



(86) Date de dépôt PCT/PCT Filing Date: 2011/10/06
(87) Date publication PCT/PCT Publication Date: 2012/04/12
(85) Entrée phase nationale/National Entry: 2013/04/02
(86) N° demande PCT/PCT Application No.: US 2011/055138
(87) N° publication PCT/PCT Publication No.: 2012/048132
(30) Priorité/Priority: 2010/10/06 (US61/390,397)

(51) Cl.Int./Int.Cl. *F01K 19/00* (2006.01),
F01K 23/02 (2006.01), *F22B 33/18* (2006.01)

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(54) Titre : UTILISATION D'UN SOUS-PRODUIT DE CHALEUR INDUSTRIELLE

(54) Title: UTILIZATION OF PROCESS HEAT BY-PRODUCT

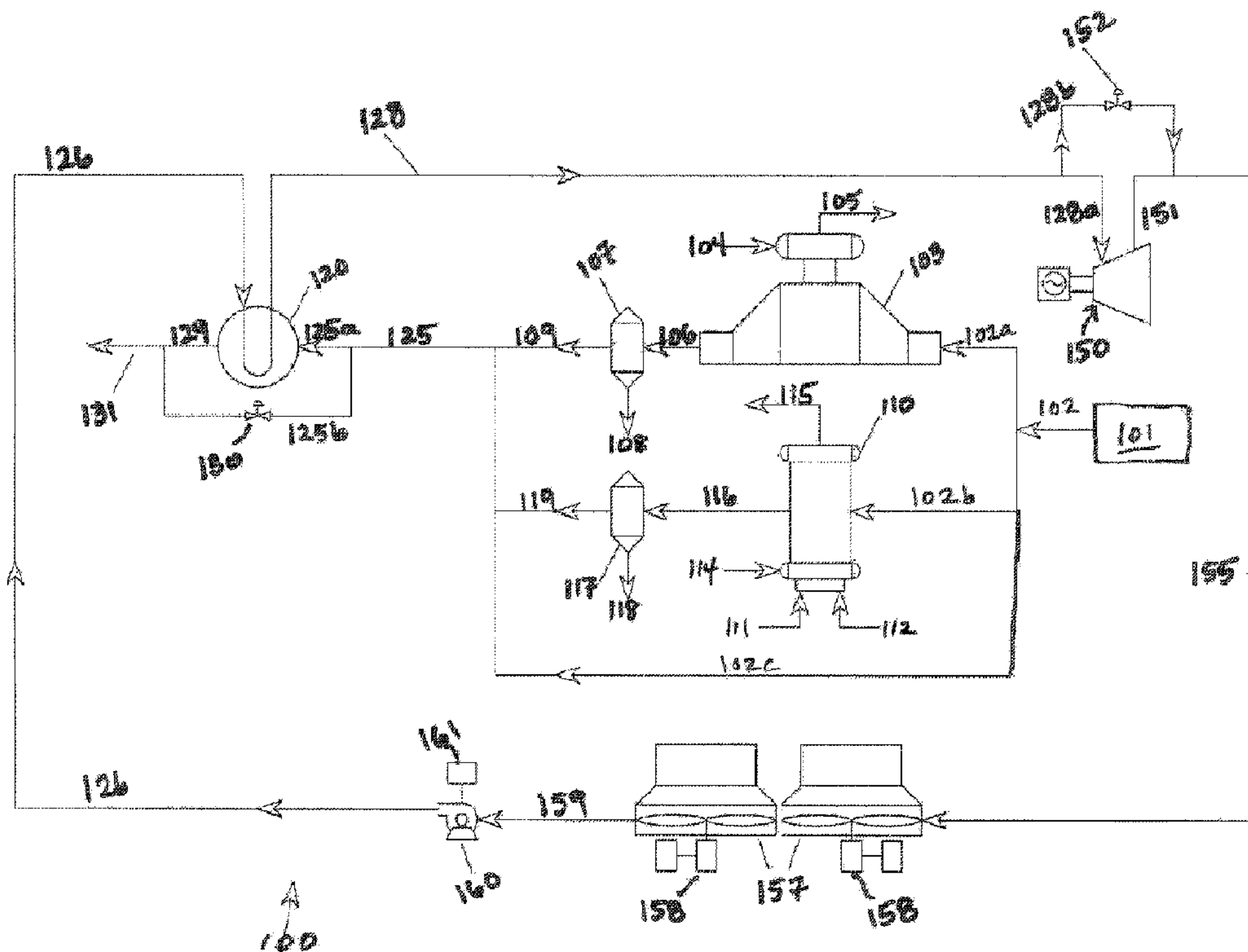
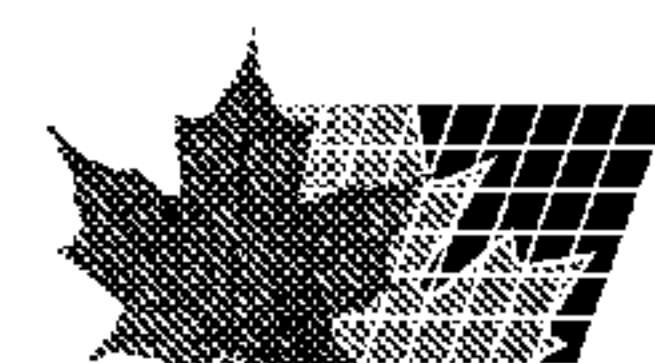


FIG. 1

(57) Abrégé/Abstract:

Heat recovery systems and methods for producing electrical and/or mechanical power from a process heat by-product are provided. Sources of process heat by-product include hot flue gas streams, high temperature reactors, steam generators, gas turbines, diesel generators, and process columns. Heat recovery systems and methods include a process heat by-product stream for directly heating a working fluid of an organic Rankine cycle. The organic Rankine cycle includes a heat exchanger, a turbine-generator system for producing power, a condenser heat exchanger, and a pump for recirculating the working fluid to the heat exchanger.



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

(19) World Intellectual Property

Organization

International Bureau

(43) International Publication Date

12 April 2012 (12.04.2012)



(10) International Publication Number

WO 2012/048132 A3

(51) International Patent Classification:

F01K 19/00 (2006.01) F22B 33/18 (2006.01)

F01K 23/02 (2006.01)

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(21) International Application Number:

PCT/US2011/055138

(22) International Filing Date:

6 October 2011 (06.10.2011)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

61/390,397 6 October 2010 (06.10.2010) US

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

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

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(54) Title: UTILIZATION OF PROCESS HEAT BY-PRODUCT

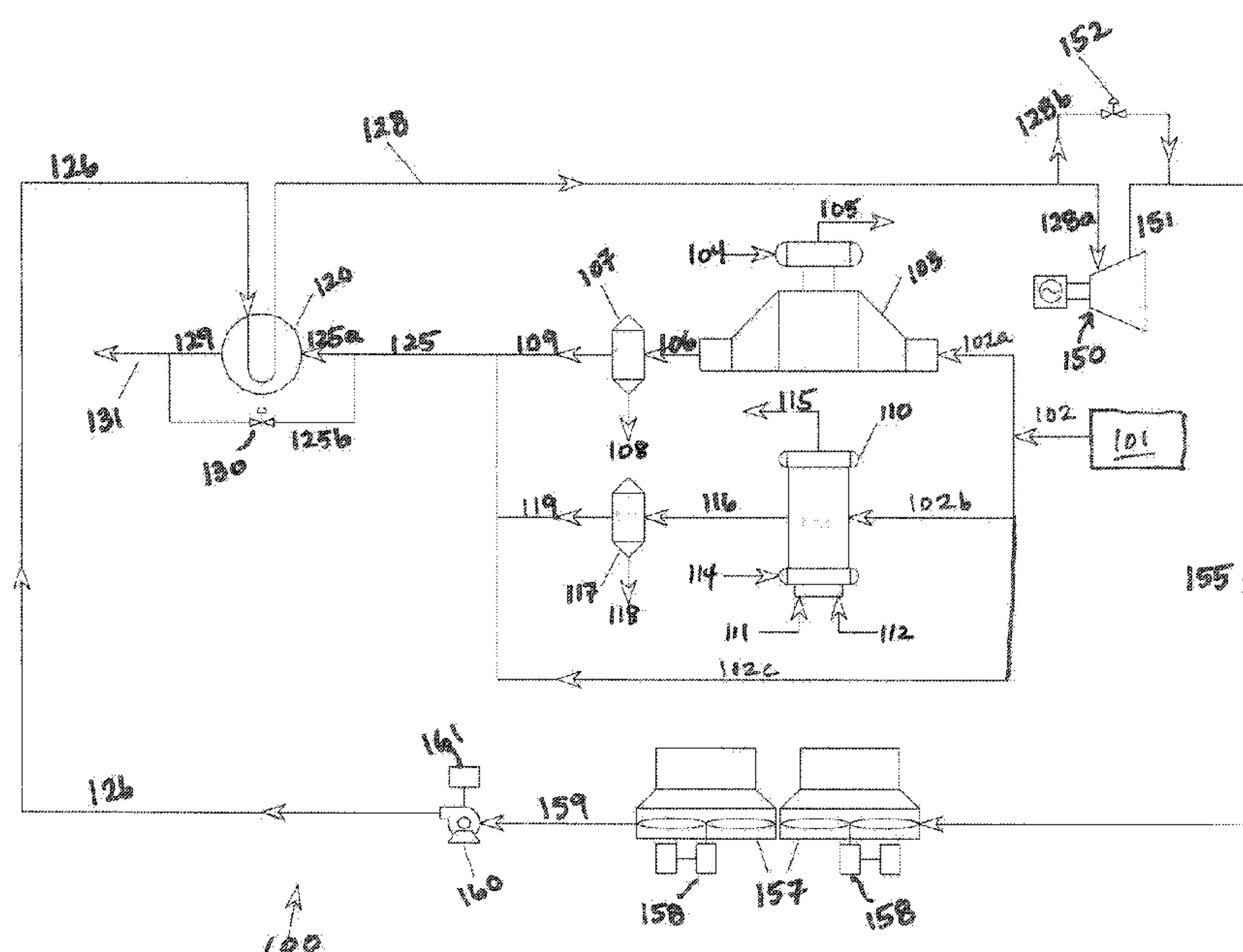


FIG. 1

(57) Abstract: Heat recovery systems and methods for producing electrical and/or mechanical power from a process heat by-product are provided. Sources of process heat by-product include hot flue gas streams, high temperature reactors, steam generators, gas turbines, diesel generators, and process columns. Heat recovery systems and methods include a process heat by-product stream for directly heating a working fluid of an organic Rankine cycle. The organic Rankine cycle includes a heat exchanger, a turbine-generator system for producing power, a condenser heat exchanger, and a pump for recirculating the working fluid to the heat exchanger.

