure, basic working fluid stream to a
 24 higher pressure, basic working fluid stream to form the heated higher pressure, basic working
 25 fluid stream and a cooled lower pressure basic working fluid stream
 26 transferring thermal energy cooled lower pressure, basic working fluid stream to an
 27 external coolant stream to form a spent coolant stream and a fully condensed lower pressure
 28 basic working fluid stream and
 29 pressurizing the fully condensed lower pressure basic working fluid stream to the

30 higher pressure basic working fluid stream

1 2 The method of claim 1 wherein the external heat source stream is a geothermal
2 stream.

1 3 A method for implementing a thermodynamic cycle comprising the steps of
2 transforming thermal energy from a fully vaporized basic working fluid stream into
3 a usable energy form to produce a lower pressure, spent stream,

4 combining the spent stream with a depressurized liquid stream to form a lower
5 pressure mixed stream,

6 transferring thermal energy from the lower pressure mixed stream to a first portion
7 of a pre heated higher pressure, basic working fluid stream to form a cooled mixed lower
8 pressure stream and a first heated, higher pressure, basic working fluid stream,

9 separating the cooled mixed lower pressure stream into a separated lower pressure
10 vapor stream and a separated lower pressure liquid stream,

11 mixing a first portion of the separated liquid stream with the separated vapor stream
12 to form a second mixed lower pressure stream,

13 transferring thermal energy from the second mixed lower pressure stream to a higher
14 pressure, basic working fluid stream to form a pre-heated higher pressure, basic working fluid
15 stream and a cooled second mixed lower pressure stream

16 condensing the cooled second mixed lower pressure stream with an external cooling
17 stream to form a fully condensed lower pressure basic working fluid stream

18 pressuring the fully condensed lower pressure basic working fluid stream to form a
19 higher pressure basic working fluid stream,

20 transferring thermal energy from a thrice cooled external heat source stream to a
21 second portion of the pre-heated higher pressure basic working fluid stream to form a second
22 heated higher pressure basic working fluid stream and a spent external heat source stream

23 combining the first and second heated higher pressure, basic working fluid streams
24 to form a combined heated higher pressure basic working fluid stream

25 transferring thermal energy from a twice cooled external heat source stream to the
26 combined heated higher pressure basic working fluid streams to form a hotter higher pressure
27 basic working fluid stream and the thrice cooled external heat source stream

combining a higher pressure separated vapor stream with the hotter higher pressure basic working fluid stream to form a mixed higher pressure stream

transferring thermal energy from a once cooled external heat source stream to the mixed higher pressure stream to form the twice cooled external stream and a partially vaporized higher pressure stream,

separating the partially vaporized higher pressure stream into a second separated vapor higher pressure stream and a second separated higher pressure liquid stream,

transferring thermal energy from an external heat source stream to the second separated vapor higher pressure stream to form the once cooled external heat source stream and the fully vaporized basic working fluid,

reducing the pressure of the second separated higher pressure liquid stream to form a reduced pressure mixed stream,

separating the reduced pressure mixed stream into the first separated vapor stream and a first reduced pressure separated liquid stream, and

reducing the pressure of the reduced pressure separated liquid stream into the lower pressure liquid stream

4 The method of claim 3, wherein the external heat source stream is a geothermal stream

5 A method for implementing a two cycle thermodynamic system comprising the steps of

combining the first compositional stream with a second compositional stream having a recirculating composition to form a combined stream

heating the combined stream to form a mixed combine stream with an external heat source stream

separating the mixed combined stream into a vapor combined stream and a liquid stream

fully vaporizing the vapor combined stream to form a fully vaporized stream with the external heat source stream

expanding and transforming thermal energy from the fully vaporized stream into a usable energy form to produce a spent stream

- 13 cooling and separating the spent stream into a first compositional precursor stream and
14 a second compositional precursor stream
15 condensing the first compositional precursor stream
16 forming the first compositional stream from the first compositional precursor stream
17 and an enriched stream having a lower concentration of a low-boiling component, and
18 forming the second compositional stream from the second compositional precursor
19 stream and two lean vapor stream having a higher concentration of the low-boiling
20 component
- 21 6 The method of claim 5 wherein the external heat source stream is a geothermal
22 stream

ABSTRACT

5 A new thermodynamic cycle is disclosed for converting energy from a low temperature stream external source into useable energy using a working fluid comprising of a mixture of a low boiling component and a higher boiling component and including a higher pressure circuit and a lower pressure circuit. The cycle is designed to improve the efficiency of the energy extraction process by recirculating a portion of a liquid stream prior to further cooling. The new thermodynamic processes and systems for accomplishing these improved efficiencies are especially well-suited for streams from low-temperature geothermal sources.

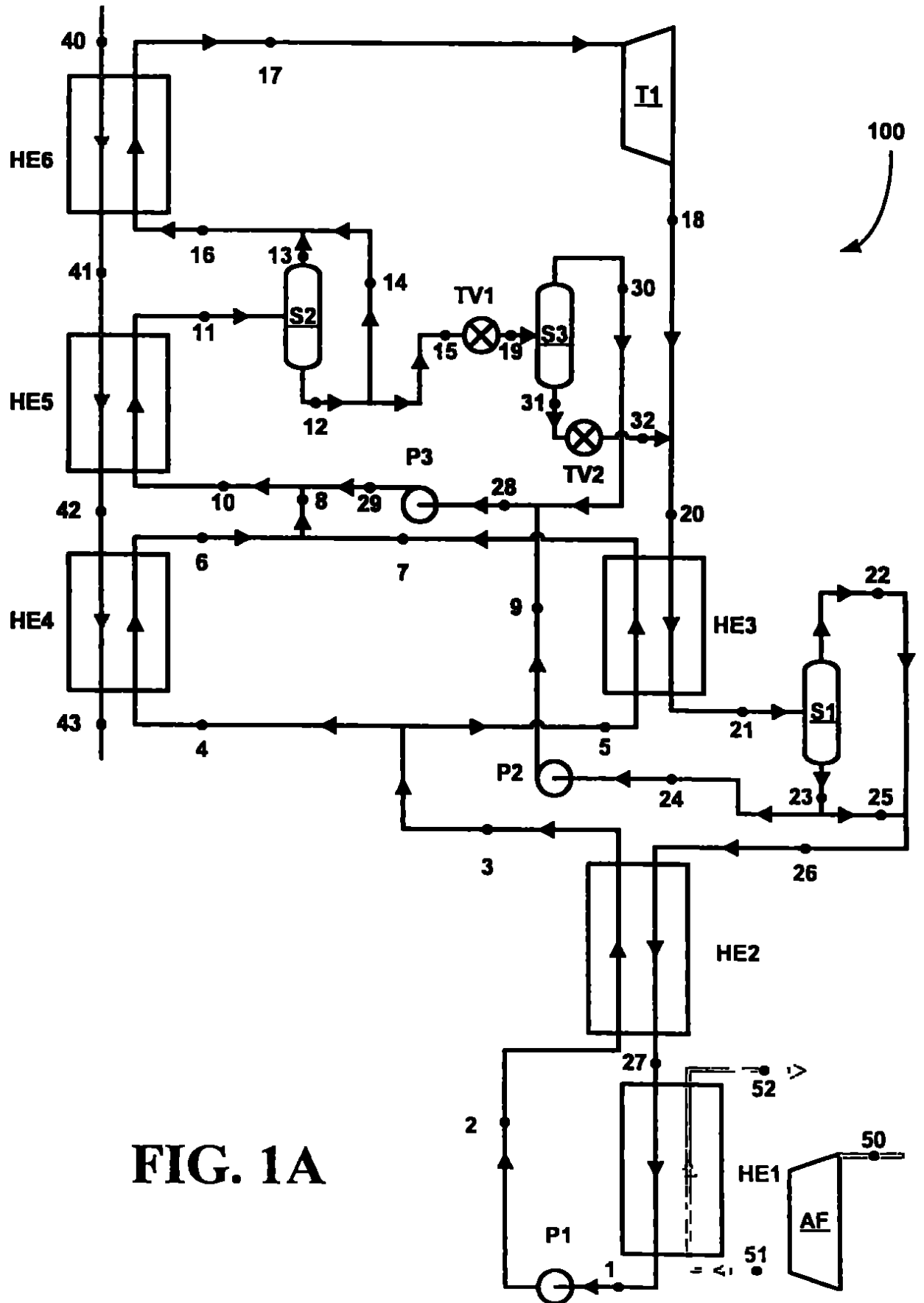


FIG. 1A

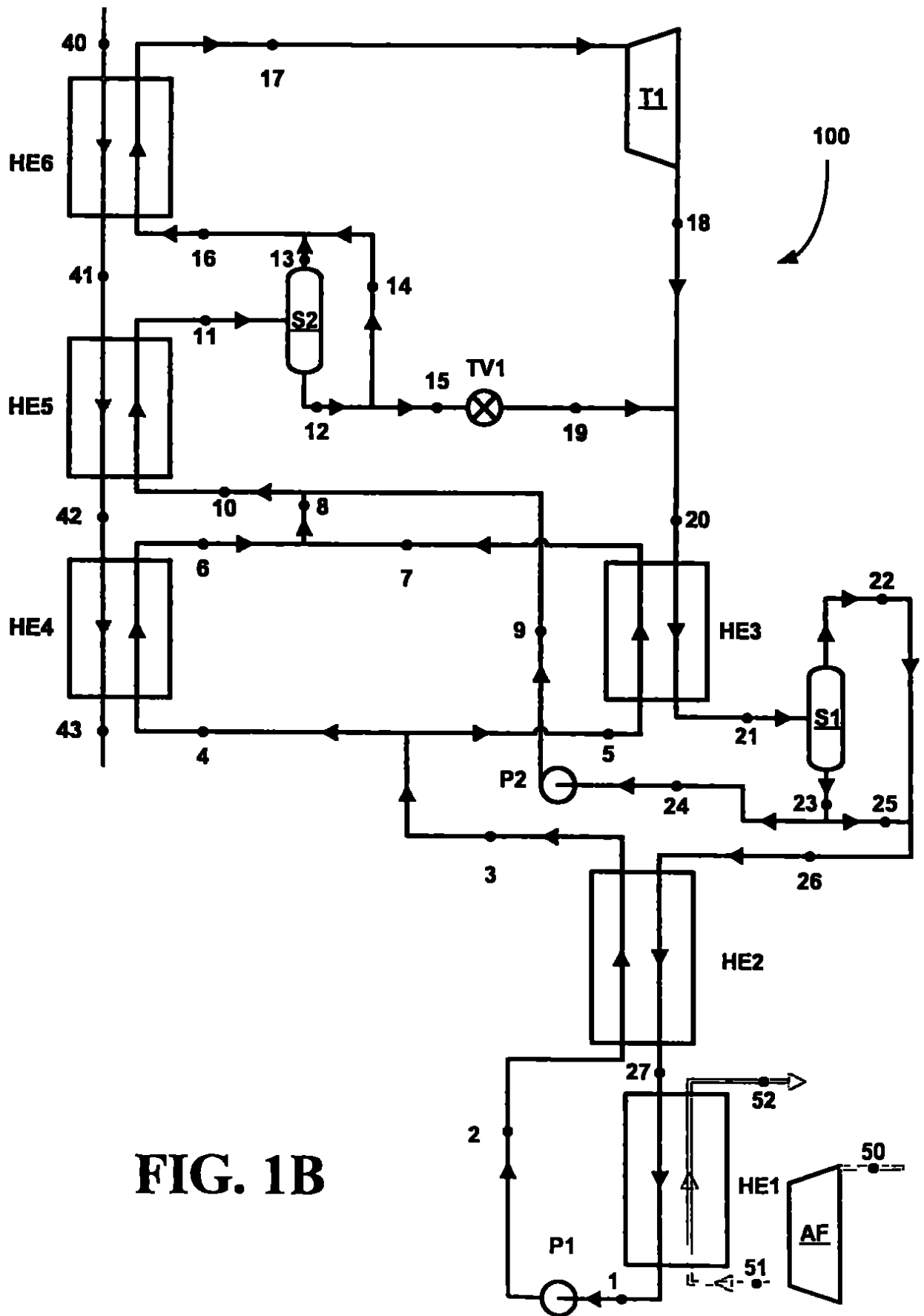
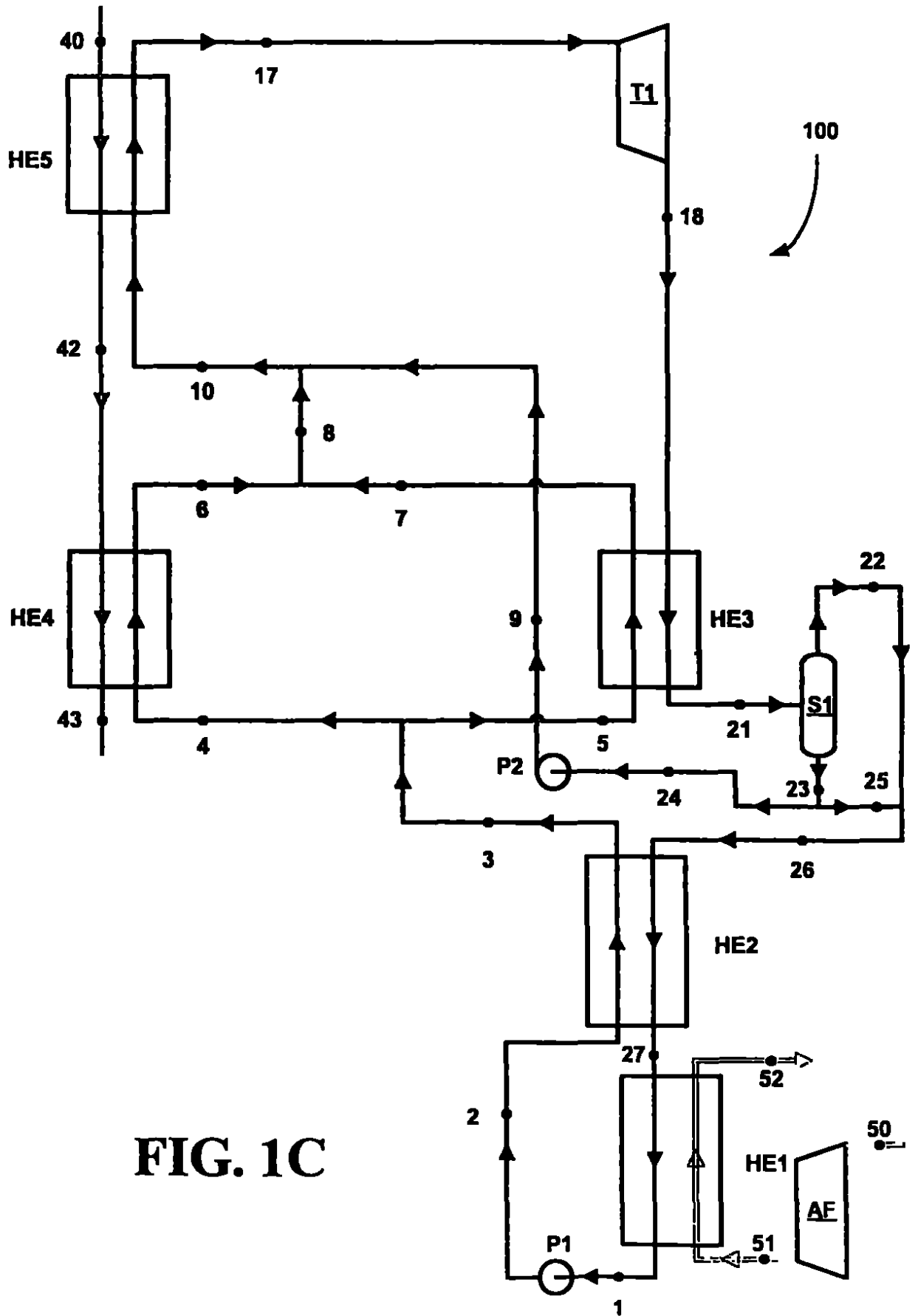


FIG. 1B



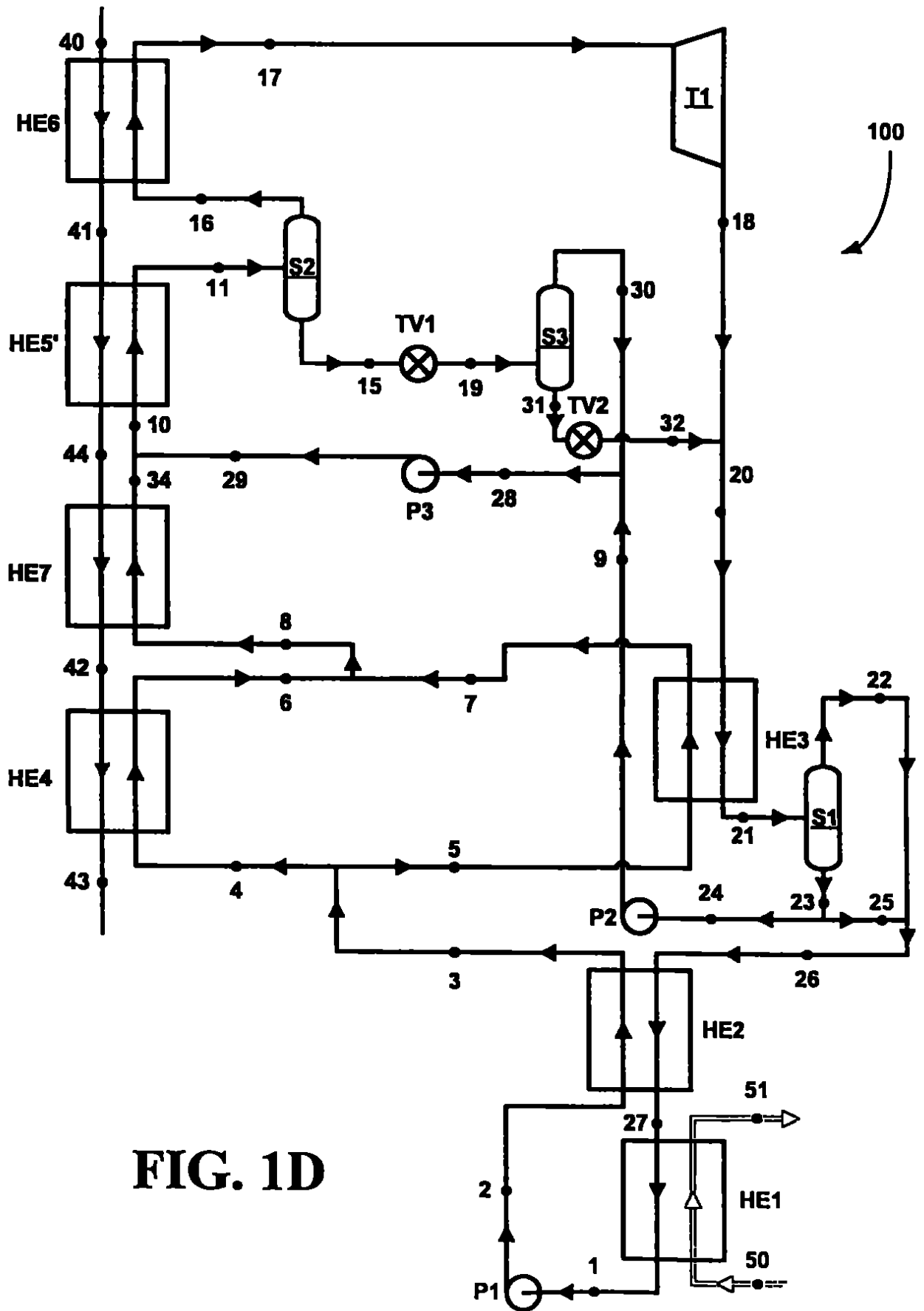


FIG. 1D

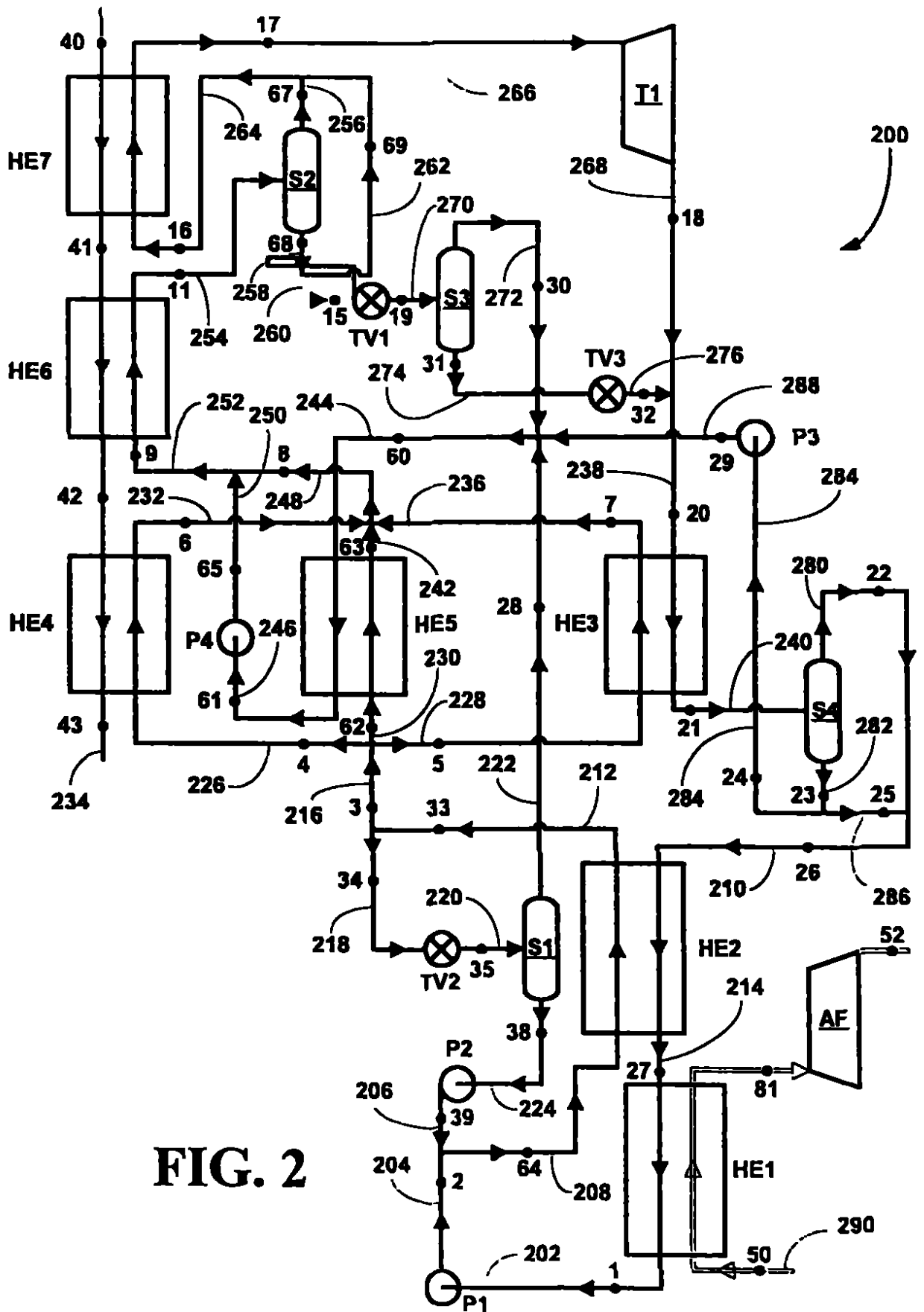


FIG. 2

129



EL 990554138 US

Mailing Label
Label 11-F June 2002



UNITED STATES POSTAL SERVICE

Post Office To Addressee

ORIGIN (POSTAL USE ONLY)				DELIVERY (POSTAL USE ONLY)			
PO ZIP Code	Day of Delivery ☐ Next ☐ Second	Post Rate Envelope		Delivery Attempt	Time ☐ AM ☐ PM	Employee Signature	
Date In	☐ 1st Day ☐ 2nd Day	Postage		Delivery Attempt	Time ☐ AM ☐ PM	Employee Signature	
Min. Day Year	☐ 1st Day ☐ 2nd Day	Return Receipt Fee		Delivery Date	Time ☐ AM ☐ PM	Employee Signature	
Time In	☐ AM ☐ PM	Return Receipt Fee		Min. Day Year	☐ AM ☐ PM	Employee Signature	
Weight	Int'l Alpha Country Code	COG Fee	Insurance Fee	☐ Signature of Addressee (Required Only) Additional conditions business to void if number of signatures in possession, I wish delivery to be made without obtaining signature of addressee or addressee's agent (I delivery employee judges that article not be left in secure location) and I authorize that delivery employee's signature constitutes valid proof of delivery. NO DELIVERY ☐ Standard ☐ Priority			
No Delivery	Acceptance Clerk Initials	Total Postage & Fees					
☐ Standard ☐ Priority		\$					
BUSINESS OF PATENT Express Mail Domestic Acc. No. K770738				Patent Agency Acc. No. or Patent Service Acc. No.			
FROM: (PLEASE PRINT) PHONE: 713 977 7000 ROBERT W STROZIER, PLLC PO BOX 0429 BELLAIRE TX 77402-0429 02019/04PCT				TO: (PLEASE PRINT) PHONE: _____ COMMISSIONER FOR PATENTS PO BOX 1450 ALEXANDRIA VA 22313-1450 MS PCT			

FOR PICKUP OR TRACKING CALL 1-800-222-1811 WWW.USPS.COM

21/ 50

F:Jc T:23

THE STAMP OF THE US PATENT OFFICE PLACED HEREON
ACKNOWLEDGES RECEIPT OF:

APPLICANT: KALINA

OR POWER CYCLE AND SYSTEM FOR UTILIZING MODERATE
AND LOW TEMPERATURE HEAT SOURCES

SERIAL NUMBER

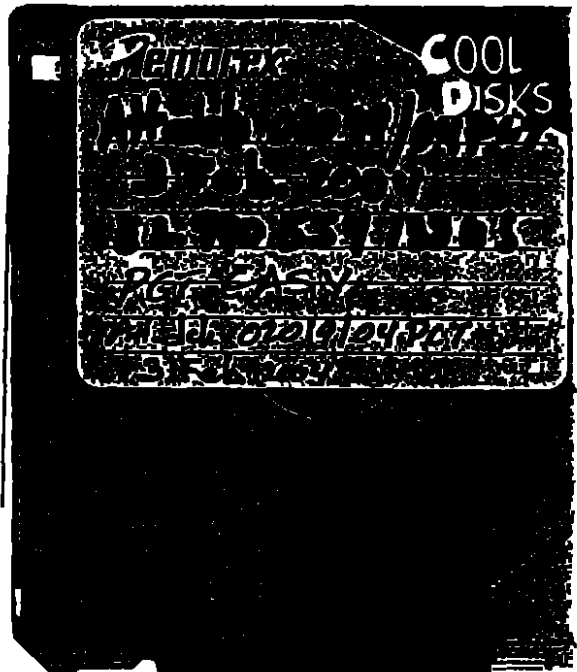
DOCKET NO: 02019/04PCT

DATE MAILED 3 FEBRUARY 2004

EXPRESS MAILING LABEL NO EL 990 554 138 US

- XI PCT REQUEST 4 PAGES
- DI PCT DESCRIPTION 21 PAGES
- DI PCT CLAIMS 4 PAGES
- DI PCT ABSTRACT 1 PAGE
- DI PCT DRAWINGS 5 SHEETS
- DI PCT FEE CALCULATION SHEET
- DI PCT EASY DISKETTE
- DI POSTCARD

□
□
□
□
□
□
□
□



Customer Copy
Label 11-F June 2002



EL 990554138 US



UNITED STATES POSTAL SERVICE®

Post Office To Addressee

ORIGIN (POSTAL USE ONLY)				DELIVERY (POSTAL USE ONLY)			
PO ZIP Code 77201	Day of Delivery ☒ Mon ☐ Tues ☐ Wed ☐ Thurs ☐ Fri ☐ Sat ☐ Sun	Flat Rate Envelope ☐	Postage \$ 13.65	Delivery Attempt Mo. Day Time ☐ AM ☐ PM	Employee Signature Date		
Class of Mail 334	Weight 19.05	Return Receipt Paid ☐	Delivery Attempt Mo. Day Time ☐ AM ☐ PM	Employee Signature Date			
Time by ☐ AM ☒ PM	Priority ☐ 1st Day ☐ 2nd Day ☐ 3rd Day	Insurance Fee \$	Delivery Date Mo. Day Time ☐ AM ☐ PM	Employee Signature Date			
No Delivery ☐ Business ☐ Holiday	Acceptance Check Initials S	Total Postage & Fees \$ 13.65					
Signature of Addressee Signature Mail Certificate No. 7770738				Signature of Addressee Signature Mail Certificate No. 7518194			
FROM: (PLS PRINT) RUBERT W STROZIEP, -PLLC PC 83X 0429 BELLAIKE TX 77402-0429 02019/04PCT				TO: (PLS PRINT) COMMISSIONER FOR PATENTS PO BOX 1450 ALEXANDRIA VA 22313-2450 MS PCT			

FOR PICKUP OR TRACKING CALL 1-800-222-1811 www.usps.com

PD BELLAIKE
02019/04PCT
FOR PICKUP OR TRACKING CALL 1-800-222-1811 www.usps.com
21/ 50 F:JL 1:23

THE STAMP OF THE US PATENT OFFICE PLACED HEREON
ACKNOWLEDGES RECEIPT OF

THE STAMP OF THE US PATENT OFFICE PLACED HEREON
ACKNOWLEDGES RECEIPT OF
PCT/US 04/03025
APPLICANTS KALINA
FOR POWER CYCLE AND SYSTEM FOR UTILIZING MODERATE
AND LOW TEMPERATURE HEAT SOURCES
DOCKET NO 02019/04PCT
SERIAL NUMBER
DATE MAILED 3 FEBRUARY 2004
EXPRESS MAILING LABEL NO EL 990 554 138 US

- ☒ PCT REQUEST 4 PAGES
 - ☒ PCT DESCRIPTION 21 PAGES
 - ☒ PCT CLAIMS 4 PAGES
 - ☒ PCT ABSTRACT 1 PAGE
 - ☒ PCT DRAWINGS 5 SHEETS
 - ☒ PCT FEE CALCULATION SHEET
 - ☒ PCT EASY DISKETTE
 - ☒ POSTCARD
- 7518223
UT20 Rec'd PCT/PTO 03 FEB 2004



PATENT COOPERATION TREATY

FEB 18 2004

131

From the RECEIVING OFFICE

PCT

To
ROBERT W STROZIER
P O BOX 429
BELLAIRE TEXAS 77402-0429

NOTIFICATION CONCERNING PAYMENT
OF PRESCRIBED FEES

(PCT Rules 14, 15 and 16 and Administrative
Instructions, Sections 102b4(c), 304
323(b), 707(b) and 803)

Date of mailing
(day/month/year) 13 Feb.2004

Applicant's or agent's file reference
02018/04PCT

PAYMENT DUE
see item 3 for time limits

International application No
PCT/US2004/003025

International filing date/Date of receipt
(day/month/year) 03 Feb.2004

Priority date (day/month/year)
03 Feb 2003

Applicant
KALEX INC

1 The applicant is hereby notified that this receiving Office has received

- ☐ the payment of all the prescribed fees, and ☐ an overpayment, which will be refunded in due course.
☒ no or insufficient payment of the prescribed fees and the applicant is hereby invited to pay the balance due, as summarized under item 2 within the time limit(s) indicated under item 3

2 Fees and payment calculation

3 174.00	-	0 00	=	3,174.00
Total fees payable		Amount paid		Balance

- ☒ The details of the calculation are given in the Annex.

3 Time limit(s) for payment and amount(s) payable (Rules 14.1, 15.4 and 16.1(f)):

- ☒ within ONE MONTH from the date of receipt of the international application (for the transmittal fee (if any), the search fee and the international filing fee). The amount payable for each fee is the amount applicable on the date of receipt of the international application.
☒ within 16 MONTHS from the priority date (only for the fee for priority documents). The applicant's attention is drawn to the fact that the request made by the applicant under Rule 17.1(b) will be considered not to have been made unless the fee is paid within that time limit.

4 Additional observations (if necessary)

- ☒ The search copy will not be transmitted to the International Searching Authority until the search fee is paid (therefore the start of the international search will be delayed) (Rule 23.1(a) and (b))

Name and mailing address of the receiving Office
Mail Stop PCT Commissioner for Patents
P O Box 1450 Alexandria, VA 22313 1450

Authorized officer
Ariessa Smith

Facsimile No 703-305-3230

Telephone No 703-305-3230

Form PCT/RO/102 (January 2004)

BY Am DATE 2/25/04
FOR ACTION ON FOLLOWING DATES

3/1/04

ANNEX TO FORM PCT/RO/102
CALCULATION OF THE PRESCRIBED FEES

International application No.
PCT/US2004/003025

132

T Transmittal Fee

Prescribed amount		300 00	T	
Amount paid	-	0 00		☐ correct amount
Balance	-	300 00		☐ overpayment
				☒ balance due

S Search Fee

Prescribed amount		1 818 00	S	
Amount paid	-	0 00		☐ correct amount
Balance	-	1 818 00		☐ overpayment
				☒ balance due

I International Filing Fee

Fixed amount for first 30 sheets		961 00	I1
$\frac{5}{\text{Number of sheets in excess of 30}} \times \frac{11 00}{\text{Fee per sheet}}$	=	55 00	I2
Additional component: $400 \times \frac{0 00}{\text{Fee per sheet}}$	=	0 00	I3

Reduction where the international application is filed
(See PCT Applicant's Guide, Volume I General Part,
for details on the availability of this reduction)
using the PCT-EASY software: - 0.00 **I4**

or
in electronic form where the text of the
description, claims and abstract is not in
character coded format. - 0 00 **I5**

or
in electronic form where the text of the
description, claims and abstract is in character
coded format: - 0 00 **I6**

Sub-total = 1 016.00 **I1+I2+I3-I4**

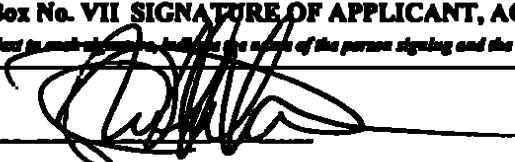
Prescribed total amount (The amount to be entered at I is the sub-total
entered at I1+I2+I3-I4, except where the applicant is (for all applicants
are) entitled to a reduction of 75%, in which case the amount to be
entered at I is 75% of the sub-total (I1+I2+I3-I4) certain applicants from
certain States are entitled to a reduction of 75% of the international
filing fee see Notes to the Fee Calculation Sheet as annexed to the
Request Form, PCT/RO/101 for details)

		1 016 00	I	
Amount paid	-	0 00		☐ correct amount
Balance	-	1 016 00		☐ overpayment
				☒ balance due

P Fee for Priority Document

Prescribed amount		40 00	P	
Amount paid	-	0 00		☐ correct amount
Balance	-	40 00		☐ overpayment
				☒ balance due

Sheet No		International application No PCT/US2004/003025
Box No III AGENT OR COMMON REPRESENTATIVE OR ADDRESS FOR CORRESPONDENCE		
The following person is ☒ agent ☐ common representative and ☐ has been appointed earlier and represents the applicant(s) also for international preliminary examination ☐ is hereby appointed and any earlier appointment of (an) agent(s) /common representative is hereby revoked ☐ is hereby appointed, specifically for the procedure before the International Preliminary Examining Authority in addition to the agent(s)/common representative appointed earlier		
Name and address. <i>(Family name followed by given name for a legal entity full official designation. The address must include postal code and name of country.)</i> Robert W Strozzer PLLC Robert W Strozzer P O Box 428 Bellaire TX 77401		Telephone No. 713 977 7000 Facsimile No 713 977 7011 Teleprinter No. n/a Agent's registration No. with the Office 34 024
☐ Address for correspondence Mark this check-box where no agent or common representative is/has been appointed and the space above is used instead to indicate a special address to which correspondence should be sent.		
Box No. IV BASIS FOR INTERNATIONAL PRELIMINARY EXAMINATION		
Statement concerning amendments * 1 ☒ The applicant wishes the international preliminary examination to start on the basis of ☒ the international application as originally filed. the description ☒ as originally filed ☐ as amended under Article 34 the claims ☒ as originally filed ☐ as amended under Article 19 (together with any accompanying statement) ☐ as amended under Article 34 the drawings ☒ as originally filed ☐ as amended under Article 34 2 ☐ The applicant wishes any amendment to the claims under Article 19 to be considered as reversed. 3 ☐ The applicant wishes the start of the international preliminary examination to be postponed until the expiration of 20 months from the priority date unless the International Preliminary Examining Authority receives a copy of any amendments made under Article 19 or a notice from the applicant that he does not wish to make such amendments (Rule 69 1(d)). <i>(This check-box may be marked only where the time limit under Article 19 has not yet expired.)</i> * Where no check-box is marked, international preliminary examination will start on the basis of the international application as originally filed or where a copy of amendments to the claims under Article 19 and/or amendments of the international application under Article 34 are received by the International Preliminary Examining Authority before it has begun to draw up a written opinion or the international preliminary examination report, as so amended.		
Language for the purposes of international preliminary examination English ☒ which is the language in which the international application was filed ☐ which is the language of a translation furnished for the purposes of international search ☐ which is the language of publication of the international application ☐ which is the language of the translation (to be) furnished for the purposes of international preliminary examination		
Box No V ELECTION OF STATES		
The applicant hereby elects all eligible States <i>(that is all States which have been designated and which are bound by Chapter II of the PCT)</i> excluding the following States which the applicant wishes not to elect		

Sheet No	International application No. PCT/US2004/003025																																		
Box No VI CHECK LIST																																			
The demand is accompanied by the following elements, in the language referred to in Box No. IV for the purposes of international preliminary examination <table style="width:100%; border-collapse: collapse;"><tr><td style="width: 60%;">1 translation of international application</td><td style="width: 10%; text-align: center;">sheets</td><td style="width: 10%;"></td><td style="width: 10%; text-align: center;">received</td><td style="width: 10%; text-align: center;">not received</td></tr><tr><td>2 amendments under Article 34</td><td style="text-align: center;">sheets</td><td></td><td style="text-align: center;">☐</td><td style="text-align: center;">☐</td></tr><tr><td>3 copy (or where required, translation) of amendments under Article 19</td><td style="text-align: center;">sheets</td><td></td><td style="text-align: center;">☐</td><td style="text-align: center;">☐</td></tr><tr><td>4 copy (or where required, translation) of statement under Article 19</td><td style="text-align: center;">sheets</td><td></td><td style="text-align: center;">☐</td><td style="text-align: center;">☐</td></tr><tr><td>5 letter</td><td style="text-align: center;">sheets</td><td></td><td style="text-align: center;">☐</td><td style="text-align: center;">☐</td></tr><tr><td>6 other (specify)</td><td style="text-align: center;">sheets</td><td></td><td style="text-align: center;">☐</td><td style="text-align: center;">☐</td></tr></table>	1 translation of international application	sheets		received	not received	2 amendments under Article 34	sheets		☐	☐	3 copy (or where required, translation) of amendments under Article 19	sheets		☐	☐	4 copy (or where required, translation) of statement under Article 19	sheets		☐	☐	5 letter	sheets		☐	☐	6 other (specify)	sheets		☐	☐	For International Preliminary Examining Authority use only				
1 translation of international application	sheets		received	not received																															
2 amendments under Article 34	sheets		☐	☐																															
3 copy (or where required, translation) of amendments under Article 19	sheets		☐	☐																															
4 copy (or where required, translation) of statement under Article 19	sheets		☐	☐																															
5 letter	sheets		☐	☐																															
6 other (specify)	sheets		☐	☐																															
The demand is also accompanied by the item(s) marked below <table style="width:100%; border-collapse: collapse;"><tr><td style="width: 50%; vertical-align: top;">1 ☒ fee calculation sheet</td><td style="width: 50%; vertical-align: top;">5 ☐ statement explaining lack of signature</td></tr><tr><td style="vertical-align: top;">2 ☐ original separate power of attorney</td><td style="vertical-align: top;">6 ☐ sequence listing in computer readable form</td></tr><tr><td style="vertical-align: top;">3 ☐ original general power of attorney</td><td style="vertical-align: top;">7 ☐ other (specify)</td></tr><tr><td style="vertical-align: top;">4 ☐ copy of general power of attorney reference number if any</td><td></td></tr></table>										1 ☒ fee calculation sheet	5 ☐ statement explaining lack of signature	2 ☐ original separate power of attorney	6 ☐ sequence listing in computer readable form	3 ☐ original general power of attorney	7 ☐ other (specify)	4 ☐ copy of general power of attorney reference number if any																			
1 ☒ fee calculation sheet	5 ☐ statement explaining lack of signature																																		
2 ☐ original separate power of attorney	6 ☐ sequence listing in computer readable form																																		
3 ☐ original general power of attorney	7 ☐ other (specify)																																		
4 ☐ copy of general power of attorney reference number if any																																			
Box No. VII SIGNATURE OF APPLICANT, AGENT OR COMMON REPRESENTATIVE <i>Must be made in ink or indelible ink and the name of the person signing and the capacity in which the person signs (if such capacity is not obvious from reading the demand).</i>  _____ Robert W Strozler 7/22/04 _____ DATE																																			

For International Preliminary Examining Authority use only	
1 Date of actual receipt of DEMAND	
2 Adjusted date of receipt of demand due to CORRECTIONS under Rule 60 1(b)	
3 ☐ The date of receipt of the demand is AFTER the expiration of 19 months from the priority date and item 4 or 5 below does not apply	☐ The applicant has been informed accordingly
4 ☐ The date of receipt of the demand is WITHIN the period of 19 months from the priority date as extended by virtue of Rule 80 5	
5 ☐ Although the date of receipt of the demand is after the expiration of 19 months from the priority date, the delay in arrival is EXCUSED pursuant to Rule 82	

For International Bureau use only	
Demand received from IPFA on	

Sheet No		International application No PCT/US2004/003025
Continuation of Box No II APPLICANT(S) <i>If none of the following sub-boxes is used this sheet should not be included in the demand</i>		
Name and address <i>(Family name followed by given name for a legal entity full official designation. The address must include postal code and name of country.)</i>		
State <i>(that is country)</i> of nationality		State <i>(that is country)</i> of residence
Name and address <i>(Family name followed by given name for a legal entity full official designation. The address must include postal code and name of country.)</i>		
State <i>(that is country)</i> of nationality		State <i>(that is country)</i> of residence
Name and address <i>(Family name followed by given name for a legal entity full official designation. The address must include postal code and name of country.)</i>		
State <i>(that is country)</i> of nationality		State <i>(that is country)</i> of residence
Name and address <i>(Family name followed by given name for a legal entity full official designation. The address must include postal code and name of country.)</i>		
State <i>(that is country)</i> of nationality		State <i>(that is country)</i> of residence
☐ Further applicants are indicated on another continuation sheet		

The demand must be filed directly with the competent International Preliminary Examining Authority or if two or more Authorities are
jointly chosen by the applicant. The full name or two-letter code of that Authority may be indicated by the applicant on the line below.
IPEA/ US

PCT

CHAPTER II

DEMAND

under Article 31 of the Patent Cooperation Treaty
The undersigned requests that the international application specified below be the subject of
international preliminary examination according to the Patent Cooperation Treaty and
hereby elects all eligible States (except where otherwise indicated).

For International Preliminary Examining Authority use only			
Identification of IPEA		Date of receipt of DEMAND	
Box No. I IDENTIFICATION OF THE INTERNATIONAL APPLICATION		Applicant's or agent's file reference 02019/04PCT	
International application No PCT/US2004/003025	International filing date (day/month/year) 03 Feb 2004 (03.02.04)	(Earliest) Priority date (day/month/year) 03 Feb 2003 (03.02.2003)	
Title of invention Power Cycle and System for Utilizing Moderate and Low Temperature Heat Sources			
Box No. II APPLICANT(S)			
Name and address (Family name followed by given name for a legal entity, full official designation. The address must include postal code and name of country.) KALEX, LLC 2630 Carlmont Drive Belmont, CA 94002 United States of America USA		Telephone No. 850 343 8089	
		Facsimile No. 850.595- 1792	
		Teleprinter No. N/A	
		Applicant's registration No. with the Office 34 024	
State (that is, country) of nationality US		State (that is, country) of residence US	
Name and address (Family name followed by given name for a legal entity full official designation. The address must include postal code and name of country.) Alexander I Kalina 105 Glengarry Way Hillsborough CA 94010-7313 US			
State (that is, country) of nationality US		State (that is, country) of residence US	
Name and address (Family name followed by given name for a legal entity full official designation. The address must include postal code and name of country.)			
State (that is, country) of nationality		State (that is, country) of residence	
☐ Further applicants are indicated on a continuation sheet			

PATENT C OPERATION TREATY

738

From the INTERNATIONAL SEARCHING AUTHORITY

PCT

To
STROZIER Robert W
P O Box 429
Bellaire TX 77042-0429
UNITED STATES OF AMERICA

NOTIFICATION OF TRANSMITTAL OF
THE INTERNATIONAL SEARCH REPORT AND
THE WRITTEN OPINION OF THE INTERNATIONAL
SEARCHING AUTHORITY OR THE DECLARATION

(PCT Rule 44.1)

Date of mailing (day/month/year) 02/07/2004	
Applicant's or agent's file reference 02019/04PCT	FOR FURTHER ACTION See paragraphs 1 and 4 below
International application No PCT/US2004/003025	International filing date (day/month/year) 03/02/2004
Applicant KALEX INC	

- 1 ☒ The applicant is hereby notified that the international search report and the written opinion of the International Searching Authority have been established and are transmitted herewith.
- Filing of amendments and statement under Article 19:**
The applicant is entitled, if he so wishes, to amend the claims of the International Application (see Rule 48).
- When?** The time limit for filing such amendments is normally 2 months from the date of transmittal of the International Search Report, however for more details, see the notes on the accompanying sheet.
- Where?** Directly to the International Bureau of WIPO 34 chemin des Colombettes
1211 Geneva 20 Switzerland Facsimile No. (41-22) 740 14.35
- For more detailed instructions, see the notes on the accompanying sheet.
- 2 ☐ The applicant is hereby notified that no international search report will be established and that the declaration under Article 17(2)(a) to that effect and the written opinion of the International Searching Authority are transmitted herewith.
- 3 ☐ With regard to the protest against payment of (an) additional fee(s) under Rule 40.2, the applicant is notified that:
- ☐ the protest together with the decision thereon has been transmitted to the International Bureau together with the applicant's request to forward the texts of both the protest and the decision thereon to the designated Offices.
- ☐ no decision has been made yet on the protest; the applicant will be notified as soon as a decision is made.
- 4 **Reminders**
- Shortly after the expiration of 18 months from the priority date the international application will be published by the International Bureau. If the applicant wishes to avoid or postpone publication a notice of withdrawal of the international application, or of the priority claim, must reach the International Bureau as provided in Rules 90bis.1 and 90bis.3 respectively before the completion of the technical preparations for international publication.
- The applicant may submit comments on an informal basis on the written opinion of the International Searching Authority to the International Bureau. The International Bureau will send a copy of such comments to all designated Offices unless an international preliminary examination report has been or is to be established. These comments would also be made available to the public but not before the expiration of 30 months from the priority date.
- Within 18 months from the priority date but only in respect of some designated Offices, a demand for international preliminary examination must be filed if the applicant wishes to postpone the entry into the national phase until 30 months from the priority date (in some Offices even later) otherwise the applicant must, within 20 months from the priority date perform the prescribed acts for entry into the national phase before those designated Offices.
- In respect of other designated Offices the time limit of 30 months (or later) will apply even if no demand is filed within 18 months.
- See the Annex to Form PCT/IB/301 and, for details about the applicable time limits, Office by Office see the *PCT Applicant's Guide* Volume II National Chapters and the WIPO internet site.

Name and mailing address of the International Searching Authority  European Patent Office P.B. 5818 Patentlaan 2 NL-2280 HV Rijswijk Tel (+31-70) 340-2040 Tx 31 851 epo nl Fax (+31-70) 340-3016	Authorized officer Line Wagnersen
--	--------------------------------------

These Notes are intended to give the basic instructions concerning the filing of amendments under article 19. The Notes are based on the requirements of the Patent Cooperation Treaty, the Regulations and the Administrative Instructions under that Treaty. In case of discrepancy between these Notes and those requirements, the latter are applicable. For more detailed information, see also the PCT Applicant's Guide, a publication of WIPO.

In these Notes, "Article", "Rule" and "Section" refer to the provisions of the PCT, the PCT Regulations and the PCT Administrative Instructions respectively.

INSTRUCTIONS CONCERNING AMENDMENTS UNDER ARTICLE 19

The applicant has, after having received the international search report, one opportunity to amend the claims of the international application. It should however be emphasized that, since all parts of the international application (claims, description and drawings) may be amended during the international preliminary examination procedure, there is usually no need to file amendments of the claims under Article 19 except where, e.g. the applicant wants the letter to be published for the purposes of provisional protection or has another reason for amending the claims before international publication. Furthermore, it should be emphasized that provisional protection is available in some States only.

What parts of the international application may be amended?

Under Article 19, only the claims may be amended.

During the international phase, the claims may also be amended (or further amended) under Article 34 before the International Preliminary Examining Authority. The description and drawings may only be amended under Article 34 before the International Examining Authority.

Upon entry into the national phase, all parts of the international application may be amended under Article 28 or, where applicable, Article 41.

When?

Within 2 months from the date of transmittal of the international search report or 16 months from the priority date, whichever time limit expires later. It should be noted, however, that the amendments will be considered as having been received on time if they are received by the International Bureau after the expiration of the applicable time limit but before the completion of the technical preparations for international publication (Rule 46.1).

Where not to file the amendments?

The amendments may only be filed with the International Bureau and not with the receiving Office or the International Searching Authority (Rule 48.2).

Where a demand for international preliminary examination has been filed, see below.

How?

Either by cancelling one or more entire claims, by adding one or more new claims or by amending the text of one or more of the claims as filed.

A replacement sheet must be submitted for each sheet of the claims which, on account of an amendment or amendments, differs from the sheet originally filed.

All the claims appearing on a replacement sheet must be numbered in Arabic numerals. Where a claim is cancelled, no renumbering of the other claims is required. In all cases where claims are renumbered, they must be renumbered consecutively (Administrative Instructions, Section 205(b)).

The amendments must be made in the language in which the international application is to be published.

What documents must/may accompany the amendments?

Letter (Section 208(b)).

The amendments must be submitted with a letter.

The letter will not be published with the international application and the amended claims. It should not be confused with the "Statement under Article 19(1)" (see below, under "Statement under Article 19(1)").

The letter must be in English or French, at the choice of the applicant. However, if the language of the international application is English, the letter must be in English. If the language of the international application is French, the letter must be in French.

The letter must indicate the differences between the claims as filed and the claims as amended. It must in particular indicate in connection with each claim appearing in the international application (it being understood that identical indications concerning several claims may be grouped) whether

- (i) the claim is unchanged;
- (ii) the claim is cancelled;
- (iii) the claim is new;
- (iv) the claim replaces one or more claims as filed;
- (v) the claim is the result of the division of a claim as filed.

The following examples illustrate the manner in which amendments must be explained in the accompanying letter:

1. [Where originally there were 48 claims and after amendment of some claims there are 51]
"Claims 1 to 29, 31, 32, 34, 35, 37 to 48 replaced by amended claims bearing the same numbers, claims 30, 33 and 36 unchanged, new claims 49 to 51 added"
2. [Where originally there were 15 claims and after amendment of all claims there are 11]
"Claims 1 to 15 replaced by amended claims 1 to 11"
3. [Where originally there were 14 claims and the amendments consist in cancelling some claims and in adding new claims]
"Claims 1 to 6 and 14 unchanged; claims 7 to 13 cancelled; new claims 15, 16 and 17 added. or
"Claims 7 to 13 cancelled; new claims 15, 16 and 17 added; all other claims unchanged."
4. [Where various kinds of amendments are made]
"Claims 1, 10 unchanged; claims 11 to 13, 16 and 18 cancelled; claims 14, 15 and 16 replaced by amended claim 14, claim 17 subdivided into amended claims 15, 16 and 17; new claims 20 and 21 added."

"Statement under Article 19(1)" (Rule 48.4)

The amendments may be accompanied by a statement explaining the amendments and indicating any impact that such amendments might have on the description and the drawings (which cannot be amended under Article 19(1)).

The statement will be published with the international application and the amended claims.