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Declarations under Rule 4.17:

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| — | <i>as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))</i> | — | <i>before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))</i> |
| — | <i>as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))</i> | (88) | Date of publication of the international search report:
19 July 2012 |

Published:

- *with international search report (Art. 21(3))*

UTILIZATION OF PROCESS HEAT BY-PRODUCT

CROSS-REFERENCE TO RELATED APPLICATION

[0001] The present application claims priority to U.S. Provisional Patent Application No. 61/390,397, entitled "Utilizing Waste Heat From Refinery Operations" and filed on October 6, 2010, in the name of John David Penton *et al*, the entire disclosure of which is hereby fully incorporated herein by reference.

TECHNICAL FIELD

[0002] The present application generally relates to heat recovery and utilization. More particularly, the present application relates to the utilization of process heat by-product to generate electricity and/or mechanical power.

BACKGROUND

[0003] Objective and regulations surrounding carbon and energy usage has raised the importance of designing and retrofitting existing processes for higher levels of energy efficiency. The primary driving forces are the need to reduce greenhouse gas emissions or local pollution, reducing the energy investment requirement, and best utilizing existing supply capacities to improve the access to energy. To increase the energy efficiency of a process, it is necessary to improve the utilization of the energy inputted and reduce the energy wasted to the atmosphere. One common area of wasted energy is in the heat exhausted from sources within the oil and gas industry, from processes such as fluid catalytic cracking regenerator column overheads, steam generator exhaust, turbine exhaust, and other flue gas sources.

[0004] Currently, methods for recovering higher temperature waste heat include utilizing the heat for preheat of other processes or for the production of steam. This heat can be utilized in heat recovery steam generators or heat exchangers. One such avenue of increasing the energy efficiency of a process is to utilize the low temperature "waste heat", typically below 500 degrees Fahrenheit (°F), for power generation or mechanical power. In geothermal applications and reciprocating engines, an organic Rankine cycle system is utilized for the conversion of heat to power. The exhaust gas or brine exchanges with a working fluid to produce the desired power output. However, there are currently several

drawbacks with utilization of an organic Rankine cycle in a refining process or various flue gas exhaust systems. The current technologies have been unable to reach the necessary efficiencies at the low temperature ranges of these process streams. Additionally, current technologies have been unable to incorporate appropriate exchanger technology that would sufficiently decrease fouling and reliability risks in a process with volatile flowrates and temperatures. There are also difficulties with structurally integrating the technology within a much more complex process setting when compared to the current installations.

[0005] Therefore, a need exists for a process to effectively and efficiently capture and convert this waste heat to a useful energy source.

SUMMARY

[0006] The present invention is directed to processes for heat recovery from process heat by-product, wherein such heat recovery is realized by channeling thermal energy from a process heat by-product stream to an organic Rankine cycle—from which electricity can be derived through a turbine-driven generator. The present invention is also directed to systems for implementing such processes.

[0007] In one aspect of the invention, a process for directly utilizing process heat by-product from refinery operations includes two sub-processes that occur simultaneously and that are linked via a heater or heat exchanger. In the first sub-process, a process heat by-product stream is directed to a heater and is utilized to heat a working fluid stream of an organic Rankine cycle to produce a cooled by-product stream and a heated working fluid stream. The cooled by-product stream is then exhausted to atmosphere. In some instances, the process heat by-product stream includes flue gas from a fluid catalytic cracking unit or recovered heat from a high temperature reactor, such as a fired heater, incinerator, hydrotreater, catalytic reformer, or isomerization unit. In the second sub-process, the working fluid stream is heated by the process heat by-product stream in the heater to form a heated working fluid stream. In certain aspects, the heated working fluid stream is vaporized. The heated working fluid stream is passed through a turbine-generator set to form an expanded working fluid stream and produce electricity and/or mechanical power. The expanded working fluid stream is then directed to another heat exchanger to form a condensed working fluid stream. The condensed working fluid stream is then passed through a pump to form the working fluid stream that enters the heater of the organic Rankine cycle.

[0008] In another aspect of the invention, a process for directly utilizing waste heat by-product includes two sub-processes that occur simultaneously and that are linked via a

heater or heat exchanger. In the first sub-process, a waste heat by-product stream is directed to a heater and is utilized to heat a working fluid stream of an organic Rankine cycle to produce a cooled by-product stream and a heated working fluid stream. The cooled by-product stream is then exhausted to atmosphere. In certain aspects, the cooled by-product stream is directed to an incinerator, a scrubber, or a stack prior to being exhausted to the atmosphere. In certain aspects, the process heat by-product stream includes waste heat from a steam generator, gas turbine, or diesel generator. In the second sub-process, the working fluid stream is heated by the waste heat by-product stream in the heater to form a heated working fluid stream. In certain aspects, the heated working fluid stream is vaporized. The heated working fluid stream is passed through a turbine-generator set to form an expanded working fluid stream and produce electricity and/or mechanical power. The expanded working fluid stream is then directed to another heat exchanger to form a condensed working fluid stream. The condensed working fluid stream is then passed through a pump to form the working fluid stream that enters the heater of the organic Rankine cycle.

[0009] In yet another aspect of the invention, a process for directly utilizing a heat by-product stream includes two sub-processes that occur simultaneously and that are linked via a heater or heat exchanger. In the first sub-process, a heat by-product stream is directed to a heater and is utilized to heat a working fluid stream of an organic Rankine cycle to produce a cooled by-product stream and a heated working fluid stream. The cooled by-product stream is then exhausted to atmosphere. In certain aspects, the cooled by-product stream is directed to an incinerator, a scrubber, or a stack prior to being exhausted to the atmosphere. In the second sub-process, the working fluid stream is heated by the heat by-product stream in the heater to form a heated working fluid stream. In certain aspects, the heated working fluid stream is vaporized. The heated working fluid stream is passed through a turbine-generator set to form an expanded working fluid stream and produce electricity and/or mechanical power. The expanded working fluid stream is then directed to another heat exchanger to form a condensed working fluid stream.

[0010] The features of the present invention will be readily apparent to those skilled in the art upon a reading of the description of the preferred embodiments that follows.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] For a more complete understanding of the exemplary embodiments of the present invention and the advantages thereof, reference is now made to the following

description in conjunction with the accompanying drawings, which are briefly described as follows.

[0012] FIG. 1 is a schematic diagram of a heat recovery system for utilization of waste heat from a fluid catalytic cracking unit, according to an exemplary embodiment.

[0013] FIG. 2 is a schematic diagram of a heat recovery system for utilization of waste heat from a fluid catalytic cracking unit, according to another exemplary embodiment.

[0014] FIG. 3 is a schematic diagram of a heat recovery system for utilization of waste heat from a fluid catalytic cracking unit, according to yet another exemplary embodiment.

[0015] FIG. 4 is a schematic diagram of a heat recovery system for utilization of waste heat from a fluid catalytic cracking unit, according to yet another exemplary embodiment.

[0016] FIG. 5 is a schematic diagram of a heat recovery system for utilization of process heat by-product from a fired heater unit, according to an exemplary embodiment.

[0017] FIG. 6 is a schematic diagram of a heat recovery system for utilization of process heat by-product from a fired heater unit, according to another exemplary embodiment.

[0018] FIG. 7 is a schematic diagram of a heat recovery system for utilization of process heat by-product from a fired heater unit, according to yet another exemplary embodiment.

[0019] FIG. 8 is a schematic diagram of a heat recovery system for utilization of process heat by-product from a fired heater unit, according to yet another exemplary embodiment.

[0020] FIG. 9 is a schematic diagram of a heat recovery system for utilization of an exhaust gas stream from a steam generator unit, according to an exemplary embodiment.

[0021] FIG. 10 is a schematic diagram of a heat recovery system for utilization of an exhaust gas stream from a steam generator unit, according to another exemplary embodiment.

[0022] FIG. 11 is a schematic diagram of a heat recovery system for utilization of an exhaust gas stream from a steam generator unit, according to yet another exemplary embodiment.

[0023] FIG. 12 is a schematic diagram of a heat recovery system for utilization of an exhaust gas stream from a steam generator unit, according to yet another exemplary embodiment.

[0024] FIG. 13 is a schematic diagram of a heat recovery system for utilization of an exhaust gas stream from a gas turbine unit, according to an exemplary embodiment.

[0025] FIG. 14 is a schematic diagram of a heat recovery system for utilization of an exhaust gas stream from a gas turbine unit, according to another exemplary embodiment.

[0026] FIG. 15 is a schematic diagram of a heat recovery system for utilization of an exhaust gas stream from a gas turbine unit, according to yet another exemplary embodiment.

[0027] FIG. 16 is a schematic diagram of a heat recovery system for utilization of an exhaust gas stream from a gas turbine unit, according to yet another exemplary embodiment.

[0028] FIG. 17 is a schematic diagram of a heat recovery system for utilization of a process heat stream, according to an exemplary embodiment.

[0029] FIG. 18 is a schematic diagram of a heat recovery system for utilization of a process heat stream, according to another exemplary embodiment.

[0030] FIG. 19 is a schematic diagram of a heat recovery system for utilization of a process heat stream, according to yet another exemplary embodiment.

[0031] FIG. 20 is a schematic diagram of a heat recovery system for utilization of a process heat stream, according to yet another exemplary embodiment.

DETAILED DESCRIPTION

[0032] Illustrative embodiments of the invention are described below. In the interest of clarity, not all features of an actual implementation are described in this specification. One of ordinary skill in the art will appreciate that in the development of any such actual embodiment, numerous implementation-specific decisions must be made to achieve the developers' specific goals, such as compliance with system-related and business-related constraints, which will vary from one implementation to another. Moreover, it will be appreciated that such a development effort might be complex and time-consuming, but would nevertheless be a routine undertaking for those of ordinary skill in the art having the benefit of this disclosure.

[0033] The present invention may be better understood by reading the following description of non-limitative embodiments with reference to the attached drawings wherein like parts of each of the figures are identified by the same reference characters. The words and phrases used herein should be understood and interpreted to have a meaning consistent with the understanding of those words and phrases by those skilled in the relevant art. No special definition of a term or phrase, for example, a definition that is different from the ordinary and customary meaning as understood by those skilled in the art, is intended to be

implied by consistent usage of the term or phrase herein. To the extent that a term or phrase is intended to have a special meaning, for instance, a meaning other than that understood by skilled artisans, such a special definition will be expressly set forth in the specification in a definitional manner that directly and unequivocally provides the special definition for the term or phrase. Moreover, various streams or conditions may be referred to with terms such as "hot," "cold," "cooled," "warm," etc., or other like terminology. Those skilled in the art will recognize that such terms reflect conditions relative to another process stream, not an absolute measurement of any particular temperature.

[0034] FIG. 1 shows a direct heat recovery system 100 for utilization of a flue gas stream 102 from a fluid catalytic cracking regenerator unit 101. Generally, the flue gas stream 102 is a high temperature heat stream that is generated by the combustion of coke in the fluid catalytic cracking regenerator unit 101. In certain embodiments, the flue gas stream 102 has a temperature in the range of from about 1100 to about 1800 °F. In certain exemplary embodiments, when the combustion of coke is complete, at least a portion 102a of the flue gas stream 102 enters a waste heat steam generator 103. A boiler feed water stream 104 also enters the waste heat steam generator 103, and heat from the flue gas stream 102 is utilized to heat the boiler feed water stream 104 to produce a steam stream 105. In certain embodiments, the waste heat steam generator 103 generates steam at pressures in the range of from about 15 to about 1100 pound-force per square inch gauge (psig). A reduced heat flue gas stream 106 then exits the waste heat steam generator 103 and enters an electrostatic precipitator 107, which removes any catalyst fines 108 present in the reduced heat flue gas stream 106 to produce a reduced fines flue gas stream 109. In certain exemplary embodiments, the reduced fines flue gas stream 109 has a temperature in the range of from about 350 to about 800 °F.

[0035] In certain embodiments, when the combustion of coke is incomplete and the flue gas stream 102 contains significant amounts of carbon monoxide, at least a portion 102b of the flue gas stream 102 enters a carbon monoxide boiler 110. A fuel stream 111 and an air stream 112 also enter the boiler 110 to combust the carbon monoxide in the flue gas stream 102. A boiler feed water stream 114 also enters the boiler 110, and heat from the combustion process and the flue gas stream 102 is utilized to heat the boiler feed water stream 114 to produce a steam stream 115. In certain embodiments, the boiler 110 operates at a pressure in the range of from about 15 to about 1100 psig. A reduced heat flue gas stream 116 then exits the boiler 110 and enters an electrostatic precipitator 117 to remove any catalyst fines 118 present in the reduced heat flue gas stream 116 to produce a reduced fines flue gas stream

119. In certain embodiments, the reduced fines flue gas stream 119 has a temperature in the range of from about 350 to about 800 °F.

[0036] In certain embodiments, a portion 102a of the flue gas stream 102 can be routed through the waste heat steam generator 103, and the resulting reduced fines flue gas stream 109 can be combined with a remainder portion 102c of the flue gas stream 102 afterwards prior to entering a heat exchanger 120. The heat exchanger 120 is a part of the organic Rankine cycle. The heat exchanger 120 may be any type of heat exchanger capable of transferring heat from one fluid stream to another fluid stream. Suitable examples of heat exchangers include, but are not limited to, heaters, vaporizers, economizers, and other heat recovery heat exchangers. For example, the heat exchanger 120 may be a shell-and-tube heat exchanger, a plate-fin-tube coil type of exchanger, a bare tube or finned tube bundle, a welded plate heat exchanger, and the like. Thus, the present invention should not be considered as limited to any particular type of heat exchanger unless such limitations are expressly set forth in the appended claims. In certain other embodiments, the flue gas stream 102 can be entirely routed through the waste heat steam generator 103. In certain alternative embodiments, a portion 102b of the flue gas stream 102 can be routed through the boiler 110, and the resulting reduced fines flue gas stream 119 can be combined with the remainder portion 102c of the flue gas stream 102 afterwards prior to entering the heat exchanger 120. In certain other embodiments, the flue gas stream 102 can be entirely routed through the boiler 110. In yet other embodiments, a first portion 102a of the flue gas stream 102 can be routed through the waste heat steam generator 103, a second portion 102b of the flue gas stream 102 can be routed through the boiler 110, and the resulting reduced fines flue gas streams 109, 119 can be combined with a third portion 102c of the flue gas stream 102 afterwards prior to entering the heat exchanger 120. In certain other embodiments, the flue gas stream 102 can directly enter heat exchanger 120. One having ordinary skill in the art will recognize that the flue gas stream 102 can be treated any number of ways and in any combination to produce an input flue gas stream 125 prior to entering the heat exchanger 120.

[0037] At least a portion 125a of the input flue gas stream 125 is then utilized to heat a working fluid stream 126 in the heat exchanger 120. The portion 125a of the input flue gas stream 125 thermally contacts the working fluid stream 126 to transfer heat to the working fluid stream 126. As used herein, the phrase “thermally contact” generally refers to the exchange of energy through the process of heat, and does not imply physical mixing or direct physical contact of the materials. In certain exemplary embodiments, the working fluid stream 126 includes any working fluid suitable for use in an organic Rankine cycle. The

portion 125a of the input flue gas stream 125 and the working fluid stream 126 enter the heat exchanger 120 to produce a heated working fluid stream 128 and a reduced heat flue gas stream 129. In certain exemplary embodiments, the working fluid stream 126 has a temperature in the range of from about 80 to about 150 °F. In certain exemplary embodiments, the heated working fluid stream 128 has a temperature in the range of from about 160 to about 450 °F. In certain exemplary embodiments, the heated working fluid stream 128 is vaporized. In certain exemplary embodiments, the heated working fluid stream 128 is vaporized within a supercritical process, with conditions at a temperature and pressure above the critical point for the heated working fluid stream 128. In certain exemplary embodiments, the heated working fluid stream 128 is superheated. In certain exemplary embodiments, the working fluid stream 126 enters as a high pressure liquid and the heated working fluid stream 128 exits as a superheated vapor. In certain exemplary embodiments, the reduced heat flue gas stream 129 has a temperature in the range of from about 300 to about 750 °F. In certain embodiments, the reduced heat flue gas stream 129 is cooled to a temperature just above its dew point. The reduced heat flue gas stream 129 can then be vented to the atmosphere. In certain exemplary embodiments, a portion 125b of the input flue gas stream 125 is diverted through a bypass valve 130 and then combined with the reduced heat flue gas stream 129 to produce an exhaust flue gas stream 131 to be vented to the atmosphere. In certain exemplary embodiments, the exhaust flue gas stream 131 has a temperature in the range of from about 300 °F to about 800 °F. In certain exemplary embodiments, the entire portion 125a of the input flue gas stream 125 is directed through the heat exchanger 120, and is exhausted to the atmosphere at a temperature of about 300 °F.

[0038] At least a portion 128a of the heated working fluid stream 128 is then directed to a turbine-generator system 150, which is a part of the organic Rankine cycle. For purposes of the present application, the term "turbine" will be understood to include both turbines and expanders or any device wherein useful work is generated by expanding a high pressure gas within the device. The portion 128a of the heated working fluid stream 128 is expanded in the turbine-generator system 150 to produce an expanded working fluid stream 151 and generate power. In certain exemplary embodiments, the expanded working fluid stream 151 has a temperature in the range of from about 80 to about 440 °F. In certain embodiments, the turbine-generator system 150 generates electricity or electrical power. In certain other embodiments, the turbine-generator system 150 generates mechanical power. In certain embodiments, a portion 128b of the heated working fluid stream 128 is diverted through a bypass valve 152 and then combined with the expanded working fluid stream 151 to produce

an intermediate working fluid stream 155. In certain exemplary embodiments, the intermediate working fluid stream 155 has a temperature in the range of from about 85 to about 445 °F.

[0039] The intermediate working fluid stream 155 is then directed to one or more air-cooled condensers 157. The air-cooled condensers 157 are a part of the organic Rankine cycle. In certain exemplary embodiments, the organic Rankine cycle includes two air-cooled condensers 157 in series. Suitable examples of air-cooled condensers include, but are not limited to, air coolers and evaporative coolers. In certain exemplary embodiments, each of the air-cooled condensers 157 is controlled by a variable frequency drive 158. The air-cooled condensers 157 cool the intermediate working fluid stream 155 to form a condensed working fluid stream 159. In certain exemplary embodiments, the condensed working fluid stream 159 has a temperature in the range of from about 80 to about 150 °F. The condensed working fluid stream 159 is then directed to a pump 160. The pump 160 is a part of the organic Rankine cycle. The pump 160 may be any type of commercially available pump sufficient to meet the pumping requirements of the systems disclosed herein. In certain exemplary embodiments, the pump 160 is controlled by a variable frequency drive 161. The pump 160 returns the condensed working fluid stream 159 to a higher pressure to produce the working fluid stream 126 that is directed to the heat exchanger 120.

[0040] FIG. 2 shows a direct heat recovery system 200 according to another exemplary embodiment. The heat recovery system 200 is the same as that described above with regard to heat recovery system 100, except as specifically stated below. For the sake of brevity, the similarities will not be repeated hereinbelow. Referring now to FIG. 2, the intermediate working fluid stream 155 is then directed to one or more water-cooled condensers 257. The water-cooled condensers 257 are a part of the organic Rankine cycle. In certain exemplary embodiments, the organic Rankine cycle includes two water-cooled condensers 257 in series. The water-cooled condensers 257 cool the intermediate working fluid stream 155 to form a condensed working fluid stream 259. In certain exemplary embodiments, the condensed working fluid stream 259 has a temperature in the range of from about 80 to about 150 °F. The condensed working fluid stream 259 is then directed to the pump 160 and is returned to a higher pressure to produce the working fluid stream 126 that is directed to the heat exchanger 120.