It must be in the language in which the international application is to be published.

It must be brief: not exceeding 500 words if in English or if translated into English.

It should not be confused with and does not replace the letter indicating the differences between the claims as filed and as amended. It must be filed on a separate sheet and must be identified as such by a heading, preferably by using the words "Statement under Article 19(1)".

It may not contain any disparaging comments on the international search report or the relevance of citations contained in that report. References to citations, relevant to a given claim, contained in the international search report may be made only in connection with an amendment of that claim.

Consequence if a demand for international preliminary examination has already been filed

If, at the time of filing any amendments under Article 19, a demand for international preliminary examination has already been submitted, the applicant must preferably, at the same time of filing the amendments with the International Bureau, also file a copy of such amendments with the International Preliminary Examining Authority (see Rule 62.2(a), first sentence).

Consequence with regard to translation of the international application for entry into the national phase

The applicant's attention is drawn to the fact that, where upon entry into the national phase, a translation of the claims as amended under Article 19 may have to be furnished to the designated/elected Office, instead of, or in addition to, the translation of the claims as filed.

For further details on the requirements of each designated/elected Office, see Volume II of the PCT Applicant's Guide.

Applicant's or agent's file reference 02019/04PCT	FOR FURTHER ACTION see Form PCT/ISA/220 as well as where applicable item 5 below	
International application No. PCT/US2004/003025	International filing date (day/month/year) 03/02/2004	(Earliest) Priority Date (day/month/year) 03/02/2003
Applicant KALEX INC		

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of 4 sheets.

☒ It is also accompanied by a copy of each prior art document cited in this report.

1. Basis of the report

a. With regard to the language, the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.

☐ The international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).

b. ☐ With regard to any nucleotide and/or amino acid sequence disclosed in the international application, see Box No. I.

2. ☐ Certain claims were found unsearchable (See Box II).

3. ☐ Unity of invention is lacking (see Box III).

4. With regard to the title,

☒ the text is approved as submitted by the applicant.

☐ the text has been established by this Authority to read as follows.

5. With regard to the abstract,

☒ the text is approved as submitted by the applicant.

☐ the text has been established according to Rule 38.2(b) by this Authority as it appears in Box No. IV. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. With regards to the drawings

a. the figure of the drawings to be published with the abstract is Figure No. 1c

☐ as suggested by the applicant.

☐ as selected by this Authority because the applicant failed to suggest a figure.

☒ as selected by this Authority because this figure better characterizes the invention.

b. ☐ none of the figures is to be published with the abstract.

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US2004/003025A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 F01K25/06

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 F01K F03G

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication where appropriate of the relevant passages	Relevant to claim No.
A	EP 0 652 368 A (EXERGY INC) 10 May 1995 (1995-05-10) page 3, line 55 -page 8, line 3 abstract, figures	1-6
A	US 4 548 043 A (KALINA ALEXANDER I) 22 October 1985 (1985-10-22) column 1, line 4 -column 2, line 60 abstract, figures 1-4	1-6
A	EP 0 472 020 A (KALINA ALEXANDER IFAEVICH) 26 February 1992 (1992-02-26) page 1, line 37 -page 6, line 26 abstract, figure	1,2,5,6
P,A	US 2003/167769 A1 (BHARATHAN DESIKAN ET AL) 11 September 2003 (2003-09-11) abstract, figures 1,4	1,2,5,6
	-/--	

☒ Further documents are listed in the continuation of box C☒ Patent family members are listed in annex

Special categories of cited documents

- A document defining the general state of the art which is not considered to be of particular relevance
- E earlier document but published on or after the international filing date
- L document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document relating to an oral disclosure, use, exhibition or other means
- P" document published prior to the international filing date but later than the priority date claimed

- T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- X* document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- Y* document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
- A document member of the same patent family

Date of the actual completion of the international search

28 June 2004

Date of mailing of the international search report

02/07/2004

Name and mailing address of the ISA

European Patent Office, P. B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel (+31-70) 340-2040, Tx 31 851 apo nl
Fax (+31-70) 340-3016

Authorized officer

Zerf, 6

INTERNATIONAL SEARCH REPORT

143

International Application No
PCT/US2004/003025

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category	Citation of document with indication where appropriate of the relevant passages	Relevant to claim No
A	US 4 982 568 A (KALINA ALEXANDER I) 8 January 1991 (1991-01-08) cited in the application column 3, line 36 -column 12, line 7 abstract, figures ---	3 4
E	US 2004/055302 A1 (KALINA ALEXANDER I) 25 March 2004 (2004-03-25) the whole document ---	1-6
E	US 2004/050048 A1 (KALINA ALEXANDER I) 18 March 2004 (2004-03-18) the whole document -----	1-6

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/US2004/003025

Patent document cited in search report		Publication date		Patent family member(s)	Publication date
EP 0652368	A	10-05-1995	US	5440882 A	15-08-1995
			AT	161074 T	15-12-1997
			CN	1110762 A ,B	25-10-1995
			DE	69407261 D1	22-01-1998
			DE	69407261 T2	23-04-1998
			DK	652368 T3	09-02-1998
			EP	0652368 A1	10-05-1995
			ES	2111258 T3	01-03-1998
			GR	3026220 T3	29-05-1998
			IT	1276054 B1	24-10-1997
			JP	7208117 A	08-08-1995
			NZ	264705 A	21-12-1995
			RU	2123606 C1	20-12-1998
US 4548043	A	22-10-1985	AU	578961 B2	10-11-1988
			AU	4518685 A	01-05-1986
			BR	8504116 A	17-06-1986
			CA	1216433 A1	13-01-1987
			CN	85106253 A ,B	10-04-1986
			DE	3567059 D1	02-02-1989
			EP	0180295 A1	07-05-1986
			ES	8608624 A1	01-12-1986
			IL	75859 A	18-01-1990
			IN	165121 A1	19-08-1989
			JP	1674446 C	26-06-1992
			JP	3036129 B	30-05-1991
			JP	61104108 A	22-05-1986
			KR	9209138 B1	13-10-1992
			MX	159176 A	27-04-1989
			PT	80873 A ,B	01-08-1985
			ZA	8505491 A	26-03-1986
EP 0472020	A	26-02-1992	US	5029444 A	09-07-1991
			AT	126566 T	15-09-1995
			CN	1059014 A ,B	26-02-1992
			DE	69112155 D1	21-09-1995
			DE	69112155 T2	04-01-1996
			DK	472020 T3	27-12-1995
			EP	0472020 A1	26-02-1992
			ES	2078396 T3	16-12-1995
			GR	3017789 T3	31-01-1996
			JP	2716606 B2	18-02-1998
			JP	6026441 A	01-02-1994
			MX	9100666 A1	01-04-1992
			NZ	239143 A	23-12-1993
US 2003167769	A1	11-09-2003	NONE		
US 4982568	A	08-01-1991	IT	1240752 B	17-12-1993
			JP	2245405 A	01-10-1990
			JP	2962751 B2	12-10-1999
			NZ	232060 A	26-07-1991
US 2004055302	A1	25-03-2004	WO	2004027325 A2	01-04-2004
US 2004050048	A1	18-03-2004	NONE		

PATENT COOPERATION TREATY

145

From the
INTERNATIONAL SEARCHING AUTHORITY

To

PCT

see form PCT/ISA/220

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY (PCT Rule 43bis 1)

Date of mailing
(day/month/year) see form PCT/ISA/210 (second sheet)

Applicant's or agent's file reference
see form PCT/ISA/220

FOR FURTHER ACTION
See paragraph 2 below

International application No
PCT/US2004/003025

International filing date (day/month/year)
03 02 2004

Priority date (day/month/year)
03 02 2003

International Patent Classification (IPC) or both national classification and IPC
F01K25/06

Applicant
KALEX INC

1 This opinion contains indications relating to the following items

- ☒ Box No I Basis of the opinion
- ☒ Box No II Priority
- ☐ Box No III Non-establishment of opinion with regard to novelty inventive step and industrial applicability
- ☐ Box No IV Lack of unity of invention
- ☒ Box No V Reasoned statement under Rule 43bis.1(a)(i) with regard to novelty inventive step or industrial applicability citations and explanations supporting such statement
- ☐ Box No VI Certain documents cited
- ☐ Box No VII Certain defects in the international application
- ☐ Box No VIII Certain observations on the international application

2 FURTHER ACTION

If a demand for international preliminary examination is made this opinion will usually be considered to be a written opinion of the International Preliminary Examining Authority (IPEA). However this does not apply where the applicant chooses an Authority other than this one to be the IPEA and the chosen IPEA has notified the International Bureau under Rule 86 1bis(b) that written opinions of this International Searching Authority will not be so considered.

If this opinion is, as provided above, considered to be a written opinion of the IPEA the applicant is invited to submit to the IPEA a written reply together where appropriate with amendments before the expiration of three months from the date of mailing of Form PCT/ISA/220 or before the expiration of 22 months from the priority date whichever expires later.

For further options see Form PCT/ISA/220

3 For further details, see notes to Form PCT/ISA/220

Name and mailing address of the ISA



European Patent Office
D-80288 Munich
Tel +49 89 2399 0 Tx 523856 spru d
Fax +49 89 2399 4485

Authorized Officer

Zerf G

Telephone No +49 89 2399 8483



**WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY**International application No
PCT/US2004/003025

Box No 1 Basis of the opinion

- 1 With regard to the language this opinion has been established on the basis of the international application in the language in which it was filed unless otherwise indicated under this item
- ☐ This opinion has been established on the basis of a translation from the original language into the following language which is the language of a translation furnished for the purposes of international search (under Rules 12.3 and 23 1(b))
- 2 With regard to any nucleotide and/or amino acid sequence disclosed in the international application and necessary to the claimed invention this opinion has been established on the basis of
- a type of material
- ☐ a sequence listing
- ☐ table(s) related to the sequence listing
- b format of material
- ☐ in written format
- ☐ in computer readable form
- c time of filing/furnishing
- ☐ contained in the international application as filed
- ☐ filed together with the international application in computer readable form
- ☐ furnished subsequently to this Authority for the purposes of search
- 3 ☐ In addition in the case that more than one version or copy of a sequence listing and/or table relating thereto has been filed or furnished the required statements that the information in the subsequent or additional copies is identical to that in the application as filed or does not go beyond the application as filed as appropriate were furnished
- 4 Additional comments

147

**WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY**

International application No
PCT/US2004/003025

Box No. II Priority

- 1 ☒ The following document has not been furnished
- ☒ copy of the earlier application whose priority has been claimed (Rule 43bis 1 and 66 7(a))
 - ☐ translation of the earlier application whose priority has been claimed (Rule 43bis 1 and 66 7(b))
- Consequently it has not been possible to consider the validity of the priority claim. This opinion has nevertheless been established on the assumption that the relevant date is the claimed priority date
- 2 ☐ This opinion has been established as if no priority had been claimed due to the fact that the priority claim has been found invalid (Rules 43bis 1 and 64 1). Thus for the purposes of this opinion the international filing date indicated above is considered to be the relevant date
- 3 Additional observations if necessary

Box No. V Reasoned statement under Rule 43bis.1(a)(i) with regard to novelty, inventive step or industrial applicability, citations and explanations supporting such statement

1 Statement			
Novelty (N)	Yes	Claims	1-6
	No	Claims	
Inventive step (IS)	Yes	Claims	1-6
	No	Claims	
Industrial applicability (IA)	Yes	Claims	1-6
	No	Claims	

- 2 Citations and explanations
- see separate sheet

**WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING
AUTHORITY (SEPARATE SHEET)**

International application No

PCT/US04/03025

Re Item V

Reasoned statement with regard to novelty, inventive step or industrial applicability, citations and explanations supporting such statement

The document D1 *EP-A-0 652 368 (EXERGY INC) 10 May 1995* is regarded as being the closest prior art to the subject matter of the claims 1, 3 and 5 and shows a method for implementing a thermodynamic cycle

The subject matter of the claims 1, 3 and 5 differs mainly from this known method in that the spent stream which is expanded for transforming thermal energy into usable energy is separated to vapour and liquid

The subject matter of the claims 1, 3 and 5 is therefore new (Article 33(2) PCT)

The problem to be solved by the present invention may be regarded as to improve the efficiency of the thermodynamic cycle

The solution to this problem proposed in claims 1, 3 and 5 of the present application is considered as involving an inventive step (Article 33(3) PCT) because the use of a separator in the present thermodynamic cycle is not obvious and enables the use of condensate in two different thermodynamic states

Claims 2, 4 and 6 are dependent on claims 1, 3 and 5 respectively and as such also meet the requirements of the PCT with respect to novelty and inventive step



Europäisches Patentamt
European Patent Office
Office européen des brevets



Publication number **0 652 368 A1**

EUROPEAN PATENT APPLICATION

Application number **94307470.8**

Int. Cl.⁸ **F03G 7/04, F01K 25/06, F01K 23/04**

Date of filing **12.10.94**

Priority **03.11.93 US 147870**

California 94541 (US)

Date of publication of application
10.05.95 Bulletin 95/19

Inventor **Kalina, Alexander I**
105 Glengarry Way
Hillsborough,
California 94010 (US)

Designated Contracting States.
AT BE CH DE DK ES FR GB GR IE IT LI LU MC NL PT SE

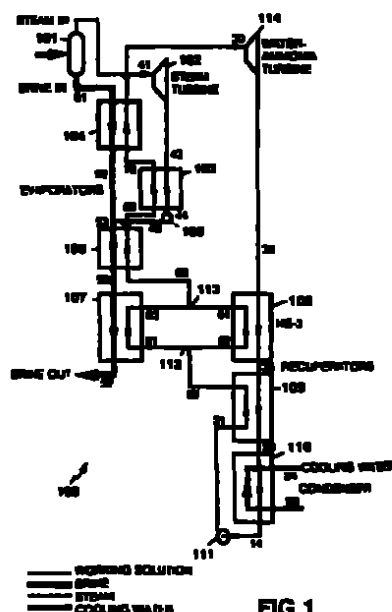
Representative **Ruffles, Graham Keith**
MARKS & CLERK,
57-60 Lincoln s Inn Fields
London WC2A 3LS (GB)

Applicant **Exergy, Inc.**
22320 Foothill Boulevard, Suite 540
Hayward,

Method and apparatus for converting heat from geothermal liquid and geothermal steam to electric power

A method and apparatus for implementing a thermodynamic cycle that includes (a) expanding a gaseous working stream transforming its energy into usable form and producing a spent working stream (b) heating a multicomponent oncoming liquid working stream by partially condensing the spent working stream and (c) evaporating the heated working stream to form the gaseous working stream using heat produced by a combination of cooling geothermal liquid and condensing geothermal steam

EP 0 652 368 A1



Rank Xerox (UK) Business Services
(3 18/1.89/2 3.41)

Background of the Invention

This invention relates to a method and apparatus for transforming thermal energy from a geothermal heat source consisting of a mixture of geothermal liquid and geothermal steam ("geofluid") into electric power. This invention further relates to utilizing the energy potential of both geothermal liquid and geothermal steam in one integrated system.

Geothermal heat sources can generally be divided into two groups. In the first group are "liquid-dominated" heat sources that produce mostly hot geothermal liquid (brine). In the second group are "steam-dominated" heat sources that produce mostly geothermal steam with some geothermal liquid.

Methods for converting the thermal energy released by geothermal heat sources into electric power present an important and growing area of energy generation. Geothermal power plants generally belong to one of two categories, namely, steam plants and binary plants.

In steam plants, the geothermal source is utilized directly to produce steam (e.g., by throttling and flashing geothermal liquid). That steam is then expanded in a turbine producing power. In binary plants, heat extracted from the geothermal liquid is used to evaporate a working fluid that circulates within the power cycle. The working fluid is then expanded in a turbine producing power.

Steam plants are generally used for steam-dominated geothermal heat sources, while binary plants are generally used for liquid-dominated geothermal heat sources. U.S. Patent No. 4,982,568 describes a method and apparatus for transforming thermal energy from geothermal liquid into electrical power in a binary plant. This method increases efficiency by using a thermodynamic cycle with a multi-component working fluid and internal recuperation.

Summary of the Invention

In a first aspect, the invention features a method of implementing a thermodynamic cycle that includes the steps of:

- expanding a gaseous working stream, transforming its energy into usable form and producing a spent working stream;

- heating a multicomponent oncoming liquid working stream by partially condensing the spent working stream and

- evaporating the heated working stream to form the gaseous working stream using heat produced by a combination of cooling geothermal liquid and condensing geothermal steam.

In preferred embodiments, the liquid working stream is superheated following evaporation using heat produced by cooling geothermal liquid to form the gaseous working stream. The multicomponent oncoming liquid working stream is preferably preheated by partially condensing the spent working stream, after which it is divided into first and second substreams. The first substream is then partially evaporated using heat produced by partially condensing the spent working stream, while the second substream is partially evaporated using heat produced by cooling geothermal liquid. The partially evaporated first and second substreams are then combined and evaporated to form the gaseous working stream using heat produced by a combination of cooling geothermal liquid and condensing geothermal steam. The difference between the boiling temperature of the second substream and the temperature of the geothermal liquid preferably is greater than the difference between the boiling temperature of the first substream and the temperature of the condensed spent working stream.

The geothermal steam is expanded, transforming its energy into usable form and producing a spent geothermal stream. The spent geothermal stream is then condensed to heat and partially evaporate the liquid working stream, after which it is combined with the geothermal liquid and used for further evaporation of the liquid working stream. Where the geothermal steam content of the geofluid is relatively high, it is preferable to perform multiple expansions of the geothermal steam. Thus, in one preferred embodiment, the spent geothermal steam produced by a first expansion of geothermal steam is divided into first and second geothermal substreams. The first geothermal substream is condensed to heat and partially evaporate the liquid working stream, and then combined with the geothermal liquid. The second geothermal substream is expanded, transforming its energy into usable form and producing a spent geothermal substream, which is then condensed to heat and partially evaporate the liquid working stream. The spent geothermal substream is then combined with the geothermal liquid.

In a second aspect, the invention features apparatus for implementing a thermodynamic cycle that includes:

- means for expanding a gaseous working stream, transferring its energy into usable form and producing a spent stream;

a heat exchanger for partially condensing the spent stream and for transferring heat from the spent stream to an oncoming multicomponent liquid working stream

a separator for separating geofluid into geothermal liquid and geothermal steam and

5 a multiplicity of heat exchangers for cooling geothermal liquid and condensing geothermal steam and for transferring heat from the geothermal liquid and geothermal steam to evaporate the liquid working stream and form the gaseous working stream

In preferred embodiments the apparatus includes a heat exchanger for cooling geothermal liquid and transferring heat from the geothermal liquid to superheat the liquid working stream and form the gaseous working stream. The apparatus also preferably includes a stream separator for dividing the heated liquid
10 working stream into first and second substreams a heat exchanger for partially condensing the spent working stream and transferring heat from the spent working stream to partially evaporate the first substream a heat exchanger for cooling the geothermal liquid and transferring heat from the cooled geothermal liquid to partially evaporate the second substream and a stream mixer for combining the partially evaporated first and second substreams

15 The apparatus further preferably includes means for expanding geothermal steam transforming its energy into usable form and producing a spent geothermal stream

a heat exchanger for condensing the spent geothermal steam and transferring heat from the spent geothermal steam to partially evaporate the liquid working stream and a stream mixer for combining the spent geothermal steam with the geothermal liquid. To accommodate geofluids with relatively high
20 geothermal steam content, the apparatus further includes a stream separator for dividing the spent geothermal steam produced in the first expansion into first and second geothermal streams a heat exchanger for condensing the first geothermal substream and transferring heat from the first geothermal substream to partially evaporate the liquid working stream a stream mixer for combining the first geothermal substream with the geothermal liquid means for expanding the second geothermal substream
25 transforming its energy into usable form and producing a spent geothermal substream a heat exchanger for condensing the spent geothermal substream and transferring heat from the spent geothermal substream to partially evaporate the liquid working stream and a stream mixer for combining the spent geothermal substream with the geothermal liquid

The invention provides an integrated system that utilizes the energy potentials of both geothermal steam and geothermal liquid (brine). The system can handle practically all geothermal resources in almost any proportion between steam and liquid. Geofluids from different wells having different temperatures and different proportions of steam and liquid may be used as well. Higher outputs and efficiencies are achieved relative to systems in which geothermal liquid and geothermal steam are utilized separately. In addition, the efficiency and output are higher relative to steam power systems that are currently used for utilization of
35 such geothermal resources.

Because the heat source for the thermodynamic cycle involves a combination of cooling geothermal liquid and condensing geothermal steam only a one stage expansion of the working fluid is necessary (as opposed to two stages of expansion with intermediate reheat). Moreover by splitting the liquid working fluid into two substreams one of which is partially evaporated by heat transferred from cooling geothermal liquid
40 and the other of which is partially evaporated by heat transferred from partially condensing spent working fluid geofluid having a high degree of mineralization (which can be cooled only to relatively high temperatures) can be used as well.

Other features and advantages of the invention will be apparent from the following description of the preferred embodiments thereof and from the claims

45 Brief Description of the Drawings

FIG 1 is a schematic representation of one embodiment of the method and apparatus of the present invention

60 FIG 2 is a schematic representation of a second embodiment of the method and apparatus of the present invention

Description of the Preferred Embodiments

55 The schematic shown in FIG 1 shows an embodiment of preferred apparatus that may be used in the above-described cycle. Specifically FIG 1 shows a system 100 that includes a gravity separator 101 a preheater in the form of a heat exchanger 109 a superheater in the form of a heat exchanger 104 and a boiler in the form of heat exchangers 103 106 107 and 108. In addition the system 100 includes turbines

102 and 114 pumps 105 and 111 and condenser 110. Further the system 100 includes stream separator 112 and stream mixer 113.

The condenser 110 may be any type of known heat rejection device. For example the condenser 110 may take the form of a heat exchanger such as a water cooled system or another type of condensing device.

As shown in FIG. 1 geofluid consisting of geothermal liquid (brine) and geothermal steam leaving the geothermal well is sent into gravity separator 101 where geothermal liquid and geothermal steam are separated. Steam leaves separator 101 with parameters as at point 41 and liquid leaves separator 101 with parameters as at point 51. Thereafter the steam is sent into steam turbine 102 where it expands producing power which is converted into electric power and leaves turbine 102 with parameters as at point 43. The steam is then sent into heat exchanger 103 where it condenses releasing its heat of condensation and being completely condensed. The condensate leaves heat exchanger 103 with parameters as at point 44. Heat from the condensation of the steam is transferred in heat exchanger 103 to the working fluid of the power cycle.

The geothermal liquid with parameters as at point 51 is cooled in heat exchanger 104 which it leaves with parameters as at point 52 and transfers heat to the working fluid of the power cycle. The temperature of the steam condensate at point 44 is substantially equal to the temperature of the geothermal liquid at point 52. The steam condensate with parameters as at point 44 is pumped by a pump 105 to a pressure equal to that of the geothermal liquid at point 52 obtaining parameters as at point 45. Thereafter the steam condensate with parameters corresponding to point 45 is combined with the geothermal liquid with parameters corresponding to point 52 obtaining parameters as at point 53.

The combined liquid having parameters as at point 53 passes through heat exchanger 106 where it is further cooled releasing heat which is transferred to the working fluid of the power cycle and obtaining parameters as at point 56. Finally liquid with parameters as at point 56 passes through heat exchanger 107 where it is further cooled releasing heat which is transferred to the working fluid of the power cycle and obtaining parameters as at point 57. Thereafter geothermal liquid is removed from the system and re-injected into the geothermal strata.

From the above discussion it can be seen that the thermodynamic power cycle according to the invention utilizes two sources of geothermal heat, i.e., heat released in the process of condensation of geothermal steam and heat released by the cooling of liquid and steam condensate (geothermal liquid). The power cycle operates as follows.

The fully condensed working fluid of the power cycle with parameters as at point 21 passes through a recuperative preheater 109 where it is preheated up to boiling temperature and exits preheater 109 with parameters as at point 60. Thereafter the working fluid is divided into two substreams at stream separator 112 having parameters correspondingly as at points 61 and 62. The first substream with parameters as at point 61 passes through heat exchanger 107 where it is heated by a stream of liquid geofluid and partially evaporated. It leaves heat exchanger 107 with parameters as at point 63.

The second substream having parameters as at point 62 passes through heat exchanger 108 where it is also heated and partially evaporated. It leaves heat exchanger 108 with parameters as at point 64. Thereafter both substreams are combined at stream mixer 113 obtaining parameters as at point 65. The combined substreams are then sent into heat exchanger 106 where further evaporation occurs using heat transferred from a stream of liquid geofluid.

The temperature difference between the boiling point of the working fluid having parameters at point 62 and the temperature of the condensing working fluid stream at point 38 is minimized. However the temperature difference between the initial boiling temperature and final temperature of the geothermal liquid used for evaporation in heat exchanger 107 can significantly exceed the minimum temperature difference between points 62 and 38 in heat exchanger 108. Thus it is possible to optimize temperature and corresponding pressure at point 60 even where the geothermal liquid can only be cooled to relatively high temperatures because of a high degree of mineralization.

The working fluid leaves heat exchanger 106 having parameters as at point 66 and enters heat exchanger 103 where evaporation is completed using heat produced by condensation of the geothermal steam. The working fluid leaves heat exchanger 103 with parameters as at point 68 and enters heat exchanger 104 where it is superheated by a stream of geothermal liquid. Thereafter the working fluid which leaves heat exchanger 104 with parameters as at point 30 enters turbine 114 where it is expanded producing power. The expanded working fluid stream then leaves turbine 114 with parameters as at point 36.

The expanded working fluid at point 36 is usually in the form of a dry or a wet saturated vapor. It then passes through heat exchanger 108 where it is partially condensed. The heat released during condensation

153

is utilized for an initial boiling of the liquid working fluid. Thereafter the expanded working fluid leaves heat exchanger 108 with parameters as at point 38 and passes through heat exchanger 109 where it is further condensed. The heat of condensation is utilized to preheat oncoming working fluid. The partially condensed working fluid with parameters as at point 29 leaves heat exchanger 109 and enters heat exchanger 110 where it is fully condensed obtaining parameters as at point 14. Condensation can be provided by cooling water, cooling air, or any other cooling medium. The condensed working fluid is then pumped to a higher pressure by pump 111 obtaining parameters as at point 21. The cycle is then repeated.

The pressure at point 43 to which geothermal steam is expanded is chosen to achieve maximum total power output from both steam turbine 102 and working fluid turbine 114. The composition of the multicomponent working fluid (which includes a lower boiling point fluid and a higher boiling point fluid) is similarly chosen to maximize total power output. Specifically the composition is chosen such that the temperature at which the expanded working fluid having parameters at point 38 condenses is higher than the temperature at which the same working fluid having parameters at point 60 boils. Examples of suitable multicomponent working fluids include an ammonia-water mixture, two or more hydrocarbons, two or more freons, mixtures of hydrocarbons and freons, or the like. In a particularly preferred embodiment, a mixture of water and ammonia is used. The multicomponent working stream preferably includes about 55% to about 95% of the low-boiling component.

Preferred parameters for the points corresponding to the points set forth in FIG. 1 are presented in Table I for a system having a water-ammonia working fluid stream. From the data it follows that the proposed system increases output in comparison with a traditional steam system by 1.55 times and in comparison with a system that separately utilizes heat from brine and steam by 1.077 times.

25

30

35

40

45

50

55

TABLE I

#	P psiA	X	T °F	H BTU/lb	G/G30	Flow lb/hr	Phase
14	112 71	7854	78 00	-12 37	1 0000	2,682,656	SatLiquid
21	408 10	7854	78 00	-11 12	1 0000	2,682,656	Liq 90°
23	•	Water	70 00	38 00	14 8173	39,749,694	
24	•	Water	94 70	62 70	14 8173	39,749,694	
29	113 01	7854	133 62	353 56	1 0000	2,682,656	Wet 4037
30	385 10	7854	386 80	811 71	1 0000	2,682,656	Vap 67°
36	113 61	7854	240 46	724 15	1 0000	2,682,656	Wet 0321
38	113 31	7854	170 00	450 61	1 0000	2,682,656	Wet 2998
40	113 61	7854	244 90	755 37	1 0000	2,682,656	SatVapor
41	224 94	Steam	391 80	1200 54	1912	513,000	SatVapor
43	84 77	Steam	316 09	1132 63	1912	513,000	Vap 0°
44	84 77	Steam	316 09	286 24	1912	513,000	SatLiquid
45	224 94	Steam	316 09	286 42	1912	513,000	Vap 0°
51	•	Brine	391 80	305 83	1 4143	3,794,000	
52	•	Brine	316 09	241 48	1 4143	3,794,000	
53	•	Brine	316 09	241 48	1 6055	4,307,000	
56	•	Brine	240 46	177 19	1 6055	4,307,000	

EP 0 852 388 A1

6 10 16 22 28 34 40 46 52 58

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100

155

57	.	Brine	170 00	117 30	1 6055	4,307,000	
60	393 10	7854	165 00	85 93	1 0000	2,682,656	Sat.Liquid
61	391 10	7854	235 46	455 64	2601	697,740	Wet 3412
62	391 10	7854	235 46	455 64	7399	1,984,916	Wet 3412
66	391 10	7854	235 46	455 64	1 0000	2,682,656	Wet 3412
69	389 10	7854	269 56	558 84	1 0000	2,682,656	Wet 2248
70	387 10	7854	311 08	720 70	1 0000	2,682,656	Wet 05

Where the initial geofluid leaving the geothermal well contains a relatively large quantity of steam it is preferable to expand and then condense the geothermal steam in two or more steps rather than in one step as shown in FIG 1 In such a case heating and evaporation of the working fluid is performed alternately by cooling the geothermal liquid and condensing the geothermal steam

In FIG 2 a system which includes two stages of expansion of geothermal steam is presented It differs from the system shown in FIG 1 by the fact that after the first stage of expansion part of the expanded steam with parameters as at 43 is sent into heat exchanger 103 A portion of partially expanded steam is further expanded in a second steam turbine 204 and then condensed in a second steam condenser shown

as heat exchanger 203 from which it is pressurized via pump 201 and then recombined with geothermal liquid. Geothermal liquid is used to heat the working fluid of the power cycle between those two steam condensers in heat exchanger 204.

While the present invention has been described with respect to a number of preferred embodiments, those skilled in the art will appreciate a number of variations and modifications of those embodiments. For example, the number of heat exchangers may be increased or decreased. In addition, the geothermal steam may undergo more than two expansions depending on the steam content of the geofluid. Thus, it is intended that the appended claims cover all such variations and modifications as fall within the true spirit and scope of the present invention.

10

Claims

1. A method of implementing a thermodynamic cycle comprising the steps of:
 - expanding a gaseous working stream transforming its energy into usable form and producing a spent working stream
 - heating a multicomponent oncoming liquid working stream by partially condensing the spent working stream and
 - evaporating the heated working stream to form the gaseous working stream using heat produced by a combination of cooling geothermal liquid and condensing geothermal steam
2. The method of claim 1 comprising superheating the liquid working stream following evaporation using heat produced by cooling geothermal liquid to form the gaseous working stream
3. The method of claim 1 comprising the steps of:
 - preheating the multicomponent oncoming liquid working stream by partially condensing the spent working stream
 - dividing the preheated liquid working stream into first and second substreams
 - partially evaporating the first substream using heat produced by partially condensing the spent working stream
 - partially evaporating the second substream using heat produced by cooling geothermal liquid
 - combining the partially evaporated first and second substreams and
 - evaporating the partially evaporated first and second substreams to form the gaseous working stream using heat produced by a combination of cooling geothermal liquid and condensing geothermal steam
4. The method of claim 3 wherein the difference between the boiling temperature of the second substream and the temperature of the geothermal liquid is greater than the difference between the boiling temperature of the first substream and the temperature of the condensed spent working stream
5. The method of claim 1 comprising the steps of:
 - expanding geothermal steam transforming its energy into usable form and producing a spent geothermal stream
 - condensing the spent geothermal stream to heat and partially evaporate the liquid working stream and
 - combining the spent geothermal stream with the geothermal liquid
6. The method of claim 1 comprising the steps of:
 - expanding geothermal steam transforming its energy into usable form and producing a spent geothermal stream
 - dividing the spent geothermal stream into first and second geothermal substreams
 - condensing the first geothermal substream to heat and partially evaporate the liquid working stream
 - combining the first geothermal substream with the geothermal liquid
 - expanding the second geothermal substream transforming its energy into usable form and producing a spent geothermal substream
 - condensing the spent geothermal substream to heat and partially evaporate the liquid working stream and
 - combining the spent geothermal substream with the geothermal liquid

- 7 A method of implementing a thermodynamic cycle comprising the steps of
 expanding a gaseous working stream transforming its energy into usable form and producing a spent working stream
 preheating an oncoming multicomponent liquid working stream by partially condensing the spent working stream
 5 dividing the preheated liquid working stream into first and second substreams
 partially evaporating the first substream using heat produced by partially condensing the spent working stream
 partially evaporating the second substream using heat produced by cooling geothermal liquid
 10 combining the partially evaporated first and second substreams
 evaporating the partially evaporated first and second substreams using heat produced by a combination of cooling geothermal liquid and condensing geothermal steam and
 superheating the evaporated liquid working stream using heat produced by cooling geothermal liquid to form the gaseous working stream
 15
8. The method of claim 7 wherein the difference between the boiling temperature of the second substream and the temperature of the geothermal liquid is greater than the difference between the boiling temperature of the first substream and the temperature of the condensed spent working stream
- 20 9. The method of claim 7 comprising the steps of
 expanding geothermal steam transforming its energy into usable form and producing a spent geothermal stream
 condensing the spent geothermal stream to heat and partially evaporate the liquid working stream and
 25 combining the spent geothermal stream with the geothermal liquid
10. The method of claim 7 comprising the steps of
 expanding geothermal steam transforming its energy into usable form and producing a spent geothermal stream
 30 dividing the spent geothermal stream into first and second geothermal substreams,
 condensing the first geothermal substream to heat and partially evaporate the liquid working stream
 combining the first geothermal substream with the geothermal liquid
 expanding the second geothermal substream transforming its energy into usable form and
 35 producing a spent geothermal substream
 condensing the spent geothermal substream to heat and partially evaporate the liquid working stream and
 combining the spent geothermal substream with the geothermal liquid
- 40 11 Apparatus for implementing a thermodynamic cycle comprising
 means for expanding a gaseous working stream transferring its energy into usable form and producing a spent stream
 a heat exchanger for partially condensing the spent stream and for transferring heat from the spent stream to an oncoming multicomponent liquid working stream
 45 a separator for separating geofluid into geothermal liquid and geothermal steam and
 a multiplicity of heat exchangers for cooling geothermal liquid and condensing geothermal steam and for transferring heat from the geothermal liquid and geothermal steam to evaporate the liquid working stream and form the gaseous working stream
- 50 12. The apparatus of claim 11 comprising a heat exchanger for cooling geothermal liquid and transferring heat from the geothermal liquid to superheat the liquid working stream and form the gaseous working stream
13. The apparatus of claim 11 comprising
 55 a stream separator for dividing the heated liquid working stream into first and second substreams
 a heat exchanger for partially condensing the spent working stream and transferring heat from the spent working stream to partially evaporate the first substream
 a heat exchanger for cooling the geothermal liquid and transferring heat from the cooled geother-

mal liquid to partially evaporate the second substream and
a stream mixer for combining the partially evaporated first and second substreams

- 14 The apparatus of claim 11 comprising
5 means for expanding geothermal steam transforming its energy into usable form and producing a spent geothermal stream
a heat exchanger for condensing the spent geothermal stream and transferring heat from the spent geothermal stream to partially evaporate the liquid working stream and
a stream mixer for combining the spent geothermal stream with the geothermal liquid
- 15 The apparatus of claim 11 comprising
means for expanding geothermal steam transforming its energy into usable form and producing a spent geothermal stream
a stream separator for dividing the spent geothermal stream into first and second geothermal
15 streams
a heat exchanger for condensing the first geothermal substream and transferring heat from the first geothermal substream to partially evaporate the liquid working stream
a stream mixer for combining the first geothermal substream with the geothermal liquid
means for expanding the second geothermal substream transforming its energy into usable form
20 and producing a spent geothermal substream
a heat exchanger for condensing the spent geothermal substream and transferring heat from the spent geothermal substream to partially evaporate the liquid working stream and
a stream mixer for combining the spent geothermal substream with the geothermal liquid
- 16 Apparatus for implementing a thermodynamic cycle comprising:
means for expanding a gaseous working stream transforming its energy into usable form and
25 producing a spent stream
a heat exchanger for partially condensing the spent stream and for transferring heat from the spent stream to an oncoming multicomponent liquid working stream
a separator for separating geofluid into geothermal liquid and geothermal steam
30 a stream separator for dividing the heated liquid working stream into first and second substreams
a heat exchanger for partially condensing the spent working stream and transferring heat from the spent working stream to partially evaporate the first substream
a heat exchanger for cooling the geothermal liquid and transferring heat from the cooled geothermal liquid to partially evaporate the second substream
35 a stream mixer for combining the partially evaporated first and second substreams
a multiplicity of heat exchangers for cooling geothermal liquid and condensing geothermal steam and for transferring heat from the geothermal liquid and geothermal steam to evaporate the liquid working stream and
40 a heat exchanger for cooling geothermal liquid and transferring heat from the geothermal liquid to superheat the liquid working stream and form the gaseous working stream
- 17 The apparatus of claim 16 comprising
means for expanding geothermal steam transforming its energy into usable form and producing a
45 spent geothermal stream
a heat exchanger for condensing the spent geothermal stream and transferring heat from the spent geothermal stream to partially evaporate the liquid working stream and
a stream mixer for combining the spent geothermal stream with the geothermal liquid
- 18 The apparatus of claim 16 comprising
50 means for expanding geothermal steam transforming its energy into usable form and producing a spent geothermal stream
a stream separator for dividing the spent geothermal stream into first and second geothermal streams
55 a heat exchanger for condensing the first geothermal substream and transferring heat from the first geothermal substream to partially evaporate the liquid working stream
a stream mixer for combining the first geothermal substream with the geothermal liquid
means for expanding the second geothermal substream transforming its energy into usable form

159

and producing a spent geothermal substream;

a heat exchanger for condensing the spent geothermal substream and transferring heat from the spent geothermal substream to partially evaporate the liquid working stream; and

a stream mixer for combining the spent geothermal substream with the geothermal liquid.

5

10

15

20

25

30

35

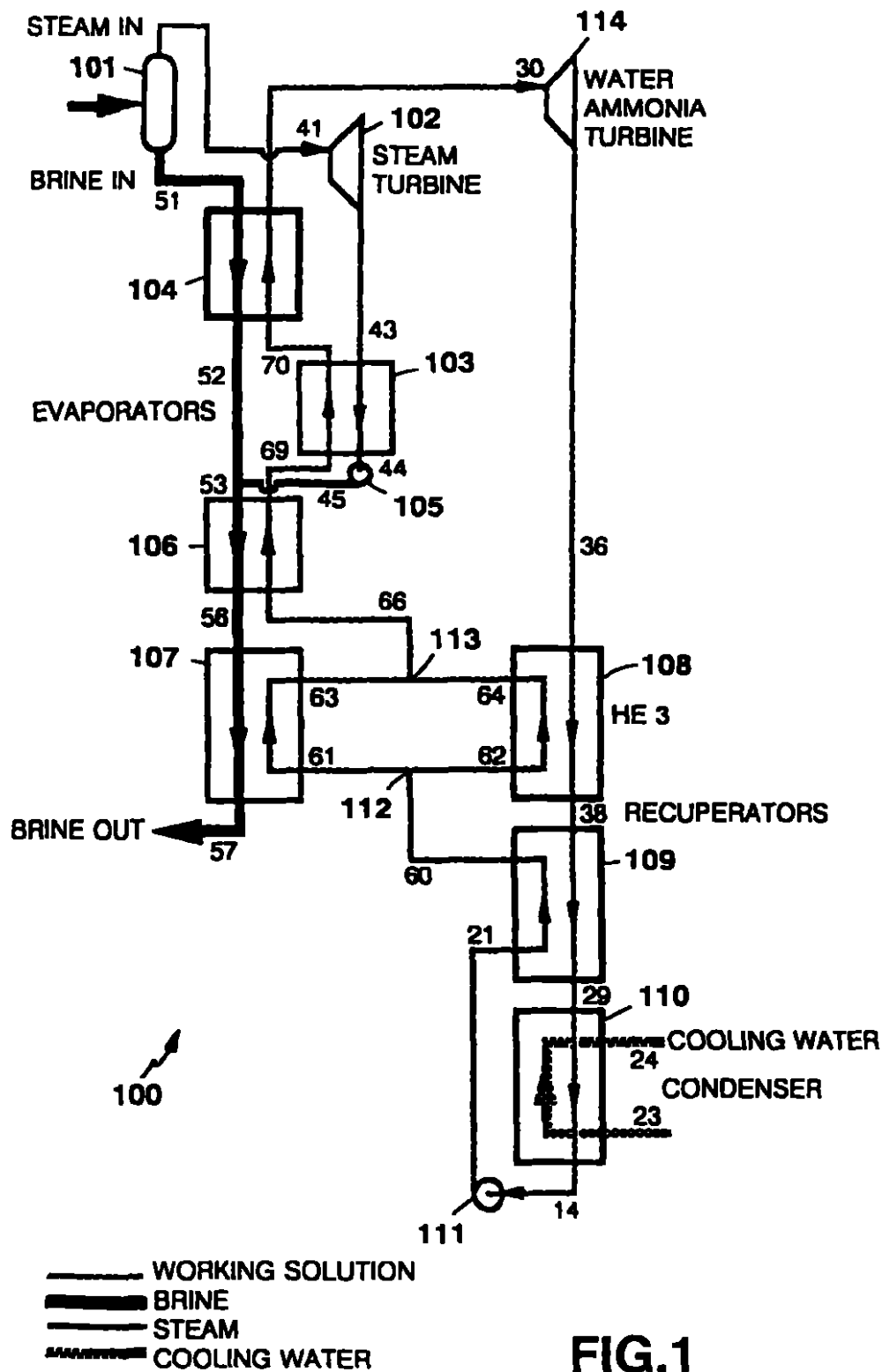
40

45

50

55

160



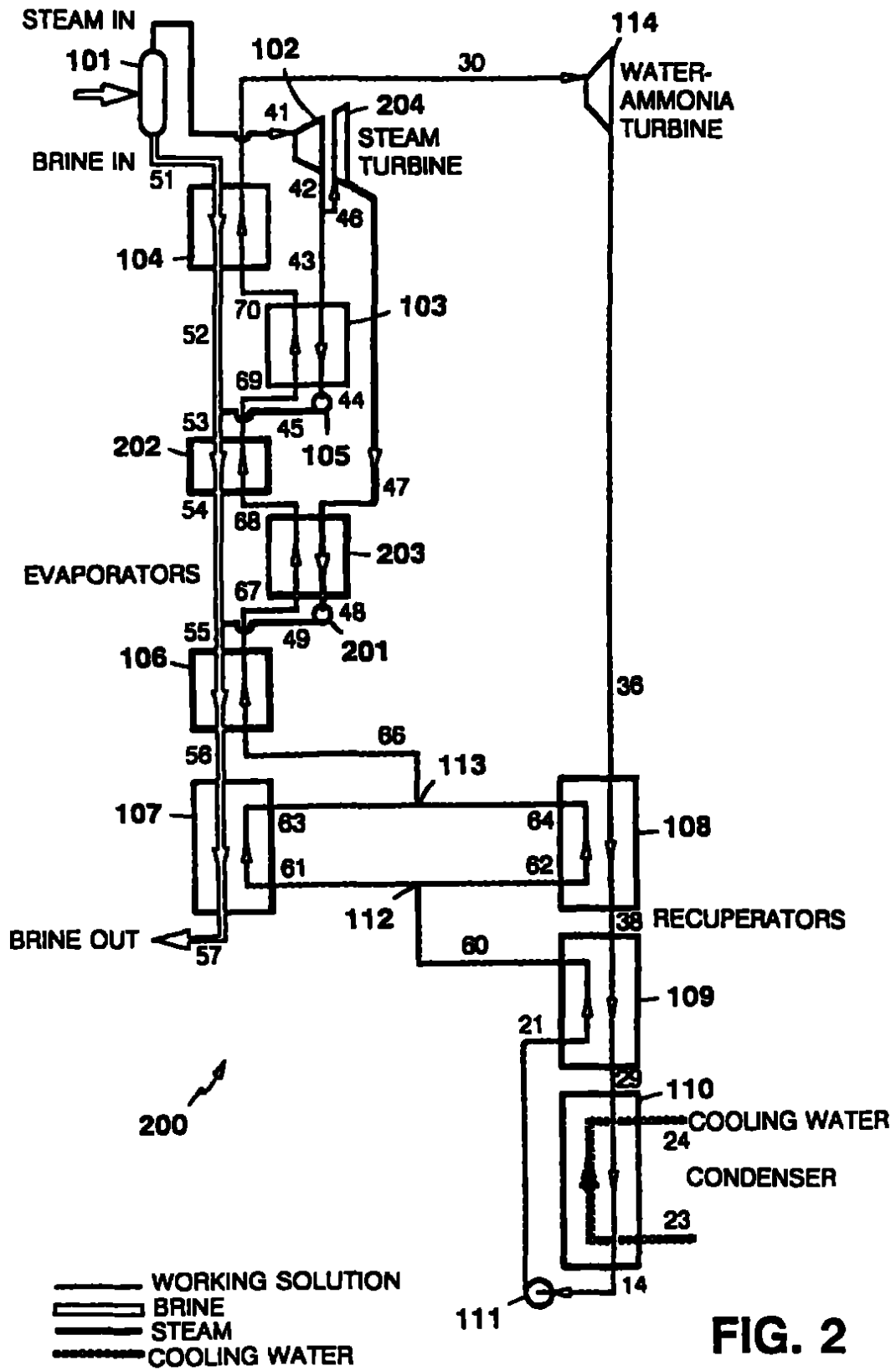


FIG. 2



European Patent
Office

EUROPEAN SEARCH REPORT

Application Number
EP 94 30 7470

162

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.4)
X	EP-A-0 372 864 (ORMAT TURBINES)	1,2,11,12	F03G7/04 F01K25/06 F01K23/04
A	* column 4, line 47 - column 6, line 16 figure 2 *	5 7,9,16,17	
A,D	US-A-4 982 568 (KALINA)	1-4,7,8,11-13	
	* column 3, line 36 - column 6, line 30, figure 1 *		
A	US-A-5 038 567 (MORTIZ)	1,7,11,16	
	* column 1, line 17 - line 62 *		
	* column 4, line 41 - column 5, line 23, figure 2 *		
A	US-A-4 996 846 (BRONICKI)		
The present search report has been drawn up for all claims			TECHNICAL FIELDS SEARCHED (Int.Cl.4) F03G F01K
Place of search THE HAGUE		Date of completion of the search 3 February 1995	Searcher Van Zoest, A
CATEGORY OF CITED DOCUMENTS			
X particularly relevant if taken alone Y particularly relevant if combined with another document of the same category A technological background O non-written disclosure P intermediate document		I : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons A : number of the same patent family, corresponding document	

EPF FORM 1500 (04/95) (FPO/CI)



Europäisches Patentamt
European Patent Office
Office européen des brevets



Publication number **0 472 020 A1**

EUROPEAN PATENT APPLICATION

Application number **91112912.0**

Int Cl⁵ **F01K 25/06**

Date of filing **31.07.91**

Priority **15.08.90 US 567914**

Date of publication of application
25.02.92 Bulletin 92/09

Designated Contracting States
AT BE CH DE DK ES FR GB GR IT LI LU NL SE

Applicant **Kalina, Alexander L.**
105 Glengarry Way
Hillsborough California 94010(US)

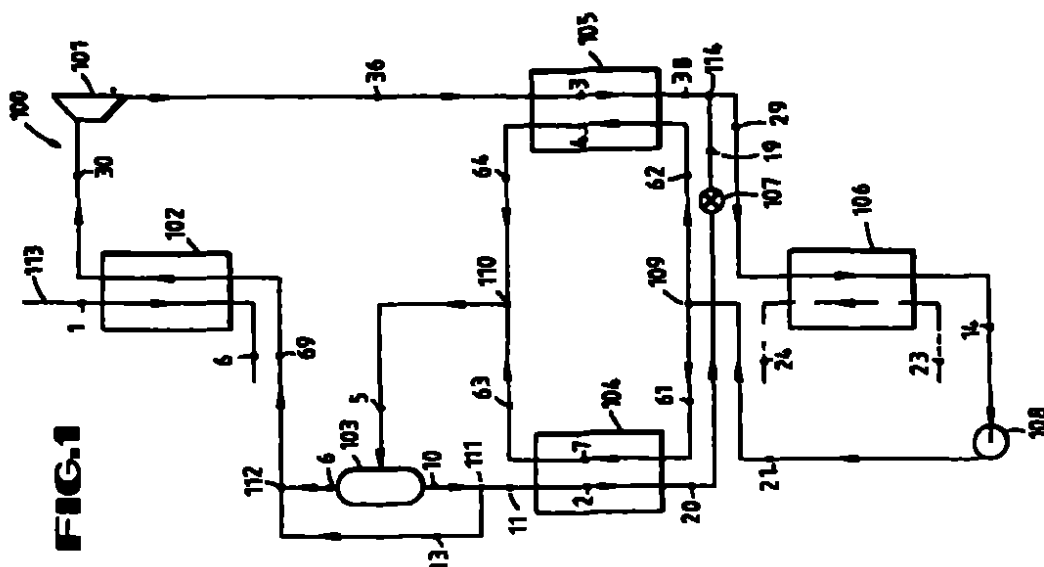
Inventor **Kalina, Alexander L.**
105 Glengarry Way
Hillsborough California 94010(US)

Representative **Patentanwalte Grünecker**
Kinkeldey Stockmair & Partner
Maximilianstrasse 58
W-8000 München 22(DE)

Method and apparatus for converting low temperature heat to electric power

A method and apparatus for implementing a thermodynamic cycle which may be used to convert low temperature heat to electric power

The cycle comprises the steps of
expanding (101) a gaseous working stream
condensing (106) the spent stream
forming from the liquid working stream an enriched stream and a lean stream
and heating (102) the enriched stream forming the gaseous working stream.



EP 0 472 020 A1

Rank Xerox (UK) Business Services

This invention relates generally to the field of thermal energy conversion into mechanical and then electrical form. More particularly, this invention relates to the conversion of low temperature heat from low temperature heat sources into electric power.

Methods for converting the thermal energy of low temperature heat sources into electric power present an important area of energy generation. There is a need for a method and apparatus for increasing the efficiency of the conversion of such low temperature heat to electric power that exceeds the efficiency of standard Rankine cycles. The present invention provides such a method and apparatus.

The present invention provides for a method for implementing a thermodynamic cycle comprising the steps of

expanding a gaseous working stream, transforming its energy into usable form and producing a spent stream

condensing the spent stream producing a liquid working stream

forming from the liquid working stream an enriched stream and a lean stream, and

heating the enriched stream forming the gaseous working stream.

The present invention also provides for an apparatus for implementing a thermodynamic cycle comprising

means for expanding a gaseous working stream, transferring its energy into usable form and producing a spent stream

a first stream mixer for mixing the spent stream with a lean stream forming a pre-condensed stream

a condenser for condensing the pre-condensed stream producing a liquid working stream

a pump for pumping the liquid working stream to an increased pressure;

a gravity separator for forming from the liquid working stream a vapor stream and a first liquid stream

a first stream separator for separating the first liquid stream producing a second liquid stream and the lean stream

a second stream mixer for mixing the second liquid stream with the vapor stream producing an enriched stream, and

a heat exchanger for heating the enriched stream with heat transferred from an external heat source producing the gaseous working stream.

Although any conventional external heat source may in general be used in conjunction with the method and apparatus of the present invention, the present invention is particularly useful for the conversion of low temperature heat from a low temperature geothermal brine or from a solar pond. As will be apparent from the following description of preferred embodiments, the method and apparatus of the present invention may enhance the efficiency of the conversion of low temperature heat to electric power for a power cycle that uses a low temperature heat source.

FIG. 1 is a schematic representation of an embodiment of the method and apparatus of the present invention.

This invention is a novel method and apparatus for implementing a thermodynamic cycle. In the method of the present invention, a gaseous working stream is expanded. This expansion transforms that stream's energy into usable form and produces a spent stream. Preferred expansion means include conventionally used turbines or turbine systems. The spent stream is condensed producing a liquid working stream. Preferred condensers are those conventionally used in the art.