[0041] FIG. 3 shows an indirect heat recovery system 300 for utilization of an input flue gas stream 325. The input flue gas stream 325 is the same as that described above with regard to input flue gas stream 125, and for the sake of brevity, the similarities will not be

repeated hereinbelow. Referring now to FIG. 3, at least a portion 325a of the input flue gas stream 325 is utilized to heat a working fluid stream 326 in a heat exchanger 320. The portion 325a of the input flue gas stream 325 thermally contacts the working fluid stream 326 and transfers heat to the working fluid stream 326. Suitable examples of the working fluid stream 326 include, but are not limited to, water, glycols, therminol fluids, alkanes, alkenes, chlorofluorocarbons, hydrofluorocarbons, carbon dioxide (CO₂), refrigerants, and mixtures of other hydrocarbon components. The portion 325a of the input flue gas stream 325 and the working fluid stream 326 enter the heat exchanger 320 to produce a heated working fluid stream 328 and a reduced heat flue gas stream 329. In certain exemplary embodiments, the working fluid stream 326 has a temperature in the range of from about 85 to about 160 °F. In certain exemplary embodiments, the heated working fluid stream 328 has a temperature in the range of from about 165 to about 455 °F. In certain exemplary embodiments, the reduced heat flue gas stream 329 has a temperature in the range of from about 300 to about 750 °F. In certain embodiments, the reduced heat flue gas stream 329 is cooled to a temperature just above its dew point. The reduced heat flue gas stream 329 can then be vented to the atmosphere. In certain exemplary embodiments, a portion 325b of the input flue gas stream 325 is diverted through a bypass valve 330 and then combined with the reduced heat flue gas stream 329 to produce an exhaust flue gas stream 331 to be vented to the atmosphere. In certain exemplary embodiments, the exhaust flue gas stream 331 has a temperature in the range of from about 300 to about 800 °F. In certain exemplary embodiments, the input flue gas stream 325 is entirely directed through the heat exchanger 320, and is exhausted to the atmosphere at a temperature of about 300 °F.

[0042] A portion 328a of the heated working fluid stream 328 enters a heat exchanger 335 to heat a working fluid stream 336 to produce a heated working fluid stream 337 and a reduced heat working fluid stream 338. The portion 328a of the heated working fluid stream 328 thermally contacts the working fluid stream 336 and transfers heat to the working fluid stream 336. In certain exemplary embodiments, the working fluid stream 336 includes any working fluid suitable for use in an organic Rankine cycle. In certain exemplary embodiments, the working fluid stream 336 has a temperature in the range of from about 80 to about 150 °F. In certain exemplary embodiments, the heated working fluid stream 337 has a temperature in the range of from about 160 to about 450 °F. In certain exemplary embodiments, the heated working fluid stream 337 is vaporized. In certain exemplary embodiments, the heated working fluid stream 337 is vaporized within a supercritical process. In certain exemplary embodiments, the heated working fluid stream 337 is

superheated. In certain exemplary embodiments, the reduced heat working fluid stream 338 has a temperature in the range of from about 85 to about 155 °F. In certain embodiments, a portion 328b of the heated working fluid stream 328 is diverted through a bypass valve 339 and then combined with the reduced heat working fluid stream 338 to produce an intermediate working fluid stream 340. In certain exemplary embodiments, the intermediate working fluid stream 340 has a temperature in the range of from about 85 to about 160 °F. The intermediate working fluid stream 340 is then directed to a pump 342. In certain exemplary embodiments, the pump 342 is controlled by a variable frequency drive 343. The pump 342 returns the intermediate working fluid stream 340 to produce the working fluid stream 326 that enters the heat exchanger 320.

[0043] At least a portion 337a of the heated working fluid stream 337 is then directed to a turbine-generator system 350, which is a part of the organic Rankine cycle. The portion 337a of the heated working fluid stream 337 is expanded in the turbine-generator system 350 to produce an expanded working fluid stream 351 and generate power. In certain exemplary embodiments, the expanded working fluid stream 351 has a temperature in the range of from about 80 to about 440 °F. In certain embodiments, the turbine-generator system 350 generates electricity or electrical power. In certain other embodiments, the turbine-generator system 350 generates mechanical power. In certain embodiments, a portion 337b of the heated working fluid stream 337 is diverted through a bypass valve 352 and then combined with the expanded working fluid stream 351 to produce an intermediate working fluid stream 355. In certain exemplary embodiments, the intermediate working fluid stream 355 has a temperature in the range of from about 85 to about 445 °F.

[0044] The intermediate working fluid stream 355 is then directed to one or more air-cooled condensers 357. The air-cooled condensers 357 are a part of the organic Rankine cycle. In certain exemplary embodiments, the organic Rankine cycle includes two air-cooled condensers 357 in series. In certain exemplary embodiments, each of the air-cooled condensers 357 is controlled by a variable frequency drive 358. The air-cooled condensers 357 cool the intermediate working fluid stream 355 to form a condensed working fluid stream 359. In certain exemplary embodiments, the condensed working fluid stream 359 has a temperature in the range of from about 80 to about 150 °F. The condensed working fluid stream 359 is then directed to a pump 360. The pump 360 is a part of the organic Rankine cycle. In certain exemplary embodiments, the pump 360 is controlled by a variable frequency drive 361. The pump 360 returns the condensed working fluid stream 359 to a

higher pressure to produce the working fluid stream 336 that is directed to the heat exchanger 335.

[0045] FIG. 4 shows an indirect heat recovery system 400 according to another exemplary embodiment. The heat recovery system 400 is the same as that described above with regard to heat recovery system 300, except as specifically stated below. For the sake of brevity, the similarities will not be repeated hereinbelow. Referring now to FIG. 4, the intermediate working fluid stream 355 is directed to one or more water-cooled condensers 457. The water-cooled condensers 457 are a part of the organic Rankine cycle. In certain exemplary embodiments, the organic Rankine cycle includes two water-cooled condensers 457 in series. The water-cooled condensers 457 cool the intermediate working fluid stream 355 to form a condensed working fluid stream 459. In certain exemplary embodiments, the condensed working fluid stream 459 has a temperature in the range of from about 80 to about 150 °F. The condensed working fluid stream 459 is then directed to the pump 360 and is returned to a higher pressure to produce the working fluid stream 336 that is directed to the heat exchanger 335.

[0046] Referring now to FIG. 5, a direct heat recovery system 500 for utilizing heat from a high temperature reactor, such as a convection section of a fired heater 502, is shown. In certain embodiments, the high temperature reactor is an incinerator, hydrotreater, catalytic reformer, or isomerization unit. Generally, the fired heater 502 is used in a refinery to heat a feedstock stream 503 going to a refinery unit. Suitable examples of refinery units include, but are not limited to, crude distillation units and vacuum distillation units. In certain embodiments, a fuel stream 505 and an air stream 506 enter a burner section of the fired heater 502 and heat the feedstock stream 503 to produce a heated feedstock stream 507. In certain embodiments, the heat from the resulting flue gas stream 508 can then be used to heat a steam stream 509 to produce a saturated or superheated steam stream 510 and a flue gas stream 511. In certain exemplary embodiments, the flue gas stream 511 has a temperature in the range of from about 350 to about 800 °F.

[0047] The flue gas stream 511 can then be utilized to heat a portion 512a of a working fluid stream 512. In certain exemplary embodiments, the working fluid stream 512 includes any working fluid suitable for use in an organic Rankine cycle. The flue gas stream 511 and the portion 512a of the working fluid stream 512 enter a heater 513 to produce a heated working fluid stream 514 and a reduced heat flue gas stream 515. The flue gas stream 511 thermally contacts the working fluid stream 512 and transfers heat to the working fluid stream 512. The heater 513 is a part of the organic Rankine cycle, and can be integrated into

the convection section of the fired heater 502. In certain exemplary embodiments, the portion 512a of the working fluid stream 512 has a temperature in the range of from about 80 to about 150 °F. In certain exemplary embodiments, the heated working fluid stream 514 has a temperature in the range of from about 160 to about 450 °F. In certain exemplary embodiments, the heated working fluid stream 514 is vaporized. In certain exemplary embodiments, the heated working fluid stream 514 is vaporized within a supercritical process. In certain exemplary embodiments, the heated working fluid stream 514 is superheated. In certain exemplary embodiments, the reduced heat flue gas stream 515 has a temperature in the range of from about 300 to about 750 °F. In certain embodiments, the reduced heat flue gas stream 515 has a temperature of about 300 °F. The reduced heat flue gas stream 515 can then be vented to the atmosphere. In certain exemplary embodiments, a portion 512b of the working fluid stream 512 is diverted through a bypass valve 517 and then combined with the heated working fluid stream 514 to produce a working fluid stream 518. In certain exemplary embodiments, the working fluid stream 518 has a temperature in the range of from about 155 to about 455 °F. In certain exemplary embodiments, the working fluid stream 512 is entirely directed through the heater 513.

[0048] At least a portion 518a of the working fluid stream 518 is then directed to a turbine-generator system 550 where the portion 518a of the working fluid stream 518 is expanded to produce an expanded working fluid stream 551 and generate power. In certain exemplary embodiments, the expanded working fluid stream 551 has a temperature in the range of from about 80 to about 440 °F. In certain embodiments, the turbine-generator system 550 generates electricity or electrical power. In certain other embodiments, the turbine-generator system 550 generates mechanical power. In certain embodiments, a portion 518b of the working fluid stream 518 is diverted through a bypass valve 552 and then combined with the expanded working fluid stream 551 to produce an intermediate working fluid stream 555. In certain exemplary embodiments, the intermediate working fluid stream 555 has a temperature in the range of from about 85 to about 445 °F.

[0049] The intermediate working fluid stream 555 is then directed to one or more air-cooled condensers 557. The air-cooled condensers 557 are a part of the organic Rankine cycle. In certain exemplary embodiments, the organic Rankine cycle includes two air-cooled condensers 557 in series. In certain exemplary embodiments, each of the air-cooled condensers 557 is controlled by a variable frequency drive 558. The air-cooled condensers 557 cool the intermediate working fluid stream 555 to form a condensed working fluid stream 559. In certain exemplary embodiments, the condensed working fluid stream 559 has a

temperature in the range of from about 80 to about 150 °F. The condensed working fluid stream 559 is then directed to a pump 560. The pump 560 is a part of the organic Rankine cycle. In certain exemplary embodiments, the pump 560 is controlled by a variable frequency drive 561. The pump 560 returns the condensed working fluid stream 559 to a higher pressure to produce the working fluid stream 512 that is directed to the heater 513.

[0050] FIG. 6 shows a direct heat recovery system 600 according to another exemplary embodiment. The heat recovery system 600 is the same as that described above with regard to heat recovery system 500, except as specifically stated below. For the sake of brevity, the similarities will not be repeated hereinbelow. Referring now to FIG. 6, the intermediate working fluid stream 555 is then directed to one or more water-cooled condensers 657. The water-cooled condensers 657 are a part of the organic Rankine cycle. In certain exemplary embodiments, the organic Rankine cycle includes two water-cooled condensers 657 in series. The water-cooled condensers 657 cool the intermediate working fluid stream 555 to form a condensed working fluid stream 659. In certain exemplary embodiments, the condensed working fluid stream 659 has a temperature in the range of from about 80 to about 150 °F. The condensed working fluid stream 659 is then directed to the pump 560 and is returned to a higher pressure to produce the working fluid stream 512 that is directed to the heater 513.

[0051] FIG. 7 shows an indirect heat recovery system 700 for utilization of a flue gas stream 711. The flue gas stream 711 is the same as that described above with regard to flue gas stream 511, and for the sake of brevity, the similarities will not be repeated hereinbelow. Referring now to FIG. 7, the flue gas stream 711 is utilized to heat a working fluid stream 712 in a heater 713. The flue gas stream 711 thermally contacts the working fluid stream 712 and transfers heat to the working fluid stream 712. Suitable examples of the working fluid stream 712 include, but are not limited to, water, glycols, therminol fluids, alkanes, alkenes, chlorofluorocarbons, hydrofluorocarbons, carbon dioxide (CO₂), refrigerants, and mixtures of other hydrocarbon components. The flue gas stream 711 and the portion 712a of the working fluid stream 712 enter the heater 713 to produce a heated working fluid stream 714 and a reduced heat flue gas stream 715. The heater 713 can be integrated into the convection section of a fired heater 702. In certain exemplary embodiments, the portion 712a of the working fluid stream 712 has a temperature in the range of from about 85 to about 160 °F. In certain exemplary embodiments, the heated working fluid stream 714 has a temperature in the range of from about 165 to about 455 °F. In certain exemplary embodiments, the reduced heat flue gas stream 715 has a temperature in the range of from about 300 to about 750 °F.

The reduced heat flue gas stream 715 can then be vented to the atmosphere. In certain exemplary embodiments, a portion 712b of the working fluid stream 712 is diverted through a bypass valve 717 and then combined with the heated working fluid stream 714 to produce a working fluid stream 718. In certain exemplary embodiments, the working fluid stream 718 has a temperature in the range of from about 165 to about 455 °F. In certain exemplary embodiments, the working fluid stream 712 is entirely directed through the heater 713.

[0052] A portion 718a of the working fluid stream 718 enters a heater 735 to heat a working fluid stream 736 to produce a heated working fluid stream 737 and a reduced heat working fluid stream 738. The portion 718a of the working fluid stream 718 thermally contacts the working fluid stream 736 and transfers heat to the working fluid stream 736. In certain exemplary embodiments, the working fluid stream 736 includes any working fluid suitable for use in an organic Rankine cycle. In certain exemplary embodiments, the working fluid stream 736 has a temperature in the range of from about 80 to about 150 °F. In certain exemplary embodiments, the heated working fluid stream 737 has a temperature in the range of from about 160 to about 450 °F. In certain exemplary embodiments, the heated working fluid stream 737 is vaporized. In certain exemplary embodiments, the heated working fluid stream 737 is vaporized within a supercritical process. In certain exemplary embodiments, the heated working fluid stream 737 is superheated. In certain exemplary embodiments, the reduced heat working fluid stream 738 has a temperature in the range of from about 85 to about 155 °F. In certain embodiments, a portion 718b of the working fluid stream 718 is diverted through a bypass valve 739 and then combined with the reduced heat working fluid stream 738 to produce an intermediate working fluid stream 740. In certain exemplary embodiments, the intermediate working fluid stream 740 has a temperature in the range of from about 85 to about 160 °F. The intermediate working fluid stream 740 is directed to a pump 742. In certain exemplary embodiments, the pump 742 is controlled by a variable frequency drive 743. The pump 742 returns the intermediate working fluid stream 740 to produce the working fluid stream 712 that enters the heater 713.

[0053] At least a portion 737a of the heated working fluid stream 737 is then directed to a turbine-generator system 750, which is a part of the organic Rankine cycle. The portion 737a of the heated working fluid stream 737 is expanded in the turbine-generator system 750 to produce an expanded working fluid stream 751 and generate power. In certain exemplary embodiments, the expanded working fluid stream 751 has a temperature in the range of from about 80 to about 440 °F. In certain embodiments, the turbine-generator system 750 generates electricity or electrical power. In certain other embodiments, the turbine-generator

system 750 generates mechanical power. In certain embodiments, a portion 737b of the heated working fluid stream 737 is diverted through a bypass valve 752 and then combined with the expanded working fluid stream 751 to produce an intermediate working fluid stream 755. In certain exemplary embodiments, the intermediate working fluid stream 755 has a temperature in the range of from about 80 to about 445 °F.

[0054] The intermediate working fluid stream 755 is then directed to one or more air-cooled condensers 757. The air-cooled condensers 757 are a part of the organic Rankine cycle. In certain exemplary embodiments, the organic Rankine cycle includes two air-cooled condensers 757 in series. In certain exemplary embodiments, each of the air-cooled condensers 757 is controlled by a variable frequency drive 758. The air-cooled condensers 757 cool the intermediate working fluid stream 755 to form a condensed working fluid stream 759. In certain exemplary embodiments, the condensed working fluid stream 759 has a temperature in the range of from about 80 to about 150 °F. The condensed working fluid stream 759 is then directed to a pump 760. The pump 760 is a part of the organic Rankine cycle. In certain exemplary embodiments, the pump 760 is controlled by a variable frequency drive 761. The pump 760 returns the condensed working fluid stream 759 to a higher pressure to produce the working fluid stream 736 that is directed to the heater 735.

[0055] FIG. 8 shows an indirect heat recovery system 800 according to another exemplary embodiment. The heat recovery system 800 is the same as that described above with regard to heat recovery system 700, except as specifically stated below. For the sake of brevity, the similarities will not be repeated hereinbelow. Referring now to FIG. 8, the intermediate working fluid stream 755 is directed to one or more water-cooled condensers 857. The water-cooled condensers 857 are a part of the organic Rankine cycle. In certain exemplary embodiments, the organic Rankine cycle includes two water-cooled condensers 857 in series. The water-cooled condensers 857 cool the intermediate working fluid stream 755 to form a condensed working fluid stream 859. In certain exemplary embodiments, the condensed working fluid stream 859 has a temperature in the range of from about 80 to about 150 °F. The condensed working fluid stream 859 is then directed to the pump 760 and is returned to a higher pressure to produce the working fluid stream 736 that is directed to the heater 735.

[0056] Referring now to FIG. 9, a direct heat recovery system 900 for utilizing a waste heat by-product stream 901 from a steam generator 902 is shown. Generally, the steam generator 902 is used wherever a source of steam is required. In certain embodiments, a fuel stream 905 and an air stream 906 enter a burner section 902a of the steam generator 902 and

heat a water stream 903 to produce a steam stream 907 and the waste heat by-product stream 901. In certain exemplary embodiments, the waste heat by-product stream 901 has a temperature in the range of from about 400 to about 1000 °F.

[0057] In certain exemplary embodiments, the waste heat by-product stream 901 is directed to a diverter valve 908 and can be separated into an exhaust stream 909 and a discharge stream 910. The discharge stream 910 can be directed to a bypass stack 911 and then discharged to the atmosphere. A portion 909a of the exhaust stream 909 can be utilized to heat a working fluid stream 912. The portion 909a of the exhaust stream 909 thermally contacts the working fluid stream 912 and transfers heat to the working fluid stream 912. In certain exemplary embodiments, the working fluid stream 912 includes any working fluid suitable for use in an organic Rankine cycle. The portion 909a of the exhaust stream 909 and the working fluid stream 912 enter a heater 913 to produce a heated working fluid stream 914 and a reduced heat exhaust stream 915. The heater 913 is a part of the organic Rankine cycle. In certain exemplary embodiments, the working fluid stream 912 has a temperature in the range of from about 80 to about 150 °F. In certain exemplary embodiments, the heated working fluid stream 914 has a temperature in the range of from about 160 to about 450 °F. In certain exemplary embodiments, the heated working fluid stream 914 is vaporized. In certain exemplary embodiments, the heated working fluid stream 914 is vaporized within a supercritical process. In certain exemplary embodiments, the heated working fluid stream 914 is superheated. In certain exemplary embodiments, the reduced heat exhaust stream 915 has a temperature in the range of from about 300 to about 900 °F. The reduced heat exhaust stream 915 can then be directed to a primary stack 916 and discharged to the atmosphere. In certain exemplary embodiments, the steam generator 902 and the heater 913 can be integrated into the primary stack 916. In certain exemplary embodiments, the reduced heat exhaust stream 915 can be directed to an incinerator or a scrubber prior to being discharged to the atmosphere. In certain exemplary embodiments, a portion 909b of the exhaust stream 909 is diverted through a bypass valve 917 and then combined with the reduced heat exhaust stream 915 to produce an exhaust stream 918. In certain exemplary embodiments, the exhaust stream 918 has a temperature in the range of from about 300 to about 905 °F. In certain exemplary embodiments, the exhaust stream 909 is entirely directed through the heater 913.

[0058] At least a portion 914a of the heated working fluid stream 914 is then directed to a turbine-generator system 950 where the portion 914a of the heated working fluid stream 914 is expanded to produce an expanded working fluid stream 951 and generate power. In certain exemplary embodiments, the expanded working fluid stream 951 has a temperature in

the range of from about 80 to about 440 °F. In certain embodiments, a portion 914b of the heated working fluid stream 914 is diverted through a bypass valve 952 and then combined with the expanded working fluid stream 951 to produce an intermediate working fluid stream 955. In certain exemplary embodiments, the intermediate working fluid stream 955 has a temperature in the range of from about 80 to about 445 °F.

[0059] The intermediate working fluid stream 955 is then directed to one or more air-cooled condensers 957. The air-cooled condensers 957 are a part of the organic Rankine cycle. In certain exemplary embodiments, the organic Rankine cycle includes two air-cooled condensers 957 in series. In certain exemplary embodiments, each of the air-cooled condensers 957 is controlled by a variable frequency drive 958. The air-cooled condensers 957 cool the intermediate working fluid stream 955 to form a condensed working fluid stream 959. In certain exemplary embodiments, the condensed working fluid stream 959 has a temperature in the range of from about 80 to about 150 °F. The condensed working fluid stream 959 is then directed to a pump 960. The pump 960 is a part of the organic Rankine cycle. In certain exemplary embodiments, the pump 960 is controlled by a variable frequency drive 961. The pump 960 returns the condensed working fluid stream 959 to a higher pressure to produce the working fluid stream 912 that is directed to the heater 913.