From the liquid working stream, an enriched stream and a lean stream are formed. The enriched stream preferably includes a higher percentage of a low boiling component than the liquid working stream includes. The lean stream preferably includes a lower percentage of a low boiling component than the liquid working stream includes.

Any conventional apparatus used to form two or more streams having different compositions from a single stream may be used to form the lean stream and the enriched stream from the liquid working stream. Preferred means for forming those streams include conventionally used gravity separators such as a conventional flash tank.

The enriched stream preferably is in the state of a vapor or a vapor-liquid mixture. The lean stream preferably is in the state of a saturated or subcooled liquid.

The enriched stream is heated to form the gaseous working stream. This heat transfer may occur via a conventional heat exchanger. Any conventional heating source may be used, including recuperative or external heat sources. Preferred external heat sources that may be used in the present invention are those having temperatures of less than about 400° F. Particularly preferred are those having temperatures of less than about 250° F, such as low temperature geothermal brine or solar pond external heat sources.

The method of the present invention preferably includes the additional step of combining at a first stream mixer the lean stream with the spent stream prior to condensing the spent stream to form the liquid

working stream. Such a stream which includes the lean stream and the spent stream may be referred to as a pre-condensed stream.

The method of the present invention preferably includes the additional steps of pumping the liquid working stream to an increased pressure and partially evaporating the liquid working stream with heat transferred from the spent stream and the lean stream. Conventional pumps and heat exchangers may be used for such purposes.

In the embodiment of the present invention in which the liquid working stream is partially evaporated, the enriched stream and the lean stream may be formed by separating vapor and liquid streams from the partially evaporated liquid working stream at a flash tank—the vapor producing the enriched stream which is heated to form the gaseous working stream and the liquid producing the lean stream. Alternatively, such a partially evaporated liquid working stream may be separated into a vapor stream and a first liquid stream at a flash tank. The first liquid stream in turn may be separated at a first stream separator into a second liquid stream and the lean stream. The second liquid stream may then be mixed at a second stream mixer with the vapor stream to produce the enriched stream. In such an embodiment of the present invention, the enriched stream should be in the state of a vapor-liquid mixture that is then heated to form the gaseous working stream.

The schematic shown in FIG. 1 shows an embodiment of preferred apparatus that may be used in the method of the present invention. Specifically, FIG. 1 shows a system 100 that includes turbine 101, heat exchangers 104, 105 and 102, condenser 108, gravity separator 103, pump 106, stream separators 109 and 111, stream mixers 110, 112 and 114, and external heat source 113.

The condenser 108 may be any type of known heat rejection device. For example, the condenser 108 may take the form of a heat exchanger such as a water cooled system or another type of condensing device.

Various types of heat sources may be used to drive the cycle of this invention. In the embodiment shown in FIG. 1, external heat source 113 represents a stream of low temperature geothermal fluid that flows from point 1 to point 9 through heat exchanger 102.

The working stream for the embodiment of the present invention shown in system 100 preferably is a multi-component working stream that comprises a low boiling component and a high boiling component. Such a preferred working stream may be an ammonia-water mixture, two or more hydrocarbons, two or more freons, mixtures of hydrocarbons and freons or the like. In general, the working stream may be mixtures of any number of compounds with favorable thermodynamic characteristics and solubility. In a particularly preferred embodiment, a mixture of water and ammonia is used.

As shown in FIG. 1, the working stream circulates through system 100. The working stream includes a gaseous working stream that flows from heat exchanger 102 to turbine 101. The working stream also includes a spent stream which flows from turbine 101 to first stream mixer 114, a pre-condensed stream which flows from first stream mixer 114 to condenser 108, a liquid working stream which flows from condenser 108 to gravity separator 103, and an enriched stream which flows from second stream mixer 112 to heat exchanger 102. The gaseous working stream, the spent stream and the enriched stream preferably each include a higher percentage of a low boiling component than is included in the pre-condensed stream and the liquid working stream.

In addition to the working stream that circulates through system 100 are a lean stream which flows from first stream separator 111 to first stream mixer 114, a first liquid stream which flows from gravity separator 103 to first stream separator 111, a second liquid stream which flows from first stream separator 111 to second stream mixer 112, and a vapor stream which flows from gravity separator 103 to second stream mixer 112. The lean stream, the first liquid stream and the second liquid stream preferably each include a lower percentage of a low boiling component than is included in the liquid working stream. The vapor stream preferably includes a higher percentage of a low boiling component than is included in the liquid working stream.

In the embodiment of the present invention shown in FIG. 1, the liquid working stream which has been completely condensed and which has a temperature that preferably is close to ambient temperature—with parameters as at point 14—is pumped by pump 106 to a higher pressure, obtaining parameters as at point 21. Thereafter, this liquid working stream is separated at stream separator 109 producing substreams with parameters as at points 61 and 62 respectively. These substreams are sent into recuperative heat exchangers 104 and 105 respectively. While passing through heat exchangers 104 and 105, the substreams of the liquid working stream are heated, achieving a boiling temperature having parameters as at points 7 and 4 respectively, and then partially evaporated. The partially evaporated substreams of the liquid working stream exit heat exchangers 104 and 105 with parameters as at points 63 and 64 respectively. Those substreams are then recombined at stream mixer 110 to reconstitute the liquid working stream with

parameters as at point 5

The liquid working stream at point 5 is preferably in a bi-phase state i.e. in a partially evaporated state. The liquid working stream is sent into gravity separator 103 such as a flash tank where the liquid separates from the vapor.

5 A vapor stream with parameters as at point 8 exits from the top of gravity separator 103 and a first liquid stream with parameters as at point 10 exits from the bottom of gravity separator 103. The first liquid stream is separated at first stream separator 111 into a lean stream and a second liquid stream having parameters as at points 11 and 13 respectively. The second liquid stream with parameters as at point 13 is combined at second stream mixer 112 with the vapor stream producing an enriched stream (enriched in
10 this embodiment of the present invention with respect to a lower boiling component when compared to the liquid working stream) having parameters as at point 89. The enriched stream preferably is in the state of a vapor liquid mixture.

The enriched stream is sent into heat exchanger 102 where it is heated by external heat source 113. The external heat source 113 shown in FIG. 1 represents a stream of geothermal brine. Such a heat source
15 typically has a temperature of less than about 400 F and may have a temperature of less than about 250 F. Alternatively, external heat source 113 may consist of some other type of low temperature stream such as one flowing from a solar pond. In the embodiment shown in FIG. 1 the geothermal brine enters heat exchanger 102 with parameters as at point 1 and exits heat exchanger 102 with parameters as at point 9. As shown in TABLE 1 the geothermal brine at point 1 may be at a temperature of 230 F.

20 The enriched stream that enters heat exchanger 102 is further heated and evaporated exiting heat exchanger 102 as the gaseous working stream. The gaseous working stream exiting heat exchanger 102 may be partially evaporated or it may be completely evaporated and superheated.

The gaseous working stream in the FIG. 1 embodiment exits heat exchanger 102 with parameters as at point 30. The gaseous working stream then enters turbine 101 where it expands producing work. A spent
25 stream exits from turbine 101 with parameters as at point 38. That spent stream is sent into heat exchanger 105 where it is cooled. The spent stream is preferably partially condensed as it passes through heat exchanger 105 to obtain parameters as at point 38. As it passes through heat exchanger 105 the spent stream transfers heat for heating and preferably partially evaporating the substream of the liquid working stream flowing from point 62 to point 64.

30 The lean stream with parameters as at point 11 passes through heat exchanger 104 where it is cooled. While passing through heat exchanger 104, the lean stream provides heat for pre-heating and preferably partially evaporating the substream of the liquid working stream flowing from point 61 to point 63. The lean stream exits heat exchanger 104 with parameters as at point 20. In the embodiment shown in FIG. 1 the lean stream passes through a pressure reduction device 107 which may be a throttle valve. After
35 exiting pressure reduction device 107 the lean stream obtains parameters as at point 18.

The lean stream and the spent stream are combined at first stream mixer 114 to produce a pre-condensed stream having parameters as at point 29. The pre-condensed stream is sent into condenser 108 where it is completely condensed by a stream of coolant flowing from point 23 to point 24. This produces
40 the liquid working stream with parameters as at point 14 which completes the cycle.

45 Convenient parameters for the points corresponding to the points set forth in FIG. 1 are presented in TABLE 1 for a system having a water-ammonia enriched stream which includes 49.5 weight % of ammonia. The theoretical performance of the system of the present invention using the parameters of TABLE 1 in the embodiment shown in FIG. 1 is included in TABLE 2. The data presented in that table shows that the proposed system theoretically should have an efficiency of 10.34% which should exceed the efficiency of the standard Rankine cycle working at the same border conditions by about 1.87 times. It should be expected that use of the heat source proposed for the embodiment shown in FIG. 1 with parameters as set forth in TABLE 1 should increase power output from 3.3MW to 5.5MW.

50

55

TABLE 1

5

	Point	P(psi)	X	T F	H (Btu/lb)	G
10	1		BRINE	230 00		9 6554
	2	37 90	0 2651	138 56	30 93	7 4728
	3	9 97	0 4950	138 56	467 66	1 0000
	4	40 10	0 2922	134 56	20 82	2 9728
	5	38 10	0 2922	142 00	58 54	8 4728
16	6	38 10	0 9408	142 00	634 62	3403
	7	40 10	0 2922	134 56	20 82	5 5000
	9		BRINE	170 62		9 6554
	10	38 10	0 2651	142 00	34 44	8 1325
	11	38 10	0 2651	142 00	34 44	7 4728
20	13	38 10	0 2651	142 00	34 44	6597
	14	8 72	0 2922	62 00	54 06	8 4728
	19	9 22	0 2651	76 79	24 12	7 4728
	20	37 70	0 2651	85 03	-24 12	7 4728
	21	42 10	0 2922	62 00	53 99	8 4728
26	23		WATER	55 00		17 4588
	24		WATER	84 96		17 4588
	29	9 22	0 2922	78 76	7 68	8 4728
	30	33 10	0 4950	217 50	823 43	1 0000
	34	10 72	0 4950	165 00	761 36	1 0000
30	38	9 22	0 4950	94 37	263 29	1 0000
	41	42 10	0 2922	62 00	53 99	5 5000
	42	42 10	0 2922	62 00	53 99	2 9728
	43	38 10	0 2922	133 58	25 53	5 5000
	44	38 10	0 2922	158 00	119 61	2 9728
36	49	38 10	0 4950	142 00	238 67	1 0000

40

45

50

55

TABLE 2

	Sum of turbine enthalpy drops = 62 08 Btu/lb	
5	Turbine work = 60 53 Btu/lb	
	Heat input = 84 78 Btu/lb	
	Heat rejection = 523 04 Btu/lb	
10	Pump power = 09 Btu/lb	
	Net power output = 60 44 Btu/lb	
15	Net thermal efficiency = 10 34%	
	Working fluid weight flow = 310705 84	
	Net output 5502 59 kW	
20		
	Second Law limit 20 90%	
	Second Law efficiency 49 45%	
25	Specific brine consumption 545 20 lb/kWe	
	Specific power output 1 83 watt-hr/lb	

While the present invention has been described with respect to a number of preferred embodiments
 30 which utilize a single preferred external heat source those skilled in the art will appreciate a number of
 variations and modifications of those embodiments. For example a different external heat source may be
 used the number of heat exchangers may be increased or decreased the number of pumps, turbines
 condensing devices separators etc. may be varied as well as the number and composition of streams
 flowing through the cycle. Thus it is intended that the appended claims cover all such variations and
 35 modifications as fall within the true spirit and scope of the present invention.

Claims

- 1 A method for implementing a thermodynamic cycle comprising the steps of
 40 expanding a gaseous working stream transforming its energy into usable form and producing a
 spent stream
 condensing the spent stream producing a liquid working stream
 45 forming from the liquid working stream an enriched stream and a lean stream and
 heating the enriched stream forming the gaseous working stream
2. The method of claim 1 further including the step of combining the lean stream with the spent stream
 50 prior to condensing the spent stream forming the liquid working stream
3. The method of claim 1 further including the step of heating the enriched stream with heat transferred
 from an external heat source having a temperature of less than about 400 °F
- 55 4. The method of claim 3 further including the step of heating the enriched stream with heat transferred
 from an external heat source having a temperature of less than about 250 °F

5. The method of claim 4 wherein the external heat source is selected from the group consisting of a low temperature geothermal brine and a solar pond
6. The method of claim 1 further including the steps of pumping the liquid working stream to an increased pressure and partially evaporating the liquid working stream with heat transferred from the spent stream and the lean stream after pumping the liquid working stream to an increased pressure
7. A method for implementing a thermodynamic cycle comprising the steps of
- expanding a gaseous working stream transforming its energy into usable form and producing a spent stream
- mixing with the spent stream a lean stream forming a pre-condensed stream
- condensing the pre-condensed stream producing a liquid working stream
- pumping the liquid working stream to an increased pressure
- partially evaporating the liquid working stream with heat transferred from the spent stream and the lean stream
- forming from the liquid working stream a vapor stream and a first liquid stream
- separating the first liquid stream producing a second liquid stream and the lean stream
- mixing the second liquid stream with the vapor stream producing an enriched stream and
- heating the enriched stream with heat transferred from an external heat source producing the gaseous working stream
8. The method of claim 7 wherein the gaseous working stream the spent stream the lean stream the pre-condensed stream the liquid working stream the first liquid stream the second liquid stream the vapor stream and the enriched stream each comprise a low boiling component and a high boiling component.
9. Apparatus for implementing a thermodynamic cycle comprising
- means for expanding a gaseous working stream transferring its energy into usable form and producing a spent stream
- a first stream mixer for mixing the spent stream with a lean stream forming a pre-condensed stream
- a condenser for condensing the pre-condensed stream producing a liquid working stream
- a pump for pumping the liquid working stream to an increased pressure
- a gravity separator for forming from the liquid working stream a vapor stream and a first liquid stream
- a first stream separator for separating the first liquid stream producing a second liquid stream and the lean stream
- a second stream mixer for mixing the second liquid stream with the vapor stream producing an enriched stream and
- a heat exchanger for heating the enriched stream with heat transferred from an external heat source producing the gaseous working stream

170

10. The apparatus of claim 9 further including a gaseous working stream a spent stream a lean stream a
precondensed stream a liquid working stream a first liquid stream a second liquid stream a vapor
stream and an enriched stream that each comprise a low boiling component and a high boiling
component.
- 5 11 The apparatus of claim 9 further including a second heat exchanger for heating the liquid working
stream with heat transferred from the lean stream and a third heat exchanger for heating the liquid
working stream with heat transferred from the spent stream
- 10 12. The apparatus of claim 9 further including an external heat source having a temperature of less than
about 400 F
13. The apparatus of claim 12 wherein the external heat source has a temperature of less than about
250 F
- 15 14 The apparatus of claim 13 wherein the external heat source is selected from the group consisting of a
low temperature geothermal brine and a solar pond

20

25

30

35

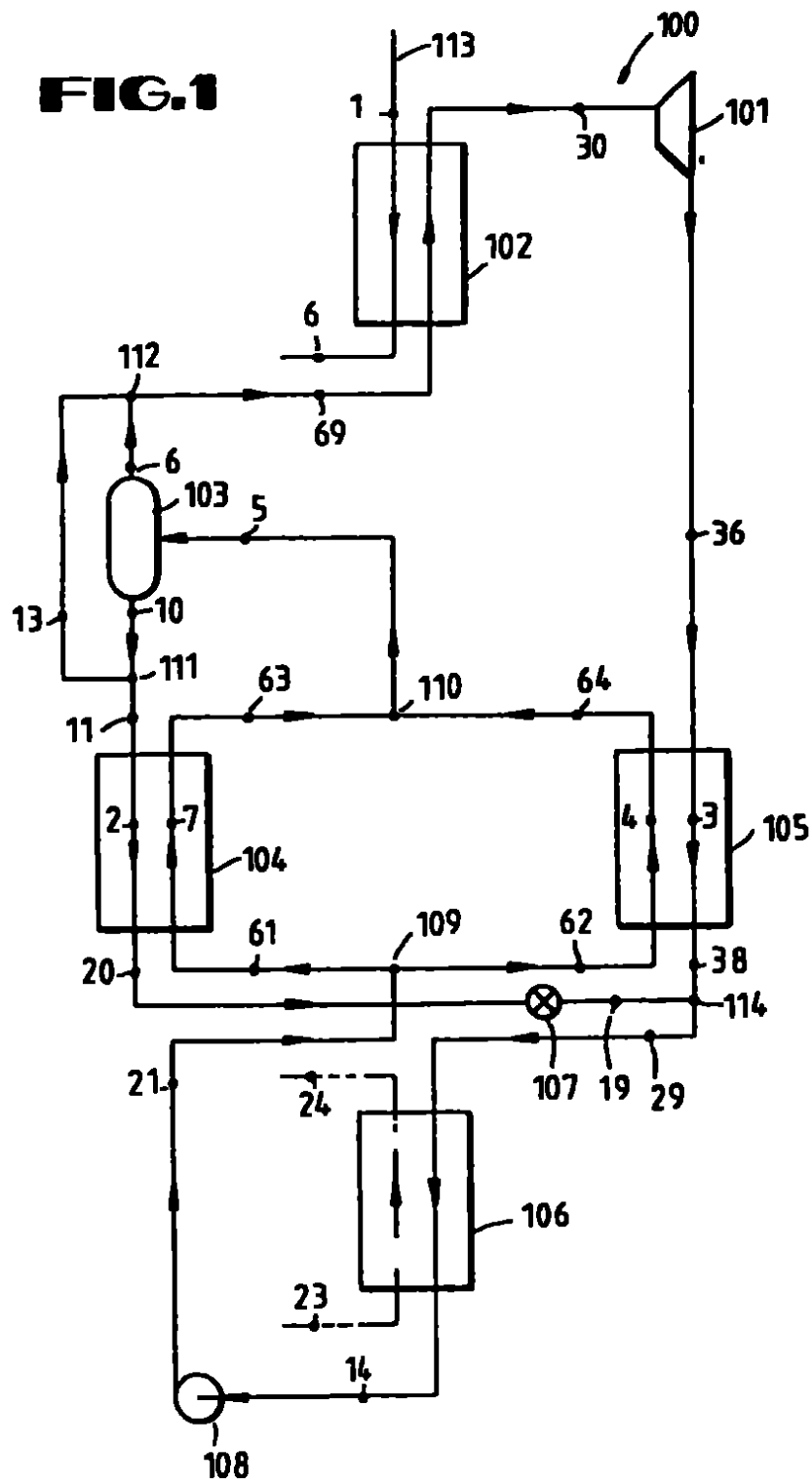
40

45

50

55

FIG.1





European Patent
Office

EUROPEAN SEARCH REPORT

Application Number

EP 91 11 2912

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. 8)
X	FR-A-1 546 326 (MAMIYA) * page 2 left column line 47 - page 3, left column line 37 figure 1 *	1 3 4	F01K25/06
X	EP-A-0 101 244 (KALINA) * page 33 line 20 - page 35, line 28; figure 5 *	1 2 6-10	
X	US-A-4 548 043 (KALINA) * column 6 line 35 - line 47 * * column 7 line 66 - column 10 line 30; figures *	1-14	
X	EP-A-0 193 184 (KALINA) * page 11 line 21 - page 14 line 38; figure 2 *	1 2 8-11	
A	EP-A-0 056 042 (KALINA) * figure 4 *	1	
A	US-A-4 586 340 (KALINA)		TECHNICAL FIELDS SEARCHED (Int. Cl. 8)
			F01K
The present search report has been drawn up for all claims			
Date of search THE NAME		Date of completion of the search 04 NOVEMBER 1991	Searcher VAN GHEEL J B H
CATEGORY OF CITED DOCUMENTS X : particularly relevant if cited alone Y : particularly relevant if combined with another document of the same category A : technological background G : non-written disclosures P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons A : member of the same patent family, corresponding document			

EP 91 11 2912 (1991)



US 2003/016776A1

173

(19) United States

(12) Patent Application Publication

(10) Pub No US 2003/016776A1

Bharathan et al

(43) Pub. Date

Sep 11, 2003

(54) MIXED WORKING FLUID POWER SYSTEM
WITH INCREMENTAL VAPOR
GENERATION

(52) US Cl

60/676 60/670

(76) Inventors: Desikan Bharathan, Arvada, CO (US)
Yahab Hassanli, Denver, CO (US)

(57)

ABSTRACT

Correspondence Address:

Paul J. White

Senior Counsel

National Renewable Energy Laboratory

1617 Cole Boulevard

Golden, CO 80401 (US)

A power generating system (110) comprising a heat source (116) and an incremental vapor generator system (112) operatively associated with the heat source (116). The incremental vapor generator system (112) includes a first heating section (136) and a second heating section (138). The first heating section (136) receives a mixed working fluid (114) and generates a first heated working fluid stream comprising a vapor portion (120) and a liquid portion. The second heating section (138) is operatively associated with the first heating section (136) and receives the liquid portion from the first heated working fluid stream. The second heating section (138) generates a second heated working fluid stream comprising a vapor portion (122). An energy conversion device (126) operatively associated with the incremental vapor generator system (112) converts into useful work heat energy contained in the vapor portions (120, 122) of the first and second heated working fluid streams.

(21) Appl. No. 10/258,718

(22) PCT Filed Jul 19, 2001

(86) PCT No PCT/US01/22773

Publication Classification

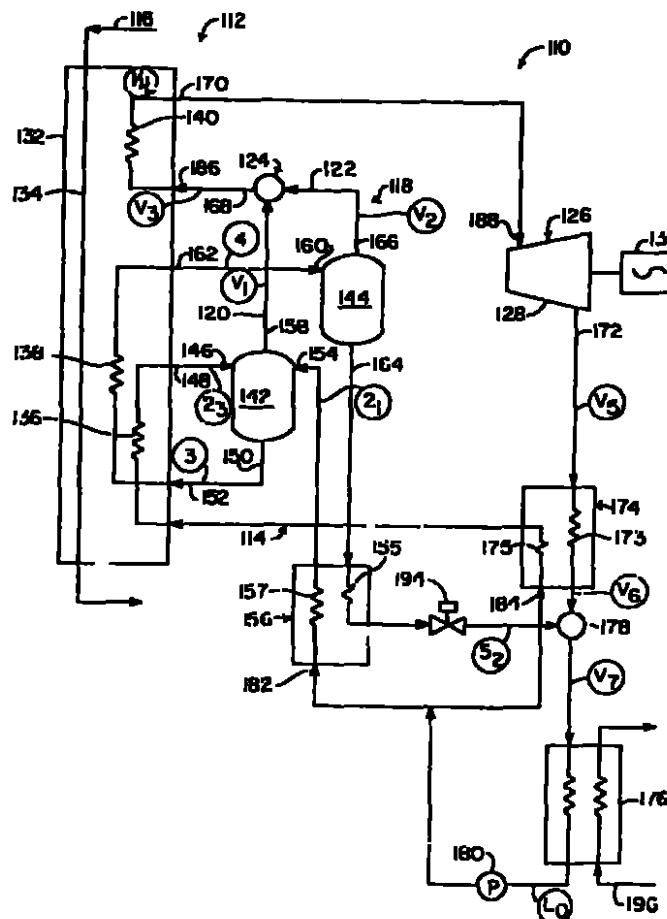
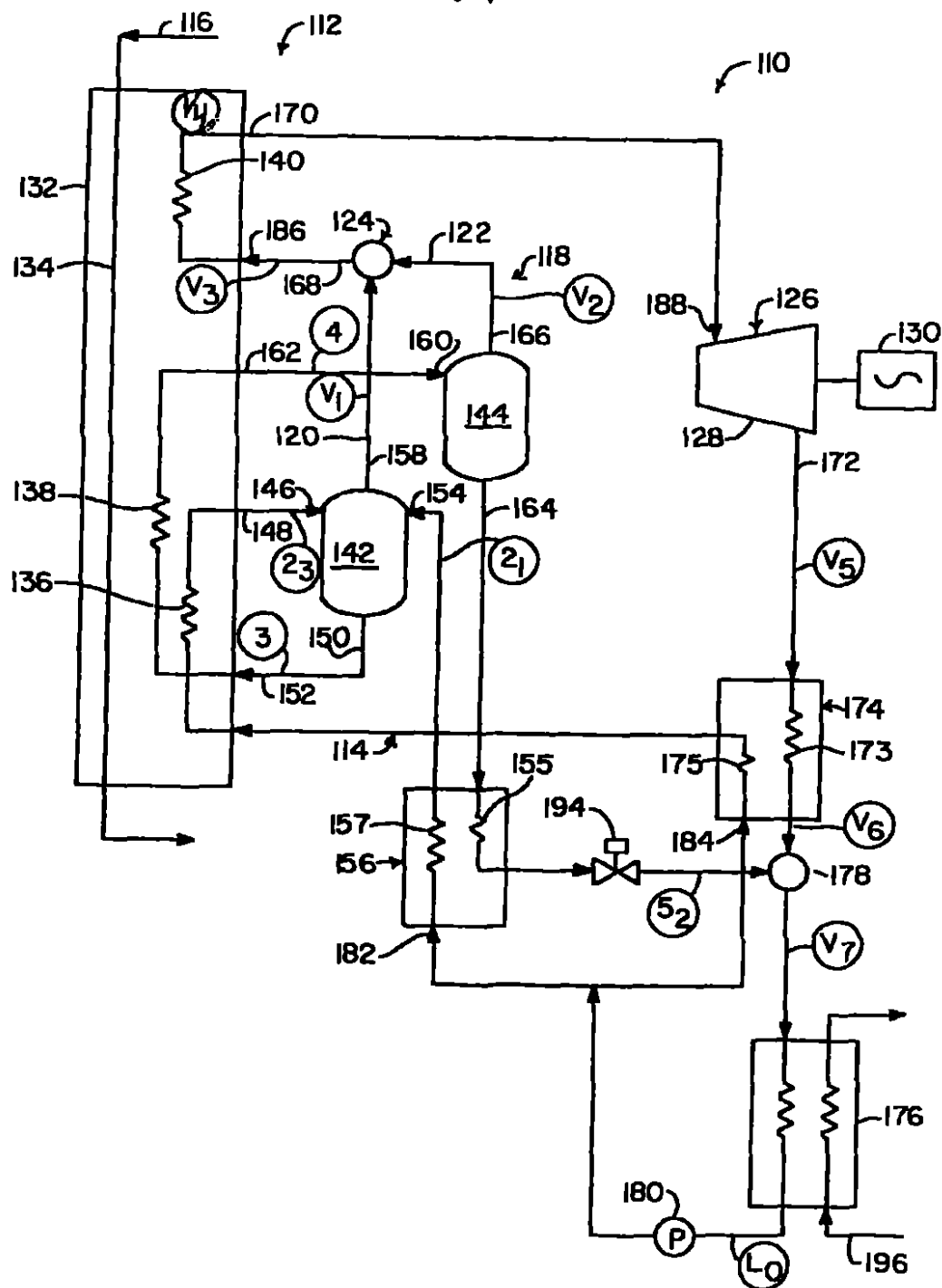
(51) Int. Cl.⁷ F01K 1/00; F01K 13/00

Fig 1



125

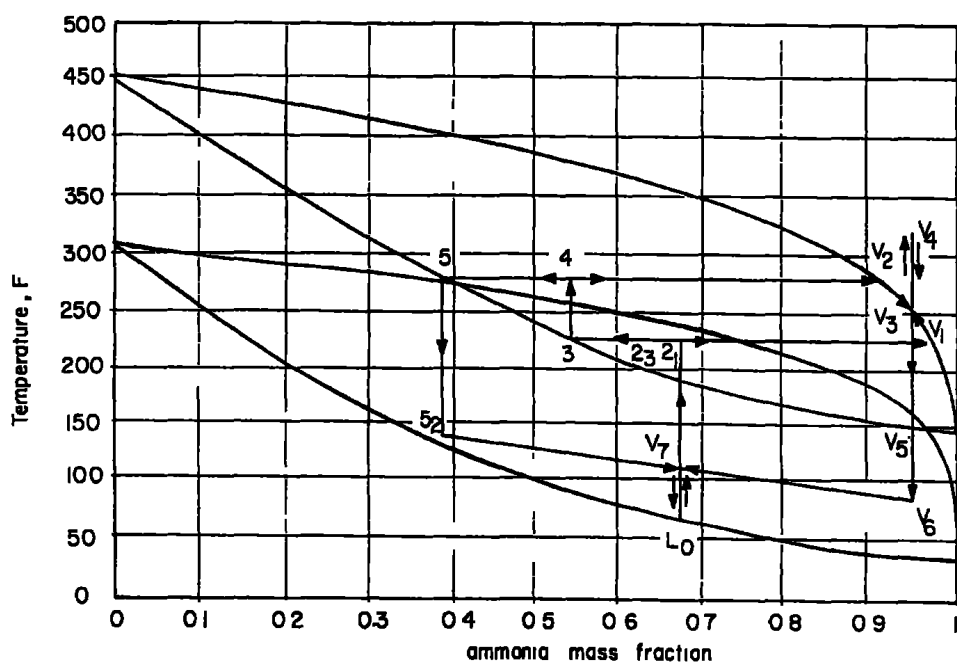


Fig 2

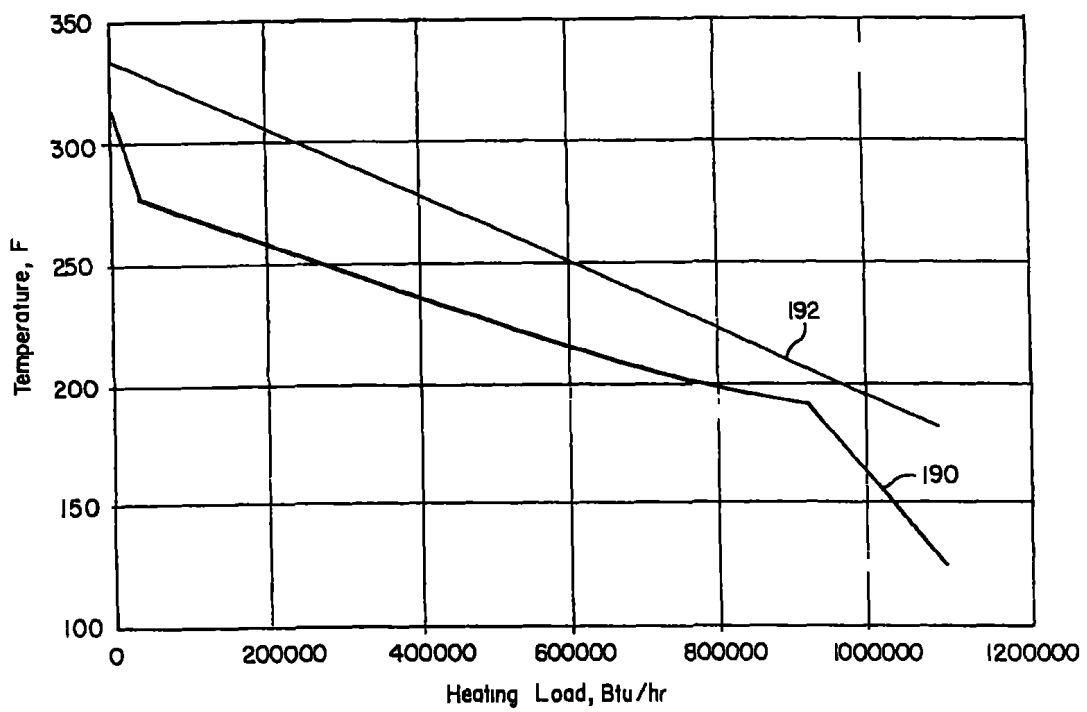
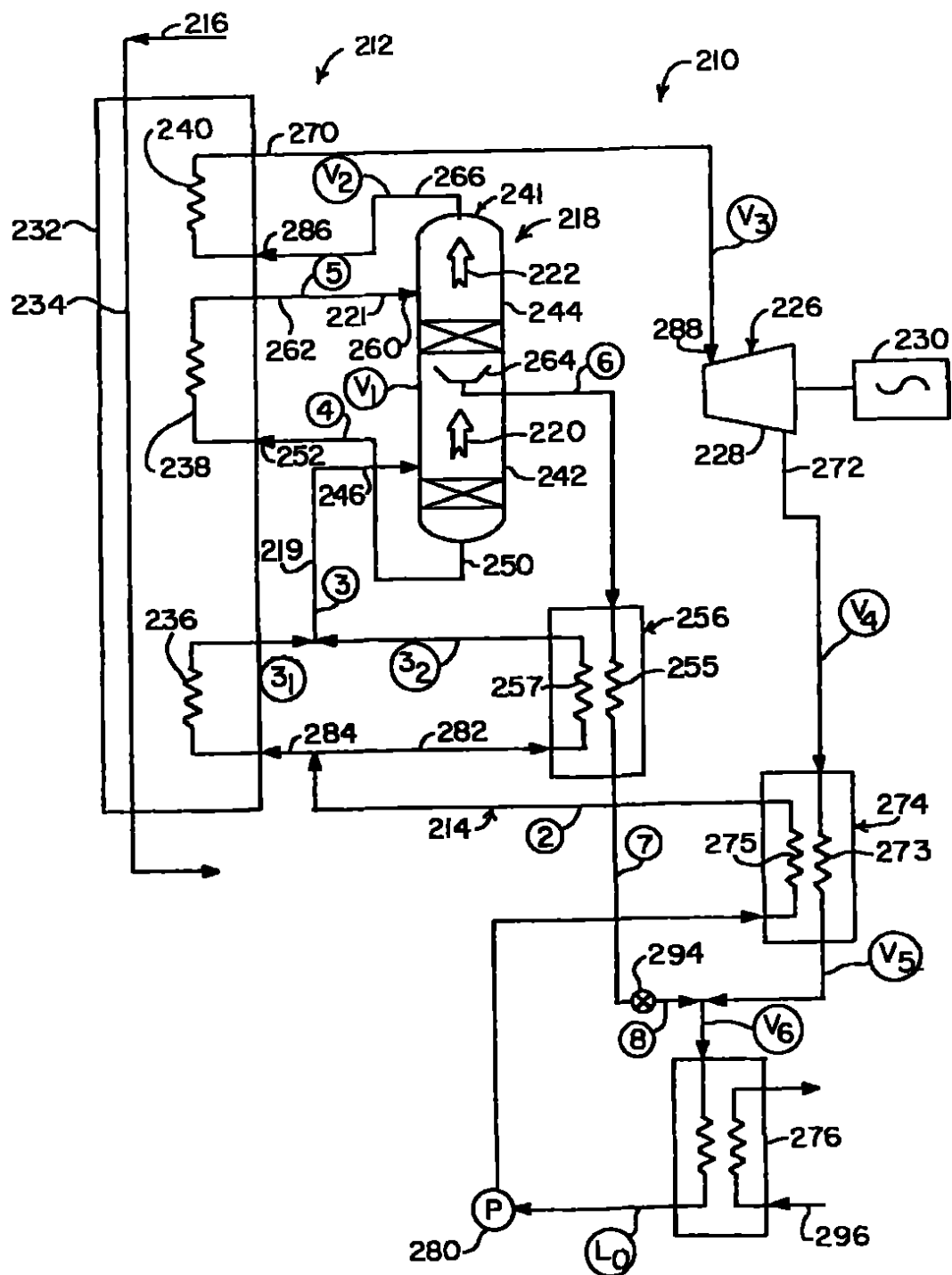


Fig 3

177



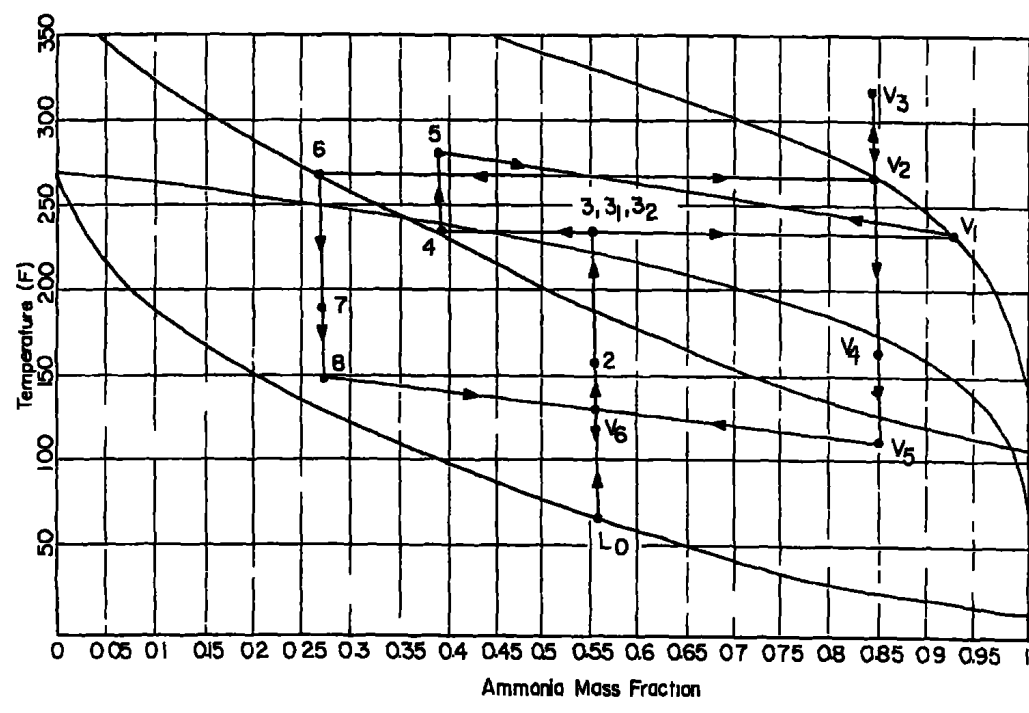


Fig 5

29

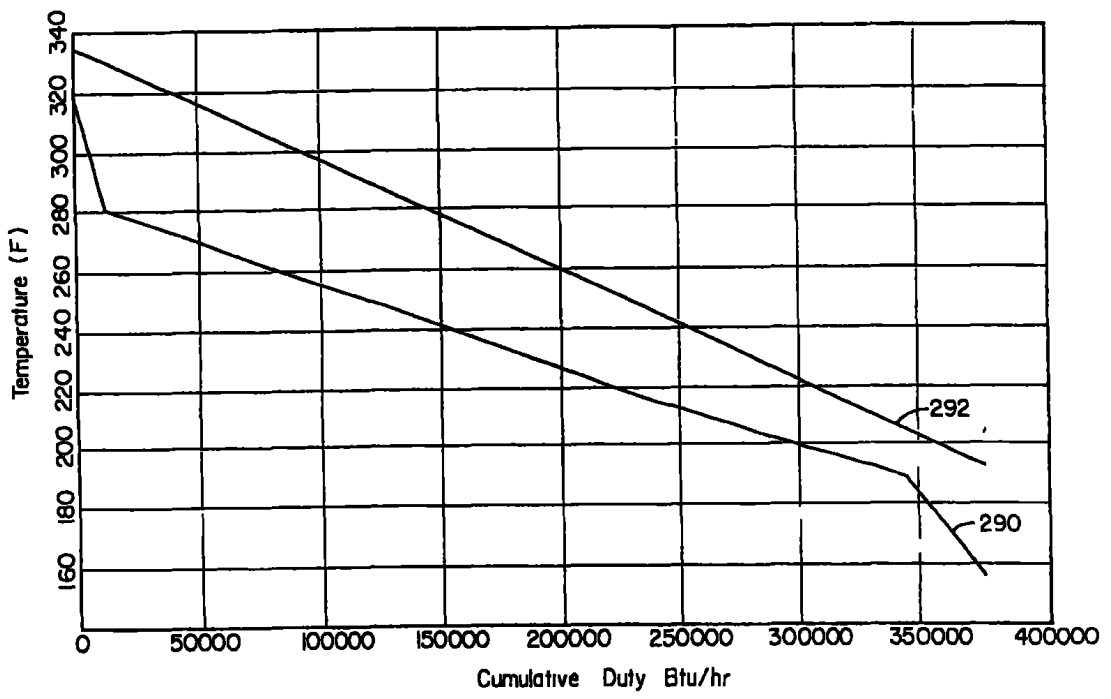


Fig 6

180

MIXED WORKING FLUID POWER SYSTEM WITH INCREMENTAL VAPOR GENERATION

CONTRACTUAL ORIGIN OF THE INVENTION

[0001] The United States Government has rights in this invention pursuant to Contract No. DLA76-99C(1)0337 between the U.S. Department of Energy and the National Renewable Energy Laboratory a division of the Midwest Research Institute.

TECHNICAL FIELD

[0002] This invention relates to power generation systems in general and more specifically to power generation systems utilizing mixed working fluids.

BACKGROUND ART

[0003] Power generation systems or power plants are well-known in the art and are widely used to generate electricity. Most such power generation systems generate electricity from heat energy derived from burning fossil fuels (e.g., coal or natural gas) and are referred to herein as thermal power plants. In addition to using heat energy derived from burning fossil fuels, thermal power plants can also be used with a wide variety of other heat sources, such as solar, geothermal, and nuclear sources.

[0004] Traditionally, thermal power plants have operated in accordance with the well-known Rankine thermodynamic cycle. In the Rankine cycle, a so-called "pure" working fluid, such as water, is heated to produce vapor or steam. The steam is then expanded, typically through a turbine, in order to convert heat energy contained therein into mechanical work. In the case of an electric power generation system, the turbine is operatively connected to an electrical generator which produces the electricity. While power plants operating in accordance with the Rankine cycle are well-known and widely used, certain characteristics of the Rankine cycle impose fundamental limitations on the thermodynamic efficiency of the cycle. For example, a Rankine cycle operating with a pure working fluid suffers some thermodynamic irreversibilities due to the fact that the pure working fluid vaporizes at substantially constant temperature. These irreversibilities can be larger or smaller depending on the temperature difference between the heating medium and working fluid.

[0005] Partly in an effort to solve some of the limitations associated with the use of a pure working fluid in the Rankine cycle, other types of thermodynamic cycles (e.g., any of the so-called Kalina cycles) have been developed which utilize mixed working fluids. Briefly, a mixed component working fluid comprises two or more vaporizable components which vaporize and condense progressively over a temperature range, rather than at the relatively constant temperature of a so-called "pure" working fluid (e.g., water). Accordingly, thermodynamic cycles utilizing mixed working fluids can, if properly designed, realize increased efficiencies over similar thermodynamic cycles (e.g., the Rankine cycle) that utilize pure working fluids such as water.

[0006] One design consideration for mixed working fluid systems relates to the boiler or vapor generator that is used to vaporize the mixed working fluid. That is, since the mixed

working fluid vaporizes over a temperature range, it is generally preferred to design the vapor generator so that heating function of the mixed working fluid closely follows the cooling function of the heating medium (i.e., closely matching the heating and cooling functions of the working and heating fluids reduces the thermodynamic irreversibilities during the heating cycle, thus increasing the overall thermodynamic efficiency of the system). In accordance with this consideration, thermodynamic cycles utilizing mixed fluids often make use of countercurrent heat exchangers, in which the heating medium and mixed working fluid flow in opposite directions. In this manner, the heating function of the mixed working fluid can be made to more closely follow the cooling function of the heating medium.

[0007] While such countercurrent heat exchangers have been used in mixed working fluid systems to achieve some performance and efficiency gains, there is still room for improvement, particularly in light of other requirements or limitations of the particular type of power generation system in which the heat exchanger is to be used. For example, a primary consideration of geothermal power generation systems relates to the so-called "brine effectiveness," that is, the amount of useful work that can be extracted or derived from a given brine flow rate. A desirable geothermal power generation system will seek to maximize brine effectiveness.

DISCLOSURE OF INVENTION

[0008] A power generating system according to the present invention may comprise a heat source and an incremental vapor generator system operatively associated with the heat source. The incremental vapor generator system includes a first heating section and a second heating section. The first heating section receives a mixed working fluid and generates a first heated working fluid stream comprising a vapor portion and a liquid portion. The second heating section is operatively associated with the first heating section and receives the liquid portion from the first heated working fluid stream. The second heating section generates a second heated working fluid stream comprising a vapor portion. An energy conversion device operatively associated with the incremental vapor generator system converts into useful work heat energy contained in the vapor portions of the first and second heated working fluid streams.

[0009] Also disclosed is a method for generating power from a mixed working fluid that comprises the steps of incrementally heating the mixed working fluid to produce a first vapor stream and a second vapor stream and converting into useful work heat energy contained in the first and second vapor streams.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] Illustrative and presently preferred embodiments of the invention are shown in the accompanying drawings in which:

[0011] FIG. 1 is a schematic diagram of a power generating system according to the present invention utilizing parallel flow incremental vapor generation.

[0012] FIG. 2 is an equilibrium/phase diagram of the mixed working fluid at the various stations of the power generating system shown in FIG. 1.

[0013] FIG. 3 is a graphical representation of the heating and cooling functions of the mixed working fluid and the heating fluid for the power generating system shown in FIG. 1.

[0014] FIG. 4 is a schematic diagram of a second embodiment of a power generating system according to the present invention utilizing serial flow incremental vapor generation.

[0015] FIG. 5 is an equilibrium/phase diagram of the mixed working fluid at the various stations of the power generating system shown in FIG. 4, and

[0016] FIG. 6 is a graphical representation of the heating and cooling functions of the mixed working fluid and the heating fluid for the power generating system of FIG. 4.

BEST MODELS FOR CARRYING OUT THE INVENTION

[0017] A power generating system 110 according to one embodiment of the present invention is shown in FIG. 1 and may comprise an incremental vapor generator system 112 for vaporizing a mixed working fluid 114. The incremental vapor generator system 112 incrementally vaporizes the mixed working fluid 114 with heat energy extracted from a heat source such as, for example, geothermal brine 116. Alternatively and as will be described in greater detail below, the present invention may be utilized with other types of heat sources and/or other types of heating fluids.

[0018] In the embodiment shown in FIG. 1 the incremental vapor generator system 112 comprises a parallel flow incremental vapor generation system 118 in which the mixed working fluid 114 is incrementally vaporized to form a first vapor portion 120 and a second vapor portion 122. The first and second vapor portions 120 and 122 thereafter may be combined in a vapor mixer 124 before being directed to an energy conversion system 126 which converts energy contained in the first and second vapor portions 120 and 122 into useful work heat. In the embodiment shown in FIG. 1, energy conversion system 126 comprises a turbine 128 and an electrical generator 130. Accordingly, heat energy contained in the first and second vapor portions 120, 122 is converted into electrical energy by the energy conversion system 126. In an alternate embodiment described below, the incremental vapor generator system may comprise a series flow incremental vapor generation system 218 (FIG. 4) in which the mixed working fluid is incrementally vaporized in a serial manner.

[0019] The parallel flow incremental vapor generating system 118 utilized in the first embodiment 110 of the power generating system according to the present invention is shown in FIG. 1 and may comprise a heat exchanger or vaporizer 132 having a primary loop 134 through which is caused to flow the heating fluid, e.g., geothermal brine 116. The heat exchanger or vaporizer 132 may also comprise first and second heating sections 136 and 138 that are in thermal communication with the primary loop 134 so that heat energy contained in the heating fluid (e.g., brine 116) is transferred to the mixed working fluid 114 flowing through the first and second heating sections 136 and 138, respectively. The heat exchanger 132 may also be provided with a third heating section 140 suitable for additionally heating the first and second vapor portions 120 and 122 in a manner that will be described in more detail below.

[0020] The first and second heating sections 136 and 138 are operatively associated with respective first and second separator systems 142 and 144. The first and second separator systems 142 and 144 separate liquid and vapor portions from the heated mixed working fluid introduced therein by the first and second heating sections 136 and 138, respectively. More specifically, a first inlet 146 of the first separator 142 is connected to the outlet 148 of the first heating section 136, whereas a liquid outlet 150 of the first separator 142 is connected to the inlet 152 of the second heating section 138. A second inlet 154 of first separator 142 is connected to a high temperature recuperator 156. A vapor outlet 158 of first separator 142 is connected to the vapor mixer 124.

[0021] The second separator 144 is provided with an inlet 160 that is connected to the outlet 162 of the second heating section 138. A liquid outlet 164 of second separator 144 is connected to the high temperature recuperator 156, whereas a vapor outlet 166 is connected to the vapor mixer 124.

[0022] The vapor mixer 124 is provided with a vapor outlet 168 which, in the embodiment shown and described herein, is connected to the third heating section 140. The third heating section 140 is used to further heat (e.g., superheat) the vaporized mixed working fluid 114 exiting the mixer 124. The outlet 170 of the third heating section 140 is connected to the energy conversion system 126. As mentioned above, the energy conversion system 126 may comprise a turbine 128 and electrical generator 130. The exhaust outlet 172 of turbine 128 is connected to a low temperature recuperator 174. The low temperature recuperator 174 is in turn connected to a condenser 176 via a mixer 178. The condenser 176 is operatively connected to the heat exchanger 132 via a pump 180 and the high and low temperature recuperators 156 and 174, respectively.

[0023] The power generation system 110 may be operated as follows to convert into useful work heat energy contained in the heating fluid (e.g., geothermal brine 116). As was briefly described above, the mixed working fluid 114 utilized herein vaporizes progressively over an increasing temperature range. That is, the temperature of the vapor and liquid comprising the heated mixed working fluid 114 increases with increasing quality. The point at which vaporization begins (i.e., at 0% quality) is referred to herein as the "bubble point" whereas the point at which vaporization is complete (i.e., at 100% quality) is referred to herein as the "dew point." By way of example, the mixed working fluid 114 utilized in the preferred embodiments shown and described herein comprises a mixture of ammonia and water. Alternatively, other mixed working fluids could be used as well.

[0024] Referring now to FIGS. 1 and 2 simultaneously, the mixed working fluid feed stream 114 exits the condenser 176 at about the bubble point for the mixture. This corresponds to station L₀ in FIG. 1 and the corresponding point L₀ in FIG. 2. Before proceeding with the description, it should be noted that various points in the system 110 that are of interest thermodynamically are referred to herein as "stations" and are indicated in FIGS. 1 and 4 as circled numbers or circled letter-number combinations. Such stations are indicated on the equilibrium/phase diagrams (e.g., FIGS. 2 and 5) as points having corresponding numbers or letter-number combinations. Hence, station L₁ is designated

in FIG. 1 as circled legend "1." The corresponding point in the equilibrium phase diagram illustrated in FIG. 2 is also designated "1."

[0025] Continuing now with the description the pump 180 increases the pressure of the mixed working fluid 114 to a point suitable for use in the high pressure side of the power generation system 110. The flow of the working fluid 114 is then split with a first stream 182 being directed through the high temperature recuperator 156 and a second stream 184 being directed to the low temperature recuperator 174. The heating characteristics of the high temperature recuperator 156 and the flow rate of the first stream 182 are selected so that the first stream 182 is heated to a point above its bubble point at the particular pressure involved (e.g. about 425 pounds per square inch absolute (psia)). That is, the first stream 182 is heated to a quality greater than zero. By way of example in one preferred embodiment the first stream 182 is heated to a quality in the range of about 10% to about 40% (30% preferred). This quality corresponds to a vapor portion in the range of about 80% to about 96% (90% preferred) on a volume basis. The heated first stream 182 is then directed to the inlet 154 of first separator system 142. This is identified as station 2₁ in FIG. 1 and as point 2₁ in FIG. 2.

[0026] The second stream 184 is heated by the low temperature recuperator 174 and thereafter is directed to the first heating section 136 of heat exchanger 132 where it is additionally heated to a temperature that exceeds the bubble point. This corresponds to station 2₂ in FIG. 1 and to point 2₂ in FIG. 2. It is generally preferred that the heating characteristics of the low temperature recuperator 174 and the first heating section 136, as well as the flow rate of the second stream 184 be such that the mixed working fluid 114 comprising the second stream 184 is heated to about the same quality as the first stream 182. That is, it is preferred that the points 2₁ and 2₂ on FIG. 2 be approximately coincident. The heated second stream 148 from the first heating section 136 is then directed to the first inlet 146 of the first separator 142.