[0060] FIG. 10 shows a direct heat recovery system 1000 according to another exemplary embodiment. The heat recovery system 1000 is the same as that described above with regard to heat recovery system 900, except as specifically stated below. For the sake of brevity, the similarities will not be repeated hereinbelow. Referring now to FIG. 10, the intermediate working fluid stream 955 is then directed to one or more water-cooled condensers 1057. The water-cooled condensers 1057 are a part of the organic Rankine cycle. In certain exemplary embodiments, the organic Rankine cycle includes two water-cooled condensers 1057 in series. The water-cooled condensers 1057 cool the intermediate working fluid stream 955 to form a condensed working fluid stream 1059. In certain exemplary embodiments, the condensed working fluid stream 1059 has a temperature in the range of from about 80 to about 150 °F. The condensed working fluid stream 1059 is then directed to the pump 960 and is returned to a higher pressure to produce the working fluid stream 912 that is directed to the heater 913.

[0061] FIG. 11 shows an indirect heat recovery system 1100 for utilization of an exhaust stream 1109 from a steam generator 1102. The exhaust stream 1109 is the same as that described above with regard to exhaust stream 909, and for the sake of brevity, the similarities will not be repeated hereinbelow. A portion 1109a of the exhaust stream 1109

can be utilized to heat a working fluid stream 1112. The portion 1109a of the exhaust stream 1109 thermally contacts the working fluid stream 1112 and transfers heat to the working fluid stream 1112. Suitable examples of the working fluid stream 1112 include, but are not limited to, water, glycols, therminol fluids, alkanes, alkenes, chlorofluorocarbons, hydrofluorocarbons, carbon dioxide (CO₂), refrigerants, and mixtures of other hydrocarbon components. The portion 1109a of the exhaust stream 1109 and the working fluid stream 1112 enter a heater 1113 to produce a heated working fluid stream 1114 and a reduced heat exhaust stream 1115. In certain exemplary embodiments, the working fluid stream 1112 has a temperature in the range of from about 85 to about 160 °F. In certain exemplary embodiments, the heated working fluid stream 1114 has a temperature in the range of from about 165 to about 455 °F. In certain exemplary embodiments, the reduced heat exhaust stream 1115 has a temperature in the range of from about 300 to about 900 °F. The reduced heat exhaust stream 1115 can then be directed to a primary stack 1116 and discharged to the atmosphere. In certain exemplary embodiments, the steam generator 1102 and the heater 1113 can be integrated into the primary stack 1116. In certain exemplary embodiments, the reduced heat exhaust stream 1115 can be directed to an incinerator or a scrubber prior to being discharged to the atmosphere. In certain exemplary embodiments, a portion 1109b of the exhaust stream 1109 is diverted through a bypass valve 1117 and then combined with the reduced heat exhaust stream 1115 to produce an exhaust stream 1118. In certain exemplary embodiments, the exhaust stream 1118 has a temperature in the range of from about 300 to about 905 °F. In certain exemplary embodiments, the exhaust stream 1109 is entirely directed through the heater 1113.

[0062] At least a portion 1114a of the heated working fluid stream 1114 enters a heater 1135 to heat a working fluid stream 1136 to produce a heated working fluid stream 1137 and a reduced heat working fluid stream 1138. The portion 1114a of the heated working fluid stream 1114 thermally contacts the working fluid stream 1136 and transfers heat to the working fluid stream 1136. In certain exemplary embodiments, the working fluid stream 1136 includes any working fluid suitable for use in an organic Rankine cycle. In certain exemplary embodiments, the working fluid stream 1136 has a temperature in the range of from about 80 to about 150 °F. In certain exemplary embodiments, the heated working fluid stream 1137 has a temperature in the range of from about 160 to about 450 °F. In certain exemplary embodiments, the heated working fluid stream 1137 is vaporized. In certain exemplary embodiments, the heated working fluid stream 1137 is vaporized within a supercritical process. In certain exemplary embodiments, the heated working fluid stream

1137 is superheated. In certain exemplary embodiments, the reduced heat working fluid stream 1138 has a temperature in the range of from about 85 to about 155 °F. In certain embodiments, a portion 1114b of the working fluid stream 1114 is diverted through a bypass valve 1139 and then combined with the reduced heat working fluid stream 1138 to produce an intermediate working fluid stream 1140. In certain exemplary embodiments, the intermediate working fluid stream 1140 has a temperature in the range of from about 85 to about 160 °F. The intermediate working fluid stream 1140 is directed to a pump 1142. In certain exemplary embodiments, the pump 1142 is controlled by a variable frequency drive 1143. The pump 1142 returns the intermediate working fluid stream 1140 to produce the working fluid stream 1112 that enters the heater 1113.

[0063] At least a portion 1137a of the heated working fluid stream 1137 is then directed to a turbine-generator system 1150, which is a part of the organic Rankine cycle. The portion 1137a of the heated working fluid stream 1137 is expanded in the turbine-generator system 1150 to produce an expanded working fluid stream 1151 and generate power. In certain exemplary embodiments, the expanded working fluid stream 1151 has a temperature in the range of from about 80 to about 440 °F. In certain embodiments, the turbine-generator system 1150 generates electricity or electrical power. In certain other embodiments, the turbine-generator system 1150 generates mechanical power. In certain embodiments, a portion 1137b of the heated working fluid stream 1137 is diverted through a bypass valve 1152 and then combined with the expanded working fluid stream 1151 to produce an intermediate working fluid stream 1155. In certain exemplary embodiments, the intermediate working fluid stream 1155 has a temperature in the range of from about 80 to about 445 °F.

[0064] The intermediate working fluid stream 1155 is then directed to one or more air-cooled condensers 1157. The air-cooled condensers 1157 are a part of the organic Rankine cycle. In certain exemplary embodiments, the organic Rankine cycle includes two air-cooled condensers 1157 in series. In certain exemplary embodiments, each of the air-cooled condensers 1157 is controlled by a variable frequency drive 1158. The air-cooled condensers 1157 cool the intermediate working fluid stream 1155 to form a condensed working fluid stream 1159. In certain exemplary embodiments, the condensed working fluid stream 1159 has a temperature in the range of from about 80 to about 150 °F. The condensed working fluid stream 1159 is then directed to a pump 1160. The pump 1160 is a part of the organic Rankine cycle. In certain exemplary embodiments, the pump 1160 is controlled by a variable frequency drive 1161. The pump 1160 returns the condensed working fluid stream

1159 to a higher pressure to produce the working fluid stream 1136 that is directed to the heater 1135.

[0065] FIG. 12 shows an indirect heat recovery system 1200 according to another exemplary embodiment. The heat recovery system 1200 is the same as that described above with regard to heat recovery system 1100, except as specifically stated below. For the sake of brevity, the similarities will not be repeated hereinbelow. Referring now to FIG. 12, the intermediate working fluid stream 1155 is directed to one or more water-cooled condensers 1257. The water-cooled condensers 1257 are a part of the organic Rankine cycle. In certain exemplary embodiments, the organic Rankine cycle includes two water-cooled condensers 1257 in series. The water-cooled condensers 1257 cool the intermediate working fluid stream 1155 to form a condensed working fluid stream 1259. In certain exemplary embodiments, the condensed working fluid stream 1259 has a temperature in the range of from about 80 to about 150 °F. The condensed working fluid stream 1259 is then directed to the pump 1160 and is returned to a higher pressure to produce the working fluid stream 1136 that is directed to the heater 1135.

[0066] Referring now to FIG. 13, a direct heat recovery system 1300 for utilizing a waste heat by-product stream 1301 from a gas turbine 1302 is shown. In certain alternative embodiments, the gas turbine is replaced with a diesel generator (not shown). In certain embodiments, a fuel stream 1305 and an air stream 1306 enter the gas turbine 1302 and is combusted to produce energy and the waste heat by-product stream 1301. In certain exemplary embodiments, the waste heat by-product stream 1301 has a temperature in the range of from about 450 to about 1400 °F.

[0067] In certain exemplary embodiments, the waste heat by-product stream 1301 is directed to a diverter valve 1308 and can be separated into an exhaust stream 1309 and a discharge stream 1310. The discharge stream 1310 can be directed to a bypass stack 1311 and then discharged to the atmosphere. A portion 1309a of the exhaust stream 1309 can be utilized to heat a working fluid stream 1312. The portion 1309a of the exhaust stream 1309 thermally contacts the working fluid stream 1312 and transfers heat to the working fluid stream 1312. In certain exemplary embodiments, the working fluid stream 1312 includes any working fluid suitable for use in an organic Rankine cycle. The portion 1309a of the exhaust stream 1309 and the working fluid stream 1312 enter a heater 1313 to produce a heated working fluid stream 1314 and a reduced heat exhaust stream 1315. The heater 1313 is a part of the organic Rankine cycle. In certain exemplary embodiments, the working fluid stream 1312 has a temperature in the range of from about 80 to about 150 °F. In certain exemplary

embodiments, the heated working fluid stream 1314 has a temperature in the range of from about 160 to about 450 °F. In certain exemplary embodiments, the heated working fluid stream 1314 is vaporized. In certain exemplary embodiments, the heated working fluid stream 1314 is vaporized within a supercritical process. In certain exemplary embodiments, the heated working fluid stream 1314 is superheated. In certain exemplary embodiments, the reduced heat exhaust stream 1315 has a temperature in the range of from about 250 to about 1000 °F. The reduced heat exhaust stream 1315 can then be directed to a primary stack 1316 and discharged to the atmosphere. In certain exemplary embodiments, the reduced heat exhaust stream 1315 can be directed to an incinerator or a scrubber prior to being discharged to the atmosphere. In certain exemplary embodiments, a portion 1309b of the exhaust stream 1309 is diverted through a bypass valve 1317 and then combined with the reduced heat exhaust stream 1315 to produce an exhaust stream 1318. In certain exemplary embodiments, the exhaust stream 1318 has a temperature in the range of from about 250 to about 1100 °F. In certain exemplary embodiments, the exhaust stream 1309 is entirely directed through the heater 1313.

[0068] At least a portion 1314a of the heated working fluid stream 1314 is then directed to a turbine-generator system 1350 where the portion 1314a of the heated working fluid stream 1314 is expanded to produce an expanded working fluid stream 1351 and generate power. In certain exemplary embodiments, the expanded working fluid stream 1351 has a temperature in the range of from about 80 to about 440 °F. In certain embodiments, a portion 1314b of the heated working fluid stream 1314 is diverted through a bypass valve 1352 and then combined with the expanded working fluid stream 1351 to produce an intermediate working fluid stream 1355. In certain exemplary embodiments, the intermediate working fluid stream 1355 has a temperature in the range of from about 80 to about 445 °F.

[0069] The intermediate working fluid stream 1355 is then directed to one or more air-cooled condensers 1357. The air-cooled condensers 1357 are a part of the organic Rankine cycle. In certain exemplary embodiments, the organic Rankine cycle includes two air-cooled condensers 1357 in series. In certain exemplary embodiments, each of the air-cooled condensers 1357 is controlled by a variable frequency drive 1358. The air-cooled condensers 1357 cool the intermediate working fluid stream 1355 to form a condensed working fluid stream 1359. In certain exemplary embodiments, the condensed working fluid stream 1359 has a temperature in the range of from about 80 to about 150 °F. The condensed working fluid stream 1359 is then directed to a pump 1360. The pump 1360 is a part of the organic Rankine cycle. In certain exemplary embodiments, the pump 1360 is controlled by a

variable frequency drive 1361. The pump 1360 returns the condensed working fluid stream 1359 to a higher pressure to produce the working fluid stream 1312 that is directed to the heater 1313.

[0070] FIG. 14 shows a direct heat recovery system 1400 according to another exemplary embodiment. The heat recovery system 1400 is the same as that described above with regard to heat recovery system 1300, except as specifically stated below. For the sake of brevity, the similarities will not be repeated hereinbelow. Referring now to FIG. 14, the intermediate working fluid stream 1355 is then directed to one or more water-cooled condensers 1457. The water-cooled condensers 1457 are a part of the organic Rankine cycle. In certain exemplary embodiments, the organic Rankine cycle includes two water-cooled condensers 1457 in series. The water-cooled condensers 1457 cool the intermediate working fluid stream 1355 to form a condensed working fluid stream 1459. In certain exemplary embodiments, the condensed working fluid stream 1459 has a temperature in the range of from about 80 to about 150 °F. The condensed working fluid stream 1459 is then directed to the pump 1360 and is returned to a higher pressure to produce the working fluid stream 1312 that is directed to the heater 1313.

[0071] FIG. 15 shows an indirect heat recovery system 1500 for utilization of an exhaust stream 1509. The exhaust stream 1509 is the same as that described above with regard to exhaust stream 1309, and for the sake of brevity, the similarities will not be repeated hereinbelow. A portion 1509a of the exhaust stream 1509 can be utilized to heat a working fluid stream 1512. The portion 1509a of the exhaust stream 1509 thermally contacts the working fluid stream 1512 and transfers heat to the working fluid stream 1512. Suitable examples of the working fluid stream 1512 include, but are not limited to, water, glycols, therminol fluids, alkanes, alkenes, chlorofluorocarbons, hydrofluorocarbons, carbon dioxide (CO₂), refrigerants, and mixtures of other hydrocarbon components. The portion 1509a of the exhaust stream 1509 and the working fluid stream 1512 enter a heater 1513 to produce a heated working fluid stream 1514 and a reduced heat exhaust stream 1515. In certain exemplary embodiments, the working fluid stream 1512 has a temperature in the range of from about 85 to about 160 °F. In certain exemplary embodiments, the heated working fluid stream 1514 has a temperature in the range of from about 165 to about 455 °F. In certain exemplary embodiments, the reduced heat exhaust stream 1515 has a temperature in the range of from about 250 to about 1000 °F. The reduced heat exhaust stream 1515 can then be directed to a primary stack 1516 and discharged to the atmosphere. In certain exemplary embodiments, the reduced heat exhaust stream 1515 can be directed to an incinerator or a

scrubber prior to being discharged to the atmosphere. In certain exemplary embodiments, a portion 1509b of the exhaust stream 1509 is diverted through a bypass valve 1517 and then combined with the reduced heat exhaust stream 1515 to produce an exhaust stream 1518. In certain exemplary embodiments, the exhaust stream 1518 has a temperature in the range of from about 250 to about 1100 °F. In certain exemplary embodiments, the exhaust stream 1509 is entirely directed through the heater 1513.

[0072] At least a portion 1514a of the heated working fluid stream 1514 enters a heater 1535 to heat a working fluid stream 1536 to produce a heated working fluid stream 1537 and a reduced heat working fluid stream 1538. The portion 1514a of the heated working fluid stream 1514 thermally contacts the working fluid stream 1536 and transfers heat to the working fluid stream 1536. In certain exemplary embodiments, the working fluid stream 1536 includes any working fluid suitable for use in an organic Rankine cycle. In certain exemplary embodiments, the working fluid stream 1536 has a temperature in the range of from about 80 to about 150 °F. In certain exemplary embodiments, the heated working fluid stream 1537 has a temperature in the range of from about 160 to about 450 °F. In certain exemplary embodiments, the heated working fluid stream 1537 is vaporized. In certain exemplary embodiments, the heated working fluid stream 1537 is vaporized within a supercritical process. In certain exemplary embodiments, the heated working fluid stream 1537 is superheated. In certain exemplary embodiments, the reduced heat working fluid stream 1538 has a temperature in the range of from about 85 to about 155 °F. In certain embodiments, a portion 1514b of the working fluid stream 1514 is diverted through a bypass valve 1539 and then combined with the reduced heat working fluid stream 1538 to produce an intermediate working fluid stream 1540. In certain exemplary embodiments, the intermediate working fluid stream 1540 has a temperature in the range of from about 85 to about 160 °F. The intermediate working fluid stream 1540 is directed to a pump 1542. In certain exemplary embodiments, the pump 1542 is controlled by a variable frequency drive 1543. The pump 1542 returns the intermediate working fluid stream 1540 to produce the working fluid stream 1512 that enters the heater 1513.

[0073] At least a portion 1537a of the heated working fluid stream 1537 is then directed to a turbine-generator system 1550, which is a part of the organic Rankine cycle. The portion 1537a of the heated working fluid stream 1537 is expanded in the turbine-generator system 1550 to produce an expanded working fluid stream 1551 and generate power. In certain exemplary embodiments, the expanded working fluid stream 1551 has a temperature in the range of from about 80 to about 440 °F. In certain embodiments, the

turbine-generator system 1550 generates electricity or electrical power. In certain other embodiments, the turbine-generator system 1550 generates mechanical power. In certain embodiments, a portion 1537b of the heated working fluid stream 1537 is diverted through a bypass valve 1552 and then combined with the expanded working fluid stream 1551 to produce an intermediate working fluid stream 1555. In certain exemplary embodiments, the intermediate working fluid stream 1555 has a temperature in the range of from about 80 to about 445 °F.

[0074] The intermediate working fluid stream 1555 is then directed to one or more air-cooled condensers 1557. The air-cooled condensers 1557 are a part of the organic Rankine cycle. In certain exemplary embodiments, the organic Rankine cycle includes two air-cooled condensers 1557 in series. In certain exemplary embodiments, each of the air-cooled condensers 1557 is controlled by a variable frequency drive 1558. The air-cooled condensers 1557 cool the intermediate working fluid stream 1555 to form a condensed working fluid stream 1559. In certain exemplary embodiments, the condensed working fluid stream 1559 has a temperature in the range of from about 80 to about 150 °F. The condensed working fluid stream 1559 is then directed to a pump 1560. The pump 1560 is a part of the organic Rankine cycle. In certain exemplary embodiments, the pump 1560 is controlled by a variable frequency drive 1561. The pump 1560 returns the condensed working fluid stream 1559 to a higher pressure to produce the working fluid stream 1536 that is directed to the heater 1535.

[0075] FIG. 16 shows an indirect heat recovery system 1600 according to another exemplary embodiment. The heat recovery system 1600 is the same as that described above with regard to heat recovery system 1500, except as specifically stated below. For the sake of brevity, the similarities will not be repeated hereinbelow. Referring now to FIG. 16, the intermediate working fluid stream 1555 is directed to one or more water-cooled condensers 1657. The water-cooled condensers 1657 are a part of the organic Rankine cycle. In certain exemplary embodiments, the organic Rankine cycle includes two water-cooled condensers 1657 in series. The water-cooled condensers 1657 cool the intermediate working fluid stream 1555 to form a condensed working fluid stream 1659. In certain exemplary embodiments, the condensed working fluid stream 1659 has a temperature in the range of from about 80 to about 150 °F. The condensed working fluid stream 1659 is then directed to the pump 1560 and is returned to a higher pressure to produce the working fluid stream 1536 that is directed to the heater 1535.

[0076] Referring now to FIG. 17, a direct heat recovery system 1700 for utilizing a heat by-product stream 1701 from a process column 1702 is shown. Suitable examples of process columns include, but are not limited to, distillation columns and strippers. In certain exemplary embodiments, the heat by-product stream 1701 has a temperature in the range of from about 170 to about 700 °F. A portion 1701a of the heat by-product stream 1701 can be utilized to heat a working fluid stream 1712. The portion 1701a of the heat by-product stream 1701 thermally contacts the working fluid stream 1712 and transfers heat to the working fluid stream 1712. In certain exemplary embodiments, the working fluid stream 1712 includes any working fluid suitable for use in an organic Rankine cycle. The portion 1701a of the heat by-product stream 1701 and the working fluid stream 1712 enter a heater 1713 to produce a heated working fluid stream 1714 and a reduced heat exhaust stream 1715. The heater 1713 is a part of the organic Rankine cycle. In certain exemplary embodiments, the working fluid stream 1712 has a temperature in the range of from about 80 to about 150 °F. In certain exemplary embodiments, the heated working fluid stream 1714 has a temperature in the range of from about 160 to about 450 °F. In certain exemplary embodiments, the heated working fluid stream 1714 is vaporized. In certain exemplary embodiments, the heated working fluid stream 1714 is vaporized within a supercritical process. In certain exemplary embodiments, the heated working fluid stream 1714 is superheated. In certain exemplary embodiments, the reduced heat exhaust stream 1715 has a temperature in the range of from about 90 to about 500 °F. The reduced heat exhaust stream 1715 can then be vented to the atmosphere. In certain exemplary embodiments, a portion 1701b of the heat by-product stream 1701 is diverted through a bypass valve 1717 and then combined with the reduced heat exhaust stream 1715 to produce an exhaust stream 1718. In certain exemplary embodiments, the exhaust stream 1718 has a temperature in the range of from about 90 to about 510 °F. In certain exemplary embodiments, the heat by-product stream 1701 is entirely directed through the heater 1713.

[0077] At least a portion 1714a of the heated working fluid stream 1714 is then directed to a turbine-generator system 1750 where the portion 1714a of the heated working fluid stream 1714 is expanded to produce an expanded working fluid stream 1751 and generate power. In certain exemplary embodiments, the expanded working fluid stream 1751 has a temperature in the range of from about 80 to about 440 °F. In certain embodiments, a portion 1714b of the heated working fluid stream 1714 is diverted through a bypass valve 1752 and then combined with the expanded working fluid stream 1751 to produce an

intermediate working fluid stream 1755. In certain exemplary embodiments, the intermediate working fluid stream 1755 has a temperature in the range of from about 80 to about 455 °F.