[0027] The first separator system 142 receives the first and second heated streams 182 and 184 and separates the two streams 182 and 184 into a liquid portion and a vapor portion. The liquid portion exits the liquid outlet 150 of the separator 142 and is directed to the inlet 152 of the second heating section 138. The vapor portion exits the vapor outlet 158 of the first separator 142 as first vapor stream 120. The first vapor stream 120 is at about the dew point (i.e., 100% quality) for the particular concentration of the mixed working fluid 114 comprising the vapor portion stream 120. This corresponds to station v₁ in FIG. 1 and to point v₁ in FIG. 2.

[0028] Before proceeding with the description it should be noted that the concentrations of the constituents (e.g., ammonia and water) comprising the mixed working fluid 114 are different for the liquid and vapor portions. For example with reference now to FIG. 2 in one preferred embodiment wherein the mixed working fluid 114 comprises a mixture of ammonia and water the first vapor portion stream 120 (corresponding to point v₁ in FIG. 2) of the mixed working fluid 114 comprises a higher concentration of ammonia (e.g. slightly greater than about 0.95 on a mass basis) than does the liquid portion (point 3 in FIG. 2)

(i.e. the mixed working fluid 114). The liquid portion of the mixed working fluid 114 at point 3 has an ammonia concentration that is slightly less than about 0.55 (on a mass basis). Consequently any characteristics (e.g., quality) specifically recited herein for the mixed working fluid 114 at a particular station refer to the working fluid 114 in the particular state (e.g., vapor or liquid) and at the corresponding concentration at the referenced station. For example, at station v₁ the mixed working fluid 114 comprises a vapor having an ammonia concentration that is slightly greater than about 0.95 and is at about the dew point (i.e., a quality of about 100%) for the mixture at that particular ammonia concentration. At station 3 the mixed working fluid 114 comprises a liquid having an ammonia concentration that is slightly less than about 0.55 and is at about the bubble point (i.e., a quality of about 0%) for the mixture at the lower ammonia concentration. The ammonia concentrations (i.e. mass fractions) for the ammonia/water mixed working fluid 114 that may be utilized in the preferred embodiments of the present invention are shown in FIGS. 2 and 4 for the corresponding liquid and vapor portions of the mixed working fluid at the various stations.

[0029] With the foregoing points in mind the liquid portion of the mixed working fluid 114 from the first separator 142 is at about the bubble point of the liquid portion of mixed working fluid 114 at the corresponding ammonia concentration. That is, the liquid portion is at about the bubble point for the lower ammonia concentration of the liquid portion of the mixed working fluid 114. This corresponds to station 3 in FIG. 1 and to point 3 in FIG. 2. The liquid portion is directed into the inlet 152 of the second heating section 138 whereupon it is heated to a temperature in excess of the bubble point. It is generally preferred that the liquid portion be heated in the second heating section 138 to about the same quality as the mixed working fluid at stations 2₁ and 2₂. That is, the quality of the mixed working fluid stream exiting the second heating section 138 should be about the same as the qualities of the working fluid streams exiting the first heating section 136 and the high temperature recuperator 156. For example, in the embodiment shown and described herein the mixed working fluid stream exits the second heating section 138 at a quality in the range of about 10% to about 40% (30% preferred), which corresponds to a vapor portion in the range of about 80% to about 96% (90% preferred) on a volume basis. This corresponds to station 4 in FIG. 1 and to point 4 in FIG. 2.

[0030] The second separator system 144 receives the heated mixed fluid from the second heating section 138 and separates the heated mixed fluid into a liquid portion and a vapor portion. The liquid portion exits the liquid outlet 164 of the separator 144 and is directed to the high temperature recuperator 156 whereupon it surrenders a portion of its heat to the first working stream 182. The vapor portion from separator 144 exits the vapor outlet 166 as the second vapor portion stream 122. The second vapor portion stream 122 is at about the dew point (i.e., 100% quality) for the higher ammonia concentration of the mixed working fluid 114 that comprises the second vapor portion stream 122. See station v₂ in FIG. 1 and point v₂ in FIG. 2.

[0031] The vapor mixer 124 receives the first and second vapor streams 120 and 122 and combines them into a combined vapor stream 186. The combined vapor stream 186 corresponds to station v₃ in FIG. 1 and to point v₃ in

FIG. 2. The combined vapor stream 186 may be additionally heated (e.g., superheated) by the third heating section 140 to a temperature greater than the dew point temperature for the combined vapor stream 186. The superheated stream 188 exiting the third heating section 140 corresponds to station v_3 in FIG. 1 and to point v_3 in FIG. 2. The stream 188 is then directed to the energy conversion system 126.

[0032] The energy conversion system 126 extracts heat energy from the superheated stream 188, converting it into useful work. In the embodiment shown and described herein, heat energy contained in the first and second vapor streams 120 and 122 (which comprise combined stream 186 and superheated stream 188) is converted into electrical work by the turbine 128 and the electrical generator 130 comprising the energy conversion system 126.

[0033] The exhaust stream 172 from the turbine 128 corresponds to station v_2 in FIG. 1 and to point v_2 in FIG. 2 and is at a temperature that is greater than the dew point temperature for the mixed working fluid at the reduced pressure on the low pressure side of the power generating system 110. By way of example, in the embodiment shown and described herein, the mixed working fluid 114 is at a pressure of about 71 psia on the low pressure side. Alternatively, the exhaust stream could exit the turbine 128 at a temperature below the dew point of the mixed working fluid if the turbine is capable of handling wet mixtures. The exhaust stream 172 from turbine 128 is thereafter directed to the low temperature recuperator 174 wherein it surrenders a portion of its heat energy to the second working fluid stream 184. The cooled exhaust stream 172 exits the low temperature recuperator 174 at station v_6 at a temperature between the bubble and dew points for the mixed working fluid. By way of example, in one preferred embodiment, the cooled exhaust stream 172 exits the low temperature recuperator 174 at a quality in the range of about 0% to about 100% (45% preferred). See also point v_6 in FIG. 2.

[0034] The mixed working fluid exiting the low temperature recuperator 174 is then mixed with the liquid portion exiting the high temperature recuperator 136 in the mixer 178. The combined working fluid stream exits mixer 178 at station v_1 , which corresponds to point v_1 in FIG. 2. The combined working fluid stream is then condensed to the bubble point (station L_0 in FIG. 1 and point L_0 in FIG. 2) by the condenser 176. The condensed stream is then returned to the high pressure side of the system by pump 180 and the cycle is repeated.

[0035] A significant advantage of the power generating system 110 according to the present invention is that it results in closely matched heating and cooling curves for the working and heating fluids, respectively. For example, with reference now to FIG. 3, the heating curve or function 190 of the mixed working fluid closely follows the cooling curve or function 192 of the heating fluid (e.g., brine 116). The closely matched heating and cooling functions 190 and 192 improves thermodynamic efficiency by reducing the irreversibilities occurring in the heat exchanger 132. The closely matched heating and cooling functions also allow the brine 116 to be cooled to a lower temperature closer to the bubble point of the working fluid than is possible with prior systems. Consequently, the power generating system 110 of the present invention substantially reduces the heating fluid (e.g., brine 116) flow rate required for a given amount of

useful work. Accordingly, the power generating system 110 can be used with considerable advantage in geothermal power generation systems wherein it is desired to minimize the brine flow rate per kilowatt of electricity produced.

[0036] Having briefly described one embodiment of the power generating system 110, as well as some of its more significant features and advantages, the various embodiments of the power generating system according to the present invention will now be described in detail. However, before proceeding with the description, it should be noted that while the various embodiments of the power generating system are shown and described herein as they could be used in a geothermal electrical generating system utilizing hot brine 116 as the heating fluid, the present invention is not limited in use in geothermal electrical generating systems. In fact, power generating systems according to the present invention could be used with any of a wide variety of heating fluids and working fluids that are now known in the art or that may be developed in the future as would be obvious to persons having ordinary skill in the art after having become familiar with the teachings of the present invention. Consequently, the present invention should not be regarded as limited to the particular applications and/or heating and working fluids shown and described herein.

[0037] With the foregoing considerations in mind, one embodiment of a power generating system 110 according to the present invention comprises an incremental vapor generator system 112 for vaporizing a mixed working fluid 114 utilizing heat obtained from a suitable heat source. By way of example, in the embodiments shown and described herein, the heat source may comprise geothermal brine 116. The geothermal brine 116 comprises the heat source or heating fluid and is used to vaporize the working fluid 114 in the incremental vapor generator system 112.

[0038] The working fluid 114 used in the power generation system 110 may comprise any of a wide range of mixed non-azeotropic fluids now known in the art or that may be developed in the future suitable for use in the particular application. As used herein, the term "mixed fluid" refers to any fluid wherein the temperature of the vapor and liquid components increases with increasing quality. By way of example, in the embodiments shown and described herein, the mixed working fluid comprises a mixture of ammonia and water.

[0039] As was briefly mentioned above, in one embodiment of the invention, the incremental vapor generator system 112 comprises a parallel flow incremental vapor generation system 118. In the parallel flow incremental vapor generation system 118, the mixed working fluid 114 is incrementally vaporized to form a first vapor portion 120 and a second vapor portion 122. The first and second vapor portions 120 and 122 are combined (i.e., in a parallel manner) before being directed to the energy conversion system 126, hence the designation parallel flow incremental vapor generation system 118.

[0040] With reference now primarily to FIG. 1, the parallel flow incremental vapor generating system 118 utilized in one embodiment of the power generating system 110 according to the present invention comprises a heat exchanger or vaporizer 132 having a primary loop 134 through which is caused to flow the heating fluid. As mentioned above, in the embodiment shown and described herein, the heating fluid comprises geothermal brine 116.

Alternatively other types of heating fluids may be used as would be obvious to persons having ordinary skill in the art after having become familiar with the teachings of the present invention.

[0041] The heat exchanger or vaporizer 132 may also comprise first and second heating sections 136 and 138 arranged so that they are in thermal communication with the primary loop 134. Accordingly heat energy contained in the brine 116 is transferred to the mixed working fluid 114 flowing in the first and second heating sections 136 and 138 respectively. The heat exchanger 132 may also be provided with a third heating section 140 suitable for additionally heating the first and second vapor portions 120 and 122. For example, in the embodiment shown and described herein the third heating section 140 is used to heat the first and second vapor portions 120 and 122 above the dew point a process that is commonly known as "superheating."

[0042] It is generally preferred that the heat exchanger 132 comprise a counter-current heat exchanger in which the inlet end of the primary loop 134 is thermally adjacent the "hottest" heating section (e.g., the third heating section 140) and in which the outlet end is thermally adjacent the "coolest" heating section (e.g., the first heating section 136). Such an arrangement makes it easier to more closely match the heating function 190 of the working fluid 114 with the cooling function 192 of the heating fluid (e.g., brine 116). See FIG. 3.

[0043] The exact number of heating sections (e.g., heating sections 136, 138, and 140) comprising the heat exchanger 132 may vary depending on the particular application, the particular heating and working fluids used as well as on the number of stages (e.g., vapor separators) used to achieve the incremental heating of the working fluid in the manner shown and described herein. That is, the number of heating sections comprising the heat exchanger in any given application could be readily determined by persons having ordinary skill in the art after having become familiar with the teachings of the present invention and by applying the teachings to the particular application. Consequently the present invention should not be regarded as limited to a heat exchanger having any particular number of heating sections.

[0044] The heat exchanger 132 may be constructed from any of a wide range of materials and in accordance with any of a wide range of techniques that are now known in the art or that may be developed in the future that would be suitable for the particular application. However since heat exchangers of the type described herein could be readily fabricated by persons having ordinary skill in the art after having become familiar with the teachings of the present invention and since the details of such heat exchangers are not necessary to understand or practice the present invention the heat exchangers used in the embodiments shown and described herein will not be described in further detail herein.

[0045] The first and second heating sections 136 and 138 of the heat exchanger 132 are operatively associated with first and second separator systems 142 and 144. As will be described in greater detail below the first and second separator systems 142 and 144 separate liquid and vapor portions (not shown) from the heated mixed working fluid introduced therein by the first and second heating sections 136 and 138, respectively.

[0046] The first separator system 142 comprises a first inlet 146, a second inlet 154, a liquid outlet 150, and a vapor outlet 158. The first inlet 146 is connected to the outlet 148 of the first heating section 136 so that heated mixed working fluid from the first heating section 136 enters the separator system 142. The second inlet 154 of the first separator system 142 is connected to the high temperature recuperator 156 so that the first mixed working fluid stream 182 from the high temperature recuperator 156 is also directed into the separator system 142. The liquid outlet 150 of the first separator system 142 is connected to the inlet 152 of the second heating section 138 of heat exchanger 132. The vapor outlet 158 of the first separator system 142 is connected to the vapor mixer 124.

[0047] The first separator system 142 may comprise any of a wide range of separator systems that are well known in the art that would be suitable for separating vapor and liquid portions from an incoming wet mixture stream (e.g., the heated working fluid 114). Consequently the present invention should not be regarded as limited to any particular type of separator system.

[0048] The second separator system 144 may be similar to the first separator system 142, except that the second separator system 144 is provided with but a single inlet 160 connected to the outlet 162 of the second heating section 138. The arrangement is such that the second separator system 144 receives the heated mixed working fluid 114 from the second heating section 138 of heat exchanger 132. A liquid outlet 164 of the second separator 144 is connected to the high temperature recuperator 156, whereas a vapor outlet 166 is connected to the vapor mixer 124.

[0049] The high temperature recuperator 156 connected to the liquid outlet 164 of second separator system 144 is used to recover heat contained in the liquid portion separated by the second separator 144. The recovered heat is used to pre-heat the first mixed working fluid stream 182. In the embodiment shown and described herein the liquid outlet 164 of the second separator 144 is connected to a heating loop 155 of the high temperature recuperator 156 whereas a heated loop 157 of high temperature recuperator 156 is connected between the pump 180 and the second inlet 154 of first separator system 142. The separated liquid portion in the heating loop surrenders heat to the first mixed working fluid stream 182 in the heated loop 157 thereby pre-heating the first mixed working fluid stream 182. Thereafter the separated liquid portion passes through an expansion valve 194 before entering the low pressure side of the system 110.

[0050] The vapor mixer 124 is connected to the vapor outlets 158 and 166 of the respective first and second separator systems 142 and 144 and receives the corresponding first and second vapor portions 120 and 122. A vapor outlet 168 on the mixer 124 is connected to the third heating section 140. The outlet 170 of the third heating section 140 is connected to the energy conversion system 126.

[0051] The vapor mixer 124 may comprise any of a wide range of devices known in the art or that may be developed in the future that would be suitable for mixing together the first and second vapor portions 120 and 122. Consequently the present invention should not be regarded as limited to any particular type of vapor mixer system.

[0052] The energy conversion system 126 may comprise any of a wide range of systems and devices suitable for

185

converting into useful work heat energy contained in the heated mixed working fluid 114 exiting the parallel flow vapor generator 118 (or third heating section 140, if a third heating section is used) By way of example, in the embodiment shown and described herein the energy conversion system 126 comprises a turbine 128 and an electric generator 130 connected thereto. The turbine 128 and electric generator 130 may comprise any of a wide range of systems and devices that are well known in the art and readily commercially available. Consequently the turbine 128 and electric generator 130 utilized in one preferred embodiment of the invention will not be described in greater detail herein.

[0053] The exhaust outlet 172 of turbine 128 is connected to a low temperature recuperator 174. The low temperature recuperator 174 recovers heat contained in the turbine exhaust stream and uses it to pre-heat the second mixed working fluid stream 184. More specifically the exhaust outlet 172 of turbine 128 is connected to a heating loop 173 of the low temperature recuperator 174, whereas a heated loop 175 of the low temperature recuperator 174 is connected between the pump 180 and the first heating section 136 of the heat exchanger 132. The turbine exhaust stream in the heating loop 173 surrenders heat to the second mixed working fluid stream 184 in the heated loop 175, thereby pre-heating the second mixed working fluid stream 184 before the same enters the first heating section 136. Thereafter the exhaust stream is combined in the mixer 178 with the separated liquid portion exiting the expansion valve 194. A condenser 176 connected to the mixer 178 receives the combined cooled mixed working fluid 114, condenses it and returns it to pump 180.

[0054] The condenser 176 may comprise any of a wide range of condensers that are well-known in the art or that may be developed in the future that would be suitable for condensing the combined cooled mixed working fluid 114 from the mixer 178. By way of example, in the embodiment shown and described herein, the condenser 176 comprises an air-cooled condenser in which air 196 is used to condense the mixed working fluid 114 flowing in the condenser 176. Alternatively other cooling media besides air may be used to condense the mixed working fluid 114.

[0055] The power generation system 110 may be operated as follows to convert into useful work heat energy derived from the heating fluid. Consider for example a geothermal power generation system which generates electricity from geothermal brine 116 extracted from the earth. The geothermal brine 116 serves as the heating fluid and, in the example described herein, enters the primary loop 134 of the heat exchanger 132 at a temperature of about 335° F. although other temperatures are possible. The mixed working fluid 114 may comprise a mixture of ammonia and water and is maintained at a pressure of about 425 pounds per square inch absolute (psia) on the high pressure side of the power generating system 110. The low pressure side of the power generating system 110 is maintained at a pressure of about 71 psia. Alternatively other mixed fluids may be used at other pressures, as would be obvious to persons having ordinary skill in the art after having become familiar with the teachings of the present invention. The ammonia/water mixture that comprises the mixed working fluid 114 vaporizes progressively over an increasing temperature range.

That is, the temperature of the vapor and liquid comprising the heated mixed working fluid increases with increasing quality.

[0056] Referring now to FIGS. 1-3 the mixed working fluid feed stream 114 exits the condenser 176 at station 1₁, at about the bubble point for the mixture 114. This station corresponds to point 1₁ in FIG. 2. The pump 180 increases the pressure of the mixed working fluid 114 to a pressure suitable for use in the high pressure side of the power generating system 110. In the embodiment shown and described herein, the high pressure side of the system 110 is maintained at a pressure of about 425 psia. Therefore, the pump 180 increases the pressure of the mixed working fluid 114 to a pressure of about 425 psia. The mixed working fluid stream 114 exiting the pump 180 is then split into a first working fluid stream 182 and a second working fluid stream 184. The first working fluid stream 182 is directed through the heated loop 157 of the high temperature recuperator 156 whereupon it is heated by the liquid portion from the second separator 144 passing through the heating loop 155. The heating characteristics of the high temperature recuperator 156 and the flow rate of the first stream 182 are such that the first stream 182 is heated to a temperature in excess of its bubble point. This corresponds to station 2₁ in FIG. 1 and to point 2₁ in FIG. 2.

[0057] By way of example in the embodiment shown and described herein the first stream 182 is heated to a quality in the range of about 10% to about 40% (30% preferred). This quality range corresponds to a vapor portion range of about 80% to about 96% (90% preferred) on a volume basis. So heating the first working fluid stream 182 to a vapor portion in the range specified herein provides for good heat transfer characteristics in the high temperature recuperator 156. That is, some loss of efficiency in the high temperature recuperator 156 will occur if the first working fluid stream 182 is heated to a vapor portion that is substantially greater than the vapor portion range specified herein. After being heated in the high temperature recuperator 156 the heated first working fluid stream 182 is directed to the inlet 154 of the first separator system 142.

[0058] The second working fluid stream 184 is directed to the heated loop 175 of the low temperature recuperator 174 whereupon it is pre-heated by the exhaust stream 172 exiting the turbine 128. Thereafter the pre-heated second working fluid stream 184 is directed to the first heating section 136 of heat exchanger 132 which heats the second working fluid stream 184 to a temperature in excess of the bubble point. This corresponds to station 2₂ in FIG. 1 and to point 2₂ in FIG. 2. It is generally preferred that the flow rate of the second stream 184 be matched to the heating characteristics of the low temperature recuperator 174 and the first heating section 136 so that the mixed working fluid 114 comprising the second working fluid stream 184 is heated to about the same quality as the first stream 182. That is, it is preferred that the points 2₁ and 2₂ in FIG. 2 be approximately coincident. Stated another way the second working fluid stream 184 is heated to a quality in the range of about 10% to about 40% (30% preferred) which corresponds to a vapor portion in the range of about 80% to about 96% (90% preferred).

[0059] In the embodiment shown and described herein the mass ratio of the first working fluid stream 182 to the second

186

working fluid stream 184 is about 1-4. That is, most of the working fluid 114 is directed to the second stream 184 with only a small amount (i.e., 1% on a mass basis) being directed through the high temperature recuperator 136 as first working fluid stream 182. Of course, the mixed working fluid stream 114 may be divided in accordance with other mass ratios depending on the characteristics of the particular system.

[0060] Referring back now primarily to FIG. 1 the first separator system 142 receives the first and second heated streams 182 and 184 and separates the two streams 182 and 184 into a liquid portion and a vapor portion. The liquid portion exits the liquid outlet 150 of the first separator 142 and is directed to the inlet 152 of the second heating section 138. The vapor portion exits the vapor outlet 158 of the first separator 142 as a first vapor portion stream 120. The first vapor portion stream is at about the dew point (i.e., 100% quality) for the mixed working fluid 114. This corresponds to station v_1 in FIG. 1 and to point v_1 in FIG. 2.

[0061] The liquid portion from the first separator 142 is at about the bubble point of the mixed working fluid 114. See station 3 in FIG. 1 and point 3 in FIG. 2. The liquid portion is directed into the inlet 152 of the second heating section 138 whereupon it is heated to a temperature in excess of the bubble point. It is generally preferred that the liquid portion be heated to about the same quality as the mixed working fluid at stations 2₁ and 2₂. That is, the quality of the mixed working fluid stream exiting the second heating section 138 should be about the same as the qualities of the working fluid streams exiting the first heating section 136 and the high temperature recuperator 136. For example, in the embodiment shown and described herein, the mixed working fluid stream exits the second heating section 138 at a quality in the range of about 10% to about 40% (30% preferred). This corresponds to a vapor portion in the range of about 80% to about 96% (90% preferred). See station 4 in FIG. 1 and point 4 in FIG. 2. As discussed above heating the mixed working fluid to the quality ranges specified herein provides a good balance between temperature rise and heat transfer efficiency in the second heating section 138.

[0062] The second separator system 144 receives the heated mixed fluid from the second heating section 138 and separates the heated mixed fluid into a liquid portion and a vapor portion. The liquid portion exits the liquid outlet 164 of the separator 144 and is directed to the high temperature recuperator 136 whereupon it surrenders a portion of its heat to the first working fluid stream 182. Thereafter the cooled liquid portion is expanded through the expansion valve 194 to the low pressure side of the power generating system 110. See station 5₁ in FIG. 1 and point 5₁ in FIG. 2. The cooled, expanded liquid portion is then combined with the turbine exhaust stream in mixer 178.

[0063] The vapor portion from the second separator 144 exits the vapor outlet 166 of separator 144 as the second vapor portion stream 122. The second vapor portion stream 122 is at about the dew point (i.e., 100% quality) and corresponds to station v_2 in FIG. 1 and to point v_2 in FIG. 2.

[0064] The vapor mixer 124 receives the first and second vapor streams 120 and 122 and combines them into a combined vapor stream 186. The combined vapor stream 186 corresponds to station v_3 in FIG. 1 and to point v_3 in

FIG. 2. If desired the combined vapor stream 186 may be additionally heated by the third heating section 140 to a temperature greater than the dew point temperature for the combined vapor stream 186. That is, the combined vapor stream 186 may be superheated in the third heating section 140. The superheated stream 188 exiting the third heating section 140 is designated as station v_4 in FIG. 1 and corresponds to point v_4 in FIG. 2. The stream 188 is then directed to the energy conversion system 126.

[0065] The energy conversion system 126 extracts heat energy from the superheated stream 188 converting it into useful work. In the embodiment shown and described herein heat energy contained in the first and second vapor streams 120 and 122 (which comprise combined stream 186 and superheated stream 188) is converted into electrical work by the turbine 128 and the electrical generator 130 comprising the energy conversion system 126.

[0066] The superheated stream 188 is expanded in the turbine 128 and exits the turbine 128 as exhaust stream 172. See station v_5 in FIG. 1 and point v_5 in FIG. 2. It is generally preferred that the expansion process be terminated before the mixed working fluid 114 is cooled below the dew point temperature. By way of example in the embodiment shown and described herein, the mixed working fluid 114 is expanded to a pressure of about 71 psia and to a temperature of about 190° F. which is below the dew point. That is, the mixed working fluid 114 is cooled to a temperature below the dew point temperature since in the embodiment shown and described herein, the energy conversion device 126 functions effectively with wet mixtures. The exhaust stream 172 is thereafter directed to the low temperature recuperator 174 whereupon it surrenders a portion of its heat energy to the second working fluid stream 184 flowing in the heated loop 175 of low temperature recuperator 174. The cooled exhaust stream 172 exits the low temperature recuperator 174 at station v_6 at a temperature between the bubble and dew points for the mixed working fluid. See point v_6 in FIG. 2. By way of example, in the embodiment shown and described herein, the cooled exhaust stream 172 exits the low temperature recuperator 174 at a quality in the range of about 0% to about 100% (45% preferred).

[0067] The mixed working fluid exiting the low temperature recuperator 174 is then mixed in mixer 178 with the liquid portion flowing through the expansion valve 194. The combined working fluid stream that exits mixer 178 is designated as station v_7 and corresponds to point v_7 in FIG. 2. The combined working fluid stream is then condensed by the condenser 176 to about the bubble point (i.e., at station L_1 in FIG. 1 and point L_1 in FIG. 2). The condensed stream is then returned to the high pressure side of the system by pump 180 and the cycle is repeated.

[0068] The power generating system 110 just described results in the closely matched heating and cooling functions 190 and 192 shown in FIG. 3. That is, the heating curve 190 of the mixed working fluid 114 closely follows the cooling curve 192 of the heating fluid (e.g., geothermal brine 116).

[0069] As mentioned above the first embodiment 110 of the power generating system according to the present invention utilizes a parallel flow vapor generator system 118 in which the working fluid is incrementally vaporized to produce first and second vapor portion streams 120 and 122 which are then combined in a parallel manner (e.g., by mixer

187

124) before being superheated (if desired) and directed to the energy conversion system 126. However other incremental vaporization arrangements are possible in accordance with the teachings of the present invention.

[0070] With reference now to FIGS 4-6 a second embodiment 210 of a power generating system according to the present invention embodies an incremental vapor generator system 212 that comprises a series flow vapor generator system 218. Briefly in the series flow vapor generator system 218 the mixed working fluid 214 is incrementally vaporized to form a first vapor portion 220 and a second vapor portion 222. The first vapor portion 220 is then used to condense or separate a liquid portion from a heated mixed working fluid stream 221 from which is derived the second vapor portion 222. Since in the case of the mixed working fluid 214, the liquid is "lean" and the first vapor portion 220 is "rich" the first vapor portion 220 condenses on the lean liquid. The heat of condensation causes additional vapor to be produced. Accordingly the series flow vapor generator system 218 produces the vapor streams 220 and 222 in a serial manner.

[0071] With reference now primarily to FIG. 4, the serial flow incremental vapor generating system 218 utilized in the second embodiment 210 of the power generating system according to the present invention comprises a heat exchanger or vaporizer 232 having a primary loop 234 through which is caused to flow the heating fluid. In the embodiment shown and described herein, the heating fluid comprises geothermal brine 216, although other types of heating fluids may be used, as would be obvious to persons having ordinary skill in the art after having become familiar with the teachings of the present invention. The heat exchanger or vaporizer 232 may also comprise first and second heating sections 236 and 238 arranged so that they are in thermal communication with the primary loop 234 so that heat energy contained in the brine 216 is transferred to the mixed working fluid 214 flowing in the first and second heating sections 236 and 238, respectively. The heat exchanger 232 may also be provided with a third heating section 240 suitable for additionally heating the combined first and second vapor portions 220 and 222. For example, and as was the case for the first embodiment 110 the third heating section 240 of the second embodiment 210 is used to heat the first and second vapor portions 220 and 222 above the dew point.

[0072] It is generally preferred that the heat exchanger 232 be of the counter-current type in which the inlet end of the primary loop 234 is thermally adjacent the "hottest" heating section (e.g. the third heating section 240) and the outlet end is thermally adjacent the "coolest" heating section (e.g. the first heating section 236). Such an arrangement allows the system 210 to more closely match the heating function 290 of the working fluid 214 with the cooling function 292 of the heating fluid (e.g. brine 216). See FIG. 6.

[0073] The exact number of heating sections (e.g. heating sections 236, 238 and 240) comprising the heat exchanger 232 may vary depending on the particular application, the particular heating and working fluids used, as well as the number of stages used to achieve the incremental heating of the working fluid 214 in the serial manner described herein. The number of heating sections comprising the heat exchanger in any given application could be readily deter-

mined by persons having ordinary skill in the art after having become familiar with the teachings of the present invention and by applying the teachings to the particular application. Consequently the present invention should not be regarded as limited to a heat exchanger having any particular number of heating sections.

[0074] The heat exchanger 232 may be constructed from any of a wide range of materials and in accordance with any of a wide range of techniques that are now known in the art or that may be developed in the future that would be suitable for the particular application. However since heat exchangers of the type described herein could be readily fabricated by persons having ordinary skill in the art after having become familiar with the teachings of the present invention and since the details of such heat exchangers are not necessary to understand or practice the present invention the heat exchangers used in the embodiments shown and described herein will not be described in further detail herein.

[0075] The first and second heating sections 236 and 238 of the heat exchanger 232 are operatively associated with an integral separator system 241 comprising a first separator section 242 and a second separator section 244. As will be described in greater detail below the first and second separator sections 242 and 244 comprising the integral separator system 241 separate liquid and vapor portions (not shown) from respective first and second heated mixed working fluid streams 219 and 221.

[0076] The first separator section 242 of integral separator system 241 is provided with an inlet 246 that is connected to the high temperature recuperator 256 and the first heating section 236 in the manner best seen in FIG. 4. The arrangement is such that the first separator section 242 receives the first heated working fluid stream 219. The liquid outlet 250 of the first separator section 242 is connected to an inlet 252 of the second heating section 238.

[0077] The second separator section 244 of integral separator system 241 is provided with an inlet 260 connected to the outlet 262 of second heating section 238 so that the second separator section 244 receives the second heated working fluid stream 221 from the second heating section 238. The second separator section 244 is also provided with a collector 264 for collecting additional amounts of separated liquid. The collector 264 is connected to a heating loop 255 of the high temperature recuperator 256. A vapor outlet 266 provided in the second separator section 244 is connected to the third heating section 240. The outlet 270 of the third heating section 240 is connected to the energy conversion system 226.

[0078] The high temperature recuperator 256 is connected to the collector 264 of the second separator section 244 of integral separator 241. The high temperature recuperator 256 receives heat contained in the liquid portion separated by the second separator section 244 of the integral separator 241. The recovered heat is used to heat the pre-heated second working fluid stream 282. In the embodiment shown and described herein the collector 264 is connected to the heating loop 255 of the high temperature recuperator 256 whereas a heated loop 257 of high temperature recuperator 256 is connected in parallel with the first heating section 236 of the heat exchanger 232. The heating loop 255 is con-

ected to an expansion valve 294 which returns the cooled liquid portion to the low pressure side of the power generating system 210.

[0079] As was the case for the first embodiment 110 (FIG. 1) of the power generating system the energy conversion system 226 of the second embodiment 210 of the power generating system may comprise any of a wide range of systems and devices suitable for converting into useful work heat energy contained in the heated mixed working fluid 214 exiting the series flow vapor generator 218 (or third heating section 240 if a third heating section is used). By way of example, the energy conversion system 226 comprises a turbine 228 and an electric generator 230 connected thereto. The turbine 228 and electric generator 230 may comprise any of a wide range of systems and devices that are well-known in the art and readily commercially available. Consequently the turbine 228 and electric generator 230 utilized in one preferred embodiment of the invention will not be described in greater detail herein.

[0080] The exhaust outlet 272 of turbine 228 is connected to a low temperature recuperator 274. The low temperature recuperator 274 recovers heat contained in the turbine exhaust stream and uses it to pre-heat the mixed working fluid stream 214. More specifically the exhaust outlet 272 of turbine 228 is connected to a heating loop 273 of the low temperature recuperator 274 whereas a heated loop 275 of the low temperature recuperator 274 is connected between the pump 280 and the parallel arrangement of the heating loop 257 of the high temperature recuperator 256 and the first heating section 236 of heat exchanger 232. The turbine exhaust stream in the heating loop 273 surrenders heat to the mixed working fluid stream 214 in the heated loop 275, thereby pre-heating the mixed working fluid stream 214 before the same enters the high temperature recuperator 256 and the first heating section 236. Thereafter the exhaust stream is combined with the separated liquid portion exiting the expansion valve 294. A condenser 276 connected to the low temperature recuperator 274 and expansion valve 294 receives the combined cooled mixed working fluid 214, condenses it and returns it to pump 280.

[0081] The condenser 276 may comprise any of a wide range of condensers that are well-known in the art or that may be developed in the future that would be suitable for condensing the combined cooled mixed working fluid 214. By way of example, in the embodiment shown and described herein the condenser 276 comprises an air-cooled condenser in which air 296 is used to condense the mixed working fluid 214 flowing in the condenser 276.

[0082] The second embodiment 210 of the power generation system of the present invention may be operated as follows to convert into useful work heat energy derived from the heating fluid i.e., geothermal brine 216 extracted from the earth. As was the case for the first embodiment the geothermal brine 216 may enter the primary loop 234 of the heat exchanger 232 at a temperature of about 335° F. although other temperatures are possible. The mixed working fluid 214 may comprise a mixture of ammonia and water and is maintained at a pressure of about 250 psia on the high pressure side of the power generating system 210. The low pressure side is maintained at a pressure of about 43 psia. Alternatively other mixed working fluids may be used at other pressures, as would be obvious to persons having

ordinary skill in the art after having become familiar with the teachings of the present invention.

[0083] With reference now to FIGS. 4-6 the mixed working fluid stream 214 exits the condenser 276 at station 1₁, about the bubble point for the mixture 214. This station corresponds to point 1₁ in FIG. 5. The pump 280 increases the pressure of the mixed working fluid 214 to a pressure suitable for use in the high pressure side of the power generating system 210. In the embodiment shown and described herein the high pressure side of the system 210 is maintained at a pressure of about 250 psia. Therefore the pump 280 increases the pressure of the mixed working fluid 214 to a pressure of about 250 psia. The mixed working fluid stream 214 exiting the pump 280 is then directed to the heated loop 275 of the low temperature recuperator 274 which pre-heats the mixed working fluid 214. See station 2 of FIG. 4 and corresponding point 2 in FIG. 5. The pre-heated mixed working fluid stream 214 is then split or divided into a first stream 282 and a second stream 284. The first stream 282 is directed through the heated loop 257 of the high temperature recuperator 256 whereupon it is heated by the liquid portion extracted from the second separator section 244 by the collector 264. The heating characteristics of the high temperature recuperator 256 and the flow rate of the first stream 282 are such that the first stream 282 is heated to a temperature in excess of its bubble point. This corresponds to station 3₁ in FIG. 4 and to point 3₁ in FIG. 5.

[0084] In the embodiment shown and described herein, the first stream 282 is heated to a quality in the range of about 10% to about 40% (30% preferred). This quality range corresponds to a vapor portion range of about 80% to about 96% (90% preferred) on a volume basis. So heating the first working fluid stream 282 to a vapor portion in the specified range provides for good heat transfer characteristics in the high temperature recuperator 256. That is, some loss of efficiency in the high temperature recuperator 256 will be experienced if the first working fluid stream 282 is heated to a vapor portion that is substantially greater than the vapor portion range described herein. After being heated in the high temperature recuperator 256 the heated first working fluid stream 282 mixed with the heated working fluid stream 284 exiting the first heating section 236 and directed into the inlet 246 of first separator section 242 as first heated working fluid stream 219. See station 3 in FIG. 4 and corresponding point 3 in FIG. 5.

[0085] The second stream 284 is directed to the first heating section 236 of the heat exchanger 232 which heats the second working fluid stream 284 to a temperature in excess of the bubble point. This corresponds to station 3₂ in FIG. 4 and to point 3₂ in FIG. 5. It is generally preferred that the flow rate of the second stream 284 be matched to the heating characteristics of the first heating section 236 so that the mixed working fluid 214 comprising the second working fluid stream 284 is heated to about the same quality as the first stream 282. That is, it is preferred that the points 3₁ and 3₂ in FIG. 5 be approximately coincident. Stated another way the second working fluid stream 284 is heated to a quality in the range of about 10% to about 40% (30% preferred) which corresponds to a vapor portion in the range of about 80% to about 96% (90% preferred).

[0086] In the embodiment shown and described herein, the mass ratio of the first working fluid stream 282 to the second

189

working fluid stream 284 is about 1.4. That is, most of the working fluid 214 is directed to the second stream 284 with only a small amount (i.e. $\frac{1}{4}$ on a mass basis) being directed through the high temperature recuperator 256 as first working fluid stream 282. Of course, the mixed working fluid 214 may be divided in accordance with other mass ratios depending on the characteristics of the particular system.

[0087] Still referring primarily to FIG. 4, the first separator section 242 in integral separator system 241 receives the first and second heated streams 282 and 284 as combined first heated working fluid stream 219 and separates the stream 219 into a liquid portion and a vapor portion 220. The liquid portion exits the liquid outlet 250 of the first separator section 242 and is directed to the inlet 252 of the second heating section 238. The vapor portion 220 is at about the dew point (i.e. 100% quality) for the mixed working fluid 214. This corresponds to station v_1 in FIG. 4 and to point v_1 in FIG. 5.

[0088] The liquid portion from the first separator 242 is at about the bubble point of the mixed working fluid 214. See station 4 in FIG. 4 and point 4 in FIG. 5. The liquid portion is directed into the inlet 252 of the second heating section 238 whereupon it is heated to a temperature in excess of the bubble point. This corresponds to station 5 in FIG. 4 and to point 5 in FIG. 5. It is generally preferred that the liquid portion be heated to about the same quality as the mixed working fluid at stations 3₁ and 3₂. That is, the quality of the mixed working fluid stream exiting the second heating section 238 should be about the same as the qualities of the working fluid streams exiting the first heating section 236 and the high temperature recuperator 256. For example, in the embodiment shown and described herein, the mixed working fluid stream exits the second heating section 238 at a quality in the range of about 10% to about 40% (30% preferred). This corresponds to a vapor portion in the range of about 80% to about 98% (90% preferred). As discussed above, heating the mixed working fluid to the quality ranges specified herein provides a good balance between temperature rise and heat transfer efficiency in the second heating section 238.

[0089] The second separator section 244 of integral separator system 241 receives the heated mixed fluid from the second heating section 238 as second heated mixed working fluid stream 221. The second separator section 244 separates the second heated working fluid stream 221 into a liquid portion (not shown) and a vapor portion 222. As mentioned earlier, the first vapor portion 220 from the first separator section 242 is used to further separate the vapor portion from the heated mixed working fluid stream 221. Since the liquid portion to be separated from the second heated mixed working fluid stream is "lean" (e.g. lower ammonia concentration) and since the first vapor portion 220 is "rich" (i.e. higher ammonia concentration) portions of the first vapor portion 220 will condense on the lean liquid portion in the second separator section 244. The heat of condensation causes additional amounts of vapor portion 222 to be produced.

[0090] The liquid portion drained from separator 244 is collected by the collector 264 and exits the integral separator system 241. This corresponds to station 6 in FIG. 4 and to point 6 in FIG. 5. The collected liquid portion then proceeds to the high temperature recuperator 256 whereupon it sur-

renders a portion of its heat to the first working fluid stream 282. See station 7 in FIG. 4 and corresponding point 7 in FIG. 5. Thereafter the cooled liquid portion is expanded through the expansion valve 294 to the low pressure side of the power generating system 210. See station 8 in FIG. 4 and point 8 in FIG. 5. The cooled, expanded liquid portion is then combined with the turbine exhaust stream at station v_6 and corresponding point v_6 in FIG. 5.

[0091] The vapor portion 222 produced in the second separator portion 244 combines with residual amounts of the first vapor portion 220 from the first separator portion 242 and exits the integral vapor separator system 241 as combined vapor stream 286. This corresponds to station v in FIG. 4 and to point v in FIG. 5. The combined vapor stream 286 may be additionally heated by the third heating section 240 to a temperature that is greater than the dew point temperature for the combined vapor stream 286. That is, the combined vapor stream 286 is superheated in the third heating section 240. The superheated stream 288 exiting the third heating section 240 corresponds to station v_3 in FIG. 4 and to point v_3 in FIG. 5. The stream 288 is then directed to the energy conversion system 226.

[0092] As was the case for the first embodiment 110, the energy conversion system 226 of the second embodiment 210 extracts heat energy from the superheated stream 288 converting it into useful work. In the embodiment shown and described herein, heat energy contained in the first and second vapor streams 220 and 222 (which comprise combined stream 286 and superheated stream 288) is converted into electrical work by the turbine 228 and the electrical generator 230 comprising the energy conversion system 226.

[0093] The superheated stream 288 is expanded in the turbine 228 and exits the turbine 228 as exhaust stream 272. See station v_4 in FIG. 4 and point v_4 in FIG. 5. It is generally preferred that the expansion process be terminated before the mixed working fluid 214 is cooled below the dew point temperature. By way of example, in the embodiment shown and described herein the mixed working fluid 214 is expanded to a pressure of about 43 psia and to a temperature of about 160° F. which is below the dew point of the mixed working fluid 214 at the designated pressure. The mixed working fluid 214 can be cooled to a temperature below the dew point temperature since the energy conversion device 226 can function effectively with wet mixtures. The exhaust stream 272 is thereafter directed to the low temperature recuperator 274 where it surrenders a portion of its heat energy to the working fluid stream 214 flowing in the heated loop 275 of low temperature recuperator 274. The cooled exhaust stream 272 exits the low temperature recuperator 274 at station v_5 at a temperature between the bubble and dew points for the mixed working fluid. See point v_5 in FIG. 5. By way of example, in this embodiment the cooled exhaust stream 272 exits the low temperature recuperator 274 at a quality in the range of about 0% to about 100% (45% preferred).

[0094] The mixed working fluid exiting the low temperature recuperator 274 is then mixed with the liquid portion flowing through the expansion valve 294. See station v in FIG. 4 and point v in FIG. 5. The combined working fluid stream is then condensed by the condenser 276 to about the bubble point (station 1₁ in FIG. 4 and point 1₁ in FIG. 5).

The condensed stream is then returned to the high pressure side of the system 210 by pump 218 and the cycle is repeated.

[0093] The second embodiment 210 of the power generating system just described results in the closely matched heating and cooling functions 290 and 292 shown in FIG. 6. That is, the heating curve 290 of the mixed working fluid 214 closely follows the cooling curve 292 of the heating fluid (e.g., geothermal brine 216).

[0096] It is contemplated that the inventive concepts herein described may be variously otherwise embodied and it is intended that the appended claims be construed to include alternative embodiments of the invention except insofar as limited by the prior art.

1. A power generating system comprising:

a heat source

an incremental vapor generator system operatively associated with said heat source, said incremental vapor generator system comprising:

a first heating section, said first heating section receiving a mixed working fluid and generating a first heated working fluid stream comprising a vapor portion and a liquid portion;

a second heating section operatively associated with said first heating section, said second heating section receiving the liquid portion from said first heated working fluid stream, said second heating section generating a second heated working fluid stream comprising a vapor portion and

an energy conversion device operatively associated with said incremental vapor generator system, said energy conversion device converting into useful work heat energy contained in the vapor portions of the first and second heated working fluid streams.

2. The power generating system of claim 1 further comprising:

a condensing system operatively associated with said energy conversion device, said condensing system receiving an exhaust stream from said energy conversion device and condensing the exhaust stream to form a condensed mixed working fluid and

a pump system operatively associated with said condensing system and said incremental vapor generator system, said pump transferring the condensed mixed working fluid from said condensing system to said incremental vapor generator system.

3. The power generating system of claim 1 further comprising a first separator system having an inlet, a vapor outlet and a liquid outlet, the inlet of said first separator system being operatively associated with said first heating section, the liquid outlet of said first separator system being operatively associated with said second heating section, said first separator system separating the vapor portion and the liquid portion of said first heated working fluid stream.

4. The power generating system of claim 3 further comprising a second separator system having an inlet, a vapor outlet and a liquid outlet, the inlet of said second separator being operatively associated with said second heating section.

5. The power generating system of claim 4 further comprising a vapor mixer having a first inlet, a second inlet and an outlet, the first inlet of said vapor mixer being operatively associated with the vapor outlet of said first separator system, the second inlet of said vapor mixer being operatively associated with the vapor outlet of said second separator system, the outlet of said vapor mixer being operatively associated with said power conversion system.

6. The power generating system of claim 5 further comprising a third heating section operatively associated with said heat source, the outlet of said vapor mixer and said energy conversion device, said third heating section additionally heating the first and second vapor streams.

7. The power generating system of claim 4 wherein said first and second separator systems comprise an integral system wherein the vapor portion of said first heated working fluid stream from said first separator system at least partially condenses in said second separator system, the liquid portion from said second heated working fluid stream.

8. The power generating system of claim 7 further comprising a third heating section operatively associated with said heat source, said integral first and second separator systems, and said energy conversion device, said third heating section additionally heating the first and second vapor streams.

9. A method for generating power from a mixed working fluid comprising:

incrementally heating the mixed working fluid to produce a first vapor stream and a second vapor stream and

converting into useful work heat energy contained in the first and second vapor streams.

10. The method of claim 9 wherein said step of incrementally heating comprises:

heating the mixed working fluid to produce a first heated working fluid stream comprising a vapor portion and a liquid portion

separating the vapor portion and the liquid portions of the first heated working fluid stream, the separated vapor portion forming the first vapor stream and

additionally heating the liquid portion from the first heated working fluid stream to produce the second vapor stream.

11. The method of claim 10 further comprising combining the first and second vapor streams into a combined vapor stream.

12. The method of claim 11 further comprising additionally heating the combined vapor stream to produce a superheated vapor stream.

13. The method of claim 10, further comprising using the vapor portion from the first heated working fluid stream to condense on the liquid portion from the second heated working fluid stream and to produce additional portions of the vapor portion from the first heated working fluid stream.

14. The method of claim 13 further comprising combining the additional portions of the vapor portion from the first heated working fluid stream and the second vapor streams to form a combined vapor stream.

15. The method of claim 14 further comprising additionally heating the combined vapor stream to produce a superheated vapor stream.

16. A power generating system comprising:

a heat source;

incremental vapor generating means operatively associated with said heat source for incrementally generating a first vapor stream and a second vapor stream from a mixed working fluid; and

power conversion means operatively associated with said incremental vapor generating means for converting the useful work heat energy contained in said first and second vapor streams.

17. The power generating system of claim 16 further comprising separator means operatively associated with said incremental vapor generating means for separating the first and second vapor streams from a heated working fluid stream from said incremental vapor generating means.

18. The power generating system of claim 17 further comprising means for combining said first vapor stream and said second vapor stream to form a combined vapor stream; the combined vapor stream being directed to said power conversion means.

19. The power generating system of claim 17 wherein said separator means comprises means for using a portion of the first vapor stream to condense on a liquid portion from the heated mixed working fluid.

20. The power generating system of claim 16 further comprising:

condensing means operatively associated with said power conversion means for condensing a vapor stream from said power conversion means into a returned mixed working fluid; and

recirculating means operatively associated with said condensing means for recirculating the returned mixed working fluid to said incremental vapor generating means.

21. An incremental vapor generator system for vaporizing a mixed working fluid comprising:

a first heating section operatively associated with a heat source; said first heating section receiving the mixed working fluid and generating a first heated working fluid stream comprising a vapor portion and a liquid portion;

a separator system operatively associated with said first heating section; said separator system separating the vapor portion and the liquid portion of the first heated working fluid stream; and

a second heating section operatively associated with the heat source and said separator system; said second heating section receiving the liquid portion from the first heated working fluid stream; said second heating section generating a second heated working fluid stream comprising a vapor portion.

* * *

United States Patent [19]
Kalina

[11] Patent Number 4,982,568
[45] Date of Patent: Jan. 8, 1991

[54] METHOD AND APPARATUS FOR
CONVERTING HEAT FROM GEOTHERMAL
FLUID TO ELECTRIC POWER

[76] Inventor Alexander L. Kalina, 105 Glen Garry
Way Hillsborough, Calif. 94010
[21] Appl. No. 327,299
[22] Filed Mar. 22, 1989

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 295,829, Jan. 11 1989,
abandoned.

[51] Int. Cl.³ F01K 21/06; F03G 7/00
[52] U.S. Cl. 60/649; 60/641 2;
60/653 60/671 60/679
[58] Field of Search 60/641.2, 651 653,
60/649, 671 673, 679, 692, 691

References Cited

U.S. PATENT DOCUMENTS

4,346,561	8/1982	Kalina	60/673
4,489,563	12/1984	Kalina	60/673
4,548,043	10/1985	Kalina	60/673
4,586,340	5/1986	Kalina	60/673
4,604,867	8/1986	Kalina	60/653
4,732,005	3/1988	Kalina	60/673
4,763,480	8/1988	Kalina	60/649

OTHER PUBLICATIONS

Burns & McDonnell Engineering Co., "Heber Geothermal Binary Demonstration Plant Design, Construction, and Early Startup," prepared for Electric Power Research Institute, pp. 2, 4, 9-10, 24-25, 55-56, 10/1987
Blum, "Aspects of the Kalina Technology Applied to Geothermal Power Production," prepared for the U.S. Dept. of Energy Idaho Operation's Office, pp. 14, 20, 26, 9/1989

Primary Examiner—Stephen F. Huser
Attorney, Agent, or Firm—Arnold, White & Durkee

[57] ABSTRACT

A method and apparatus for implementing a thermodynamic cycle, which includes heating and preferably partially evaporating a multicomponent liquid working stream with heat released from the partial condensation of a returning spent stream. The preferably partially evaporated working stream is then completely evaporated with heat transferred from an external heat source, which is preferably a geothermal heat source. The evaporated stream is expanded to produce the spent stream, which, in turn, is condensed to produce the multicomponent liquid working stream.

33 Claims, 3 Drawing Sheets

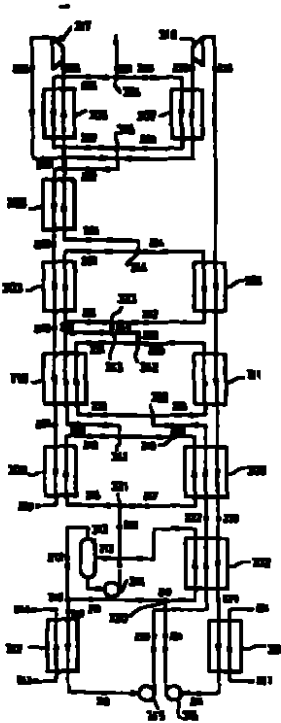


FIG. 1

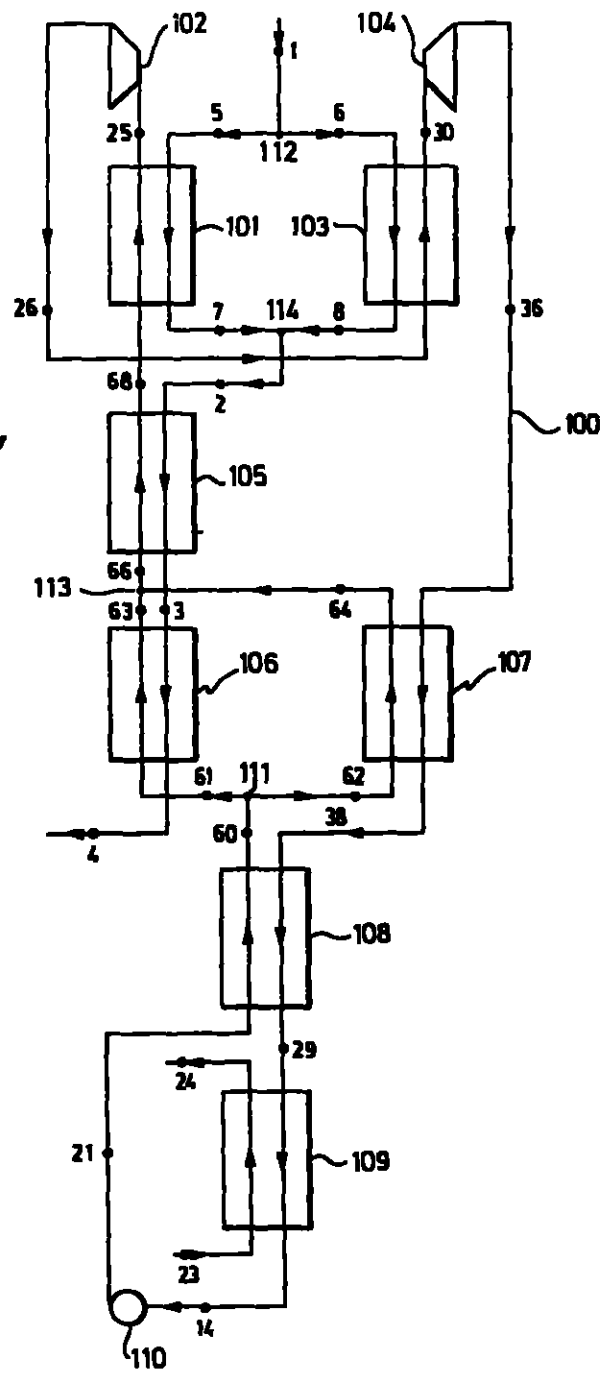
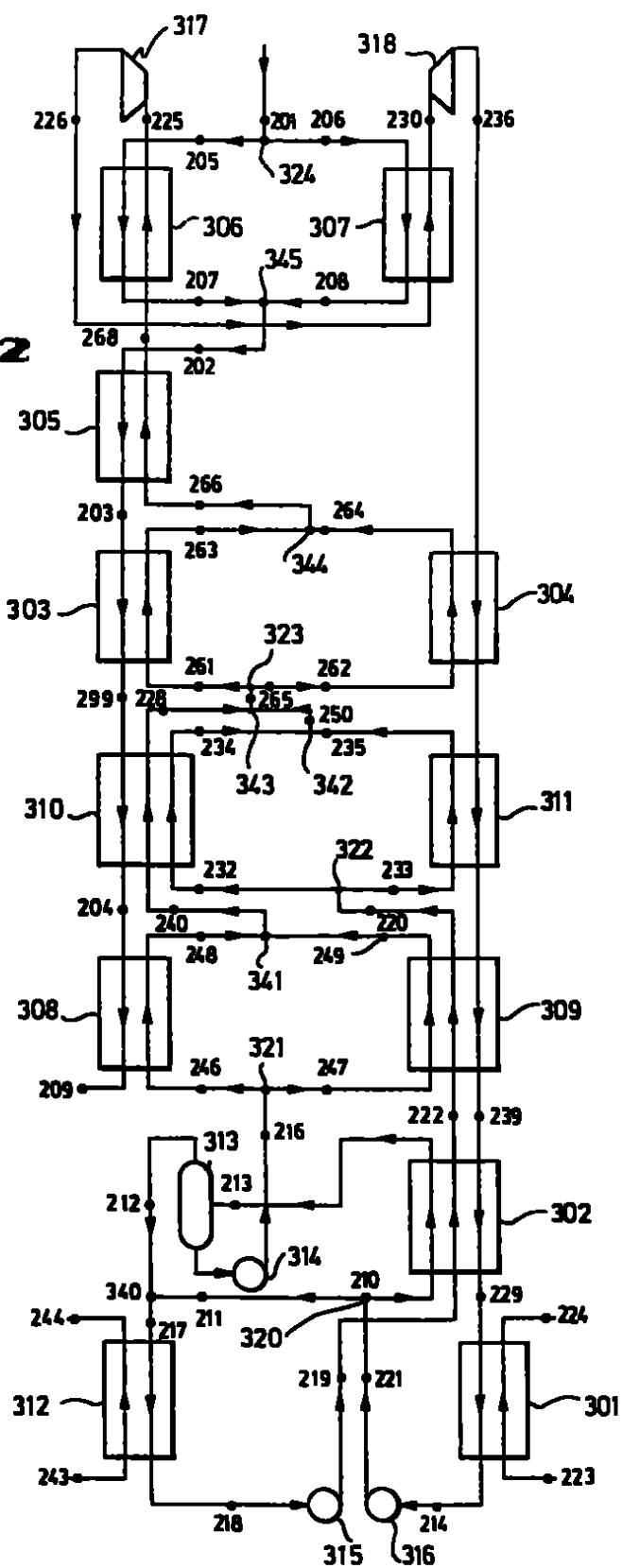
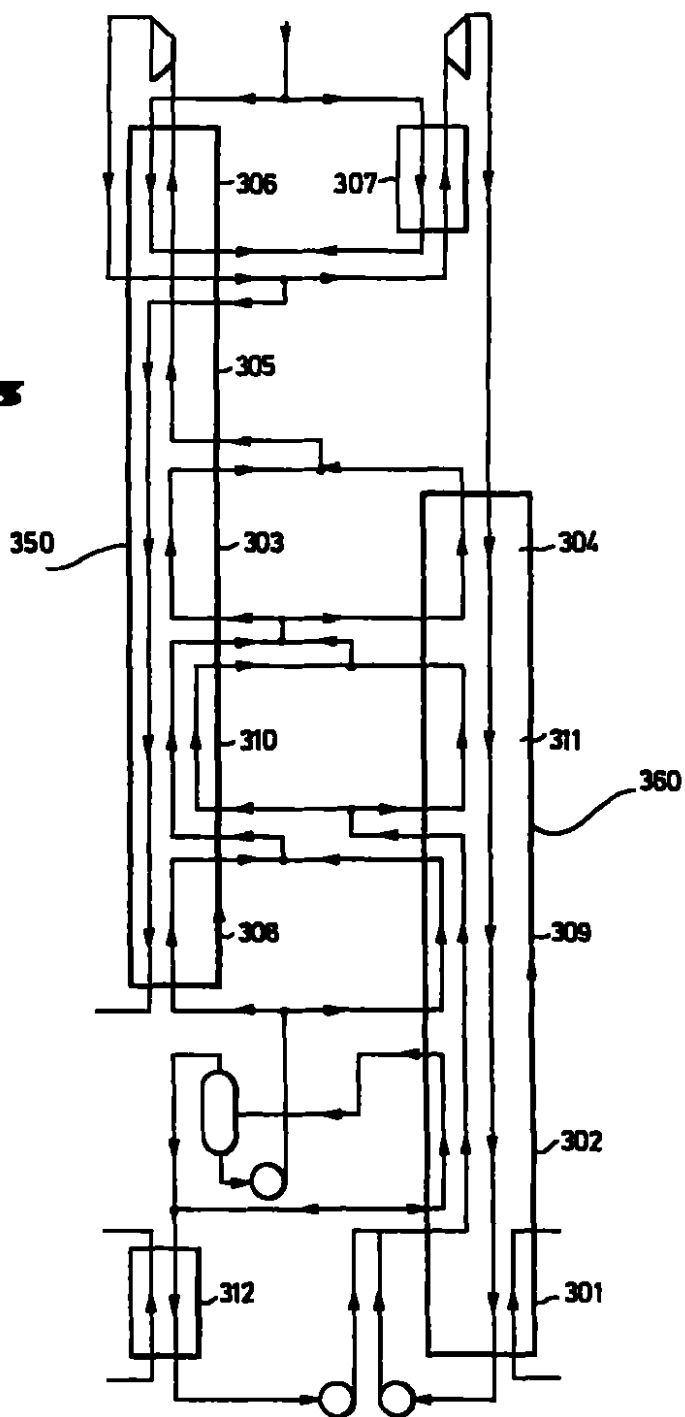


FIG. 2



195

FIG. 3



METHOD AND APPARATUS FOR CONVERTING
HEAT FROM GEOTHERMAL FLUID TO
ELECTRIC POWER

BACKGROUND OF THE INVENTION

This is a continuation-in-part application of Ser. No. 295,829, filed Jan. 11 1989 abandoned

1 Field of the Invention

This invention relates generally to methods and apparatus for transforming thermal energy from a heat source into mechanical and then electrical form using a working fluid that is expanded and regenerated. This invention further relates to a method and apparatus for improving the thermal efficiency of a thermodynamic cycle via the heating of a multicomponent liquid working stream with heat released by the partial condensation of an expanded spent stream.

2. Brief Description of the Background Art

Methods for converting the thermal energy that geothermal fluid releases, into electric power presents an important and growing area of energy generation. Geothermal power plants generally belong to one of two categories: namely steam plants and binary plants.

In steam plants, the geothermal source is utilized directly to produce steam. That steam is then expanded in a turbine, producing power. In binary plants, heat extracted from the geofluid is used to evaporate a working fluid that circulates within the power cycle. That working fluid is then expanded in a turbine, producing power.

One problem resulting from the use of a geothermal source is that geofluid (brine) can generally be cooled to moderate temperatures only. The reason for this is believed to be that further cooling can cause precipitation of silica, which may plug heat exchanger surfaces. Typically, geothermal brine may not be cooled to a temperature less than 160°-180° F. Once it reaches that temperature, it should be rejected into the geothermal strata.

The most advanced technology currently being used to convert the heat from geothermal heat sources into electric power appears to be the so-called supercritical organic Rankine cycle. That process, however, is associated with significant losses, which appear to result for the following reasons: working fluid, after being condensed at ambient temperature, has to be heated by a geothermal brine which has a relatively high temperature, for the reasons stated above. As a result of such a mismatch between the temperature of the working fluid and the relatively high temperature of the geothermal brine, thermodynamic losses are incurred, leading to relatively low efficiency.

For example, the advanced geothermal power plant that is located at Heber, Calif., appears to have a thermal efficiency of about 13.2%. In contrast, the theoretical limit for the border condition at Heber is apparently about 27.15%. Thus, what appears to be the most advanced geothermal plant has a thermodynamic, or Second Law, efficiency of apparently about 48.62%. The efficiency of the subcritical organic Rankine cycle, which is widely used for geothermal application, is, of course, even lower than the efficiency of the supercritical organic Rankine cycle being used at Heber.

Replacing conventional systems, which use the thermal energy of geothermal fluids for relatively low temperature processes, with a system that more adequately matches the temperature of the working fluid with the temperature of the geothermal source may substantially

reduce thermodynamic losses resulting from the temperature mismatching of conventional systems. Reducing those losses can substantially increase the efficiency of the system.

SUMMARY OF THE INVENTION

It is one feature of the present invention to provide a significant improvement in the efficiency of a thermodynamic cycle by heating a multicomponent liquid working stream with heat released by the partial condensation of an expanded spent stream.

In accordance with one embodiment of the present invention, a method for implementing a thermodynamic cycle includes the step of expanding a gaseous working stream, transforming its energy into usable form. That expansion produces a spent stream. The spent stream is then partially condensed to provide heat. A multicomponent oncoming liquid working stream is heated using the heat produced by the partial condensation of the spent stream and heat from an external heat source, until the multicomponent liquid working stream is evaporated. The evaporation of the multicomponent liquid working stream produces the gaseous working stream.

In a preferred embodiment of the present invention, the difference in the pressure of the multicomponent oncoming liquid working stream and the spent stream ensures that the multicomponent oncoming liquid working stream will begin to evaporate at a temperature that is lower than the temperature at which the spent stream begins to condense. To create such a multicomponent liquid working stream, the working fluid used in the process of the present invention may be a mixture comprising a high-boiling component and a low-boiling component, which begins to boil at a temperature that is lower than the temperature at which the high-boiling component begins to boil. In a particularly preferred embodiment of the present invention, the multicomponent oncoming liquid working stream includes about 55% to about 95% of the low-boiling component.

Such a mixture is preferred because such a mixture boils at variable temperatures so that the temperature at which boiling begins at any given pressure (the bubbling point) is lower than the temperature at which evaporation is completed (the dew point). Conversely if such a mixture is condensed, the temperature at which condensation starts is higher than the temperature at which condensation ends. The difference between the dew point temperature and the bubbling point temperature depends on the properties of the components comprising the mixture and the composition of the mixture itself.

The mixture employed as a working fluid preferably has an initial boiling temperature at high pressure (the boiler pressure) that is significantly lower than the initial temperature of condensation at low pressure (the condenser pressure). Under appropriate temperatures and pressures, such a feature may allow use of part of the heat rejected during the initial condensation of the spent stream to cause the initial evaporation of the multicomponent oncoming liquid working stream. Such a feature may allow use of that heat to preheat the working fluid as well.

However, if the pressure of the multicomponent oncoming liquid working stream is significantly higher than the pressure of the spent stream, heat transferred from the spent stream, as the spent stream begins to condense, to the multicomponent oncoming liquid

working stream may be insufficient to partially evaporate the multicomponent oncoming liquid working stream. In such an embodiment of the present invention, heat transferred from the partial condensation of the spent stream is used to preheat the multicomponent oncoming liquid working stream, without partially evaporating the multicomponent oncoming liquid working stream.

Although any conventional heat source may in general, be used in conjunction with the system of the present invention, the system is particularly useful for the conversion of geothermal energy into electric power. As will be apparent from the following description of preferred embodiments, the system of the present invention may enable heat extracted from geothermal brine to be used for relatively high temperature purposes only which may increase the thermodynamic reversibility of the system and may result in an increased efficiency of a power cycle that uses such a heat source.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG 1 is a schematic representation of one embodiment of the method and apparatus of the present invention.

FIG 2 is a schematic representation of a second embodiment of the method and apparatus of the present invention.

FIG 3 is a schematic representation of the embodiment of FIG 2 in which four heat exchangers have replaced the twelve heat exchangers of the FIG 2 embodiment.

DESCRIPTION OF PREFERRED EMBODIMENTS

The schematic shown in FIG 1 shows an embodiment of preferred apparatus that may be used in the above described cycle. Specifically FIG 1 shows a system 100 that includes a boiler in the form of heat exchangers 103, 106, and 107 a preheater in the form of heat exchanger 108, and a superheater in the form of heat exchanger 101. In addition, the system 100 includes turbines 102 and 104, reheater 103, pump 110, and condenser 109. Further the system 100 includes stream separators 111 and 112 and stream mixers 113 and 114.

The condenser 109 may be any type of known heat rejection device. For example, the condenser 109 may take the form of a heat exchanger such as a water cooled system, or another type of condensing device.

Various types of heat sources may be used to drive the cycle of this invention. In the embodiment shown in FIG 1, the heat source is a stream of geothermal fluid that flows from point 1 to point 4 through heat exchangers 101, 103, 105, and 106.

The working stream used in the system 100 preferably is a multicomponent working stream that comprises a lower boiling point fluid—the low-boiling component—and a higher boiling point fluid—the high-boiling component. Such a preferred working stream may be an ammonia-water mixture, two or more hydrocarbons, two or more freons, mixtures of hydrocarbons and freons, or the like. In general the stream may be mixtures of any number of compounds with favorable thermodynamic characteristics and solubility. In a particularly preferred embodiment, a mixture of water and ammonia is used. The multicomponent working stream preferably includes about 55% to about 95% of the low-boiling component.

As shown in FIG 1 a working stream circulates through system 100. The working stream includes a gaseous working stream that flows from heat exchanger 105 to turbine 102. The working stream also includes a spent stream, which flows from turbine 102 to condenser 109, and a liquid working stream which flows from condenser 109 to heat exchanger 103.

In the cycle of the present invention, the liquid working stream, which has been completely condensed and which has a temperature that preferably is close to ambient temperature—with parameters as at point 14—is pumped by pump 110 to a selected high pressure, obtaining parameters as at point 21. Thereafter that stream passes through recuperative preheater 108, where it is preheated by a returning spent stream, obtaining parameters as at point 60. The liquid working stream at point 60 preferably has parameters corresponding to those at or near its boiling point, i.e. it preferably is in the state of a saturated liquid or a slightly subcooled liquid.

The liquid working stream is then split at stream separator 111 into two substreams, having parameters as at points 61 and 62, respectively. Those two substreams form first and second parts of the liquid working stream.

The substream flowing by point 61, i.e., the first part of the liquid working stream, passes through exchanger 106 where it boils, being heated—in this embodiment of the invention—by a stream of geofluid flowing from point 1 to point 4. That substream exits heat exchanger 106, having parameters as at point 63.

The other substream, flowing by point 62, i.e., the second part of the liquid working stream, passes through recuperative heat exchanger 107 where it is heated by a returning spent stream. That substream is preferably partially evaporated producing a stream having parameters as at point 64. In a particularly preferred embodiment, the parameters for the partially evaporated working fluid at points 63 and 64 are nearly identical.

The substreams passing by points 63 and 64 (which are first and second parts of a heated liquid working stream) are recombined at stream mixer 113 into one stream, i.e., a heated liquid working stream, obtaining parameters as at point 66. The heated liquid working stream, which in this embodiment of the present invention has been partially evaporated with parameters as at point 66, passes through heat exchanger 105 where it is heated—in this embodiment—by a stream of geofluid. In a particularly preferred embodiment, the partially evaporated working fluid is completely evaporated as it passes through heat exchanger 105. The partially evaporated working fluid entering heat exchanger 105, however need not be completely evaporated at that step of the cycle. In either event, the working fluid exits heat exchanger 105 with parameters as at point 68.

The working stream, at point 68, is preferably in a state of a saturated vapor. However it can be in a state of an incompletely evaporated mixture or a superheated vapor as well. In the particularly preferred embodiment set forth herein, that working fluid stream is a gaseous working fluid stream, having parameters as at point 68 (as shown in Table I). That stream passes through heat exchanger 101 where it is superheated by a stream of geofluid to form a superheated gaseous working stream with parameters as at point 25. The stream with parameters as at point 25 is sent into the high pressure turbine 102 where it expands, producing power and obtaining parameters as at point 26.

197

In the embodiment shown in FIG 1 the spent stream, with parameters as at point 34, is then sent into reheater 100 where it is reheated by a stream of geofluid obtaining parameters as at point 30. The spent stream is then sent to the low pressure turbine 104 where it is finally expanded, producing power and obtaining parameters as at point 36.

In a particularly preferred embodiment of the system of the present invention, the parameters of the spent stream at point 36 correspond to those of a stream that is in the state of a saturated vapor. The pressure, at point 36, may be conveniently selected to ensure the complete condensation of the spent stream, as it passes through condenser 103, at the available temperature of the cooling medium flowing through condenser 109 from point 23 to point 24, which is preferably water or air.

The spent stream passes from point 36 through heat exchanger 107 where it partially condenses, providing heat for the initial evaporation of the liquid working stream passing from point 62 to point 64, i.e., the second part of the liquid working stream. After the partially condensed spent stream exits from heat exchanger 107 it obtains parameters as at point 38. The partially condensed spent stream then passes through recuperative preheater 108 where it further condenses, providing heat for preheating the oncoming liquid working stream. The partially condensed spent stream exits recuperative preheater 108 with parameters as at point 29. The partially condensed spent stream then enters condenser 109 where it is cooled by water or air flowing from point 23 to point 24. The above described liquid working stream, having parameters as at point 14, exits from condenser 109 completing the cycle.

In the embodiment of the present invention shown in FIG 1, the external heat source for completing the evaporation of the liquid working stream is a stream of geofluid, having initial parameters as at point 1. That stream is split at stream separator 112, into two substreams, having parameters as at points 5 and 6, respectively. The substreams passing by points 5 and 6 pass through heat exchangers 101 and 102, respectively providing heat for superheating the above described gaseous working stream and for reheating the spent stream. The substream passing by point 5 exits heat exchanger 101 with parameters as at point 7 and the substream passing by point 6 exits heat exchanger 102 with parameters as at point 8.

Thereafter the substreams of geofluid are combined at stream mixer 114 into one stream having parameters as at point 2. That stream of geofluid passes through heat exchanger (boiler) 105 where it is cooled, providing heat for the complete evaporation of the partially evaporated, i.e., heated, liquid working stream. The geofluid stream exits heat exchanger 105 with parameters as at point 3. The stream of geofluid then passes through heat exchanger 106 where it is cooled, providing heat for the initial evaporation of a first part of the liquid working stream (a second part of the liquid working stream is initially evaporated by recuperation of heat from the returning spent stream, as described above). The stream of geofluid exits heat exchanger 106 with parameters as at point 4, after which it may be pumped into the geofluid strata.

As is apparent from the above description, a unique feature of the above described embodiment of the present invention is that the initial temperature of condensation of the returning spent stream (the stream passing by point 36) is higher than the initial boiling temperature of

the second part of the oncoming liquid working stream (the stream passing by point 62).

The relationship between the initial condensation temperature of the returning spent stream and the initial boiling temperature of the liquid working stream of that embodiment enables the partial evaporation of the liquid working stream via recuperation of heat from the returning spent stream. That feature should enable the power system and cycle of the above described embodiment of the present invention to provide a significant increase in efficiency when compared with the presently available organic and supercritical organic Rankine cycles.

It will be apparent to those skilled in the art that the pressure of the oncoming liquid working stream, at point 62, may be so high that the partial condensation of the returning spent stream will heat that portion of the liquid working stream, but will not cause that stream to begin to evaporate. However an embodiment of the present invention in which the difference in pressure between the liquid working stream and the returning spent stream enables heat from the partial condensation of the spent stream to partially evaporate the liquid working stream is preferred over an embodiment in which the pressure of the oncoming liquid working stream, at point 62, is so high as to inhibit partial evaporation of that stream, despite the transfer of heat produced by the partial condensation of the returning spent stream.

Preferred parameters for the points corresponding to the points set forth in FIG 1 are presented in Table I for a system having a water-ammonia working fluid stream which includes 83.05 wt. % of ammonia. All calculations used to generate the parameters of Table I were performed for what appear to be the same border conditions and the same limitations as have been used in the above referenced Heber geothermal plant A comparison in performance of the Heber geothermal power plant and the potential performance of the system of the present invention, using what appear to be the same border conditions, is included in Table II.

TABLE I

Point	T [°C]	X	T °F	H (Btu/lb)	Q
1	—	BRINE	367.00	—	2.6369
2	—	BRINE	333.96	—	2.6369
3	—	BRINE	222.26	—	2.6369
4	—	BRINE	178.22	—	2.6369
5	—	BRINE	367.00	—	.9891
6	—	BRINE	367.00	—	1.6415
7	—	BRINE	333.96	—	.9891
8	—	BRINE	333.96	—	1.6415
14	89.30	0.8305	60.00	-20.33	1.0000
21	432.44	0.8305	60.00	-18.78	1.0000
23	—	WATER	53.00	—	16.8761
24	—	WATER	78.07	—	16.8761
29	402.44	0.8305	332.00	776.80	1.0000
36	231.20	0.8305	273.78	736.73	1.0000
38	89.60	0.8305	121.93	402.82	1.0000
39	227.20	0.8305	352.00	792.06	1.0000
40	90.80	0.8305	222.26	726.46	1.0000
41	89.90	0.8305	170.00	519.86	1.0000
42	432.44	0.8305	165.00	98.25	1.0000
43	432.44	0.8305	165.00	98.25	.4039
44	432.44	0.8305	217.26	444.29	.9771
45	432.44	0.8305	217.26	444.29	.9771
46	432.44	0.8305	217.26	444.29	1.0000
48	407.44	0.8305	307.75	743.60	1.0000

TABLE II

Power Output	MW	Thermal Efficiency	Second Law Efficiency
Heber Plant	99.2	13.2	46.62
Proposed System	80.785	18.04	66.04

The results shown in Table II suggest that the system of the present invention could potentially increase the power output from the same geothermal source by a factor of about 1.37. Such an enhanced power output could significantly reduce the overall cost of a geothermal power plant.

When a geothermal power plant is operating, and a significant portion of its power output must be spent to circulate geothermal brine, the power needed to circulate the geothermal brine generally remains constant, irrespective of the efficiency of the power plant. For the Heber power plant, this power is apparently equal to about 12MW. The net output of the Heber power plant is, therefore, apparently equal to about 47.2MW. In contrast, the net output of the proposed system of the present invention could be equal to about 68.785MW. As a result, the net efficiency of the proposed system potentially could be about 1.46 times higher than the net efficiency of the Heber geothermal plant.

Because the cost to provide geothermal brine for a power plant is apparently identical for either the Heber plant system or the system of the present invention, the proposed system could potentially provide for a significantly lower cost for the geofluid supplied to the cycle per 1 kW of net output.

In the system of FIG. 1, the composition of the working fluid flowing through the cycle remains constant. An increased efficiency for the cycle may be obtained, however, if the composition of the working fluid is varied at different parts of the cycle. FIG. 2 provides such an embodiment of the present invention in which the liquid working stream is split into working streams having different compositions before the oncoming liquid working stream is completely evaporated to produce the gaseous working stream.

In accordance with the embodiment of FIG. 1 of the present invention, a method for implementing a thermodynamic cycle includes the step of expanding a gaseous working stream, transforming its energy into usable form (as in the FIG. 1 embodiment). That expansion produces a spent stream that is partially condensed to provide heat to heat an oncoming liquid working stream (as in the FIG. 1 embodiment).

However, the oncoming liquid working stream of the FIG. 2 embodiment is generated in a different manner from the FIG. 1 embodiment. In the FIG. 2 embodiment, the spent stream is condensed to produce a first liquid working stream. The first liquid working stream is divided into enriched and lean substreams through the following steps. Initially, the first liquid working stream is separated into first and second liquid substreams. The first liquid substream is heated to form a partially evaporated liquid substream that is separated to form a vapor stream and a liquid stream. The vapor stream is combined with the second liquid substream to form the enriched substream. The enriched substream is enriched with a higher percentage of a lower boiling component than is contained in the first liquid working stream. The liquid stream comprises the lean substream, which includes a lower percentage of a low boiling

component than is contained in the first liquid working stream.

The enriched substream is condensed and then heated by the returning spent stream, until it is preferably partially evaporated. The lean substream is combined with the preferably partially evaporated enriched substream to form the oncoming liquid working stream that is heated (preferably partially evaporated) by the returning spent stream and then completely evaporated by an external heat source, such as a geothermal heat source, to form the gaseous working stream.

In the embodiment shown in FIG. 2, the completely condensed first liquid working stream (having a temperature which is close to the initial temperature of the cooling source (e.g., cooling water) flowing from point 223 to point 224 of FIG. 2) with parameters as at point 214 is pumped to an intermediate pressure by pump 316 to obtain parameters as at point 221. The first liquid working stream is divided at stream separator 320 into first and second liquid substreams having parameters as at points 210 and 211, respectively. The first liquid substream is sent into recuperative heat exchanger 302, where it is heated to form a partially evaporated liquid substream with parameters as at point 213.

The partially evaporated liquid substream is then sent into separator 313 (which may be a flash tank), where it is separated into a vapor stream, with parameters as at point 212, and a liquid stream, with parameters as at point 215. The vapor stream is then combined with the second liquid substream at stream mixer 308 to form an enriched substream, with parameters as at point 217. That enriched substream is then sent into condenser 312, where it is completely condensed by a stream of cooling water flowing from point 243 to point 244, to obtain parameters as at point 218. The enriched substream is then pumped to an increased pressure by pump 315, obtaining parameters as at point 219. Thereafter, the enriched substream is sent parallel with the first liquid substream, flowing from point 210 to point 213, into heat exchanger 302, where the enriched substream is heated, obtaining parameters as at point 222.

Meanwhile, the liquid stream, which comprises the lean substream, has been pumped to an increased pressure by pump 314 to obtain parameters as at point 216. The temperatures of the streams flowing past points 216 and 222 preferably are approximately equal.

The preceding process steps yield an enriched substream, flowing by point 222, that is enriched with a higher percentage of a lower boiling component than is contained in the first liquid working stream and a lean substream, flowing by point 216, that includes a lower percentage of a lower boiling component than is contained in the first liquid working stream.

The enriched and lean substreams are sent into heat exchangers 309 and 308. The lean substream is separated at stream separator 321 into first and second lean substreams, having parameters as at points 246 and 247 respectively before the first lean substream enters heat exchanger 308 and the second lean substream enters heat exchanger 309. The enriched substream enters heat exchanger 309 only.

In the embodiment shown in FIG. 2, heat exchanger 309 is a recuperative heat exchanger in which the returning spent stream exchanges heat with the second lean substream and the enriched substream. In heat exchanger 308, heat is transferred to the first lean substream from a stream of geofluid passing from point 204 to point 209. (Mineralization may not allow cooling of

geothermal brine to a sufficiently low temperature to warrant use of heat exchanger 308. Under those circumstances, heat exchanger 308 preferably should be removed from the system, and both the enriched and lean substreams sent into heat exchanger 309 only.)

The preheated enriched substream exits heat exchanger 309 with parameters as at point 220, which preferably correspond to those of a liquid stream in a state of a saturated liquid. The first and second lean substreams exit heat exchangers 308 and 309, obtaining parameters as at points 248 and 249 respectively. Those substreams are combined at stream mixer 341 to reconstitute the lean substream, which has become a preheated lean substream with parameters as at point 240 (those parameters preferably correspond to those of a liquid stream in the state of a subcooled liquid). The temperatures of the streams flowing past points 220 and 240 are preferably about equal.

The preheated enriched substream is separated into first and second enriched substreams, having parameters as at points 232 and 233, respectively, at stream separator 322. The first enriched substream is sent into heat exchanger 310, along with the reconstituted and preheated lean substream. While passing through heat exchanger 310, the first enriched substream and the preheated lean substream are heated with heat transferred from a stream of geofluid passing from point 299 to point 294.

The second enriched substream is sent into heat exchanger 311, where it is heated by heat released from the returning spent stream.

The first and second enriched substreams preferably begin to boil as they pass through heat exchangers 310 and 311 to form first and second parts of a partially evaporated enriched substream with parameters as at points 234 and 235, respectively. Those substreams are combined at stream mixer 342 to reconstitute the enriched substream, which has become a partially evaporated enriched substream, with parameters as at point 236 (those parameters preferably correspond to those of a stream in a bi-phase state). The preheated lean substream exits from heat exchanger 310 as a heated lean substream with parameters as at point 238, which preferably correspond to those of a saturated liquid. The temperatures and pressures of the streams flowing past points 230 and 238 are preferably approximately equal.

The partially evaporated enriched substream and the heated lean substream are combined at stream mixer 343 to form a partially evaporated oncoming liquid working stream (corresponding, in essence, to the oncoming liquid working stream flowing by point 60 in the FIG 1 embodiment of the present invention) with parameters as at point 268, corresponding to those of a stream in a bi-phase state.

As in the FIG 1 embodiment of the present invention, the oncoming liquid working stream (in a bi-phase state in the FIG 2 embodiment in contrast to the single phase state in the FIG 1 embodiment) is then split at stream separator 323 into two substreams, which comprise first and second parts of the partially evaporated oncoming liquid working stream, having parameters as at points 261 and 262, respectively. The substream flowing by point 261 passes through exchanger 303 where it further boils, being heated—in this embodiment of the invention—by a stream of geofluid flowing from point 283 to point 299. That substream exits heat exchanger 303 as a first part of a further evaporated working stream having parameters as at point 263.

The other substream, flowing by point 262, passes through recuperative heat exchanger 304 where it is heated by the returning spent stream. That substream also further boils producing a second part of a further evaporated working stream having parameters as at point 264. In a particularly preferred embodiment the parameters for the further evaporated working fluid at points 263 and 264 are nearly identical.

The substreams passing by points 263 and 264 are recombined at stream mixer 344 into one stream, a further evaporated working stream with parameters as at point 266. The further evaporated working stream with parameters as at point 266, passes through heat exchanger 305 where it is heated—in this embodiment—by a stream of geofluid flowing from point 282 to point 293. In a particularly preferred embodiment, the further evaporated working fluid is completely evaporated as it passes through heat exchanger 305, obtaining parameters as at point 268, which preferably correspond to a gaseous working stream in a state of a saturated vapor. That stream passes through heat exchanger 306 where it is superheated by a stream of geofluid flowing from point 285 to point 297 forming a superheated gaseous working stream with parameters as at point 225. The superheated gaseous working stream with parameters as at point 225 is sent into the high pressure turbine 317 where it expands to an intermediate pressure, producing work, and obtaining parameters as at point 226.

Like the embodiment shown in FIG 1, the spent stream, with parameters as at point 226, is then sent into reheater 307 where it is reheated by a stream of geofluid flowing from point 286 to point 298, obtaining parameters as at point 230. The spent stream is then sent to the low pressure turbine 318 where it is further expanded, producing work, and obtaining parameters as at point 236. In a particularly preferred embodiment, the parameters of the spent stream at point 236 correspond to those of a stream that is in the state of a saturated vapor.

The spent stream passes from point 236 through heat exchanger 304 where it partially condenses, providing heat for the further evaporation of the second part of the partially evaporated liquid working stream passing from point 262 to point 264. After the partially condensed spent stream exits from heat exchanger 304, it obtains parameters as at point 237. The partially condensed spent stream then passes through recuperative heat exchangers 311, 309, and 302, obtaining parameters as at points 238, 239, and 229, respectively. While passing through those heat exchangers, the spent stream further condenses, providing heat for partially evaporating the second enriched substream, preheating the enriched substream and the second lean substream, and partially evaporating the first liquid substream.

The partially condensed spent stream then enters condenser 301 where it is cooled by water or air flowing from point 223 to point 224, to produce the above described first liquid working stream, having parameters as at point 214, completing the cycle of FIG 2.

Like the embodiment of FIG 1, the external heat source for the FIG 2 embodiment of the present invention for completing the evaporation of the liquid working stream is a stream of geofluid, having initial parameters as at point 201. That stream is split at stream separator 334 into two substreams, having parameters as at points 205 and 206, respectively. The substreams passing by points 205 and 206 pass through heat exchangers 306 and 307 respectively providing heat for superheat-

ing the above described gaseous working stream and for reheating the spent stream. The substream passing by point 205 exits heat exchanger 306 with parameters as at point 207 and the substream passing by point 206 exits heat exchanger 307 with parameters as at point 208.

Thereafter the substreams of geofluid are combined at stream mixer 345 into one stream having parameters as at point 202. That stream of geofluid passes through heat exchanger (boiler) 305 where it is cooled, providing heat for the complete evaporation of the further evaporated working stream. The geofluid stream exits heat exchanger 305 with parameters as at point 203. The stream of geofluid then passes through heat exchangers 303 and 310, where it is cooled providing heat for the further evaporation of a first part of the partially evaporated liquid working stream, the mutual evaporation of the first enriched substream, and the preheating of the lean substream. The stream of geofluid exits heat exchangers 303 and 310 with parameters as at points 209 and 204, respectively.

If not inhibited by mineralization of the brine, the stream of geofluid may be sent through heat exchanger 308 to preheat the first lean substream, where it is further cooled yielding a stream with parameters as at point 209. The stream of geofluid may be re injected into the geostate after exiting from heat exchanger 308.

The several heat exchangers shown in FIG. 2 represent, in essence, calculation zones. Although real apparatuses may be used as shown in FIG. 2, that system may alternatively comprise only four actual heat exchangers, i.e., heat exchangers 312 and 307 and a single heat exchanger in place of heat exchangers 306, 305, 303, 310, and 308, and a single heat exchanger in place of heat exchangers 204, 311, 309, 302, and 301. Such a system is shown in FIG. 3, in which heat exchanger 308 is used in place of heat exchangers 306, 305, 303, 310, and 308, and heat exchanger 309 is used in place of heat exchangers 204, 311, 309, 302, and 301.

The FIG. 2 embodiment of the present invention offers some potential advantages over the FIG. 1 embodiment. One advantage is that by splitting the liquid working stream, exiting from the condenser 301, into lean and enriched substreams, the overall pressure at which the liquid working stream boils may be increased from what it would have been if the liquid working stream was not split. (For the same temperature, the enriched substream would begin to boil at a higher pressure than the liquid working stream would begin to boil.) Such an increased overall boiling pressure should reduce energy losses in the process of transferring heat from the geofluid, or other external heat source, to the cycle's working stream.

The increased overall boiling pressure also should increase the efficiency of the cycle and the power output per unit of heat input, or per unit of geofluid flow in the embodiment of the present invention employing a geofluid as the external heat source.

Another advantage of the FIG. 2 embodiment of the present invention, over the FIG. 1 embodiment, is that the FIG. 2 embodiment should permit a greater degree of flexibility especially when a geofluid is used as the external heat source. The FIG. 2 embodiment allows for adjustment of the system to a wide variety of border conditions, sustaining high thermodynamic efficiency.

Parameters for the points corresponding to the points set forth in FIG. 2 are presented in Table III for a system having a water-ammonia working fluid stream. All calculations used to generate the parameters of Table

III were performed for the same border conditions used for calculating the parameters of Table I.

The thermal efficiency and power output per 1000 lbs. of geofluid of the FIG. 2 embodiment, using the parameters shown in Table III should be significantly greater than those for the FIG. 1 embodiment, using the parameters shown in Table I.

TABLE III

Point	P[psia]	X	T °F	H [Btu/lb]	G
201	—	BRINE	367.00	—	2.7084
202	—	BRINE	329.94	—	2.7084
203	—	BRINE	218.22	—	2.7084
204	—	BRINE	170.00	—	2.7084
205	—	BRINE	367.00	—	8.999
206	—	BRINE	367.00	—	1.0485
207	—	BRINE	329.94	—	8.999
208	—	BRINE	329.94	—	1.0485
209	—	BRINE	170.00	—	2.7084
210	131.89	0.8540	60.00	-13.72	9618
211	131.89	0.8540	60.00	-13.72	9382
212	128.39	0.9998	67.45	526.46	1386
213	128.39	0.8540	67.45	193.01	9618
214	93.08	0.8540	60.00	-13.89	1.0000
215	128.39	0.7748	67.45	-4.54	6232
216	521.61	0.7748	67.45	-2.83	6232
217	128.39	0.9830	80.39	498.04	3768
218	127.89	0.9830	70.00	37.51	3768
219	326.61	0.9830	70.00	39.30	3768
220	316.61	0.9830	165.00	151.23	3768
221	131.89	0.8540	60.00	-13.72	1.0000
222	521.61	0.9830	67.45	59.17	3768
223	—	WATER	53.00	—	19.4131
224	—	WATER	66.96	—	19.4131
225	496.61	0.8540	152.00	738.04	1.0000
226	290.54	0.8540	266.99	709.66	1.0000
228	511.61	0.7748	187.22	109.69	6232
229	93.38	0.8540	82.28	284.38	1.0000
230	245.54	0.8540	152.00	779.54	1.0000
232	516.61	0.9830	165.00	151.23	1145
233	516.61	0.9830	165.00	151.23	3632
234	511.61	0.9830	187.22	345.75	1145
235	511.61	0.9830	187.22	345.75	2632
236	94.68	0.8540	218.22	711.77	1.0000
237	94.68	0.8540	282.88	640.45	1.0000
238	93.68	0.8540	170.00	337.20	1.0000
239	93.53	0.8540	155.96	282.52	1.0000
240	516.61	0.7748	165.00	81.94	6232
243	—	WATER	53.00	—	26.7031
244	—	WATER	70.28	—	26.7031
250	511.61	0.9830	187.22	345.75	3768
261	511.61	0.8540	187.22	273.98	3025
262	511.61	0.8540	187.22	273.98	4975
263	306.61	0.8540	213.22	416.92	3025
264	306.61	0.8540	213.22	416.92	4975
265	511.61	0.8540	187.22	273.98	1.0000
266	306.61	0.8540	213.22	416.92	1.0000
268	301.61	0.8540	310.99	725.35	1.0000
299	—	BRINE	192.22	—	2.7084

While the present invention has been described with respect to a number of preferred embodiments, which utilize a single preferred external heat source, those skilled in the art will appreciate a number of variations and modifications of those embodiments. For example, a different external heat source may be used, the number of heat exchangers may be increased or decreased, the number of pumps, turbines, condensing devices, separators, etc. may be varied, as well as the number and composition of streams flowing through the cycle. Thus, it is intended that the appended claims cover all such variations and modifications as fall within the true spirit and scope of the present invention.

What is claimed is:

1. A method for implementing a thermodynamic cycle comprising the steps of

202

expanding a gaseous working stream transforming its energy into usable form and producing a spent stream;
reheating and expanding the spent stream, to transform its energy into usable form;
heating a multicomponent oncoming liquid working stream by partially condensing the spent stream to preheat and partially evaporate the multicomponent oncoming liquid working stream to produce a heated liquid working stream, and
evaporating the heated liquid working stream using heat produced by an external heat source, to form the gaseous working stream.

1. The method of claim 1 wherein heat from the external heat source is used to completely evaporate the heated liquid working stream.

3. The method of claim 2 wherein the external heat source is a fluid stream that exchanges heat with the spent stream to reheat the spent stream prior to expansion of the spent stream, and that exchanges heat with the gaseous working stream to superheat the gaseous working stream, and that exchanges heat with the heated liquid working stream to completely evaporate the heated liquid working stream to form the gaseous working stream, and that exchanges heat with a first part of the multicomponent oncoming liquid working stream to partially evaporate the oncoming liquid working stream to form a first part of the heated liquid working stream.

4. The method of claim 3 wherein the external heat source is a geothermal fluid stream produced by a geothermal source.

5. The method of claim 1 further comprising the steps of

condensing completely the spent stream, after the spent stream was partially condensed to provide heat to heat the multicomponent oncoming liquid working stream, to form a first liquid working stream;

dividing the first liquid working stream into an enriched substream, that is enriched with a higher percentage of a lower boiling component than is contained in the first liquid working stream, and a lean substream, that includes a lower percentage of a low boiling component than is contained in the first liquid working stream;

heating the enriched substream with heat transferred from the spent stream, after the spent stream has been partially condensed to heat the multicomponent oncoming liquid working stream and before the spent stream has been completely condensed to form the first liquid working stream; and
combining the enriched substream with the lean substream to form the multicomponent oncoming liquid working stream.

6. The method of claim 5 further comprising the steps of

dividing the first liquid working stream into first and second liquid substreams;
heating the first liquid substream to form a partially evaporated liquid substream;
separating the partially evaporated liquid substream to form a vapor stream and a liquid stream, the liquid stream comprising the lean substream, and
combining the vapor stream with the second liquid substream to form the enriched substream.

7. The method of claim 6 further comprising the steps of

completely condensing the enriched substream and pumping the enriched substream to an increased pressure prior to heating the enriched substream with heat transferred from the spent stream and
pumping the lean substream to an increased pressure and heating the lean substream with heat transferred from an external heat source prior to combining the enriched substream with the lean substream to form the multicomponent oncoming liquid working stream

8. The method of claim 7 further comprising the steps of

separating the enriched substream into first and second enriched substreams,
heating the first enriched substream with heat transferred from an external heat source;
heating the second enriched substream with heat transferred from the spent stream,
separating the lean substream into first and second lean substreams;
heating the first lean substream with heat transferred from an external heat source;
heating the second lean substream with heat transferred from the spent stream; and
combining the first and second enriched substreams to regenerate the enriched substream and combining the first and second lean substreams to regenerate the lean substream before the lean substream and the enriched substream are combined to form the multicomponent oncoming liquid working stream.

9. A method for implementing a thermodynamic cycle comprising the steps of:

expanding a superheated gaseous working stream, transforming its energy into usable form and producing a spent stream;
reheating and expanding the spent stream, to transform its energy into usable form;
heating a multicomponent oncoming liquid working stream, by partially condensing the spent stream, to produce a heated liquid working stream;
completely condensing the spent stream, after heat produced by partially condensing the spent stream has been used to heat the multicomponent oncoming liquid working stream, to produce the multicomponent oncoming liquid working stream;
evaporating the heated liquid working stream using heat produced by a geothermal external heat source to form a gaseous working stream; and
superheating the gaseous working stream to form the superheated gaseous working stream.

10. The method of claim 9 further comprising the steps of

pumping the multicomponent oncoming liquid working stream, formed by the complete condensation of the spent stream, to a higher pressure;
transferring heat from the geothermal external heat source to the spent stream to reheat the spent stream prior to expansion of the spent stream;
transferring heat from the geothermal external heat source to the gaseous working stream to superheat the gaseous working stream,
transferring heat from the geothermal external heat source to a first part of the multicomponent oncoming liquid working stream after the multicomponent oncoming liquid working stream has been pumped to a higher pressure, to partially evaporate a first part of the multicomponent oncoming liquid

working stream to form a first part of the heated liquid working stream,

partially condensing the spent stream to preheat and partially evaporate a second part of the multicomponent oncoming liquid working stream to produce a second part of the heated liquid working stream, and

combining the first and second parts of the heated liquid working stream to form the heated liquid working stream.

11. The method of claim 10 wherein the gaseous working stream, the spent stream, the multicomponent oncoming liquid working stream, the heated liquid working stream, and the superheated gaseous working stream are each multicomponent working streams that comprise a low-boiling component and a high-boiling component.

12. A method for implementing a thermodynamic cycle comprising the steps of

expanding a superheated gaseous working stream, transforming its energy into usable form and producing a spent stream,

reheating the spent stream with heat transferred from a geothermal external heat source;

expanding the spent stream to transform its energy into usable form;

further evaporating a second part of a partially evaporated multicomponent oncoming liquid working stream, by partially condensing the spent stream, to produce a second part of a further evaporated working stream,

partially evaporating a second enriched substream with heat transferred from the further condensation of the spent stream to form a second part of a partially evaporated enriched substream,

preheating an enriched substream and a lean substream with heat transferred from the further condensation of the spent stream to form a preheated enriched substream and a preheated lean substream;

partially evaporating a first liquid substream with heat transferred from the further condensation of the spent stream to form a partially evaporated liquid substream;

condensing completely the spent stream to form a first liquid working stream,

pumping the first liquid working stream to an increased pressure;

separating the first liquid working stream into the first liquid substream and a second liquid substream;

separating the partially evaporated liquid substream into a vapor stream and a liquid stream, after the first liquid substream has been partially evaporated with heat transferred from the further condensation of the spent stream to form the partially evaporated liquid substream, the liquid stream comprising the lean substream, the lean substream including a lower percentage of a low boiling component than is contained in the first liquid working stream;

combining the vapor stream with the second liquid substream to form the enriched substream, the enriched substream enriched with a higher percentage of a lower boiling component than is contained in the first liquid working stream,

completely condensing the enriched substream and pumping the enriched substream to an increased pressure prior to preheating the enriched sub-

stream with heat transferred from the further condensation of the spent stream to form the preheated enriched substream,

pumping the lean substream to an increased pressure prior to preheating the lean substream with heat transferred from the further condensation of the spent stream to form the preheated lean stream;

separating the preheated enriched substream into a first enriched substream and the second enriched substream prior to the second enriched substream being partially evaporated with heat transferred from the further condensation of the spent stream to form the second part of the partially evaporated enriched substream,

partially evaporating the first enriched substream with heat transferred from the geothermal external heat source to form a first part of the partially evaporated enriched substream,

heating the preheated lean substream with heat transferred from the geothermal external heat source to form a heated lean substream,

combining the first and second parts of the partially evaporated enriched substream to form the partially evaporated enriched substream;

combining the heated lean substream with the partially evaporated enriched substream to form the partially evaporated multicomponent oncoming liquid working stream,

separating the partially evaporated multicomponent oncoming liquid working stream into the second part of the partially evaporated multicomponent oncoming liquid working stream and a first part of the partially evaporated multicomponent oncoming liquid working stream prior to further evaporating the second part of the partially evaporated multicomponent oncoming liquid working stream by partially condensing the spent stream, to produce the second part of the further evaporated working stream;

further evaporating the first part of the partially evaporated multicomponent oncoming liquid working stream with heat transferred from the geothermal external heat source to form a first part of the further evaporated working stream;

combining the first and second parts of the further evaporated working stream to form the further evaporated working stream;

completely evaporating the further evaporated working stream with heat produced by the geothermal external heat source to form a gaseous working stream; and

superheating the gaseous working stream with heat produced by the geothermal external heat source to form the superheated gaseous working stream.

13. The method of claim 12 wherein each of the streams flowing through the cycle are multicomponent streams that comprise about 55% to about 95% of an ammoniac low-boiling component and about 5% to about 45% of a water high-boiling component.

14. A method for implementing a thermodynamic cycle comprising the steps of

expanding a gaseous working stream, transforming its energy into usable form and producing a spent stream,

partially condensing the spent stream to provide heat; forming an oncoming liquid working stream that begins to evaporate at a temperature that is lower

17

than the temperature at which the spent stream begins to condense; and
evaporating the oncoming liquid working stream using heat produced by partially condensing the spent stream, and heat from an external heat source, to form the gaseous working stream.

15. The method of claim 14 further including the steps of reheating and expanding the spent stream, to transform its energy into usable form, and partially evaporating the liquid working stream with heat transferred from the spent stream.

16. The method of claim 15 wherein heat from the partially condensed spent stream is used to preheat the liquid working stream prior to heat from the spent stream being used to partially evaporate the liquid working stream.

17. The method of claim 16 further comprising the step of condensing the partially condensed spent stream, after heat from that stream has been used to preheat the liquid working stream, to produce the liquid working stream.

18. The method of claim 17 further comprising the step of superheating the gaseous working stream prior to expanding the gaseous working stream.

19. The method of claim 18 further comprising the step of pumping the liquid working stream, formed by the condensation of the partially condensed spent stream, to a higher pressure prior to preheating the liquid working stream with heat transferred from the partially condensed spent stream.

20. The method of claim 19 wherein heat from the external heat source is used to evaporate the partially evaporated liquid working stream.

21. The method of claim 20 wherein the external heat source is a fluid stream that exchanges heat with the spent stream to reheat the spent stream prior to expansion of the spent stream, and that exchanges heat with the gaseous working stream to superheat the gaseous working stream, and that exchanges heat with the partially evaporated liquid working stream to completely evaporate the partially evaporated liquid working stream to form the gaseous working stream, and that exchanges heat with the liquid working stream to partially evaporate the liquid working stream to form the partially evaporated liquid working stream.

22. The method of claim 21 wherein the external heat source is a geothermal fluid stream produced by a geothermal source.

23. The method of claim 14 wherein the gaseous working stream, the spent stream, and the oncoming liquid working stream, are each multicomponent working streams that comprises a low-boiling component and a high-boiling component.

24. The method of claim 23 wherein each of the multicomponent working streams contains from about 55% to about 95% of the low-boiling component.

25. Apparatus for implementing a thermodynamic cycle comprising:

18

means for expanding a gaseous working stream, transforming its energy into usable form and producing a spent stream,

a heat exchanger for partially condensing the spent stream and for transferring heat from the spent stream as it begins to condense to partially evaporate an oncoming liquid working stream,

means for forming the oncoming liquid working stream that begins to evaporate at a temperature that is lower than the temperature at which the spent stream begins to condense; and

an external heat source for completely evaporating the oncoming liquid working stream, using heat produced by the external heat source, to form the gaseous working stream.

26. The apparatus of claim 25 further including means for reheating and expanding the spent stream to transform its energy into usable form.

27. The apparatus of claim 26 further comprising a second heat exchanger for transferring heat from the partially condensed spent stream to the liquid working stream to preheat the liquid working stream.

28. The apparatus of claim 27 further comprising a condenser for condensing the partially condensed spent stream after heat from heat stream has been used to preheat the liquid working stream in the second heat exchanger to produce the liquid working stream.

29. The apparatus of claim 28 further comprising a third heat exchanger for superheating the gaseous working stream prior to the expansion of the gaseous working stream.

30. The apparatus of claim 29 further comprising a pump for pumping the liquid working stream, formed by the condensation of the partially condensed spent stream, to a higher pressure prior to the preheating of the liquid working stream with heat transferred from the partially condensed spent stream in the second heat exchanger.

31. The apparatus of claim 30 further comprising a fourth heat exchanger for transferring heat from the external heat source to evaporate the partially evaporated liquid working stream.

32. The apparatus of claim 31 wherein the external heat source is a fluid stream that exchanges heat with the spent stream to reheat the spent stream prior to expansion of the spent stream, and that exchanges heat with the gaseous working stream to superheat the gaseous working stream, and that exchanges heat with the partially evaporated liquid working stream to completely evaporate the partially evaporated liquid working stream to form the gaseous working stream, and that exchanges heat with the liquid working stream in a fifth heat exchanger to partially evaporate the liquid working stream to form the partially evaporated liquid working stream.

33. The apparatus of claim 32 wherein the external heat source is a geothermal fluid stream produced by a geothermal source.

• • • • •

60

65

United States Patent [19]
Kalina

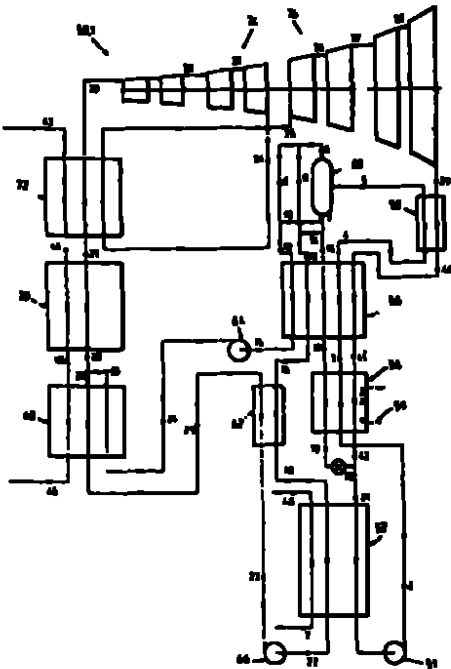
[11] **Patent Number** 4,548,043
[45] **Date of Patent** Oct. 22, 1985

[54] **METHOD OF GENERATING ENERGY**
[76] **Inventor** Alexander L. Kalina, 12214 Clear
Fork Houston, Tex 77077
[21] **Appl No.** 665,842
[22] **Filed** Oct. 26, 1984
[51] **Int. Cl.** -- -- F01K 25/06; F01K 25/10
[52] **U.S. Cl.** -- -- 60/673
[58] **Field of Search** -- -- 60/649 673
[56] **References Cited**

4 489 563 12/1984 Kalina -- -- 60/673
Primary Examiner—Allen M. Ostrager
Attorney, Agent, or Firm—Arnold White & Durkee

[57] **ABSTRACT**
A method of generating energy in which working fluid fractions of differing compositions are generated, are subjected to heating in a first evaporator stage, are combined, the combined stream is then evaporated and is expanded to convert its energy into usable form. Thereafter the combined stream is processed to regenerate the differing working fluid fractions for reuse.

U.S. PATENT DOCUMENTS
4,344,561 8/1982 Kalina -- -- 60/673
23 Claims, 5 Drawing Figures



206

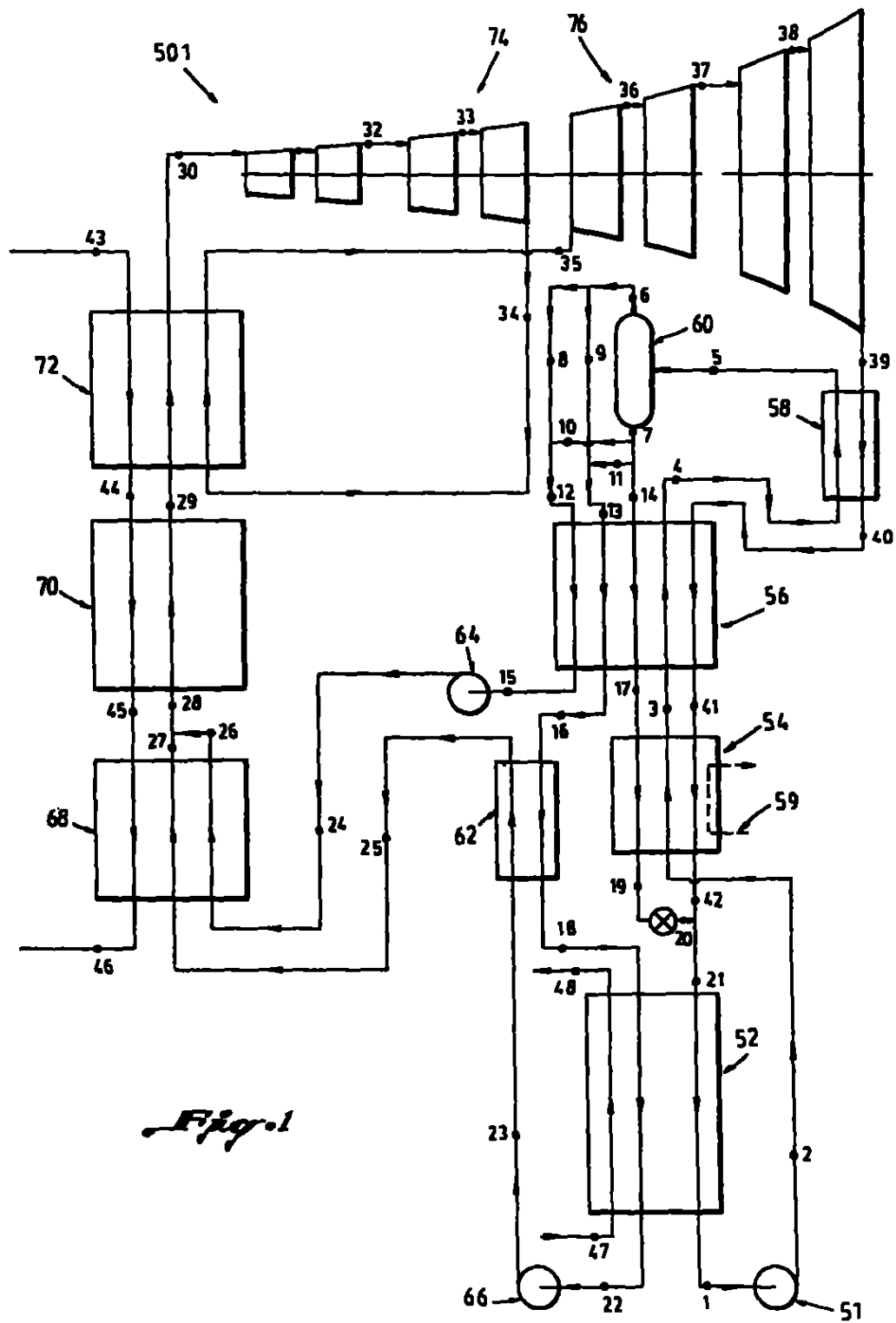
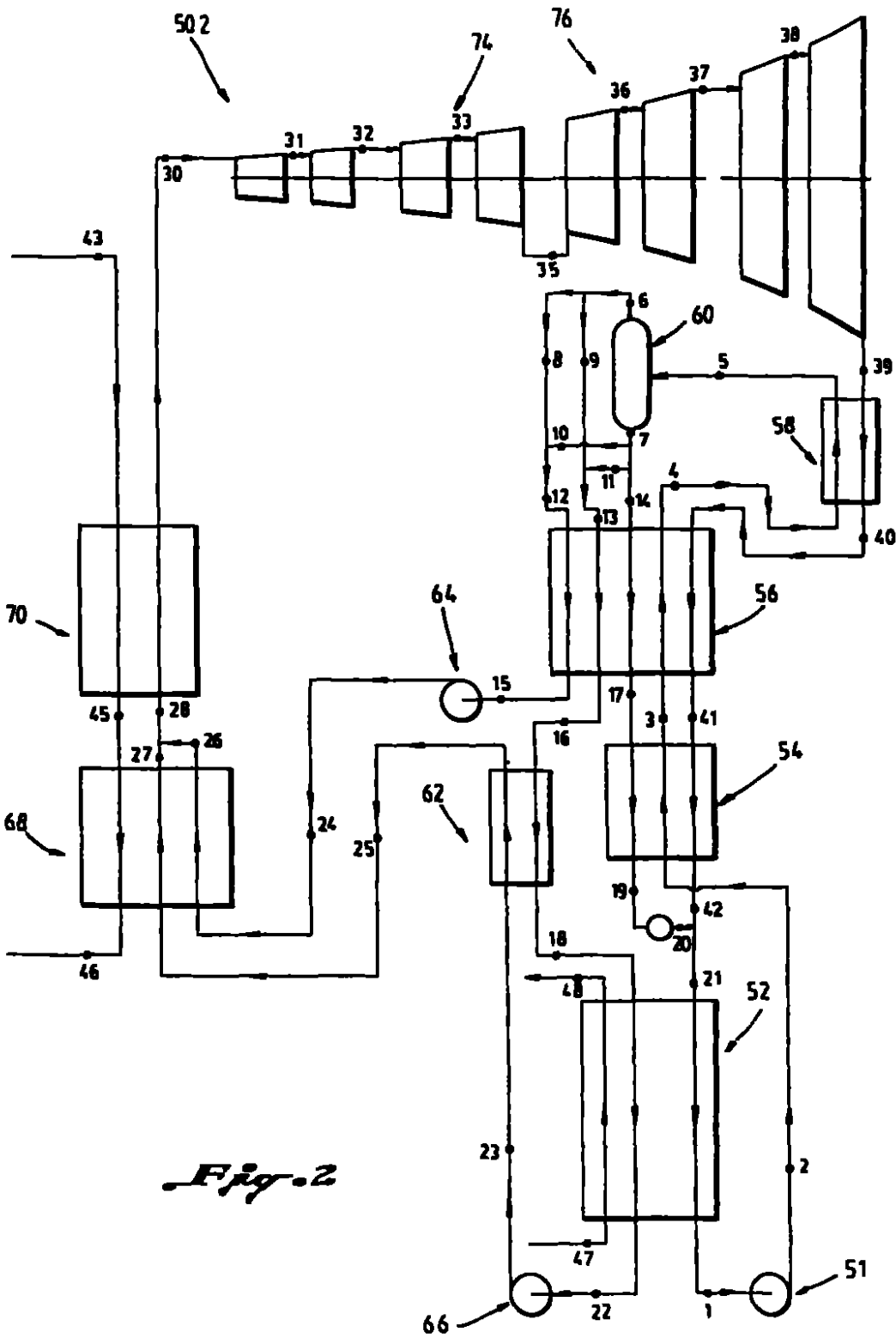


Fig. 1

207



200

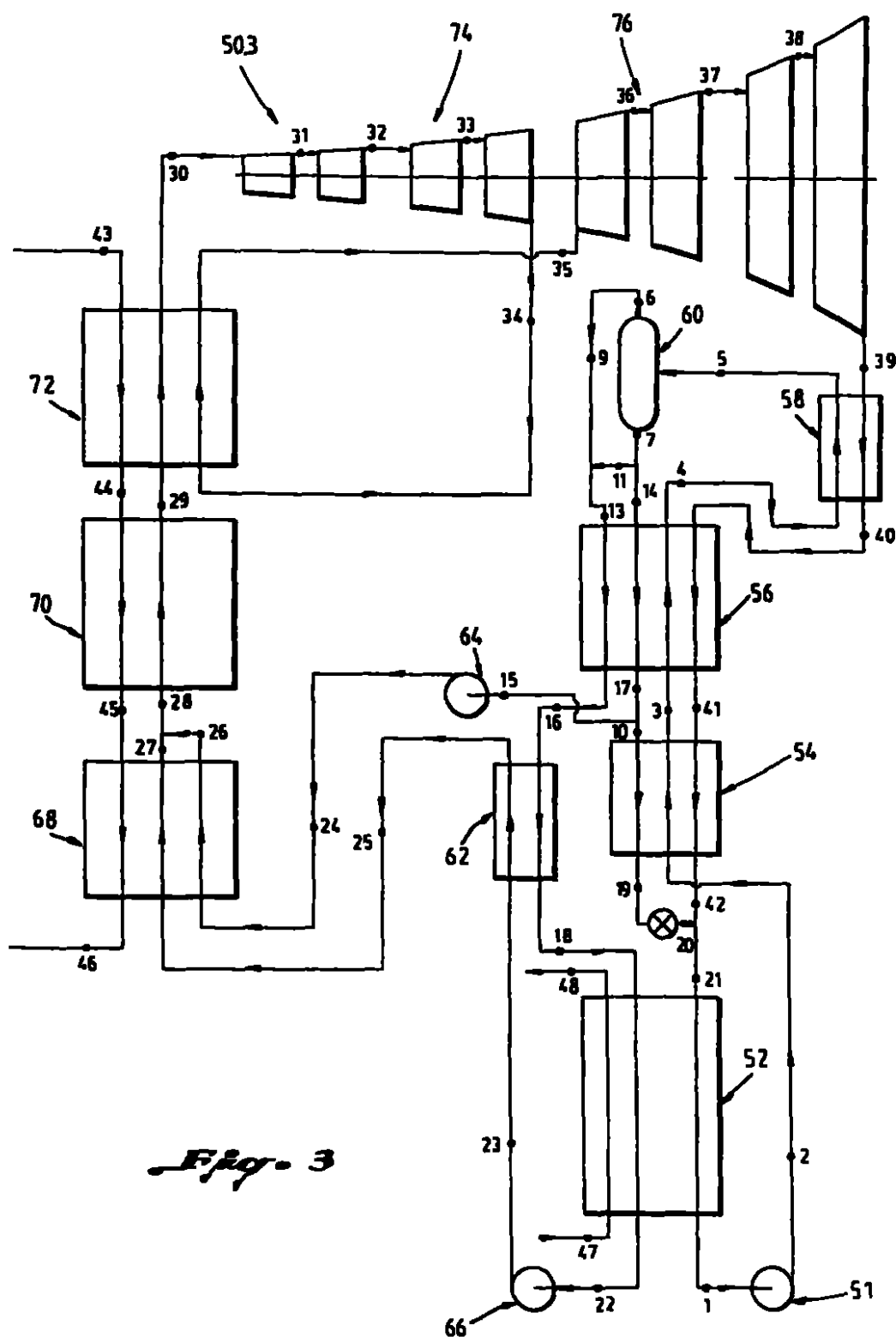


Fig. 3

209

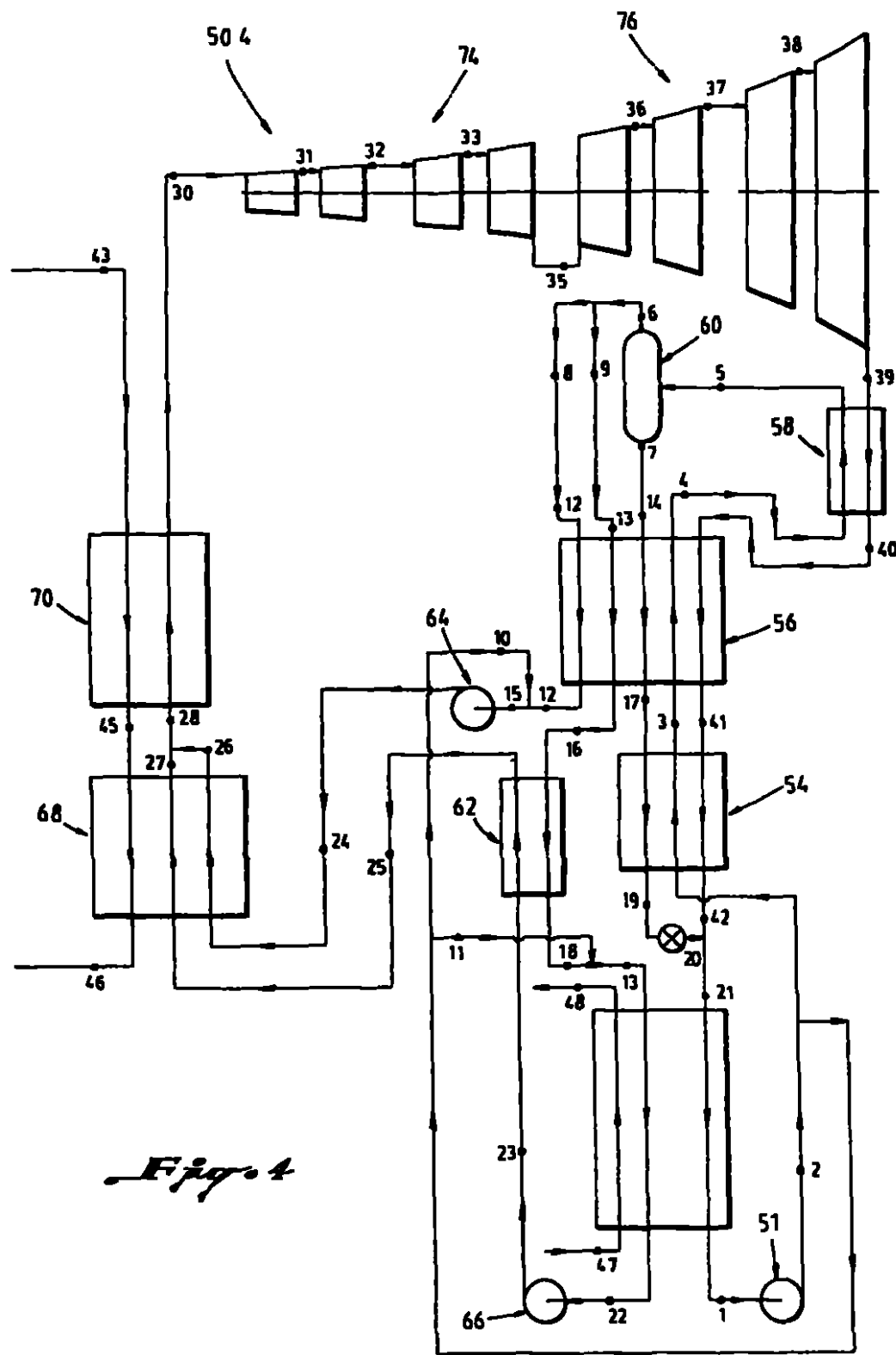
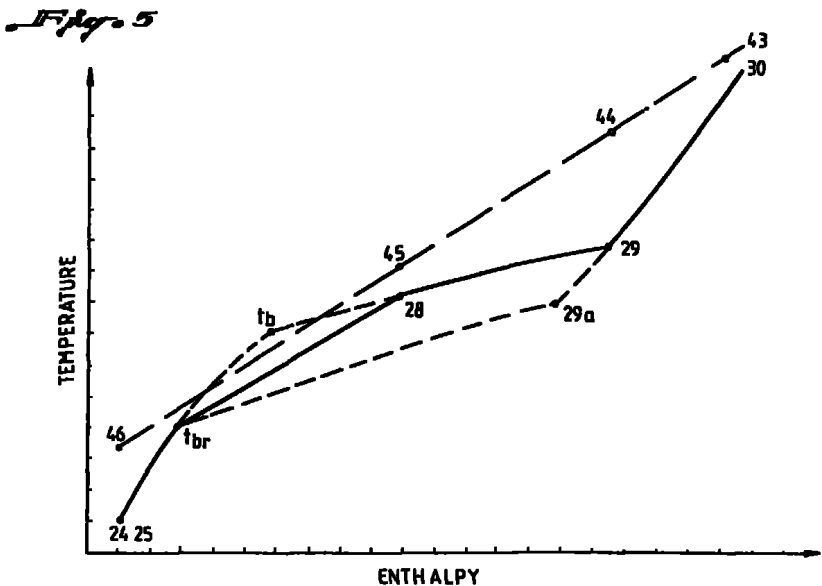


Fig. 4



METHOD OF GENERATING ENERGY

This invention relates to the generation of energy. More particularly this invention relates to a method of transforming the energy of a heat source into usable form by using a working fluid which is expanded and regenerated. The invention further relates to a method of improving the heat utilization efficiency in a thermodynamic cycle and thus to a new thermodynamic cycle utilizing the method.

The most commonly employed thermodynamic cycle for producing useful energy from a heat source, is the Rankine cycle. In the Rankine cycle a working fluid such as water ammonia or a freon is evaporated in an evaporator utilizing an available heat source. The evaporated gaseous working fluid is then expanded across a turbine to transform its energy into usable form. The spent gaseous working fluid is then condensed in a condenser using an available cooling medium. The pressure of the condensed working medium is then increased by pumping it to an increased pressure whereafter the working liquid at high pressure is again evaporated, and so on to continue with the cycle. While the Rankine cycle works effectively it has a relatively low efficiency.

A thermodynamic cycle with an increased efficiency over that of the Rankine cycle, would reduce the installation costs per Kw. At current fuel prices, such an improved cycle would be commercially viable for utilizing various waste heat sources.

Applicant's prior U.S. Pat. No. 4,346,561 filed Apr. 24, 1980 relates to a system for generating energy which utilizes a binary or multicomponent working fluid. This system termed the Exergy system, operates generally on the principle that a binary working fluid is pumped as a liquid to a high working pressure. It is heated to partially vaporize the working fluid, it is flashed to separate high and low boiling working fluids, the low boiling component is expanded through a turbine to drive the turbine, while the high boiling component has heat recovered therefrom for use in heating the binary working fluid prior to evaporation, and is then mixed with the spent low boiling working fluid to absorb the spent working fluid in a condenser in the presence of a cooling medium.

Applicant's Exergy cycle is compared theoretically with the Rankine cycle in Applicant's prior patent to demonstrate the improved efficiency and advantages of Applicant's Exergy cycle. This theoretical comparison has demonstrated the improved effectiveness of Applicant's Exergy cycle over the Rankine cycle when an available relatively low temperature heat source such as surface ocean water for example, is employed.

Applicant found, however that Applicant's Exergy cycle provided less theoretical advantages over the conventional Rankine cycle when higher temperature available heat sources were employed.

Applicant then devised a further invention to provide an improved thermodynamic cycle for such applications. This invention utilizes a distillation system in which part of a working fluid is distilled to thereby assist in regeneration of the working fluid component. This invention is the subject matter of Applicant's prior patent application Ser. No. 405,942 which was filed on Aug. 6, 1982, now U.S. Pat. No. 4,489,563.

Applicant believes that a thermodynamic cycle can be improved if effective steps can be taken to reduce the

effect of the pinch point problem when a working fluid is evaporated with a heating source.

It is accordingly one of the objects of this invention to provide a thermodynamic cycle in which the effect of the pinch point problem can be reduced.

In accordance with one aspect of this invention a method of generating energy comprises:

- (a) subjecting at least a portion of an initial composite stream having an initial composition of higher and lower boiling components, to distillation at an intermediate pressure in a distillation system to distill or evaporate part of the stream and thus generate an enriched vapor fraction which is enriched with a lower boiling component relatively to both a rich working fluid fraction and a lean working fluid fraction,
- (b) mixing the enriched vapor fraction with part of the composite stream and absorbing it therein to produce at least one rich working fluid fraction which is enriched relatively to a composite working fluid with a lower boiling component,
- (c) generating at least one lean working fluid fraction from part of the composite stream, the lean working fluid fraction being impoverished relatively to such a composite working fluid with a lower boiling component,
- (d) using a remaining part of the initial composite stream as a condensation stream,
- (e) condensing vapor contained in the rich and lean working fluid fractions to the extent that it is present in either,
- (f) increasing the pressures of the rich and lean working fluid fractions in liquid form to a charged high pressure level,
- (g) feeding the rich working fluid fraction and the lean working fluid fraction separately to a first evaporator stage to heat the lean working fluid fraction towards its boiling point, and to evaporate at least part of the rich working fluid fraction,
- (h) mixing the lean and rich working fluid fractions to generate a composite working fluid,
- (i) evaporating the composite working fluid in a second evaporator stage to produce a charged composite working fluid,
- (j) expanding the charged composite working fluid to a spent low pressure level to transform its energy into usable form, and
- (k) condensing the spent composite working fluid in an absorption stage by cooling and absorbing it in the condensation stream at a pressure lower than the intermediate pressure to regenerate the initial composite stream.

The lean and rich working fluid fractions, to the extent that they are not generated in liquid form, are cooled to condense them, preferably completely or substantially completely into liquid form before their pressures are increased to the charged high pressure level.

The rich and lean working fluid fractions will usually both require condensation to generate them in liquid form before they are pumped to the charged high pressure level.

In one embodiment of the invention the entire initial composite stream may be subjected to distillation in the distillation system to produce the enriched vapor fraction, and to produce a stripped liquid fraction from which the enriched vapor fraction has been stripped.

In one example of this embodiment of the invention the enriched vapor fraction may be divided into first and second enriched vapor fraction streams, and the stripped liquid fraction may be divided into first, second and third stripped liquid fraction streams. The first enriched vapor fraction stream may then be mixed with the first stripped liquid fraction stream to produce the rich working fluid fraction, the second enriched vapor fraction stream may be mixed with the second stripped liquid fraction stream to generate the lean working fluid fraction, and the third stripped liquid fraction stream may comprise the remaining part of the initial composite stream which is used as the condensation stream.

In an alternative example of this embodiment of the invention, the stripped liquid fraction may be divided into first, second and third stripped liquid fraction streams, the enriched vapor fraction may be mixed with the first stripped liquid fraction stream to produce the rich working fluid fraction, the second stripped liquid fraction stream may be used as the part of the initial composite stream comprising the lean working fluid fraction, and the third stripped liquid fraction stream may be used as the remaining part of the initial composite stream to constitute the condensation stream.

In an alternative embodiment of the invention only portion of the initial composite stream may be subjected to distillation in the distillation system to produce the enriched vapor fraction, and to produce a stripped liquid fraction from which the enriched vapor fraction has been stripped.

In this embodiment of the invention the enriched vapor fraction may for example, be divided into first and second enriched vapor fraction streams and the stripped liquid fraction may be used to constitute or comprise the condensation stream. In this example of the invention, the remaining part of the initial composite stream which is not subjected to distillation may be divided, for example, into first and second composite streams. The first and second enriched vapor fraction streams may be mixed with the first and second composite streams respectively to produce the rich working fluid fraction and the lean working fluid fraction.

It will readily be appreciated that depending upon conditions and circumstances including available heating and cooling sources, the rich and lean working fluid fractions may be generated by mixing varying proportions of the enriched vapor fraction with varying proportions of one or more stripped liquid fractions, one or more initial composite stream fractions which are not subjected to distillation, or by making any combination which will achieve the desired rich and lean working fluid fractions for reducing the pinch point problem in accordance with this invention.

It will further be appreciated that by making appropriate selections from the enriched vapor fraction, from the stripped liquid fraction and from the initial composite stream two, three or more working fluid fractions may be produced which have a range of low boiling component concentrations and which are of appropriate quantities to allow effective separate heating in a first evaporator stage, followed by combining two or more of the streams, followed by separate heating in a subsequent evaporator stage, again followed by mixing of the fluid streams to reduce the number of streams, again followed by evaporation in a subsequent evaporator stage, and so on until a single composite working fluid has been produced which can then be evaporated and expanded to convert its energy into usable form.

In a preferred embodiment of the invention, the condensation stream will be throttled down to the pressure of the spent composite working fluid for absorbing the spent composite working fluid therein in the absorption stage.

The condensation stream and the spent composite working fluid may be cooled in the absorption stage utilizing any appropriate and available cooling medium.

The initial composite stream generated in the absorption stage, or the portion thereof which is to be subjected to distillation may be subjected to distillation by heating in one or more heat exchangers using any suitable and available heating medium.

Applicant's presently preferred method of subjecting the initial composite stream, or portion thereof to distillation is by means of relatively low temperature heat. This provides the advantage that the quantity of heat loss in the heat exchanger system will be substantially less, and that low temperature heat may be used for this purpose which cannot conveniently be utilized in other aspects of the cycle.

In a presently preferred embodiment of the invention, distillation may be effected by passing the initial composite stream, or portion thereof in heat exchange relationship with one or more of the following heating sources.

- (a) the spent composite working fluid;
- (b) the condensation stream;
- (c) the lean working fluid fraction,
- (d) the rich working fluid fraction; and
- (e) an auxiliary heating source.

Applicant believes that in many applications of the cycle of this invention, no auxiliary heating source will be required. Applicant thus believes that sufficient heat can be extracted from the spent composite working fluid, from the condensation stream, and from the lean and rich working fluid fractions to provide for effective distillation or evaporation of part of the initial composite stream to produce the enriched vapor fraction which is enriched with respect to the lower boiling component or components of the composite stream.

When the initial composite stream is subjected to such distillation, the lower boiling component or components will naturally evaporate or distill first thereby producing the enriched vapor fraction.

The compositions of the rich working fluid and lean working fluid fractions are preferably selected so that they can be heated most effectively in the first evaporator stage with the available heating medium. The first evaporator stage will generally be the low temperature stage of the evaporator.

Thus, for example, the composition should be selected and the relative quantities should be selected such that the lean working fluid fraction will be heated towards its boiling point in the first evaporator stage, while the rich working fluid fraction will be heated towards its saturated vapor stage.

Preferably the rich working fluid fraction should be enriched as much as possible with the lower boiling component or components, consistent with the use of a lean working fluid fraction which can have a boiling point at the dew point of the rich working fluid fraction.

In a presently preferred embodiment, the compositions and quantities will be selected so that the lean working fluid will be heated to its boiling point or to substantially its boiling point in the first evaporator stage, while the rich working fluid fraction will be

212

evaporated substantially or completely to be in the form of a saturated vapor in the first evaporator stage.

While both the lean working fluid fraction and the rich working fluid fraction may be heated to a higher temperature in the first evaporator stage, Applicant believes that this will not provide any real thermodynamic advantage in the cycle of this invention.

The rich and lean working fluid fractions are thus selected so that after they have passed through the first evaporator stage, they are substantially or at least generally in equilibrium both in temperature and pressure to reduce any thermodynamic losses which may occur during mixing.

When lean and rich working fluid fractions are first generated in accordance with this invention, they will usually both contain vapor and must therefore be cooled to condense them completely. They are then pumped separately to the charged high pressure level before being fed to the first evaporator stage. While the lean working fluid fraction may sometimes contain no vapor and will therefore not have to be cooled, the rich working fluid fraction will usually contain vapor and will have to be cooled to condense the vapor and provide the fraction in liquid form for effective pressure increase.

They may be cooled utilizing any available cooling medium. In accordance with Applicant's presently preferred embodiment of the invention, the lean working fluid fraction will be cooled by passing it in heat exchange relationship with the initial composite stream which is being subjected to distillation.

Similarly in accordance with Applicant's presently preferred embodiment, the rich working fluid fraction will be cooled by passing it in heat exchange relationship with an auxiliary cooling source. A preheater system may also be employed between the cooled rich working fluid fraction and the rich working fluid fraction which has not yet been cooled with the cooling medium of the auxiliary cooling source.

In the preferred application of the invention, the rich and lean working fluid fractions will be cooled so that their temperatures will be generally equal or close before they are fed to the first evaporator stage.

After the lean and rich working fluid fractions have passed through the first evaporator stage, and have been mixed to constitute the composite working fluid, they may be heated in the second evaporator stage to evaporate the composite working fluid completely or at least substantially completely.

Applicant believes that the best thermodynamical advantages will be provided if the composite working fluid is evaporated completely in the second evaporator stage. Applicant believes that it will be less advantageous if the composite working fluid is not evaporated completely.

If the composite working fluid is evaporated only partially some of that fluid, which will have been heated to a relatively high temperature, will not be available to generate energy. This will therefore reduce the efficiency of the process. By evaporating the composite working fluid completely in the second evaporation stage using a relatively high temperature heat, and utilizing all or substantially all of the evaporated composite working fluid as the charged composite working fluid, Applicant believes that high temperature energy utilization will be the most efficient and effective.

In a presently preferred embodiment of the invention the composite working fluid from the second evaporator stage, will be superheated in a superheater stage.

The charged composite working fluid may be expanded to a spent low pressure level to transform its energy into usable form, utilizing any suitable and available device for this purpose. Devices of this nature are generally in the form of turbines and will generically be referred to in the specification as turbines.

Various single and multi-stage turbines are available and can be selected to provide the appropriate pressure and temperature ranges for effective utilization of this invention.

In an embodiment of the invention a multi-stage turbine system may be used and at least part of the composite working fluid may be recycled to the superheater stage after passing through a high pressure stage of the turbine, and before entering a low pressure stage of the turbine.

It will readily be appreciated by those skilled in the art that relatively low temperature heat for the distillation system of this invention may be obtained from various sources depending upon circumstances. It may be obtained in the form of spent relatively high temperature heat, in the form of the lower temperature part of relatively higher temperature heat from a heat source, in the form of relatively lower temperature waste or other heat which is available from the or from a heat source, and/or in the form of relatively lower temperature heat which is generated in the method of this invention and cannot be utilized efficiently or more effectively or at all for evaporation of the composite working fluid.

Various types of heat sources may be used in the evaporator stage of the cycle of this invention to evaporate the composite working fluid. In each instance, depending upon available heat sources, the cycle can be adjusted to utilize such heat sources in the most effective manner. For example, Applicant anticipates that heat sources may be used from sources as high as 1,000° F or more, down to heat sources such as those obtained from ocean thermal gradients. Heat sources such as, for example, low grade primary fuel, waste heat, geothermal heat, solar heat and ocean thermal energy conversion systems are believed all to be capable of development for use in this invention.

The working fluid for use in this invention may be any multi-component working fluid which comprises a mixture of two or more low and high boiling fluids. The fluids may be mixtures of any of a number of compounds with favorable thermodynamic characteristics and having an appropriate or wide range of solubility. Thus, for example, the working fluid may comprise a binary fluid such as an ammonia-water mixture, two or more hydrocarbons, two or more freons, mixtures of hydrocarbons and freons, or the like.

Applicant's presently preferred working fluid is a water-ammonia mixture.

Enthalpy-concentration diagrams for ammonia-water are readily available and are generally accepted. The National Bureau of Standards will supply upon request an article published in the National Bureau of Standards list as Project 758-80. This paper was prepared by Wiltec Research Company Inc., 488 South 500 West, Provo, Utah, 84601 in 1983 and deals with the experimental study of water-ammonia mixtures and their properties in a wide range of temperatures and pres-

tures. A copy of this paper is attached to this specification and is incorporated herein by reference.

Ammonia-water provides a wide range of boiling temperatures and favorable thermodynamic characteristics. Ammonia-water is therefore a practical and potentially useful working fluid in many applications of this invention. Applicant believes, however, that when equipment economics and turbine design become paramount considerations in developing commercial embodiments of the invention, mixtures of freon-22 with toluene or other hydrocarbon or freon combinations will become more important for consideration.

In general standard equipment may be utilized in carrying out the method of this invention. Thus, equipment such as heat exchangers, tanks, pumps, turbines, valves and fittings of the type used in typical thermodynamic cycles such as, for example, Rankine cycles, may be employed in carrying out the method of this invention. Applicant believes that the constraints upon materials of construction would be the same for this invention as for conventional Rankine cycle power or refrigeration systems. Applicant believes, however, that higher thermodynamic efficiency of this invention will result in lower capital cost per unit of useful energy recovered, primarily saving in the cost of heat exchanger and boiler equipment. Applicant believes that this invention will provide a reduction in the total cost per unit of energy produced.

The invention is now described in detail with reference to certain preferred embodiments of the invention and with reference to the accompanying drawings.

In the drawings:

FIG. 1 shows a schematic representation of one system for carrying out the method of this invention;

FIG. 2 shows a schematic representation of the system of FIG. 1, but with the superheating stage omitted;

FIG. 3 shows a schematic representation of an alternative embodiment of this invention;

FIG. 4 shows a schematic representation of yet a further alternative embodiment in accordance with this invention; and

FIG. 5 is a graphic representation of a temperature-enthalpy diagram to demonstrate how application of this invention can reduce the pinch point problem.

With reference to FIG. 1 of the drawings, reference numeral 50.1 refers generally to one embodiment of a thermodynamic system or cycle in accordance with this invention.

The system of cycle 50.1 comprises an absorption stage 52, a heat exchanger 54, a recuperator 56, a main heat exchanger 58, a separator stage 60, a preheater 62, pumps 64 and 66, a first evaporator stage 68, a second evaporator stage 70, a superheater section 72, and a multi-stage turbine comprising a high pressure stage 74 and a low pressure stage 76.

The system or cycle of this invention will now be described by way of example by reference to the use of an ammonia-water working solution as the initial composite stream.

This is a continuous system where a charged composite working fluid is expanded to convert its energy into usable form, and is then continually regenerated. A substantially constant and consistent quantity of composite working fluid will therefore be maintained in the system for long term use of the system.

In analyzing the system it is useful to commence with the point in the system identified by reference numeral 1 comprising the initial composite stream having an

initial composition of higher and lower boiling components in the form of ammonia and water. At point 1 the initial composite stream is at a spent low pressure level. It is pumped by means of a pump 51 to an intermediate pressure level where its pressure parameters will be as at point 2 following the pump 51.

From point 2 of the flow line, the initial composite stream at an intermediate pressure is heated consecutively in the heat exchanger 54, in the recuperator 56 and in the main heat exchanger 58.

The initial composite stream is heated in the heat exchanger 54, in the recuperator 56 and in the main heat exchanger 58 by heat exchange with the spent composite working fluid from the turbine sections 74 and 76. In addition, in the heat exchanger 54 the initial composite stream is heated by the condensation stream as will be hereinafter described. In the recuperator 56 the initial composite stream is further heated by the condensation stream and by heat exchange with lean and rich working fluid fractions as will be hereinafter described.

The heating in the main heat exchanger 58 is performed only by the heat of the flow from the turbine outlet and, as such is essentially compensation for under recuperation.

At point 5 between the main heat exchanger 58 and the separator stage 60 the initial composite stream has been subjected to distillation at the intermediate pressure in the distillation system comprising the heat exchangers 54 and 58 and the recuperator 56. If desired, auxiliary heating means from any suitable or available heat source may be employed in any one of the heat exchangers 54 or 58 or in the recuperator 56. This is shown, for example, by dotted line 59 in the heat exchanger 54.

At point 5 the initial composite stream has been partially evaporated in the distillation system and is sent to the gravity separator stage 60. In this stage 60 the enriched vapor fraction which has been generated in the distillation system, and which is enriched with the low boiling component, namely ammonia, is separated from the remainder of the initial composite stream to produce an enriched vapor fraction at point 6 and a stripped liquid fraction at point 7 from which the enriched vapor fraction has been stripped.

In the embodiment illustrated in FIG. 1, the enriched vapor fraction from point 6, is divided into first and second enriched vapor fraction streams as at points 9 and 8 respectively.

Further in the FIG. 1 embodiment, the stripped liquid fraction from point 7 is divided into first, second and third stripped liquid fraction streams having parameters as at points 11, 10 and 14 respectively.

The enriched vapor fraction at point 6 is enriched with the lower boiling component, namely ammonia, relatively to both a rich working fluid fraction and a lean working fluid fraction as discussed below.

The first enriched vapor fraction stream from point 9 is mixed with the first stripped liquid fraction stream at point 11 to provide a rich working fluid fraction at point 13.

The second enriched vapor fraction stream at point 8 is mixed with the second stripped liquid fraction stream at point 10 to produce a lean working fluid fraction at point 12.

The rich working fluid fraction is enriched relatively to the composite working fluid (as hereinafter discussed) with the lower boiling component comprising ammonia. The lean working fluid fraction on the other

hand, is impoverished relatively to the composite working fluid (as hereinafter discussed) with respect to the lower boiling component.

The third stripped liquid fraction at point 14 comprises the remaining part of the initial composite stream and is used to constitute the condensation stream.

The difference in composition of the lean and rich working fluid fractions at points 12 and 13 is achieved by using difference proportions of vapor to liquid in forming these two fractions.

The lean working fluid fraction is cooled between points 12 and 13 in the recuperator 56 to condense it completely and provide a condensed lean working fluid fraction at point 13.

The rich working fluid fraction at point 13 is partially condensed in the recuperator 56 to point 16. Thereafter the rich working fluid fraction is further cooled and condensed in the preheater 62 (from point 16 to 18), and is finally condensed in the absorption stage 52 by means of heat exchange with a cooling water supply through points 47 to 48.

The lean working fluid fraction at point 13 is then pumped to a charged high pressure level by means of the pump 64 to provide it with parameters as at point 24. Likewise the rich working fluid fraction is pumped to the same or substantially the same charged high pressure level by means of the pump 66. Thereafter it passes through the preheater 62 to arrive at point 25 where it is substantially at the same pressure and temperature as the lean working fluid fraction which is at point 24.

In practice the temperatures at points 24 and 25 should be sufficiently high to prevent water precipitation on the surface of the tubes in the evaporator stage 68.

The flows at points 24 and 25 are then fed separately to the first evaporator stage 68. This is the low temperature stage of the evaporator system where the rich and lean working fluid fractions are heated with the lower temperature portion of a heating source supplied originally from point 43 at high temperature, and leaving the system at point 46.

In the first evaporator stage 68 the rich working fluid fraction is preferably heated from point 25 to point 27 so that it is evaporated entirely and is preferably at point 27 in the form of a saturated vapor at its dew point. Applicant believes that this will be the most effective heat utilization in the first evaporator stage 68 and that while the rich working fluid fraction could be heated to a lower or higher temperature in this stage, this will provide no advantage and may lead to losses.

The lean working fluid fraction is likewise heated in the first evaporator stage 68 from point 24 to point 26. This is preferably heated such that the lean working fluid fraction is heated to or substantially to its boiling point by the time it reaches point 26. Again Applicant believes that this will be the most effective utilization of heat in relation to the lean working fluid fraction in the first evaporator stage 68, and that heating to a lower or higher temperature will reduce the efficiency of the cycle.

The lean and rich working fluid fractions 26 and 27 are then mixed to form, at point 28, a composite working fluid. When they are mixed they are in thermodynamical equilibrium both in regard to temperature and pressure. Thermodynamical losses on mixing should therefore be very low.

The charged composite working fluid from point 28 is then fed through the second evaporator stage 70

where it is preferably evaporated completely to produce the charged composite working fluid in gaseous form. Thus is at point 29. From point 29 to point 30 the charged composite working fluid is superheated in the superheater stage 72.

The composite working fluid with parameters at point 30 is then sent through the high pressure stage 74 of the turbine to transform its energy into usable form.

Both the high pressure stage 74 and the low pressure stage 76 of the turbine are shown to comprise four separate stages. Any appropriate turbine system may however, be used instead.

After passing through the high pressure stage 74 of the turbine the composite working fluid has parameters as at point 34, with a lower pressure and lower temperature than it had at point 30. From point 34 the composite working fluid is sent back into the superheater section 72 of the evaporator stage, where it is reheated from point 34 to point 35 and is then fed into the low pressure stage 76 of the turbine, where it is fully expanded until it reaches the spent low pressure level at point 39. At point 39 the composite working fluid preferably has such a low pressure that it cannot be condensed at this pressure and at the available ambient temperature. From point 39 the spent composite working fluid flows through the main heat exchanger 58, through the recuperator 56 and through the heat exchanger 54. Here it is partially condensed and the released heat is used to preheat the incoming flow as previously discussed.

The spent composite working fluid at point 42 is then mixed with the condensation stream at point 28. At point 20 the condensation stream has been throttled from point 19 to reduce its pressure to the low pressure level of the spent composite working fluid at point 42. The resultant mixture is then fed from point 21 through the absorption stage 52 where the spent composite working fluid is absorbed in the condensation stream to regenerate the initial composite stream at point 1.

With reference to FIG. 2 of the drawings, reference numeral 50.2 refers generally to an alternative embodiment of an energy system or cycle in accordance with this invention.

The system 50.2 corresponds in all respects with the system 50.1, except that the superheater stage 72 of FIG. 1 has been omitted, and that there is no recycle of the partially expanded composite working fluid through such a superheater stage.

With reference to FIG. 3 of the drawings, reference numeral 50.3 refers to yet a further alternative embodiment of a system or cycle in accordance with this invention.

The system 50.3 corresponds substantially with the system 50.1 of FIG. 1, and corresponding parts are identified with corresponding reference numerals.

In the system 50.3 the stripped liquid fraction at point 7 is divided into first, second and third stripped liquid fractions at points 11, 15 and 10 respectively. Further in this embodiment, only one enriched vapor fraction is produced at point 6. It is not split into two vapor fraction streams as in the case of the cycles 50.1 and 50.2.

The enriched vapor fraction at point 9 is mixed with the first stripped liquid fraction stream from point 11 to produce the rich working fluid fraction at point 13.

The rich working fluid fraction at point 13 is condensed and cooled in the same way as discussed with reference to FIG. 1 through the recuperator 56, the preheater 62 and the absorption stage 52. It is then

pumped to the charged high pressure level by means of the pump 66, passes through the preheater 62 and arrives at point 23.

The second stripped liquid fraction stream is obtained at point 15 after passing, together with the third stripped liquid fraction stream, through the recuperator 56. After point 17 the second and third stripped liquid fraction streams are split with the one being conveyed to point 13 to constitute the lean working fluid fraction. The third stripped liquid fraction stream from point 10 passes through the heat exchanger 54, is throttled from point 19 to point 20 to reach the spent low pressure level and thus constitutes the condensation stream for absorbing the spent composite working fluid from point 43 in the absorption stage 52.

The lean working fluid fraction at point 15 is pumped to the charged high pressure level by means of the pump 64 and arrives at point 24 where it has substantially the same pressure and temperature parameters as the rich working fluid fraction at point 25.

The remainder of the process is then exactly the same as described with reference to FIG. 1.

With reference to FIG. 4 of the drawings, reference numeral 50.4 refers to yet a further alternative embodiment of a thermodynamic system or cycle in accordance with this invention.

The cycle 50.4 corresponds generally with the cycle 50.2 and thus with the cycle 50.1 as illustrated in FIGS. 2 and 1 of the drawings. Corresponding parts are therefore indicated by corresponding reference numerals.

In the system 50.4, unlike the embodiments of the previous figures, only portion of the initial composite stream which is at the intermediate pressure at point 2 is subjected to distillation in the distillation stage.

In the system 50.4 the enriched vapor fraction at point 6 is again, as in the case of the system 50.1, divided into first and second enriched vapor fraction streams at points 9 and 8 respectively. These streams flow through the recuperator 56 where they are cooled for partial condensation.

The stripped liquid fraction from point 7 comprises the condensation stream. It flows from point 14 through the recuperator 56 to point 17 through the heat exchanger 54 to point 19, and then through the throttle valve to point 20 to absorb therein, in the absorption stage 52, the spent composite working fluid to regenerate the initial composite stream at point 1 as described with reference to FIG. 1.

After point 2 the remaining part of the initial composite stream which is not subjected to distillation in the distillation system is extracted and divided into first and second composite streams 11 and 10 respectively.

The second enriched vapor fraction stream from point 8, after passing through the recuperator 56, is mixed with the second composite stream from point 10, to constitute the lean working fluid fraction at point 15. This is then again pumped by means of the pump 64 to the charged high pressure level to yield the lean working fluid fraction at point 24.

The first enriched vapor fraction stream from point 9 is fed through the recuperator 56 and through the preheater 62. Thereafter from point 18, it is mixed with the first composite stream from point 11. This then yields the rich working fluid fraction at point 13 which passes through the absorption stage 52, through the pump 66, and through the preheater 62 to arrive at point 25 with the appropriate temperature and pressure parameters.

As in the case of the embodiment of FIG. 1 these two streams then pass through the first absorption stage are then mixed at point 28, and are then evaporated in the second absorption stage 70.

The embodiment illustrated in FIG. 4 corresponds with the cycle 50.2. It may also, of course, include a superheater stage 72 and a recycle loop 34 to 35 as illustrated in FIG. 1.

Persons of ordinary skill in this art will appreciate that for appropriate circumstances and conditions, a plurality of lean working fluid fractions or rich working fluid fractions can be generated by selecting quantities of enriched vapor fractions from zero up, and by selecting stripped liquid fractions and/or initial composite stream fractions in appropriate quantities as may be desired.

Applicant will now without wishing to bound by theory try to explain the theoretical basis for this invention with reference to the graph of FIG. 5. In this graph temperature is plotted against enthalpy for what Applicant believes would be a typical water-ammonia system in accordance with this invention. The points given in this graph correspond with the points used for the various parameters in the cycle 50.1 of FIG. 1.

The first evaporator stage 68 or the low temperature evaporator stage 68 can be considered as being divided into two portions. In the first portion the rich working fluid fraction and the lean working fluid fraction are heated from points 25 and 24 respectively up to the point designated t_b . Both the rich and the lean working fluid fractions are below their boiling points. In the second part of the first evaporator stage 68, beyond the point t_b , the temperatures of both the rich and lean working fluid fractions are above their bubble point temperatures.

If one were to introduce into the first separation stage only the rich working fluid fraction at its given pressure, such a fluid would begin to boil at point t_b . This is a relatively low temperature and will permit the use of the available heat source in full. However the whole boiling process will take place at a relatively low temperature which would result in increased temperature differences in most parts of the evaporator stage and consequently would result in relatively high thermodynamic losses. This theoretical process is shown in FIG. 5 by the line between point 25 and t_b , by the dotted line from point t_b to point 29a and by the dotted line from point 29a to point 29.

The cooling of the heat source is designated with a chain dotted line from point 43 through to point 46.

If a person were now trying to introduce the composite working fluid, comprising the mixture of the rich working fluid fraction at point 25 and the lean working fluid fraction at point 24, at the same given pressure, while trying to use the available heat source in full, this fluid would only begin to boil at a temperature t_b . This is a temperature which is higher than the temperature of the heat source in the corresponding part of the evaporator stage 68. This would consequently make the process impossible. This impossible process is demonstrated in FIG. 5 by the line 24- t_b - t_b -28-29. Such a process would only be possible if incomplete use is made of the available heat source and the corresponding thermodynamic losses are incurred.

When, however the rich working fluid fraction and lean working fluid fraction are introduced separately into the first evaporation stage 68 in accordance with this invention, the rich working fluid fraction will start

to boil at the relatively low temperature t_4 , thereby reducing the "pinch point" problem. At the same time, because the rich working fluid fraction and lean working fluid fraction have been combined at point 28, when they are in thermodynamical equilibrium, the boiling process will take place at a relatively high temperature. The thermodynamic losses are therefore reduced. This, in turn, permits the system to accommodate an increased pressure in the evaporator stage and consequently at the turbine inlet. This combined process is shown in FIG. 5 by the solid line 24-29.

This resultant summary of the enthalpy of the two systems, demonstrates that the curve followed by the system of this invention through the first evaporator stage 68, is further away from the heating medium line in the pinch point zone to thereby reduce the pinch point problem, while it approaches the heating medium line more closely after point 28 to reduce the thermodynamic losses.

Applicant believes that by using more than two working fluid fractions of varying composition which are combined in successive stages as they pass through successive evaporator stages, and by using superheating in an effective number of stages, the heating curve of the working fluid fraction can be smoothed to approach that of the heating fluid more closely and thereby lead to a reduction in thermodynamic losses.

In certain embodiments of the invention where the composite working fluid has been expanded from a very high pressure to a spent low pressure level, the working fluid may at point 39, have a temperature which is too low. It may also have a significant content of condensed liquid. As a result it can have an adverse effect on the performance of the last stages of the turbine 76. In addition, the quantity and quality of heat remaining in this stream after point 39 may not be sufficient to provide for distillation of the initial composite stream and thus for regeneration of the working fluid fraction. Applicant believes that this potential disadvantage may overcome by the superheater stage 72 and by the recycle loop as employed between points 34 and 35 in FIGS. 1 and 3.

I claim.

1. A method of generating energy which comprises:

- (a) subjecting at least a portion of an initial composite stream having an initial composition of higher and lower boiling components, to distillation at an intermediate pressure in a distillation system to distill or evaporate part of the stream and thus generate an enriched vapor fraction which is enriched with a lower boiling component relatively to both a rich working fluid fraction and a lean working fluid fraction,
- (b) mixing the enriched vapor fraction with part of the composite stream and absorbing it therein to produce at least one rich working fluid fraction which is enriched relatively to a composite working fluid with a lower boiling component,
- (c) generating at least one lean working fluid fraction from part of the composite stream the lean working fluid fraction being impoverished relatively to such a composite working fluid with a lower boiling component,
- (d) using a remaining part of the initial composite stream as a condensation stream,
- (e) condensing vapor contained in the rich and lean working fluid fractions to the extent that it is present,

(f) increasing the pressures of the rich and lean working fluid fractions in liquid form to a charged high pressure level

(g) feeding the rich working fluid fraction and the lean working fluid fraction separately to a first evaporator stage to heat the lean working fluid fraction towards its boiling point, and to evaporate at least part of the rich working fluid fraction

(h) mixing the lean and rich working fluid fractions to generate a composite working fluid,

(i) evaporating the composite working fluid in a second evaporator stage to produce a charged composite working fluid,

(j) expanding the charged composite working fluid to a spent low pressure level to transform its energy into usable form and

(k) condensing the spent composite working fluid in an absorption stage by cooling and absorbing it in the condensation stream at a pressure lower than the intermediate pressure to regenerate the initial composite stream

2. A method according to claim 1, in which the lean and rich working fluid fractions, to the extent that they are not generated in liquid form, are cooled to condense them into liquid form before their pressures are increased to the charged high pressure level.

3. A method according to claim 1, in which the entire initial composite stream is subjected to distillation in the distillation system to produce the enriched vapor fraction, and to produce a stripped liquid fraction from which the enriched vapor fraction has been stripped.

4. A method according to claim 3, in which the enriched vapor fraction is divided into first and second enriched vapor fraction streams, in which the stripped liquid fraction is divided into first, second and third stripped liquid fraction streams, in which the first enriched vapor fraction stream is mixed with the first stripped liquid fraction stream to produce the rich working fluid fraction, in which the second enriched vapor fraction stream is mixed with the second stripped liquid fraction stream to generate the lean working fluid fraction, and in which the third stripped liquid fraction stream comprises the remaining part of the initial composite stream which is used as the condensation stream.

5. A method according to claim 4, in which the condensation stream is throttled down to the pressure of the spent composite working fluid for absorbing the spent composite working fluid therein.

6. A method according to claim 5, in which the condensation stream and the spent composite working fluid are cooled in the absorption stage with an available cooling medium, and in which the initial composite stream generated in the absorption stage is subjected to distillation by heating it in heat exchangers using one or more of the following heating sources

- (a) the spent composite working fluid
- (b) the condensation stream,
- (c) the lean working fluid fraction;
- (d) the rich working fluid fraction, and
- (e) an auxiliary heating source

7. A method according to claim 6, in which the auxiliary heating source when used, is a relatively low temperature source.

8. A method according to claim 4, in which the compositions of the rich working fluid and lean working fluid fractions are selected so that when heated in the first evaporator stage, the lean working fluid fraction will substantially reach its boiling point, and the rich

15

working fluid fraction will be substantially in the form of a saturated vapor

9. A method according to claim 4, in which the lean and the rich working fluid fractions are cooled in heat exchangers to condense them completely and are then pumped separately to the charged high pressure level before being fed to the first evaporator stage.

10. A method according to claim 9 in which the lean working fluid fraction is cooled by passing it in heat exchange relationship with the initial composite stream.

11. A method according to claim 9 in which the rich working fluid fraction is cooled by passing it in heat exchange relationship with an auxiliary cooling source.

12. A method according to claim 11, in which the rich working fluid fraction is further cooled by passing it in heat exchange relationship with one or more of the following cooling sources.

- (a) the initial composite stream; and
- (b) the cooled condensed rich working fluid fraction.

13. A method according to claim 9 in which the rich and lean working fluid fractions are cooled so that their temperatures will be generally equal or close before they are fed to the first evaporator stage.

14. A method according to claim 1, in which the composite working fluid produced by mixing the lean and rich working fluid fractions, is heated in the second evaporator stage to evaporate the composite working fluid substantially completely

15. A method according to claim 1, in which the composite working fluid produced by mixing the lean and the rich working fluid fractions, is heated in the second evaporator stage to substantially its dew point.

16. A method according to claim 8, in which the composite working fluid produced by mixing the lean and rich working fluid fractions, is heated in the second evaporator stage to evaporate the composite working fluid substantially completely

17. A method according to claim 1, in which the composite working fluid from the second evaporator stage is superheated in a superheater stage.

18. A method according to claim 17 in which the superheated composite working fluid is expanded in a multistage turbine system, and in which at least part of the composite working fluid is recycled to the superheater stage after passing through a high pressure stage

16

of the turbine and before entering a low pressure stage of the turbine.

19. A method according to claim 3, in which the stripped liquid fraction is divided into first, second and third stripped liquid fraction streams, in which the enriched vapor fraction is mixed with the first stripped liquid fraction stream to produce the rich working fluid fraction, in which the second stripped liquid fraction stream is used as the part of the composite stream comprising the lean working fluid fraction, and in which the third stripped liquid fraction stream is used as the remaining part of the initial composite stream to constitute the condensation stream.

20. A method according to claim 19 in which the compositions of the rich working fluid and lean working fluid fractions are selected so that when heated in the first evaporator stage, the lean working fluid fraction will substantially reach its boiling point, and the rich working fluid fraction will be substantially in the form of a saturated vapor

21. A method according to claim 1 in which only portion of the initial composite stream is subjected to distillation in the distillation system to produce the enriched vapor fraction, and to produce a stripped liquid fraction from which the enriched vapor fraction has been stripped

22. A method according to claim 21 in which the enriched vapor fraction is divided into first and second enriched vapor fraction streams, in which the stripped liquid fraction comprises the condensation stream, in which the remaining part of the initial composite stream which is not subjected to distillation is divided into first and second composite streams, and in which the first and second enriched vapor fraction streams are mixed with the first and second composite streams respectively to produce the rich working fluid fraction and the lean working fluid fraction.

23. A method according to claim 22, in which the compositions of the rich working fluid and lean working fluid fractions are selected so that when heated in the first evaporator stage, the lean working fluid fraction will substantially reach its boiling point, and the rich working fluid fraction will be substantially in the form of a saturated vapor

* * * * *

30

35

40

45



US 2004/0055302 A1

219

(10) United States

(12) Patent Application Publication

(10) Pub No US 2004/0055302 A1

Kulina

(43) Pub Date

Mar 25, 2004

(54) LOW TEMPERATURE GEOTHERMAL SYSTEM

(52) U.S. Cl.

60/649, 60/651, 60/671

(76) Inventor Alexander I Kulina Hillsborough, CA (US)

(57)

ABSTRACT

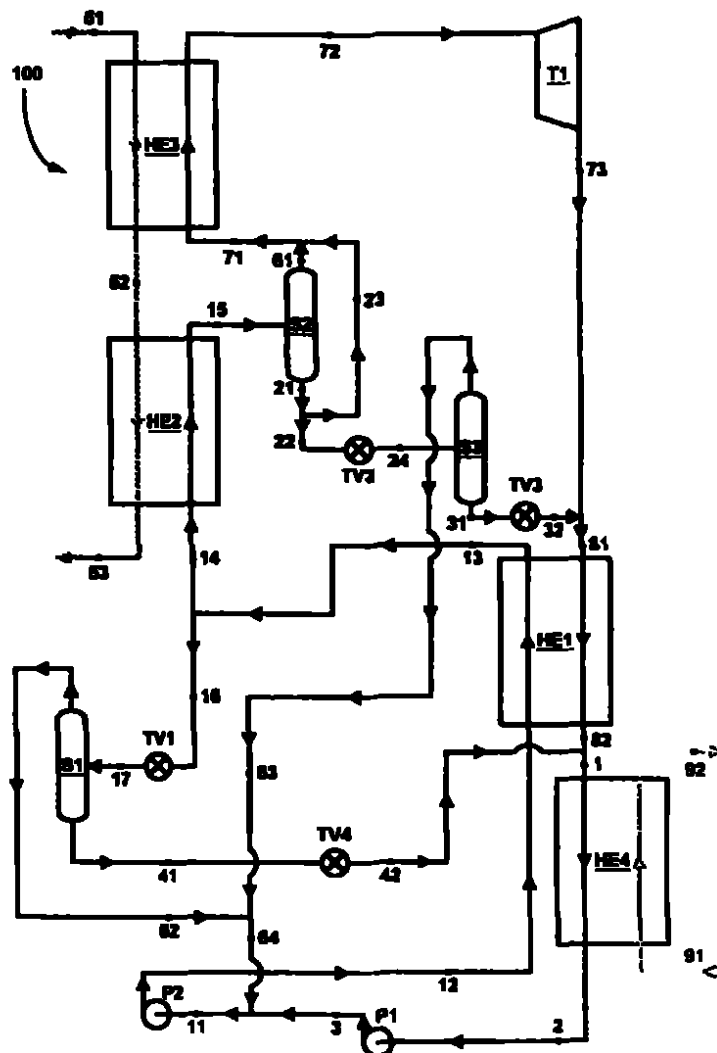
Correspondence Address
ROBERT W STROZIER, PLLC
P.O. BOX 429
BELL LAIRE, TX 77402-0429 (US)

A new thermodynamic cycle is disclosed for converting energy from a low temperature stream from an external source into usable energy using a working fluid comprising of a mixture of a low boiling component and a high boiling component. The cycle is designed to improve the efficiency of the energy extraction process by mixing into an intermediate liquid stream an enriched liquid stream from which the energy from the external source stream is extracted in a vaporization step and converted to energy in an expansion step. The new thermodynamic process and the system for accomplishing it are especially well-suited for streams from low temperature geothermal sources.

(21) Appl No 10/252,744

(22) Filed Sep 23, 2002

Publication Classification

(51) Int. Cl.⁷ F01K 25/06, F01K 25/08, F01K 25/00

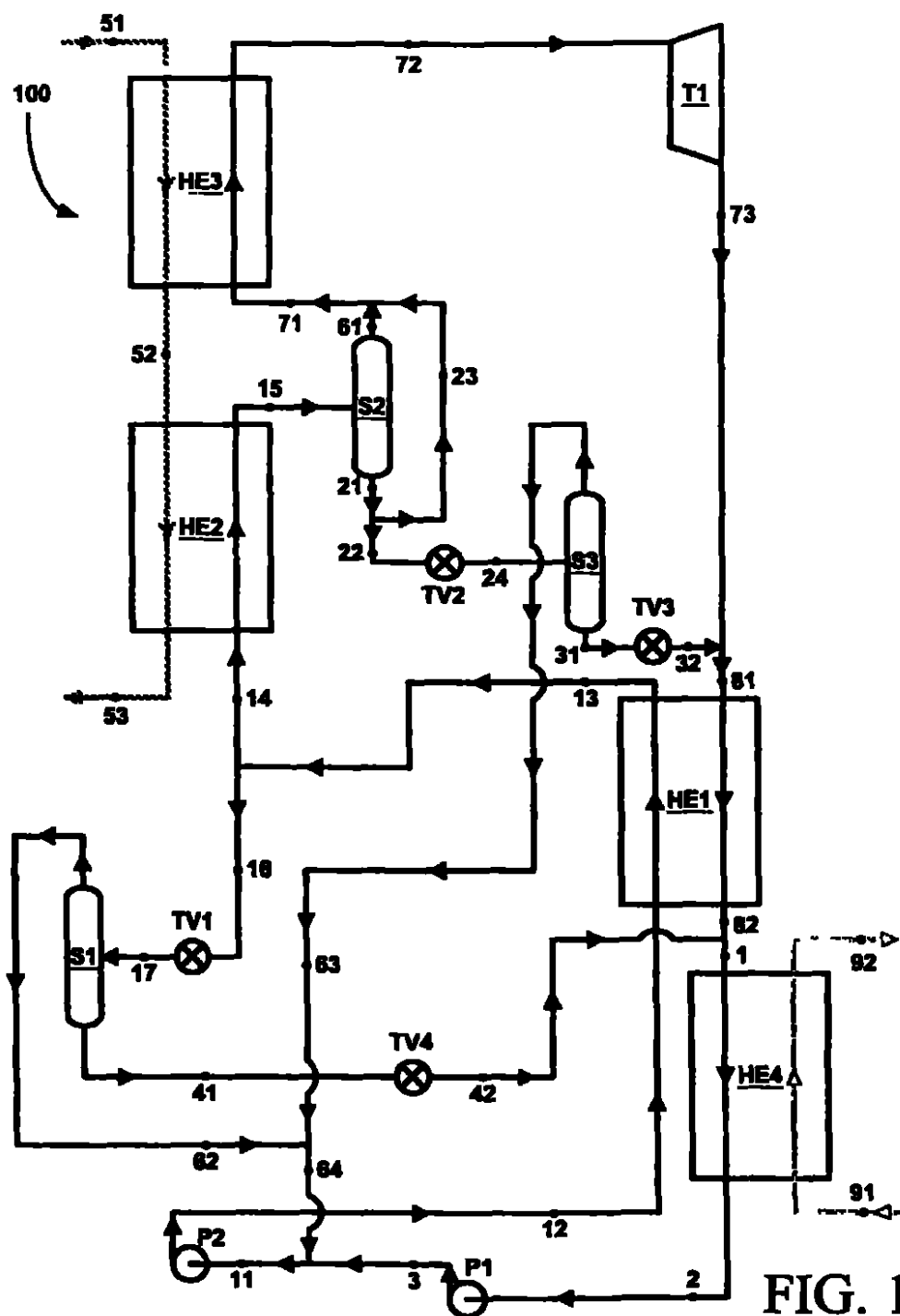


FIG. 1A

221

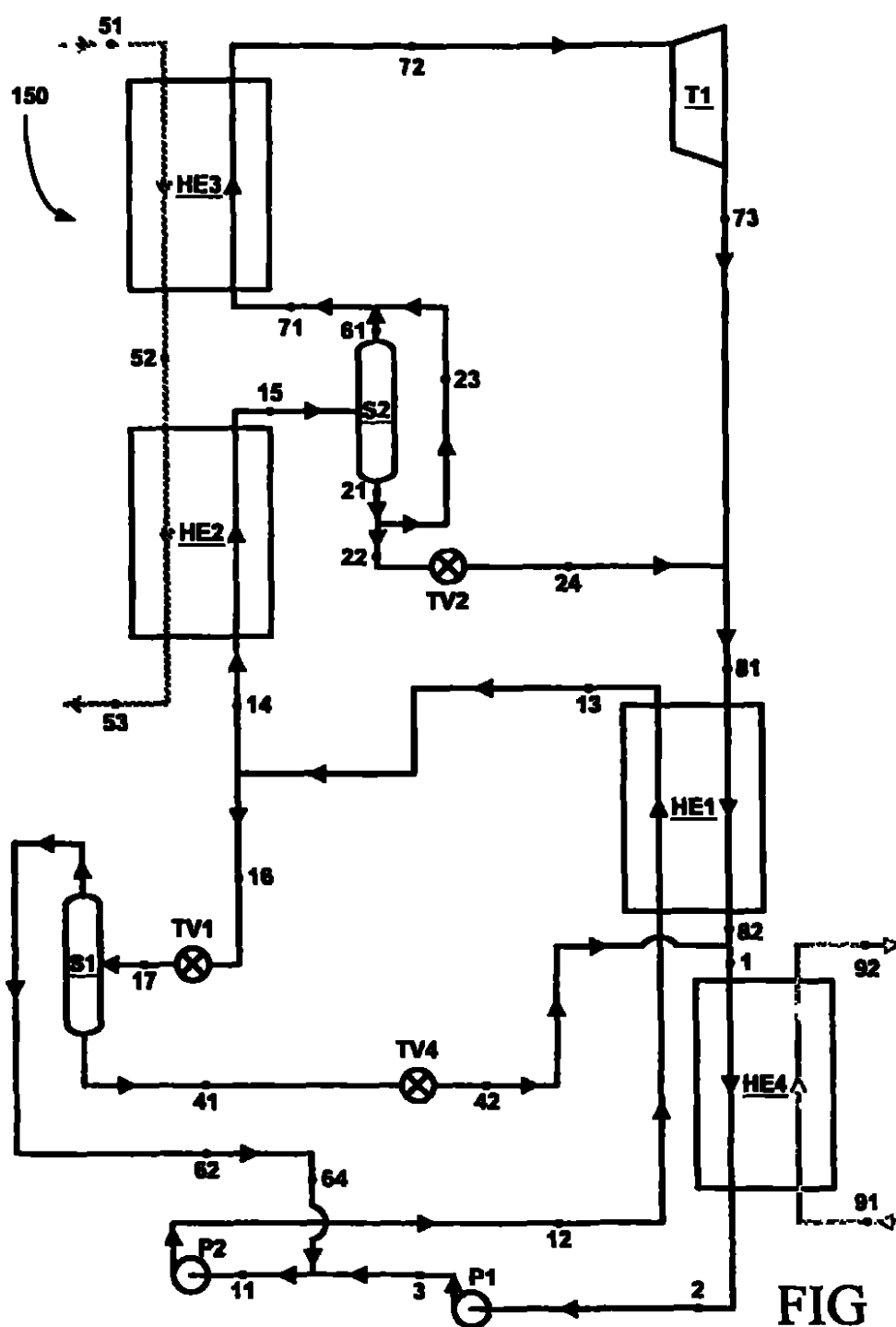


FIG 1B

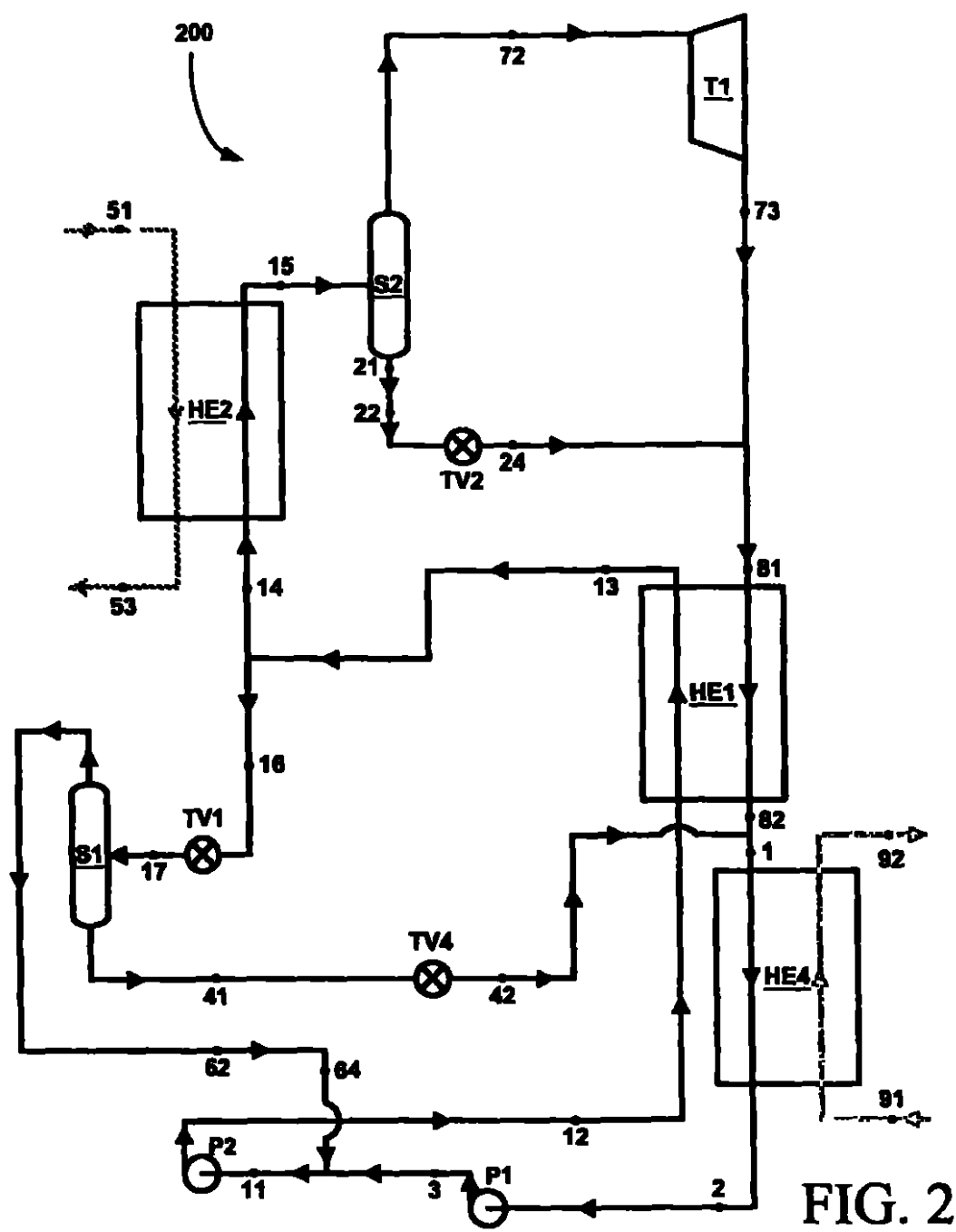


FIG. 2

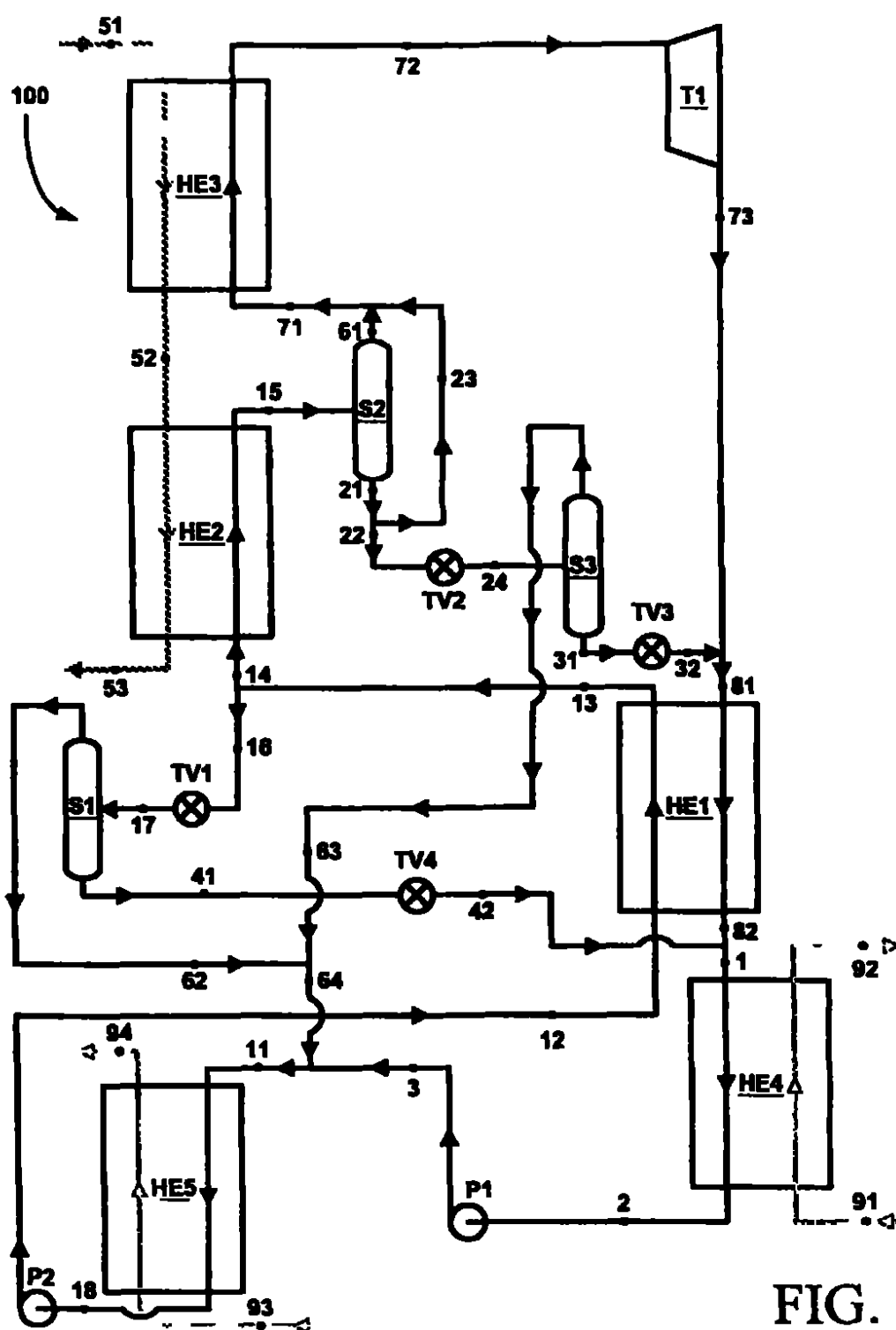


FIG. 3

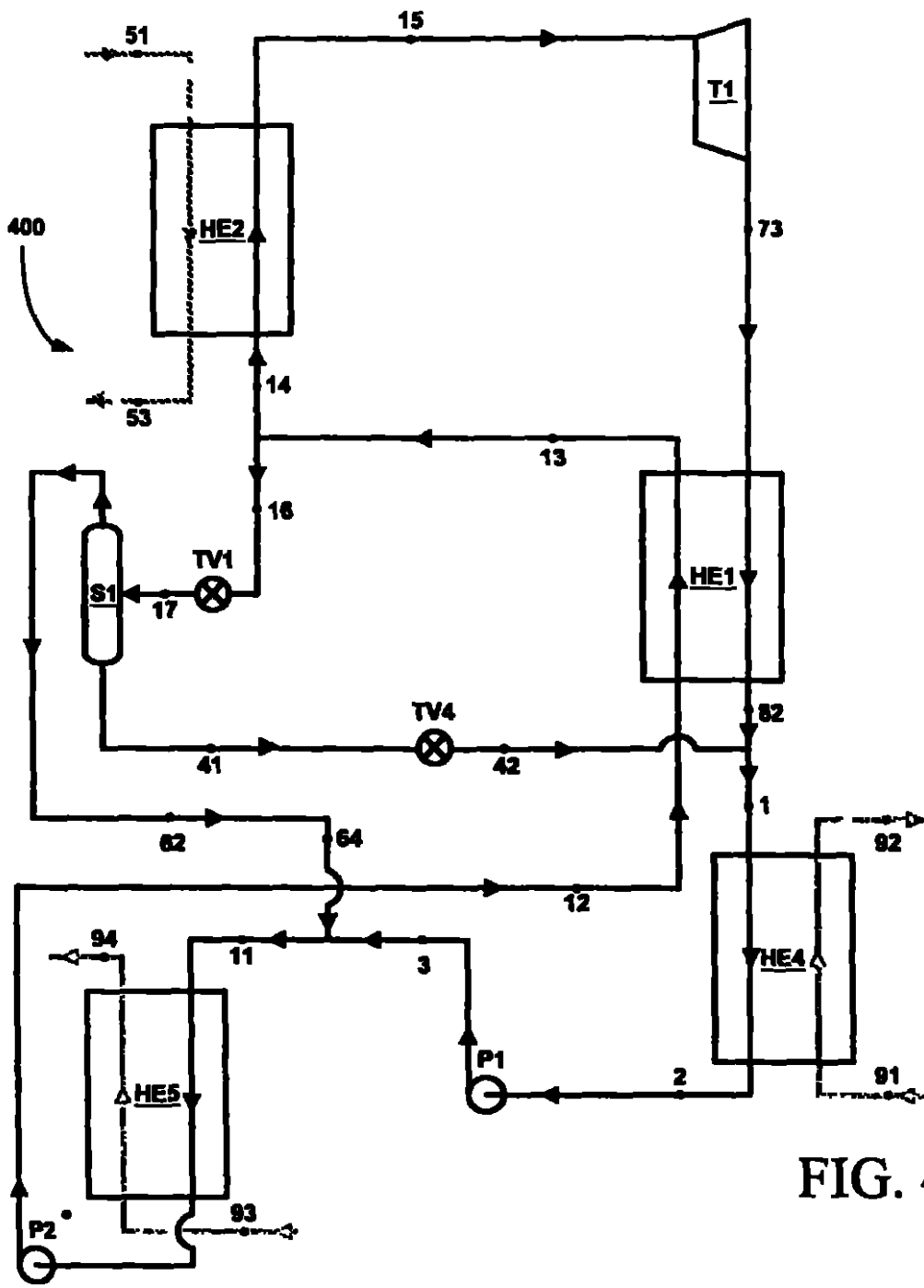


FIG. 4

LOW TEMPERATURE GEOTHERMAL SYSTEM

BACKGROUND OF THE INVENTION

[0001] 1 Field of the Invention

[0002] The present invention relates to a process and system to convert thermal energy from low temperature sources, especially from low temperature geothermal fluids, into mechanical and/or electrical energy.

[0003] More particularly the present invention relates to a process and system to convert thermal energy from moderately low temperature sources, especially from geothermal fluids, into mechanical and electrical energy where a working fluid comprises a mixture of at least two components with the preferred working fluid comprising a water-ammonia mixture. The present invention also relates to a novel thermodynamic cycle or process and a system to implement it.

[0004] 2 Description of the Related Art

[0005] Prior art methods and systems for converting heat into useful energy are well documented in the art. In fact, many such methods and systems have been invented and patented by the inventor. These prior art systems include U.S. Pat. Nos. 4,346,561; 4,489,563; 4,548,043; 4,586,340; 4,604,867; 4,674,285; 4,732,005; 4,763,480; 4,899,545; 4,982,568; 5,029,444; 5,095,708; 5,440,882; 5,450,821; 5,572,871; 5,588,298; 5,603,218; 5,649,426; 5,822,990; 5,950,433 and 5,993,918; Foreign References: 7-9481 JP and Journal References: NEDO Brochure "ECO-Energy City Project" 1994 and NEDO Report published 1996, pp. 4-6, 4-7, 4-43, 4-63, 4-53 incorporated herein by reference.

[0006] Although all of these prior art systems and methods relate to the conversion of thermal energy into other more useful forms of energy from moderately low temperature sources, all suffer from certain inefficiencies. Thus, there is a need in the art for an improved system and method for converting thermal energy from moderately low temperature sources to more useful forms of energy especially for converting geothermal energy from moderately low temperature geothermal streams into more useful forms of energy.

SUMMARY OF THE INVENTION

[0007] The present invention provides a method for implementing a thermodynamic cycle comprising the steps of expanding a gaseous working stream transforming its energy into usable form and producing a spent stream. After expansion and work extraction the spent stream is mixed with at least one lean stream to form a lean spent stream. The lean spent stream is then used to heat a liquid first working stream to form a heated first working stream and a pre-condensed stream which is then condensed to form a liquid stream. The liquid stream is then mixed with an enriched stream to form the liquid first working stream. A portion of this stream is then depressurized to an intermediate pressure and separated into an enriched vapor stream and the lean stream while a second portion of the liquid first working stream is heated to form the gaseous working stream.

[0008] The present invention provides a method for implementing a thermodynamic cycle comprising the steps of expanding a gaseous second working stream transforming

its energy into usable form and producing a low pressure spent stream. After expansion the spent stream is mixed with a first lean stream forming a lean spent stream. Heat is then transferred from this stream to a first working stream to form a heated first working stream. The cooled lean spent stream is then mixed with a second lean stream to form a pre-condensed stream which is then condensed to form a liquid stream. The liquid stream is then mixed with a first enriched vapor stream to form the first working stream. A first portion of the heated first working stream is separated into a second enriched vapor stream and the second lean stream. A second portion of the heated first working stream is then heated with an external heat source fluid stream to form a partially vaporized first working stream. The partially vaporized first working stream is then separated into a fourth enriched stream and a third lean stream. A first portion of the third lean stream is then separated into the first lean stream and a third enriched stream and the third enriched stream is mixed with the second enriched stream to form the first enriched stream. A second portion of the third lean stream is mixed with the fourth enriched stream to form the second working stream which is then fully vaporized to form the gaseous second working stream.

DESCRIPTION OF THE DRAWINGS

[0009] 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.

[0010] FIGS. 1A&B depict a diagram of a preferred embodiment of a system of this invention for converting heat from a geothermal source to a useful form of energy.

[0011] FIG. 2 depicts a diagram of another preferred embodiment of a system of this invention for converting heat from a geothermal source to a useful form of energy.

[0012] FIG. 3 depicts a diagram of another preferred embodiment of a system of this invention for converting heat from a geothermal source to a useful form of energy and

[0013] FIG. 4 depicts a diagram of another preferred embodiment of a system of this invention for converting heat from a geothermal source to a useful form of energy.

DETAILED DESCRIPTION OF THE INVENTION

[0014] The inventors have found that a system utilizing a novel thermodynamical cycle (process) can be designed to increase the work output derived from low temperature heat sources. The system and the process or method use a working fluid comprising a mixture of at least two components. The preferred working fluid for the systems and processes of this invention is a water-ammonia mixture, though other mixtures, such as mixtures of hydrocarbons and/or fluorine can be used with practically the same results. The systems and methods of this invention are more efficient for converting heat from relatively low temperature geothermal sources into a more useful form of energy. The system uses a multi-component basic working fluid to extract energy from one or more (at least one) geothermal source streams in one or more (at least one) heat exchangers or heat exchanger zones. The heat exchanged basic working fluid then transfers its gained thermal energy to one or more (at

least one) turbines and the turbines convert the gained thermal energy into mechanical energy and/or electrical energy. The system also includes pumps to increase the pressure of the basic working fluid at certain points in the system and one or more (at least one) heat exchangers which bring the basic working fluid in heat exchange relationships with one or more (at least one) cool streams. One novel feature of the systems and methods of this invention and one of the features that increases the efficiency of the systems, is the result of absorbing a vapor stream into the condensed liquid working solution stream prior to fully pressurization via pumping. The vapor stream changes the composition of the solution prior to heating and vaporization by the geothermal stream.

[0015] The basic working fluid used in the systems of this invention preferably is a multi-component fluid that comprises a lower boiling point fluid—the low-boiling component—and a higher boiling point fluid—the high-boiling component. Preferred working fluids include an ammonia-water mixture, a mixture of two or more hydrocarbons, a mixture of two or more freon, a mixture of hydrocarbons and freon or the like. In general, the fluid can comprise mixtures of any number of compounds with favorable thermodynamic characteristics and solubility. In a particularly preferred embodiment, the fluid comprises a mixture of water and ammonia.

[0016] Referring now to FIG. 1A, a flow diagram, generally 100, is shown that illustrates a preferred embodiment of a system and method of energy conversion of this invention and will be described in terms of its components and its operation.

[0017] A fully condensed basic solution of working fluid with parameters as at a point 2 enters into a pump P1 where it is pumped to a chosen elevated pressure (hereafter referred to as the “intermediate pressure”), and obtains parameters as at a point 3. The basic working solution at the point 2 is in a state of a saturated liquid and as a result of increasing pressure in the process 2-3 obtains a state of sub-cooled liquid. The stream of sub-cooled liquid, having parameters as at the point 3, is mixed with a stream of vapor having parameters as at a point 64 (see below). This vapor with parameters as at the point 64, has a significantly higher concentration of the low boiling component (e.g., in case of water-ammonia basic working solution the solution would have a higher concentration of ammonia) than the liquid with parameters as at a point 3. As a result of this mixing, the liquid fully absorbs the vapor and obtains parameters as at a point 11. The composition of the solution having parameters as at the point 11 corresponds to a state of saturated liquid, but the composition of the solution is such that a concentration of the low boiling component in the solution at the point 11 is higher than a concentration of the low boiling component in the solution at the points 2 and 3. The solution having that composition at the point 11 will hereafter be referred to as a first working solution.

[0018] The stream of first working solution with parameters as at the point 11 enters a pump P2 where it is pumped to an elevated pressure, hereafter referred to as a high pressure, and obtains parameters as at the point 12. Thereafter the stream of the first working solution passes through a heat exchanger HL1 where it is heated and obtains parameters as at a point 13. In a preferred embodiment of

this system the stream with parameters as at the point 13 corresponds to a state of saturated or slightly sub-cooled liquid. Thereafter the stream with parameters as at the point 13 is divided into two sub-streams, with parameters as at points 14 and 16 respectively.

[0019] The sub-stream with parameters as at the point 16 passes through a throttle valve TV1 where its pressure is reduced to the intermediate pressure (see above) and obtains parameters as at a point 17. As a result of the throttling in the process 16-17 the stream with parameters as at the point 17 corresponds to a state of a two-phase fluid, i.e., a mixture of saturated liquid and saturated vapor. The stream with parameters as at the point 17 is then sent into a separator S1 where liquid is separated from vapor. The vapor leaving the separator S1 with parameters as at a point 62 is then mixed with another stream of vapor having parameters as at a point 63, thus creating a stream of vapor having parameters as at the point 64. This stream of vapor with parameters as at the point 64, is then mixed with liquid stream with parameters as at the point 3 creating a stream, with parameters as at the point 11 (see above).

[0020] The sub-stream of first working solution with parameters as at the point 14, passes through a heat exchanger HL2, where it is heated and partially vaporized leaving the heat exchanger HL2 as a stream with parameters as at the point 15, corresponding to a state of a two-phase fluid. The stream of first working solution, with parameters as at the point 15 then enters into a separator S2, where liquid is separated from vapor. A liquid stream leaving the separator S2 has parameters as at a point 21 while a vapor stream leaving separator S2 has parameters as at a point 61.

[0021] The stream of liquid, with parameters as at the point 21 is then divided into two sub-streams having parameters as at points 22 and 23 respectively. The sub-stream of liquid, with parameters as at the point 22 passes through a throttle valve TV2, where its pressure is reduced to the intermediate pressure and as a result the stream obtains parameters as at a point 24, corresponding to a state of a two-phase fluid. The stream with parameters as at the point 24, is then sent into a separator S3, where it is separated into a stream of saturated vapor having parameters as at the point 63 and a stream of saturated liquid having parameters as at a point 31. The stream of vapor with parameters as at the point 63 is mixed with the stream of vapor with parameters as at the point 62 and forms the stream of vapor with parameters as at the point 64 (see above).

[0022] The sub-stream of liquid with parameters as at the point 23 is mixed with the stream of vapor with parameters as at the point 61 forming a new stream having parameters as at a point 71. The new stream with parameters as at the point 71 is referred to as a second working solution.

[0023] The stream of second working solution with parameters as at the point 71 is sent through a heat exchanger HL3, where it is heated and fully vaporized so that the stream has parameters as at a point 72. A composition of the stream of the second working solution, in the process 71-72 is chosen such that stream having the parameters at the point 72 corresponds to stream having a state of saturated or superheated vapor. The stream of second working solution with parameters as at the point 72 passes

through a turbine 11 where it is expanded producing useful work and leaves turbine 11 as a spent stream having parameters as at a point 73.

[0024] The stream of liquid with parameters as at the point 31 leaving separator 53 (see above) passes through a throttle valve TV3 where its pressure is reduced to a pressure equal to a pressure of the stream at the point 73 and the stream obtains parameters as at a point 32. Then the streams with parameters as at the points 73 and 32 are combined forming a stream of condensing solution having parameters as at a point 81. The stream with parameters as at the point 81 passes through the heat exchanger H1 in counter-flow to the entering stream with parameters as at the point 12 where the stream with parameters as at the point 81 is partially condensed releasing heat and forming a stream with parameters as at a point 82. The heat released in a process 81-82 is utilized to provide heat to the process 12-13 (see above).

[0025] The stream of liquid with parameters as at a point 41 leaving the separator 51 passes through a throttle valve TV4 where its pressure is reduced to a pressure equal to the pressure of the stream with parameters as at the point 82 and the stream obtains parameters as at a point 42. Then, after the streams with parameters as at the points 42 and 82, are combined, forming a stream of basic solution having parameters as at a point 1. The stream with parameters as at the point 1 passes through a condenser i.e., a heat exchanger HE4, where it is cooled and fully condensed forming a stream having parameters as at the point 2. The cooling and condensation of the stream with parameters as at the point 1 to the stream with parameters as at the point 2 in the process 1-2 is provided by a stream of ambient fluid (air or water) which enters the heat exchanger HE4 with parameters as at a point 91 and exits the heat exchanger HE4 with parameters as at a point 92.

[0026] A stream of hot geothermal fluid with initial parameters as at a point 51 passes through a heat exchanger HE3 in counter-flow to the stream having parameters as at the point 71 providing heat for the process 71-72 and the geothermal stream with parameter as at the point 51 forms a geothermal stream having parameters as at a point 52. Thereafter the stream geothermal fluid with parameters as at the point 52, passes through the heat exchanger H12, where it is further cooled, providing heat for the process 14-15. The thermodynamic cycle involving the basic working solution is a closed cycle.

[0027] In a simplified preferred embodiment of the system and process of this invention, generally 150, a separator 53 and a throttle valve TV3 can be excluded as shown in FIG. 1B. In such a case a pressure of the stream of liquid with parameters as at the point 22 is reduced in the throttle valve TV2 in one step to a stream having parameters at a point 24, where a pressure of the stream is equal to a pressure of the turbine exhaust stream with parameters as at the point 73. Once the pressure of the stream with parameters as at the point 22 has been reduced, forming the stream with parameters as at the point 24, the stream with parameters at the point 24 is mixed with the turbine exhaust stream with parameters as at the point 73 forming a condensing stream with parameters as at the point 81. As a result the stream of vapor with parameters as at the point 63 of the system 100 of FIG. 1A does not exist and the

absence of the stream with parameters as at the point 63 of the system 100, reduces a rate of enrichment of the basic solution in the process of mixing the stream with parameters as at the point 63 of the system 100 with the stream having parameters as at the point 64. Additionally the basic solution will become slightly richer and therefore the pressure after the turbine must be slightly increased. As a result such a simplified version will have slightly lower overall efficiency.

[0028] Referring now to FIG. 2, a further simplified preferred embodiment of this invention generally 200, is shown. The system 200 not only excludes the separator 53 and the throttle valve TV3 of the system 100 (the system 200) also excludes the heat exchanger H1C3. Thus the vapor stream with parameters as at the point 72, is forwarded directly to the turbine 11. In such a case, the separator 52 is preferred a very high quality and very efficient separator or separating apparatus to prevent or minimize droplets of liquid in the stream with parameters as at the point 72 as it enters the turbine T1.

[0029] Referring to FIG. 3, another preferred embodiment of the system and process of this invention generally 300 is shown which has enhanced efficiency through the addition of a fifth heat exchanger. When liquid streams, having parameters as at points 17 and 22 respectively are throttled in the throttling valves TV1 and TV2, the quantities of vapor produced in these processes will increase as the pressure after the throttle valves is decreased. Therefore flow rates of the streams having parameters as at the point 62 and 63 will be increased, which in turn increases a flow rate of the stream having parameters as at the point 64. But this will in turn require lowering a pressure of the liquid stream having parameters as at the point 3 leaving the pump P1 and therefore reduce an ability of the stream having parameters as at the point 3 to absorb the vapor stream having the parameters as at the point 64. When the liquid stream having parameters as at the point 3 and the vapor stream having parameters as at the point 64 are mixed it may be necessary to install an additional condenser or heat exchanger H1C5 into which the stream having parameters as at the point 11 is sent. As a result, the fully condensed stream having parameters as at a point 18 is produced. Thereafter the stream having parameters as at the point 18 is sent into the pump P2. In this preferred embodiment the streams of liquid having the parameters as at the point 32 and 42 become leaner (i.e., contain a smaller concentration of the low boiling component e.g. a smaller concentration of ammonia in a water-ammonia mixture) and a composition of the streams having parameters as at the points 1, 2 and 73 also correspondingly become leaner which results in a lowering of a pressure of the streams having parameters 1, 2 and 73 increasing the work output of the turbine 11.

[0030] The introduction of the additional condenser or heat exchanger H1C5 does not increase the total quantity of heat which is rejected to the ambient surroundings. To the contrary the amount of heat rejected to the ambient is decreased as a result of the increased output of the turbine 11. In general the embodiment 300 of FIG. 3 is more efficient than the embodiment 100 of FIG. 1.

[0031] The embodiment 300 of FIG. 3 provides for a significantly higher degree of enrichment of the basic working solution in the process of mixing it with a stream of vapor having parameters as at the point 64. Thus, in turn

allows for a significant simplification of this embodiment. The first working solution may be enriched to such an extent that it can be used as a second working solution thus excluding the need for two separate working solutions. Such a simplified version of this embodiment, generally 400, is shown in FIG. 4. The system 400 differs from the system 300 of FIG. 3 as set forth below.

[0032] The working solution from the condenser or heat exchanger H13, after being heated by a stream of turbine exhaust in the heat exchanger H11, is divided into two sub-streams having parameters as at the point 14 and 16, respectively. Thereafter, the sub-stream having parameters as at the point 14 is sent into the heat exchanger H12, where it is vaporized in counter-flow relationship to the geothermal stream having parameters as at the point 51, forming a stream having parameters as at the point 15. A composition and pressure of the working solution must be chosen such that the stream having parameters as at the point 15 corresponds to a stream having a state of saturated or superheated vapor. Thereafter, the stream of working solution having parameters as at the point 15 passes through the turbine T1 where it expands, producing useful work. The stream exits the turbine T1 having parameters as at the point 73, is sent through the heat exchanger H11, where it is partially condensed, providing heat for heating the stream having parameters as at the point 12 in the heating process 12-13. After leaving the heat exchanger H11, the stream of working solution having the parameters as at the point 73 forms a stream having parameters as at the point 82. The stream having the parameters as at the point 82 is then combined with the lean stream having parameters as at the point 42 as previously described, forming a stream of basic working solution having the parameters as at the point 1. In all other particulars, the embodiment 400 of FIG. 4 operates in the same manner as the embodiment 300 of FIG. 3.

[0033] As one can see, the variant of the proposed system presented in FIG. 4 is significantly simpler than the variant presented in FIG. 3. As compared to the system 300 presented in FIG. 3, the system 400 presented in FIG. 4 includes four heat exchangers instead of five heat exchangers, two throttled valves instead of four throttled valves and one separator instead of three separators. However, such a simplification reduces the flexibility and to some degree the efficiency of the system 400 of FIG. 4 compared to the system 300 of FIG. 3.

[0034] The choice amongst the four presented preferred embodiments of this invention depends upon the initial and final temperature of the utilized geothermal fluid stream or other heat carrying fluid stream upon the ambient temperature, and upon economic conditions in which the system has to operate. One of ordinary skill in the art can choose the particular embodiment of this invention that best suits the conditions and constraints of the environment in which the system is to be installed and operated.

[0035] In prior art (see e.g., U.S. Pat. No. 5,029,444), the basic solution after passing through the condenser is pumped in one step to a high pressure, and is then sent into two heat exchangers, one of which is heated by turbine exhaust and another by liquid returning from a separator which corresponds to liquid stream having parameters as at the point 22 of the systems of this invention. In these two heat exchangers, the basic solution is heated and then

partially vaporized. But the quantity of heat required to raise the temperature by any given temperature difference in a process of vaporization is several times greater than the quantity of heat required to pre-heat a liquid by the same temperature difference. As a result, in these heat exchangers of the prior art, the heat from the returning stream of vapor and liquid is balanced only by the process of vaporization and therefore is poorly utilized, i.e., excessive heat in the process of pre-heating is utilized only partially.

[0036] Moreover, if the initial temperature of the geothermal fluid is low, then a temperature of vapor exiting the turbine can be lower than an initial temperature of boiling of the basic solution. In this case, the pressure at which boiling occurs must be lowered so as to provide for the initial boiling of the basic solution by heat exchange with the stream of turbine exhaust. Alternately, because a temperature of the vapor exiting the turbine must be higher than the initial temperature of boiling of the basic solution, a pressure of the vapor exiting the turbine has to be increased to provide, on one hand, a higher temperature of the vapor exiting the turbine, and on the other hand, a richer basic solution so that the initial temperature of boiling for the basic solution becomes lower. These results, when compared to the systems of this invention, in a lowering of the efficiency of the system in the prior art in cases where the initial temperature of the geothermal fluid or other heat source is low.

[0037] In the prior art, in systems designed to utilize low-temperature heat sources (e.g., U.S. Pat. No. 5,953,918), the heat of condensation of the turbine exhaust stream is utilized only for preheating an upcoming high pressure stream of working solution. But for the same reason as described above, this heat is poorly utilized as well.

[0038] In contrast, in all of the embodiments of the system of this invention, the basic solution is enriched by absorbing a stream of vapor having parameters as at the point 64, thus forming the first working solution. In the embodiments 300 and 400 of FIGS. 3 and 4, respectively, this absorption is enhanced by using an additional condenser or heat exchanger H15. In the embodiments 100, 150 and 200 of FIGS. 1A, 1B and 2, the turbine exhaust is mixed with liquid from the separator S3. In the embodiment 200 of FIG. 2, the turbine exhaust is mixed with liquid from the separator S2. In all four embodiments, the heat released in the process of the condensation of the stream of turbine exhaust (whether or not the stream is mixed with additional liquid) is used only for pre-heating of the first working solution up to the boiling temperature. Because the working solution is enriched by a low-boiling component in comparison to the basic working solution, it allows a higher boiling pressure of the first and where applicable of the second working solutions. All heat from the condensation of turbine exhaust is effectively used by being sent into the heat exchanger H11, a stream of the first working solution with a weight flow rate significantly higher than the flow rate of the stream of this same solution which is sent into the boiler (Heat Exchanger H12). Excessive quantity of the first working solution is used to produce a stream of vapor with parameters as at the point 62, which is then utilized to enrich the basic solution by adding this vapor stream to it, and forming a richer stream of the first working solution.

[0039] To sum up, it is clear that the systems of this invention can provide for a higher pressure of vapor entering

229

the turbine and a lower pressure of vapor exiting the turbine, thus providing a higher efficiency to the system as a whole. A preliminary assessment shows that the proposed system can at the same border conditions, provide for an increase in power output of between 10 and 20%. It should be recognized that the working solution is in a closed thermodynamic cycle and the temperatures and pressures of the streams are self adjusting so that the system operates at maximum efficiency with little or no outside monitoring or control.

[0040] All references cited herein are incorporated by reference. While this invention has been described fully and completely it should be understood that within the scope of the appended claims, the invention may be practiced otherwise than as specifically described. Although the invention has been described 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 method for implementing a thermodynamic cycle comprising the steps of

expanding a gaseous working stream transforming its energy into usable form and producing a spent stream

mixing the spent stream with at least one lean stream to form a lean spent stream

heating a liquid first working stream with the lean spent stream to form a heated first working stream and a pre-condensed stream,

condensing the pre-condensed stream producing a liquid stream,

mixing the liquid stream with an enriched stream to form the liquid first working stream

forming, from a depressurized first portion of the liquid first working stream, an enriched vapor stream and the lean stream and

heating a second portion of the liquid first working stream to form the gaseous working stream

2 A method for implementing a thermodynamic cycle comprising the steps of

expanding a gaseous second working stream transforming its energy into usable form and producing a low pressure spent stream,

mixing the spent stream with a first lean stream forming a second spent stream

heating a first working stream with the second spent stream to form a third spent stream and a heated first working stream

mixing the third spent stream with a second lean stream to form a pre-condensed stream

condensing the pre-condensed stream to form a liquid stream

mixing the liquid stream with a first enriched vapor stream to form the first working stream

forming, from a first portion of the heated first working stream a second enriched vapor stream and the second lean stream

heating a second portion of the heated first working stream with an external heat source fluid stream to form a partially vaporized first working stream

forming, from the partially vaporized first working stream a third enriched stream and a third lean stream

forming, from a first portion of the third lean stream the first lean stream and a third enriched stream

mixing the third enriched stream with the second enriched stream to form the first enriched stream

mixing a second portion of the third lean stream with the second enriched stream to form the second working stream and

fully vaporizing the second working stream with heat from the external heat source fluid stream to form the gaseous second working stream

3 The method of claim 2 further comprising the step of pressurizing the liquid stream to an intermediate pressure, pressurizing the first working stream to a high pressure, depressurizing the first portion of the heated first working stream to the intermediate pressure

depressurizing the second lean stream to the intermediate pressure,

depressurizing the third lean stream to the intermediate pressure and

depressurizing the first lean stream to the low pressure.

4 A method for implementing a thermodynamic cycle comprising the steps of

expanding a gaseous second working stream transforming its energy into usable form and producing a low pressure spent stream

mixing the spent stream with a first lean stream forming a second spent stream

heating a first working stream with the second spent stream to form a third spent stream and a heated first working stream

mixing the third spent stream with a second lean stream to form a pre-condensed stream

condensing the pre-condensed stream to form a liquid stream

mixing the liquid stream with a first enriched vapor stream to form the first working stream

forming, from a first portion of the heated first working stream a second enriched vapor stream and the second lean stream

heating a second portion of the heated first working stream with an external heat source fluid stream to form a partially vaporized first working stream

forming, from the partially vaporized first working stream a third enriched stream and the first lean stream at the intermediate pressure.

230

mixing a second portion of the third lean stream with the second enriched stream to form the second working stream and

fully vaporizing the second working stream with heat from the external heat source fluid stream to form the gaseous second working stream

5 The method of claim 4, further comprising the step of pressurizing the liquid stream to an intermediate pressure, pressurizing the first working stream to a high pressure, depressurizing the first portion of the heated first working stream to the intermediate pressure,

depressurizing the second lean stream to the intermediate pressure, and

depressurizing the first lean stream to the low pressure.

6 A method for implementing a thermodynamic cycle, comprising the steps of

expanding a gaseous second working stream transforming its energy into usable form and producing a low pressure spent stream

mixing the spent stream with a first lean stream forming a second spent stream

heating a first working stream with the second spent stream to form a third spent stream and a heated first working stream,

mixing the third spent stream with a second lean stream to form a pre-condensed stream

condensing the pre-condensed stream to form a liquid stream,

mixing the liquid stream with a first enriched vapor stream to form the first working stream

forming, from a first portion of the heated first working stream, a second enriched vapor stream and the second lean stream

heating a second portion of the heated first working stream with an external heat source fluid stream to form a partially vaporized first working stream and

forming, from the partially vaporized first working stream, the gaseous second working stream and the first lean stream

7 The method of claim 2, further comprising the step of pressurizing the liquid stream to an intermediate pressure, pressurizing the first working stream to a high pressure, depressurizing the first portion of the heated first working stream to the intermediate pressure,

depressurizing the second lean stream to the intermediate pressure, and

depressurizing the first lean stream to the low pressure.

8 A method for implementing a thermodynamic cycle, comprising the steps of

expanding a gaseous second working stream transforming its energy into usable form and producing a low pressure spent stream

mixing the spent stream with a first lean stream forming a second spent stream,

heating a fully condensed first working stream with the second spent stream to form a third spent stream and a heated first working stream

mixing the third spent stream with a second lean stream to form a pre-condensed stream

condensing the pre-condensed stream to form a liquid stream

mixing the liquid stream with a first enriched vapor stream to form a first working stream

condensing the first working stream to form the fully condensed first working stream

forming, from a first portion of the heated first working stream, a second enriched vapor stream and the second lean stream

heating a second portion of the heated first working stream with an external heat source fluid stream to form a partially vaporized first working stream

forming, from the partially vaporized first working stream, a third enriched stream and a third lean stream

forming, from a first portion of the third lean stream, the first lean stream and a third enriched stream

mixing the third enriched stream with the second enriched stream to form the first enriched stream

mixing a second portion of the third lean stream with the second enriched stream to form the second working stream

fully vaporizing the second working stream with heat from the external heat source fluid stream to form the gaseous second working stream

9 The method of claim 2, further comprising the step of pressurizing the liquid stream to an intermediate pressure, pressurizing the first working stream to a high pressure, depressurizing the first portion of the heated first working stream to the intermediate pressure,

depressurizing the second lean stream to the intermediate pressure, and

depressurizing the third lean stream to the intermediate pressure, and

depressurizing the first lean stream to the low pressure.

10 A method for implementing a thermodynamic cycle, comprising the steps of

expanding a gaseous working stream transforming its energy into usable form and producing a low pressure spent stream

heating a fully condensed working stream with the spent stream to form a second spent stream and a heated working stream

mixing the second spent stream with a lean stream to form a pre-condensed stream

condensing the pre-condensed stream to form a liquid stream

231

mixing the liquid stream with an enriched vapor stream to form an enriched liquid stream

condensing the enriched liquid stream to form the fully condensed working stream

forming, from a first portion of the heated working stream, the enriched vapor stream and the lean stream and

fully vaporizing a second portion of the heated working stream with an external heat source fluid stream to form the gaseous working stream

11 The method of claim 2 further comprising the step of pressurizing the liquid stream to an intermediate pressure

pressurizing the enriched liquid stream to a high pressure

depressurizing the first portion of the heated working stream to the intermediate pressure and

depressurizing the lean stream to the intermediate pressure

12 An apparatus for implementing a thermodynamic cycle comprising

means for expanding a gaseous second working stream transferring its energy into usable form and producing a low pressure spent stream

a first stream mixer for mixing the low pressure spent stream with a first lean stream forming a lean spent stream

a first heat exchanger for heating a high pressure liquid first working stream with heat transferred from the lean spent stream to form a heated liquid first working stream

a second stream mixer for mixing the lean spent stream with a second lean stream to form a pre-condensed stream

a condenser for condensing the pre-condensed stream producing a liquid stream

a first pump for pumping the liquid stream to an intermediate pressure

a third stream mixer for mixing the intermediate pressure liquid stream with a first enriched vapor stream forming the liquid first working stream

a second pump for pumping the liquid first working stream to a high pressure

a first stream splitter for forming to sub-streams of the high pressure liquid first working stream

a first throttling valve for reducing the pressure of one of the sub-streams of the high pressure liquid first working stream to the intermediate pressure

a first gravity separator for forming a second enriched vapor stream and the second lean stream at the intermediate pressure from the intermediate pressure sub-stream

a fourth stream mixer for mixing the second enriched vapor stream with a third enriched vapor stream to form the first enriched vapor stream

a second throttling valve for reducing the pressure of the second lean stream at the intermediate pressure to the low pressure of the lean spent stream

a second heat exchanger for heating the other sub-stream of the high pressure liquid first working stream with heat transferred from a low-temperature fluid stream from an external heat source to produce a partially vaporized high pressure first working stream

a second gravity separator for forming from a fourth enriched vapor stream and a third lean stream from the partially vaporized high pressure first working stream

a second stream splitter for forming to sub-streams of the third lean stream

a third throttling valve for reducing the pressure of one of the sub-streams of the third lean stream to the intermediate pressure

a third gravity separator for forming the third enriched vapor stream and the first lean stream at the intermediate pressure from the intermediate pressure third lean stream

a fourth throttling valve for reducing the pressure of the intermediate pressure first lean stream to the low pressure of the spent stream

a fifth stream mixer for mixing the fourth enriched vapor stream with the other sub-stream of the third lean stream to form a second working stream and

a third heat exchanger for fully vaporizing the second working stream to form the gaseous second working stream

13 An apparatus for implementing a thermodynamic cycle comprising

means for expanding a gaseous second working stream transferring its energy into usable form and producing a low pressure spent stream

a first stream mixer for mixing the low pressure spent stream with a first lean stream forming a lean spent stream

a first heat exchanger for heating a high pressure liquid first working stream with heat transferred from the lean spent stream to form a heated liquid first working stream

a second stream mixer for mixing the lean spent stream with a second lean stream to form a pre-condensed stream

a condenser for condensing the pre-condensed stream producing a liquid stream

a first pump for pumping the liquid stream to an intermediate pressure;

a third stream mixer for mixing the intermediate pressure liquid stream with a first enriched vapor stream forming the liquid first working stream

a second pump for pumping the liquid first working stream to a high pressure

a first stream splitter for forming to sub-streams of the high pressure liquid first working stream

- a first throttle valve for reducing the pressure of one of the sub-streams of the high pressure liquid first working stream to the intermediate pressure;
 - a first gravity separator for forming the first enriched vapor stream and the second lean stream at the intermediate pressure from the intermediate pressure sub stream;
 - a second throttle valve for reducing the pressure of the second lean stream at the intermediate pressure to the low pressure of the lean spent stream;
 - a second heat exchanger for heating the other sub-stream of the high pressure liquid first working stream with heat transferred from a low-temperature fluid stream from an external heat source to produce a partially vaporized high pressure first working stream;
 - a second gravity separator for forming from a second enriched vapor stream and the first lean stream at the high pressure from the partially vaporized high pressure first working stream;
 - a second stream splitter for forming to sub-streams of the high pressure first lean stream;
 - a third throttle valve for reducing the pressure of one of the sub-streams of the high pressure first lean stream to the low pressure;
 - a fourth stream mixer for mixing the second enriched vapor stream with the other sub-stream of the high pressure first lean stream to form a second working stream; and
 - a third heat exchanger for fully vaporizing the second working stream to form the gaseous second working stream.
- 14 An apparatus for implementing a thermodynamic cycle comprising
- means for expanding a gaseous second working stream, transferring its energy into usable form and producing a low pressure spent stream;
 - a first stream mixer for mixing the low pressure spent stream with a first lean stream forming a lean spent stream;
 - a first heat exchanger for heating a high pressure liquid first working stream with heat transferred from the lean spent stream to form a heated liquid first working stream;
 - a second stream mixer for mixing the lean spent stream with a second lean stream to form a pre-condensed stream;
 - a first condenser for condensing the pre-condensed stream producing a liquid stream;
 - a first pump for pumping the liquid stream to an intermediate pressure;
 - a third stream mixer for mixing the intermediate pressure liquid stream with a first enriched vapor stream forming an enriched mixed stream;
 - a second condenser for condensing the enriched mixed stream forming the liquid first working stream;
 - a second pump for pumping the liquid first working stream to a high pressure;
 - a first stream splitter for forming to sub-streams of the high pressure liquid first working stream;
 - a first throttle valve for reducing the pressure of one of the sub-streams of the high pressure liquid first working stream to the intermediate pressure;
- 15 An apparatus for implementing a thermodynamic cycle comprising
- means for expanding a gaseous second working stream transferring its energy into usable form and producing a low pressure spent stream;
 - a first stream mixer for mixing the low pressure spent stream with a first lean stream forming a lean spent stream;
 - a first heat exchanger for heating a high pressure liquid first working stream with heat transferred from the lean spent stream to form a heated liquid first working stream;
 - a second stream mixer for mixing the lean spent stream with a second lean stream to form a pre-condensed stream;
 - a first condenser for condensing the pre-condensed stream producing a liquid stream;
 - a first pump for pumping the liquid stream to an intermediate pressure;
 - a third stream mixer for mixing the intermediate pressure liquid stream with a first enriched vapor stream forming an enriched mixed stream;
 - a second condenser for condensing the enriched mixed stream forming the liquid first working stream;
 - a second pump for pumping the liquid first working stream to a high pressure;
 - a first stream splitter for forming to sub-streams of the high pressure liquid first working stream;
 - a first throttle valve for reducing the pressure of one of the sub-streams of the high pressure liquid first working stream to the intermediate pressure;

- a first gravity separator for forming a second enriched vapor stream and the second lean stream at the intermediate pressure from the intermediate pressure rich stream
- a fourth stream mixer for mixing the second enriched vapor stream with a third enriched vapor stream to form the first enriched vapor stream
- a second throttle valve for reducing the pressure of the second lean stream at the intermediate pressure to the low pressure of the lean spent stream
- a second heat exchanger for heating the other sub-stream of the high pressure liquid first working stream with heat transferred from a low temperature fluid stream from an external heat source to produce a partially vaporized high pressure first working stream
- a second gravity separator for forming, from a fourth enriched vapor stream and a third lean stream from the partially vaporized high pressure first working stream
- a second stream splitter for forming to sub-streams of the third lean stream
- a third throttle valve for reducing the pressure of one of the sub-streams of the third lean stream to the intermediate pressure
- a third gravity separator for forming the third enriched vapor stream and the first lean stream at the intermediate pressure from the intermediate pressure third lean stream,
- a fourth throttle valve for reducing the pressure of the intermediate pressure first lean stream to the low pressure of the spent stream,
- a fifth stream mixer for mixing the fourth enriched vapor stream with the other sub-stream of the third lean stream to form a second working stream and
- a third heat exchanger for fully vaporizing the second working stream to form the gaseous second working stream
- 16. An apparatus for implementing a thermodynamic cycle comprising:
 - means for expanding a gaseous working stream transferring its energy into usable form and producing a low pressure spent stream
 - a first heat exchanger for heating a high pressure liquid working stream with heat transferred from the spent stream to form a heated high pressure liquid working stream
 - a first stream mixer for mixing the spent stream with a lean stream to form a pre-condensed stream
 - a first condenser for condensing the pre-condensed stream producing a liquid stream
 - a first pump for pumping the liquid stream to an intermediate pressure
 - a second stream mixer for mixing the intermediate pressure liquid stream with an enriched vapor stream forming an enriched mixed stream
 - a second condenser for condensing the enriched mixed stream forming the liquid first working stream
 - a second pump for pumping the liquid first working stream to a high pressure forming the high pressure liquid working stream
 - a first stream splitter for forming to sub-streams of the high pressure liquid working stream
 - a first throttle valve for reducing the pressure of one of the sub-streams of the high pressure liquid working stream to the intermediate pressure
 - a first gravity separator for forming the enriched vapor stream and the lean stream at the intermediate pressure from the intermediate pressure sub-stream
 - a second throttle valve for reducing the pressure of the lean stream at the intermediate pressure to the low pressure of the spent stream and
 - a second heat exchanger for heating the other sub-stream of the high pressure liquid working stream with heat transferred from a low temperature fluid stream from an external heat source to produce the gaseous working stream

* * * * *



US 2004/0050048 A1

239

(19) United States

(12) Patent Application Publication
Kalina

(10) Pub No US 2004/0050048 A1

(43) Pub Date Mar 18, 2004

(54) CATHETERIAL SYSTEM

(52) U.S. Cl. -

60/641,2 (60/649 (60/651

(60/671

(76) Inventor Alexander I. Kalina Hillsborough, CA
(US)Correspondence Address:
ROBERT W. STROZIER, P.L.L.C.
PO BOX 429
BRIARCLIFF, TX 77402-0429 (US)

(57)

ABSTRACT

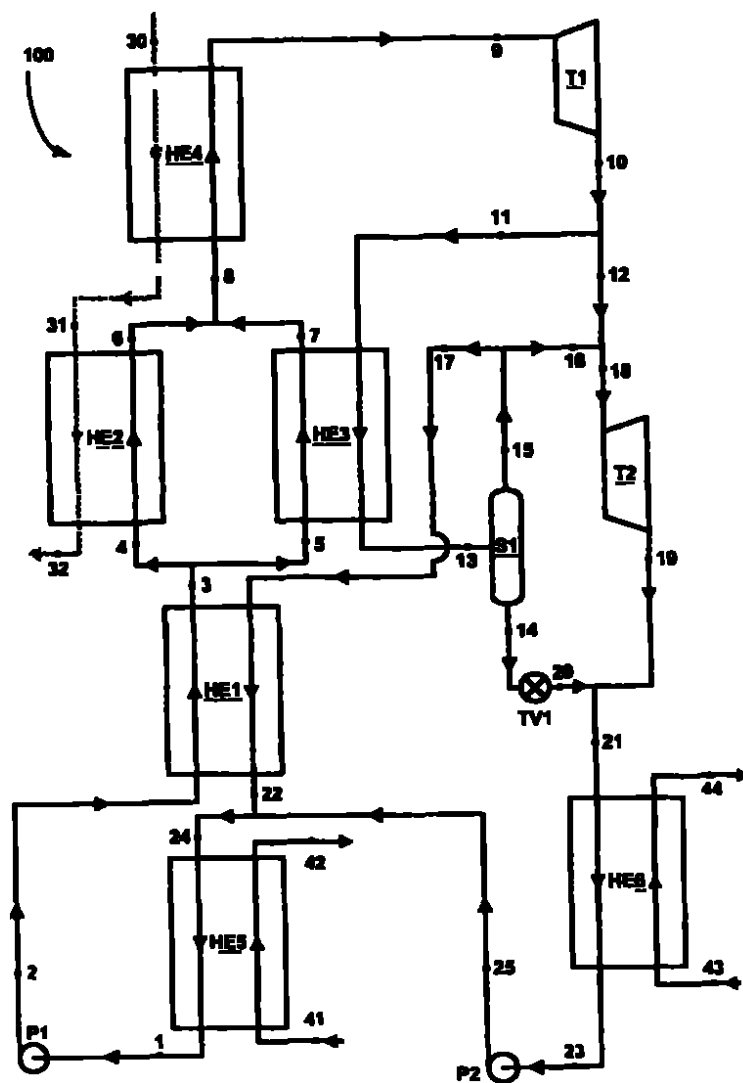
(21) Appl. No. 10/242,301

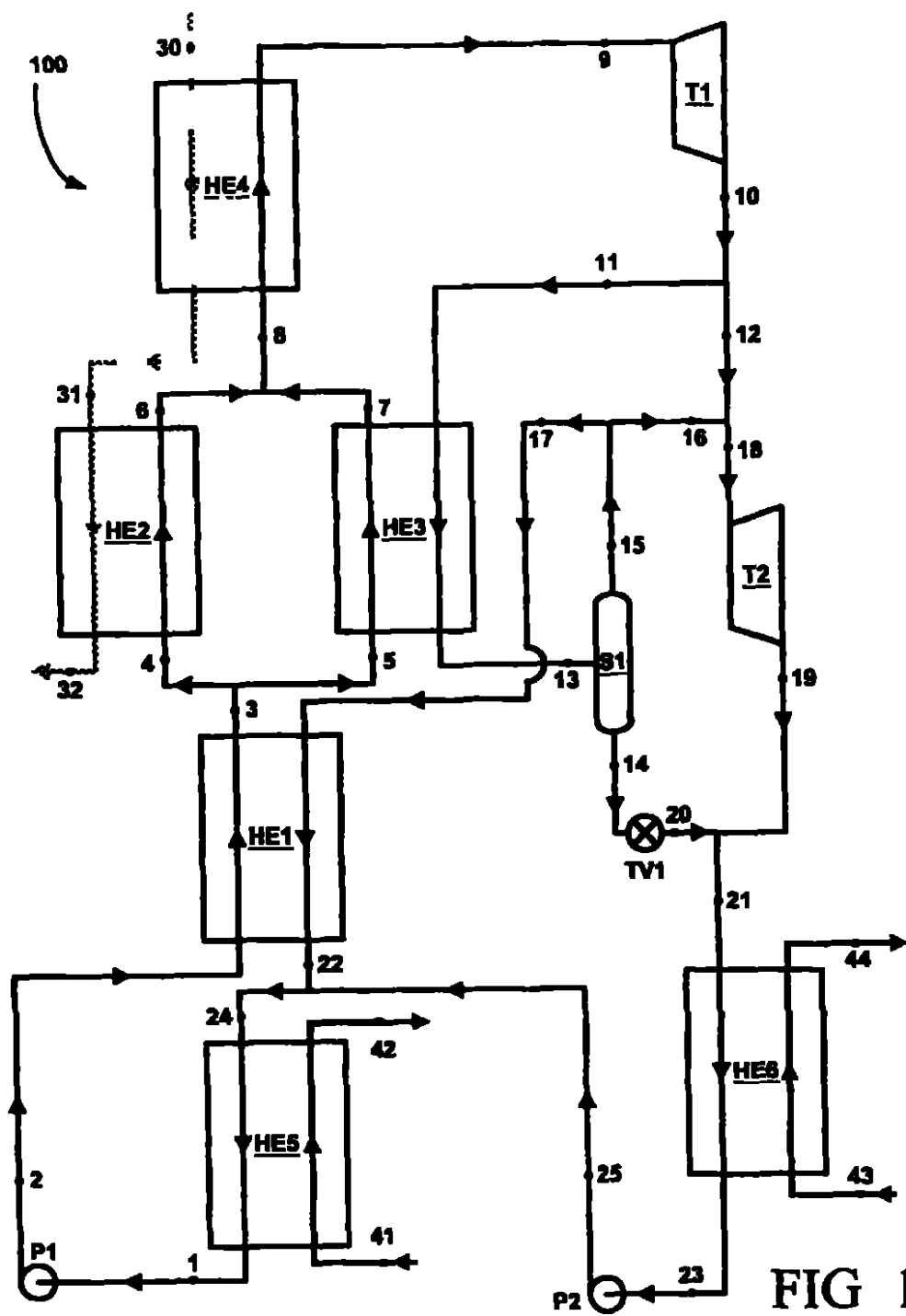
(22) Filed Sep 12, 2002

Publication Classification

(51) Int. Cl.⁷ - - - F03C 7/00 F01K 25/06
F01K 25/08 F01K 25/00

A new system and method for extracting useful work from geothermal streams is disclosed. The systems and methods of this invention can achieve an estimated 20 to 30% improvement in output efficiency. The increased efficiency is derived from a secondary energy conversion step involving a low pressure vapor stream of variable composition and a low pressure turbine which expands the vapor stream to produce the improved efficiency.





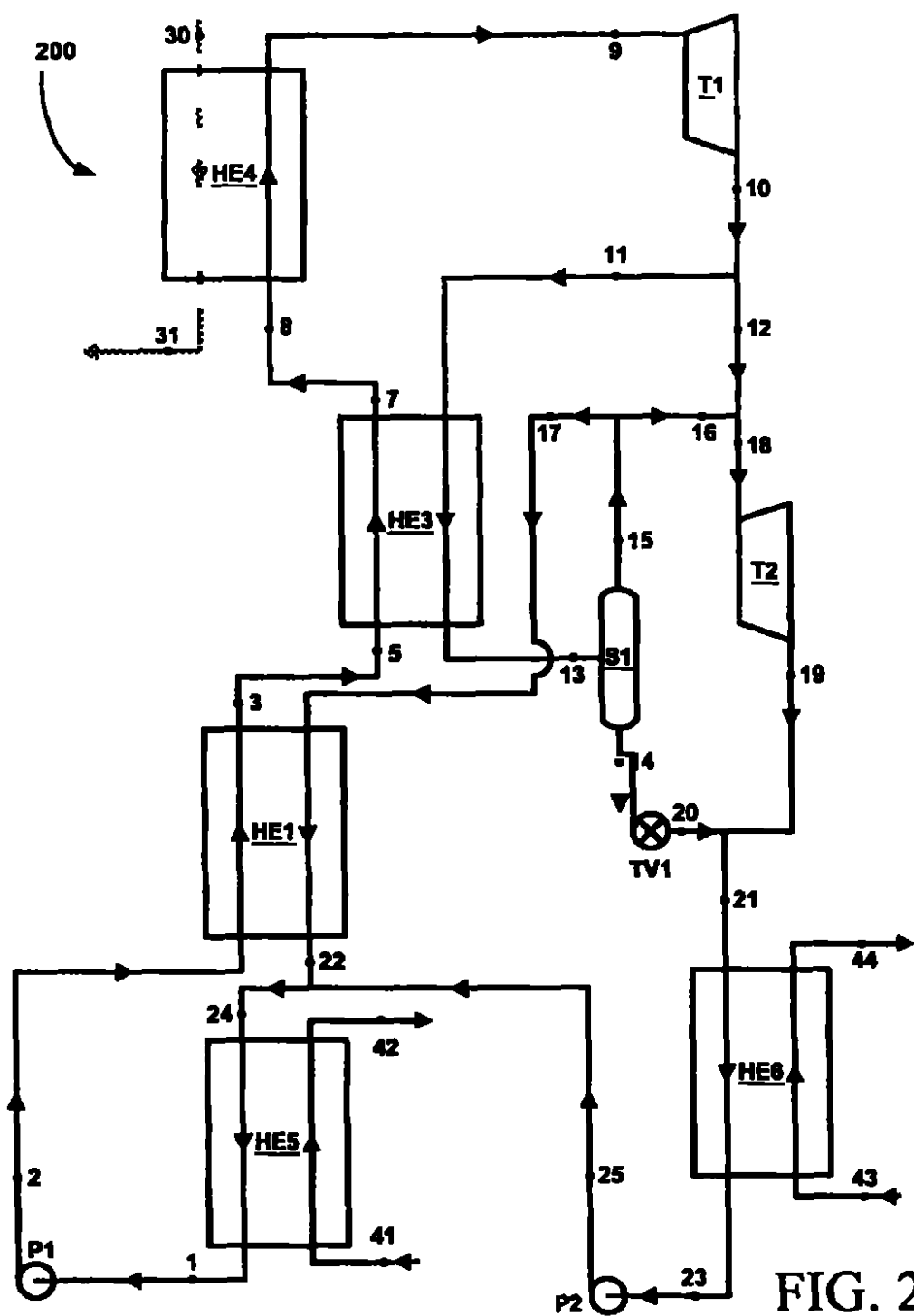


FIG. 2

237

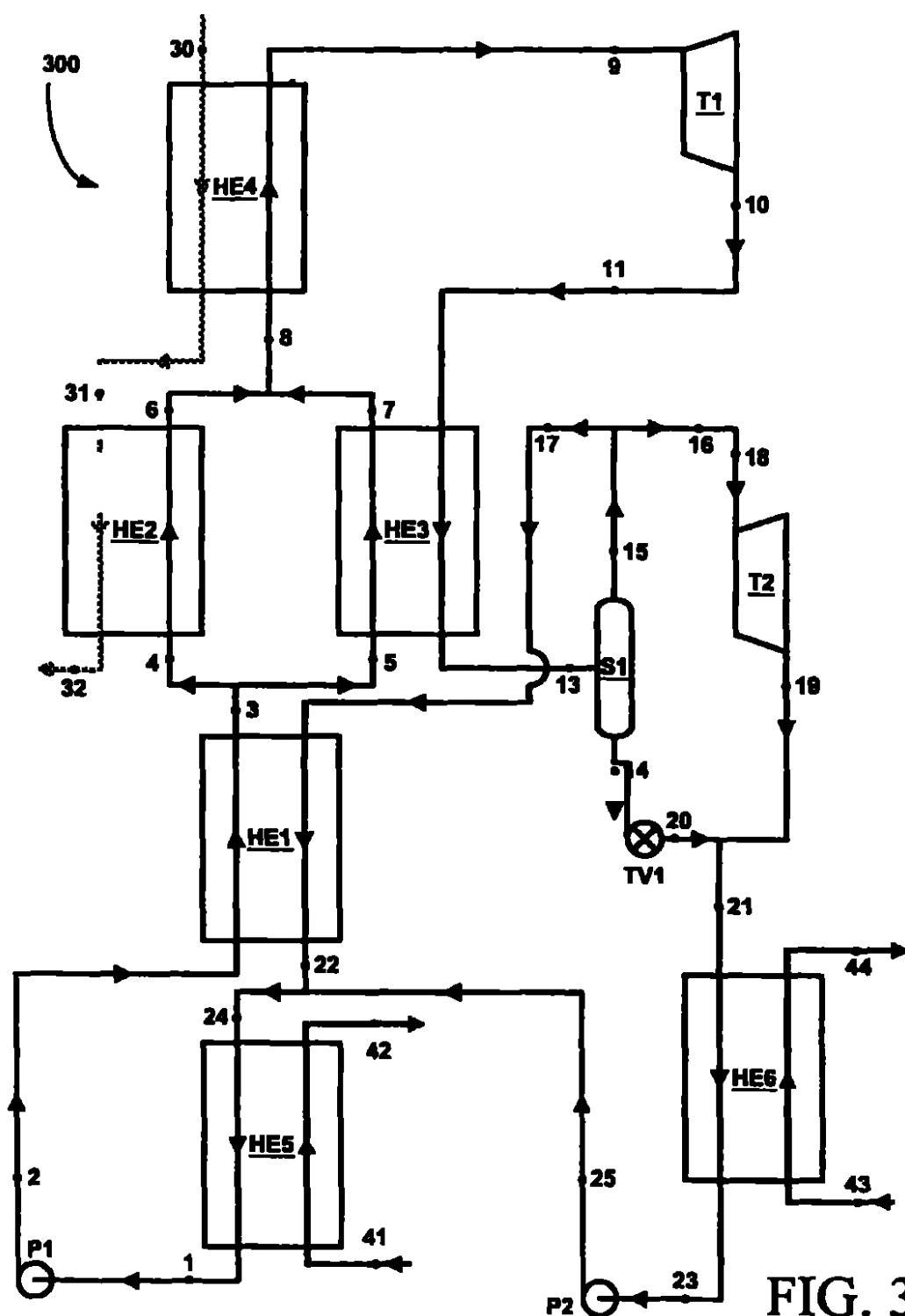


FIG. 3

GEOTHERMAL SYSTEM

BACKGROUND OF THE INVENTION

[0001] 1 Field of the Invention

[0002] The present invention relates to a process and system to convert thermal energy from moderately low temperature sources, especially from geothermal fluids, into mechanical and electrical energy.

[0003] More particularly the present invention relates to a process and system to convert thermal energy from moderately low temperature sources, especially from geothermal fluids, into mechanical and electrical energy where a working fluid comprises a mixture of at least two components, with the preferred working fluid comprising a water-ammonia mixture.

[0004] 2 Description of the Related Art

[0005] Prior art methods and systems for converting heat into useful energy are well documented in the art. In fact, many such methods and systems have been invented and patented by the inventor. These prior art systems include U.S. Pat. Nos. 4,346,561; 4,489,563; 4,548,143; 4,586,340; 4,604,867; 4,674,285; 4,732,015; 4,763,480; 4,899,545; 4,982,568; 5,029,444; 5,095,704; 5,440,882; 5,450,821; 5,572,871; 5,588,298; 5,603,218; 5,649,426; 5,822,990; 5,950,433 and 5,993,918; Foreign References 7-9481 JP and Journal References NEDO Brochure "ECO-Energy City Project" 1994 and NEDO Report published 1996, pp 4-6, 4-7, 4-43, 4-63, 4-53, incorporated herein by reference.

[0006] Although all of these prior art systems and methods relate to the conversion of thermal energy into other more useful forms of energy, all suffer from certain inefficiencies. Thus, there is a need in the art for an improved system and method for converting thermal energy to more useful forms of energy, especially for converting geothermal energy into more useful forms of energy.

SUMMARY OF THE INVENTION

[0007] The present invention provides a process for converting thermal energy from moderately low temperature sources, especially from geothermal fluids, into mechanical and/or electrical energy where the process includes the steps of expanding a fully vaporized high pressure working fluid stream transforming its energy into usable form and producing a returning, or spent, low pressure stream. The fully vaporized working stream is produced by evaporating an upcoming liquid working stream using heat derived from a heating stream from an external heat source. A sufficient portion of the spent low pressure stream and a first portion of a vapor sub-stream derived from the sufficient portion of the spent low pressure stream after partial condensation in heating the upcoming liquid working stream to form the fully high pressure vaporized working stream. An additional amount of usable energy is derived from expanding a second portion of a vapor sub-stream derived from the sufficient portion of the spent low pressure stream after partial condensation and a remainder portion of the spent low pressure stream transforming its energy into usable form and producing a secondary returning, or spent stream where an amount of usable energy is increased from about 20% to about 40% over prior art processes.

[0008] The present invention provides a system including a multi-component basic working fluid, a geothermal source stream and a cooling stream. The system further includes equipment necessary to establish a thermodynamic cycle capable of converting from about 20% to about 40% more thermal energy into mechanical energy than the prior art thermodynamic process of U.S. Pat. No. 4,982,568. A preferred system includes six heat exchangers, two pumps, a separator and a throttle valve.

[0009] The present invention provides an apparatus including a means for expanding a fully vaporized working stream transforming its energy into usable form and producing a spent stream. A first heat exchanger zone for cooling an external heat source and transferring heat from the external heat source to a heated upcoming liquid working stream to form the fully vaporized working stream and a second heat exchanger zone for partially condensing a sufficient portion of the spent stream to form a partially condensed sufficient portion of the spent stream and for transferring heat from the sufficient portion of the spent stream to a pre-heated upcoming liquid working stream. The apparatus also includes a pre-heater for partially condensing a first portion of a vapor sub-stream separated from the condensed sufficient portion of the spent stream to form a primary spent stream and for transferring heat from the vapor sub-stream to an upcoming liquid working stream and a means for expanding a second portion of the vapor sub-stream and a remaining portion of the spent stream transforming their energy into usable form and producing a secondary spent stream. The apparatus further includes a means for condensing the primary and secondary spent stream into the upcoming liquid working stream.

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 diagram of a preferred embodiment of a system of this invention for converting heat from a geothermal source to a useful form of energy.

[0012] FIG. 2 depicts a diagram of another preferred embodiment of a system of this invention for converting heat from a geothermal source to a useful form of energy and

[0013] FIG. 3 depicts a diagram of another preferred embodiment of a system of this invention for converting heat from a geothermal source to a useful form of energy.

DETAILED DESCRIPTION OF THE INVENTION

[0014] The inventors have found that a new and more efficient system and method can be constructed and designed to convert heat from a geothermal source into a more useful form of energy. The system uses a multi-component basic working fluid to extract energy from one or more (at least one) geothermal source streams in one or more (at least one) heat exchangers or heat exchanger zones. The heat exchanged basic working fluid then transfers its gained thermal energy to one or more (at least one) turbines converting the gained thermal energy into mechanical

energy and/or electrical energy. The system also includes pumps to increase the pressure of the basic working fluid at certain points in the system and one or more (at least one) heat exchangers which bring the basic working fluid in heat exchange relationships with one or more (at least one) cold streams.

[0015] The proposed system utilizes a novel thermodynamical cycle (process). The basic working fluid includes a mixture of at least two components, with the preferred basic working fluid including a water-ammonia mixture, though other mixtures, such as mixtures of hydrocarbons and/or freons can be used with practically the same results.

[0016] The basic working fluid used in the systems of this invention preferably is a multi-component fluid that comprises a lower boiling point fluid—the low-boiling component—and a higher boiling point fluid—the high-boiling component. Preferred working fluids include an ammonia-water mixture, a mixture of two or more hydrocarbons, a mixture of two or more freons, a mixture of hydrocarbons and freons, or the like. In general the fluid can comprise mixtures of any number of compounds with favorable thermodynamic characteristics and solubility. In a particularly preferred embodiment, the fluid comprises a mixture of water and ammonia.

[0017] Referring now to FIG. 1, a flow diagram generally 100, is shown that illustrates a preferred embodiment a system and method of energy conversion of this invention. The system 100 will be described in terms of its components and its operation below.

[0018] A fully condensed basic working fluid stream at a temperature close to ambient temperature and having parameters as at a point 1 enters into a pump P1 where the stream is pumped to a desired pressure and obtains parameters as at a point 2. The stream, with parameters as at the point 1 corresponds to a state of saturated liquid of the basic working fluid. The basic working fluid comprises a mixture of at least two components, preferably a mixture of ammonia and water. As a result of pumping, the liquid stream of the basic working fluid at the point 2 is in a state of sub-cooled liquid. Thereafter the liquid stream with parameters as at the point 2 passes through a pre-heater HIC1, i.e. a heat exchanger where it is heated by a counter flow stream of a fluid (see below), and the basic working fluid obtains parameters as at a point 3. In most cases, the liquid basic working fluid stream with parameters as at the point 3, is in a state of saturated or slightly sub-cooled liquid.

[0019] Thereafter the liquefied basic working fluid stream with parameters as at the point 3 is divided into two sub-streams having parameters as at points 4 and 5, respectively. The sub-stream with parameters as at a point 4 is directed into a heat exchanger HE2 where it is heated and partially vaporized by a counter flow stream of a geothermal fluid and obtains parameters as at a point 6.

[0020] The sub-stream of basic working fluid stream with parameters as at the point 5 passes through a heat exchanger HIL3 where it is heated and partially vaporized by a counter flow stream of condensing basic working fluid (see below) and obtains parameters as at a point 7. The compositions, temperatures and pressures of the basic working fluid at the points 6 and 7 are substantially the same.

[0021] Thereafter the sub-streams with parameters as at the points 6 and 7 are recombined forming a stream of basic

working fluid with parameters as at a point 8. The stream of basic working fluid with parameters as at the point 8 passes through a heat exchanger HIL4 where it is heated and fully vaporized, and may even be superheated by the counter flow stream of geothermal fluid and as a result obtains parameters as at a point 9. The stream of geothermal fluid (or another fluid which is the source of heat), with initial parameters as at a point 30, passes through the heat exchanger HIC4 in counter flow to the recombined stream of basic working fluid where the geothermal fluid is cooled providing heat for a process 8-9 (see above) and obtains parameters as at a point 31.

[0022] Thereafter the stream of geothermal fluid with parameters as at the point 31 passes through the heat exchanger HIC2 where it is further cooled, providing heat for a process 4-6 and obtaining parameters as at a point 32 and is then removed from the system.

[0023] In some conditions, the stream of geothermal fluid or some other stream of heat carrying fluid cannot be cooled to a temperature which is low enough to be used in a process 31-32 and the process 4-6. In such a case the stream of geothermal fluid or other stream is removed from the system passing only through the heat exchanger HIL4. In such a case, another preferred embodiment of the system excludes the heat exchanger HIC2 and the whole stream of basic working fluid with parameters as at the point 3 is sent only through the heat exchanger HE3 (see above) as shown in FIG. 2.

[0024] The stream of basic working fluid, with parameters as at a point 9 (see above) then passes through a high pressure turbine T1 where it is expanded producing mechanical work and leaves the turbine T1 as a returning or spent stream of the basic working fluid, with parameters as at a point 10. The pressure of the basic working fluid at the point 10 is chosen to slightly exceed the pressure of the basic working fluid at the point 1. This is necessary to fully condense the stream of the basic working fluid at the given ambient temperature (see above).

[0025] The state of the basic working fluid at the point 10 can be a slightly superheated vapor, a saturated vapor or even a wet vapor and has a pressure lower than the stream of basic working fluid at the point 9. The pressure of the basic working fluids at the point 3 (see above), where boiling of the upcoming basic working fluid begins (see above), is chosen such that condensation of the low pressure stream of basic working fluid with parameters as at the point 10, starts at a temperature which is higher than a temperature of the stream of basic working fluid at the point 3. This phenomenon where the initial temperature of condensation of a low pressure stream of basic working fluid is higher than the initial temperature of boiling of a high pressure stream of basic working fluid is possible only for a basic working fluid comprising a mixture of two or more (at least two) components.

[0026] The low-pressure stream of basic working fluid with parameters as at the point 10, is then divided into two sub-streams having parameters as at points 11 and 12 respectively. The sub-stream with parameters as at point 11 passes through the heat exchanger HIL3 where it is cooled and partially condensed, obtaining parameters as at a point 13. Heat released in a process 11-13 is utilized in a heating process 5-7 (see above). A flow rate of the sub-stream in the

process 11-13 is chosen such that a temperature of the stream of basic working fluid at point 13 is higher than a temperature of the sub-stream of basic working fluid at point 9 and corresponds to a desired pre-selected temperature difference. Generally the sub-stream with parameters as at the point 11 is sufficient to provide a quantity of heat that when combined with the heat from the geothermal source and the heat from a separated vapor sub-stream with parameters as at a point 17 is sufficient to fully vaporize the basic working fluid with parameters as at the point 9.

[0027] The composition of the basic working fluid or the pre-selected temperature difference may be chosen so that in order to provide a heat balance in the process 11-13 vs. the process 5-7 all of the stream of basic working fluid with parameters as at the point 10 must be sent into the heat exchanger HE3. In this case, another preferred embodiment of the system generally 300 of this invention as shown in FIG. 3 is shown to exclude a flow path through the point 12 because a flow rate at point 12 would be equal to zero (0) and the stream with parameters as at point 12 would not exist. Such a composition of basic working fluid is the "richest" possible composition meaning that it has the highest possible concentration of light boiling component (component with the lower boiling temperature, for example ammonia in a water-ammonia mixture). If a "leaner" composition of a working fluid i.e. one containing a lower concentration of ammonia, is chosen then only part of the stream with parameters as at the point 10 needs to be sent into the heat exchanger HE3 to provide the heat needed for process 5-7 with the remainder of the stream of basic working fluid passing through a flow path including the point 12.

[0028] The sub-stream of returning or spent basic working fluid with parameters as at the point 13, is always in a state of wet vapor and may contain a significant amount of condensed liquid. The sub-stream with parameters as at the point 13, is then forwarded to a liquid separator S1 where it is separated into a stream of saturated vapor having parameters as at a point 15 and into a stream of saturated liquid having parameters as at a point 14. The stream of saturated vapor with parameters as at the point 15 is then divided into two sub-streams having parameters as at points 16 and 17 respectively.

[0029] In the separator S1 the sub-stream of basic working fluid is separated into two sub-streams, a separated liquid stream (saturated liquid stream) and separated vapor stream (saturated vapor stream). The concentration of the light boiling component (ammonia) in the separated vapor stream leaving the separator S1 is significantly higher than the concentration of this same component in the basic working fluid as for example at the point 1. Conversely the concentration of the light boiling component in the separated liquid stream leaving the separator S1 and having parameters as at the point 14 is substantially lower than the concentration of this same component in the basic working fluid as for example at the point 1.

[0030] The sub-stream with parameters as at the point 17 then passes through the heat exchanger H11 where it is cooled and partially condensed and obtains parameters as at a point 22. Heat reclaimed in a process 17-22 is utilized to provide pre-heating of the upcoming stream of high pressure liquid basic working fluid in the process 2-3 (see above).

[0031] The sub-stream of vapor with parameters as at the point 16 is combined with the sub-stream of vapor basic

working fluid (the remaining spent stream) with parameters as at the point 12 (see above) forming a new stream of vapor with parameters as at a point 18.

[0032] If one would combine streams with parameters as at the points 22, 18 and 14 into one stream then such a stream would have a composition identical to that of the basic working fluid which can be fully condensed at the given ambient temperature at a pressure as of the stream of basic working fluid having parameters as at the point 1. However if one combines only streams 14 and 18 the composition of the resulting stream would be substantially "leaner" than the composition of the basic working fluid as at the point 1 and the combined stream can therefore be condensed at the ambient temperature at a substantially lower pressure.

[0033] Therefore the stream of vapor with parameters as at the point 18 is sent through a low pressure turbine T2 where it is expanded to produce an additional amount of mechanical work and leaves the low pressure turbine T2 with parameters as at a point 19. The sub-stream of liquid with parameters as at the point 14, then passes through a throttle valve TV1 where its pressure is reduced to a pressure equal to a pressure of the stream at the point 19 (see above) obtaining parameters as at a point 20. Thereafter the streams with parameters as at the points 19 & 20 are combined, forming a combined stream with parameters as at a point 21. As described above, the composition of the combined stream with parameters as at the point 20 is substantially "leaner" than the composition of the basic working fluid for example at the point 1.

[0034] The combined stream with parameters as at the point 21 is then sent to a heat exchanger HE6. In the heat exchanger HE6, the combined stream with parameters as at the point 21 is fully condensed by a stream of ambient cooling fluid (air, water or other) with parameters as at a point 43, and the combined stream with parameters as at the point 21 obtains parameters as at a point 23 while the cooling fluid leaves the heat exchanger HE6 with parameters as at a point 44.

[0035] The stream of condensed liquid with parameters as at the point 23 is then pumped by a pump P2 to form a stream with parameters as at a point 25 having a pressure which is equal or close to a pressure of the stream at the point 22 (see above). Thereafter the streams with parameters as at the points 22 & 25 are combined into a single stream with parameters as at a point 24. The composition of the stream with parameters as at the point 24 is equal to the composition of the basic working fluid. Thereafter the stream with parameters as at the point 24, then passes through a heat exchanger HCS, where it is fully condensed by a stream of ambient cooling fluid (air, water or other) and obtains parameters as at the point 1. The cooling fluid enters the heat exchanger H15 with parameters as at a point 41 and leaves the heat exchanger H15 with parameters as at a point 42. The thermodynamic cycle for the basic working fluid is closed.

[0036] In prior art for example as described in U.S. Pat. No. 4,982,568 the whole stream of returning basic working fluid after being partially condensed in a recuperative heat exchanger passes through a pre-heater and is then sent into a condenser. It would correspond as if in the system of FIG. 1 the stream with parameters as at the point 13

would be directly sent into the heat exchanger 11L1 and thereafter into the heat exchanger 11L5. However, the quantity of heat required for the process of pre-heating of the basic working fluid in the process 2-3 is several times smaller than the quantity of heat available from the returning, condensing stream. As a result, such an imbalance in the heat exchanger causes a substantial increase in the quantity of heat rejected to the ambient or environment in the final condenser and results in substantial energy losses and reduced thermal conversion efficiency.

[0037] In contrast in the proposed system of FIGS. 1-3 an additional energy potential is released and utilized in the low pressure turbine 12. All work produced in turbine 12 constitutes an additional and substantial increase in an output of useful work of the systems of FIGS. 1-3. Preliminary calculations and assessments have shown that this additional increase in output can be as high as 20-40% of the system of the prior art for example the system of U.S. Pat. No. 4,982,568.

[0038] An additional advantage of the systems of this invention is as follows. In the prior art the composition of the basic working fluid is chosen such that after expansion in a turbine, the whole stream of basic working fluid passes through a recuperative boiler-condenser with the requirement of maintaining a strict heat balance in this heat exchanger. This requires very accurate maintenance of the composition of the basic working fluid. But when ambient conditions change, the composition of the basic fluid must be changed as well.

[0039] In contrast to the systems of this invention in the general case of FIG. 1 only part of the stream exiting the high pressure turbine 11 is sent into a recuperative boiler-condenser (i.e. heat exchanger 11E3). Therefore, the sensitivity of the system's performance to the composition of the basic working fluid is substantially reduced and rigid control of such a composition is unnecessary. Moreover in the systems of this invention, it is very easy to vary the composition of the basic working fluid. In cases where the composition of the basic working fluid must be made richer part of the stream with parameters as at the point 25 may be sent into a storage tank and as a result the composition of the stream at the point 24 would become richer as required. To the contrary, if the composition of the basic working fluid needs to be made leaner than liquid from such a storage tank can be added to the stream with parameters as at the point 25 thus making the composition of the stream at the point 24 leaner as required.

[0040] All references cited herein are incorporated by reference. While this invention has been described fully and completely it should be understood that within the scope of the appended claims, the invention may be practiced otherwise than as specifically described. 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 method for implementing a thermodynamic cycle comprising the steps of

expanding a fully vaporized high pressure working fluid stream transforming its energy into usable form and producing a returning or spent low pressure stream

evaporating an upcoming liquid working stream using heat derived from a heating stream from an external heat source, a sufficient portion of the spent low pressure stream and a first portion of a vapor sub-stream derived from the sufficient portion of the spent low pressure stream after partial condensation in heating the upcoming liquid working stream to form the fully high pressure, vaporized working stream

expanding a second portion of a vapor sub-stream derived from the sufficient portion of the spent, low pressure stream after partial condensation and a remainder portion of the spent low pressure stream transforming its energy into usable form and producing a secondary returning or spent stream

where an amount of usable energy is increased from about 20% to about 30%.

2. The method of claim 1 wherein the fully vaporized high pressure working fluid stream is superheated.

3. The method of claim 1 wherein the heating stream is a geothermal fluid stream produced by a geothermal source.

4. The method of claim 1 further comprising the steps of

condensing completely a recombined spent fluid stream after the two expanding steps of form the upcoming liquid working stream

5. The method of claim 1 further comprising the steps of

pre-heating the upcoming liquid working fluid stream with the first portion of a vapor sub-stream derived from the sufficient portion of the spent low pressure stream to form a pre-heated liquid working fluid stream

6. The method of claim 5 further comprising the steps of heating the pre-heated liquid working fluid stream with the sufficient amount of the spent stream to form a heated liquid stream

7. The method of claim 5 further comprising the steps of

fully vaporizing the heated liquid stream with the heating stream to form the fully vaporized working fluid stream

8. A method for implementing a thermodynamic cycle comprising the steps of

expanding a fully vaporized working stream transforming its energy into usable form and producing a returning or spent stream,

evaporating an upcoming heated liquid working stream using heat from a heating stream from an external heat source to form the fully vaporized working stream

heating an upcoming pre-heated liquid working stream with a sufficient amount of the spent stream to form the upcoming heated liquid working stream and a partially condensed sufficient amount of the spent stream,

pre-heating an upcoming liquid working stream with the first portion of a vapor sub-stream derived from the sufficient portion of the spent stream to form the upcoming pre-heated liquid working stream and to form a partially condensed first portion of the vapor sub-stream

242

expanding a second portion of the vapor sub-stream and a remaining amount of the spent stream transforming their energy into usable form and producing a secondary spent stream

where an amount of usable energy is increased from about 20% to about 30%

9 The method of claim 8, wherein the fully vaporized working stream is superheated

10 The method of claim 8, wherein the heating stream is a geothermal fluid stream produced by a geothermal source

11 A method for implementing a thermodynamic cycle comprising the steps of

expanding a fully vaporized working fluid stream transforming its energy into usable form and producing a returning or spent stream

heating an upcoming, pre-heated liquid working stream by partially condensing a sufficient portion of the spent stream to partially evaporate the upcoming pre-heated liquid working stream producing a heated liquid working stream

evaporating the heated liquid working stream using heat produced by a heating stream from an external heat source to form the gaseous working stream where heat from the heating stream and the sufficient portion of the spent stream is equal or slightly greater than the heat required to fully vaporize the pre heated upcoming liquid working stream

separating the sufficient portion of the spent stream into a vapor sub-stream and a liquid sub-stream

preheating an upcoming liquid working stream by partially condensing a first portion of the vapor sub-stream to form the pre-heated upcoming liquid working stream and a primary returning stream

combining a second portion of the vapor sub-stream and a second portion of the returning or spent stream to form a secondary vapor stream

expanding the secondary vapor stream transforming its energy into usable form and producing a secondary returning or spent stream

reducing the pressure of the liquid sub-stream and combining it with the secondary returning stream to form a combined secondary returning stream

condensing the combined secondary returning stream with a cooling fluid stream

pressurizing the condensed combined secondary returning stream and combining it with the primary return stream to form a partially condensed returning working fluid stream and

fully condensing the combined returning working fluid stream with a cooling fluid stream

where an amount of usable energy is increased from about 20% to about 30%

12 The method of claim 11 wherein the fully vaporized working fluid stream is superheated

13 The method of claim 11 wherein the heating stream is a geothermal fluid stream produced by a geothermal source

14 Apparatus for implementing a thermodynamic cycle comprising

means for expanding a fully vaporized working stream transforming its energy into usable form and producing a spent stream

a first heat exchange zone for cooling an external heat source and transferring heat from the external heat source to a heated upcoming liquid working stream to form the fully vaporized working stream

a second heat exchange zone for partially condensing a sufficient portion of the spent stream to form a partially condensed sufficient portion of the spent stream and for transferring heat from the sufficient portion of the spent stream to a pre-heated upcoming liquid working stream

a pre-heater for partially condensing a first portion of a vapor sub-stream separated from the condensed sufficient portion of the spent stream to form a primary spent stream and for transferring heat from the vapor sub-stream to an upcoming liquid working stream

means for expanding a second portion of the vapor sub-stream and a remaining portion of the spent stream transforming their energy into usable form and producing a secondary spent stream

means for condensing the primary and secondary spent stream into the upcoming liquid working stream

* * * * *

243

REQUISITOS NECESARIOS PARA PRESENTACION Y AGILIZACION DEL TRAMITE

	USUARIO	RADICADOR
PATENTE DE INVENCION	()	()
MODELO DE UTILIDAD	()	()
Indicacion de que se solicita la concesion de una patente	()	()
Datos de Identificacion del solicitante o de la persona que se presenta la solicitud.	()	()
Descripcion de la invencion.	()	()
Dibujos de ser estos pertinentes.	()	()
Comprobante de Pago de las tasas establecidas	()	()
COMPLETA	()	()
INCOMPLETA	()	()
DISEÑO INDUSTRIAL	()	()
Indicacion de que se solicita el registro de Diseño Industrial	()	()
Datos de Identificacion del solicitante o de la persona que presenta la solicitud	()	()
Representacion grafica o fotografica del Diseño Industrial o muestra del Material que incorpora el diseño	()	()
Comprobante de pago de las tasas establecidas	()	()
COMPLETA	()	()
INCOMPLETA	()	()
ESQUEMA DE TRAZADO	()	()
Indicacion de que solicita el registro del esquema de trazado	()	()
Datos de Identificacion del solicitante o de la persona que presenta la solicitud	()	()
Representacion grafica del esquema de trazado	()	()
Comprobante de pago de las tasas establecidas	()	()
COMPLETA	()	()
INCOMPLETA	()	()

Firma-Responsable

Fecha

244

REPUBLICA DE COLOMBIA
SUPERINTENDENCIA DE INDUSTRIA Y COMERCIO

Bogotá,
2020

Doctor(a)
RODRÍGUEZ D'ALEMAN DILIA MARÍA

R660

REFERENCIA	Radicación No	5 75396
	Solicitud internacional	US2004/003025
	Fecha inicio fase nacional	05/09/2005
	Trámite	11
	Evento	379
	Actuación	430
	Oficio No	8466

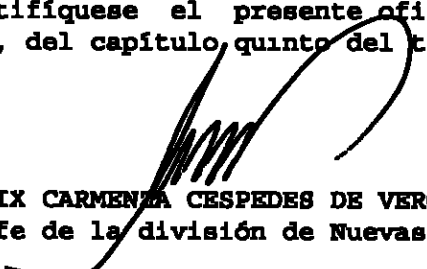
Como resultado del examen de forma, realizado con fundamento en el artículo 38 de la Decisión 486 de la Comisión de la Comunidad Andina, artículo 27 del Tratado de Cooperación en Materia de Patentes (PCT), regla 51 bis del Reglamento y Circular Única de la Superintendencia de Industria y Comercio, se le comunica que

1 La solicitud no contiene la copia del documento en que consta la cesión del derecho a la patente del inventor al solicitante o a su causante (Art 26-k) Decisión 486

2 La solicitud no contiene el poder debidamente otorgado, con el lleno de los requisitos exigidos por los artículos 63 y subsiguientes del Código de Procedimiento Civil. Adicionalmente, deberá presentar el documento que acredita la existencia y representación legal de la sociedad solicitante cuando ésta fuere persona jurídica

En cumplimiento de lo dispuesto por el artículo 39 de la Decisión 486 se le requiere para que dentro del término de dos meses siguientes a la fecha de notificación del presente oficio, complete los requisitos anteriormente enunciados. En caso de no dar cumplimiento al presente requerimiento, la solicitud se considerará abandonada y perderá su prelación.

Notifíquese el presente oficio conforme a lo dispuesto en el numeral 5.2, literal e), del capítulo quinto del título primero de la Circular Única No 10 de 2001.


ALIX CARMEN CESPEDES DE VERGEL
Jefe de la división de Nuevas Creaciones

El anterior requerimiento fue notificado por fijación en lista de fecha 16 SET 2005
adpall