[0078] The intermediate working fluid stream 1755 is then directed to one or more air-cooled condensers 1757. The air-cooled condensers 1757 are a part of the organic Rankine cycle. In certain exemplary embodiments, the organic Rankine cycle includes two air-cooled condensers 1757 in series. In certain exemplary embodiments, each of the air-cooled condensers 1757 is controlled by a variable frequency drive 1758. The air-cooled condensers 1757 cool the intermediate working fluid stream 1755 to form a condensed working fluid stream 1759. In certain exemplary embodiments, the condensed working fluid stream 1759 has a temperature in the range of from about 80 to about 150 °F. The condensed working fluid stream 1759 is then directed to a pump 1760. The pump 1760 is a part of the organic Rankine cycle. In certain exemplary embodiments, the pump 1760 is controlled by a variable frequency drive 1761. The pump 1760 returns the condensed working fluid stream 1759 to a higher pressure to produce the working fluid stream 1712 that is directed to the heater 1713.

[0079] FIG. 18 shows a direct heat recovery system 1800 according to another exemplary embodiment. The heat recovery system 1800 is the same as that described above with regard to heat recovery system 1700, except as specifically stated below. For the sake of brevity, the similarities will not be repeated hereinbelow. Referring now to FIG. 18, the intermediate working fluid stream 1755 is then directed to one or more water-cooled condensers 1857. The water-cooled condensers 1857 are a part of the organic Rankine cycle. In certain exemplary embodiments, the organic Rankine cycle includes two water-cooled condensers 1857 in series. The water-cooled condensers 1857 cool the intermediate working fluid stream 1755 to form a condensed working fluid stream 1859. In certain exemplary embodiments, the condensed working fluid stream 1859 has a temperature in the range of from about 80 to about 150 °F. The condensed working fluid stream 1859 is then directed to the pump 1760 and is returned to a higher pressure to produce the working fluid stream 1712 that is directed to the heater 1713.

[0080] FIG. 19 shows an indirect heat recovery system 1900 for utilization of heat by-product stream 1901. The heat by-product stream 1901 is the same as that described above with regard to heat by-product stream 1701, and for the sake of brevity, the similarities will not be repeated hereinbelow. A portion 1901a of the heat by-product stream 1901 can be utilized to heat a working fluid stream 1912. The portion 1901a of the heat by-product stream 1901 thermally contacts the working fluid stream 1912 and transfers heat to the

working fluid stream 1912. Suitable examples of the working fluid stream 1912 include, but are not limited to, water, glycols, therminol fluids, alkanes, alkenes, chlorofluorocarbons, hydrofluorocarbons, carbon dioxide (CO₂), refrigerants, and mixtures of other hydrocarbon components. The portion 1901a of the heat by-product stream 1901 and the working fluid stream 1912 enter a heater 1913 to produce a heated working fluid stream 1914 and a reduced heat exhaust stream 1915. In certain exemplary embodiments, the working fluid stream 1912 has a temperature in the range of from about 85 to about 160 °F. In certain exemplary embodiments, the heated working fluid stream 1914 has a temperature in the range of from about 165 to about 455 °F. In certain exemplary embodiments, the reduced heat exhaust stream 1915 has a temperature in the range of from about 90 to about 500 °F. The reduced heat exhaust stream 1915 can then be vented to the atmosphere. In certain exemplary embodiments, a portion 1901b of the heat by-product stream 1901 is diverted through a bypass valve 1917 and then combined with the reduced heat exhaust stream 1915 to produce an exhaust stream 1918. In certain exemplary embodiments, the exhaust stream 1918 has a temperature in the range of from about 90 to about 510 °F. In certain exemplary embodiments, the heat by-product stream 1901 is entirely directed through the heater 1913.

[0081] At least a portion 1914a of the heated working fluid stream 1914 enters a heater 1935 to heat a working fluid stream 1936 to produce a heated working fluid stream 1937 and a reduced heat working fluid stream 1938. The portion 1914a of the heated working fluid stream 1914 thermally contacts the working fluid stream 1936 and transfers heat to the working fluid stream 1936. In certain exemplary embodiments, the working fluid stream 1936 includes any working fluid suitable for use in an organic Rankine cycle. In certain exemplary embodiments, the working fluid stream 1936 has a temperature in the range of from about 80 to about 150 °F. In certain exemplary embodiments, the heated working fluid stream 1937 has a temperature in the range of from about 160 to about 450 °F. In certain exemplary embodiments, the heated working fluid stream 1937 is vaporized. In certain exemplary embodiments, the heated working fluid stream 1937 is vaporized within a supercritical process. In certain exemplary embodiments, the heated working fluid stream 1937 is superheated. In certain exemplary embodiments, the reduced heat working fluid stream 1938 has a temperature in the range of from about 85 to about 155 °F. In certain embodiments, a portion 1914b of the working fluid stream 1914 is diverted through a bypass valve 1939 and then combined with the reduced heat working fluid stream 1938 to produce an intermediate working fluid stream 1940. In certain exemplary embodiments, the intermediate working fluid stream 1940 has a temperature in the range of from about 85 to

about 160 °F. The intermediate working fluid stream 1940 is directed to a pump 1942. In certain exemplary embodiments, the pump 1942 is controlled by a variable frequency drive 1943. The pump 1942 returns the intermediate working fluid stream 1940 to produce the working fluid stream 1912 that enters the heater 1913.

[0082] At least a portion 1937a of the heated working fluid stream 1937 is then directed to a turbine-generator system 1950, which is a part of the organic Rankine cycle. The portion 1937a of the heated working fluid stream 1937 is expanded in the turbine-generator system 1950 to produce an expanded working fluid stream 1951 and generate power. In certain exemplary embodiments, the expanded working fluid stream 1951 has a temperature in the range of from about 80 to about 440 °F. In certain embodiments, the turbine-generator system 1950 generates electricity or electrical power. In certain other embodiments, the turbine-generator system 1950 generates mechanical power. In certain embodiments, a portion 1937b of the heated working fluid stream 1937 is diverted through a bypass valve 1952 and then combined with the expanded working fluid stream 1951 to produce an intermediate working fluid stream 1955. In certain exemplary embodiments, the intermediate working fluid stream 1955 has a temperature in the range of from about 80 to about 445 °F.

[0083] The intermediate working fluid stream 1955 is then directed to one or more air-cooled condensers 1957. The air-cooled condensers 1957 are a part of the organic Rankine cycle. In certain exemplary embodiments, the organic Rankine cycle includes two air-cooled condensers 1957 in series. In certain exemplary embodiments, each of the air-cooled condensers 1957 is controlled by a variable frequency drive 1958. The air-cooled condensers 1957 cool the intermediate working fluid stream 1955 to form a condensed working fluid stream 1959. In certain exemplary embodiments, the condensed working fluid stream 1959 has a temperature in the range of from about 80 to about 150 °F. The condensed working fluid stream 1959 is then directed to a pump 1960. The pump 1960 is a part of the organic Rankine cycle. In certain exemplary embodiments, the pump 1960 is controlled by a variable frequency drive 1961. The pump 1960 returns the condensed working fluid stream 1959 to a higher pressure to produce the working fluid stream 1936 that is directed to the heater 1935.

[0084] FIG. 20 shows an indirect heat recovery system 2000 according to another exemplary embodiment. The heat recovery system 2000 is the same as that described above with regard to heat recovery system 1900, except as specifically stated below. For the sake of brevity, the similarities will not be repeated hereinbelow. Referring now to FIG. 20, the

intermediate working fluid stream 1955 is directed to one or more water-cooled condensers 2057. The water-cooled condensers 2057 are a part of the organic Rankine cycle. In certain exemplary embodiments, the organic Rankine cycle includes two water-cooled condensers 2057 in series. The water-cooled condensers 2057 cool the intermediate working fluid stream 1955 to form a condensed working fluid stream 2059. In certain exemplary embodiments, the condensed working fluid stream 2059 has a temperature in the range of from about 80 to about 150 °F. The condensed working fluid stream 2059 is then directed to the pump 1960 and is returned to a higher pressure to produce the working fluid stream 1936 that is directed to the heater 1935.

[0085] The present invention may employ any number of working fluids in the organic Rankine cycle. Suitable examples of working fluids for use in the organic Rankine cycle include, but are not limited to, ammonia (NH₃), bromine (Br₂), carbon tetrachloride (CCl₄), ethyl alcohol or ethanol (CH₃CH₂OH, C₂H₆O), furan (C₄H₄O), hexafluorobenzene or perfluoro-benzene (C₆F₆), hydrazine (N₂H₄), methyl alcohol or methanol (CH₃OH), monochlorobenzene or chlorobenzene or chlorobenzol or benzine chloride (C₆H₅Cl), n-pentane or normal pentane (nC₅), i-hexane or isohexane (iC₅), pyridene or azabenzene (C₅H₅N), refrigerant 11 or freon 11 or CFC-11 or R-11 or trichlorofluoromethane (CCl₃F), refrigerant 12 or freon 12 or R-12 or dichlorodifluoromethane (CCl₂F₂), refrigerant 21 or freon 21 or CFC-21 or R-21 (CHCl₂F), refrigerant 30 or freon 30 or CFC-30 or R-30 or dichloromethane or methylene chloride or methylene dichloride (CH₂Cl₂), refrigerant 115 or freon 115 or CFC-115 or R-115 or chloro-pentafluoroethane or monochloropentafluoroethane, refrigerant 123 or freon 123 or HCFC-123 or R-123 or 2,2-dichloro-1,1,1-trifluoroethane, refrigerant 123a or freon 123a or HCFC-123a or R-123a or 1,2-dichloro-1,1,2-trifluoroethane, refrigerant 123b1 or freon 123b1 or HCFC-123b1 or R-123b1 or halothane or 2-bromo-2-chloro-1,1,1-trifluoroethane, refrigerant 134A or freon 134A or HFC-134A or R-134A or 1,1,1,2-tetrafluoroethane, refrigerant 150A or freon 150A or CFC-150A or R-150A or dichloroethane or ethylene dichloride (CH₃CHCl₂), thiophene (C₄H₄S), toluene or methylbenzene or phenylmethane or toluol (C₇H₈), water (H₂O), carbon dioxide (CO₂), and the like. In certain exemplary embodiments, the working fluid may include a combination of components. For example, one or more of the compounds identified above may be combined or with a hydrocarbon fluid, for example, isobutene. However, those skilled in the art will recognize that the present invention is not limited to any particular type of working fluid or refrigerant. Thus, the present invention should not be

considered as limited to any particular working fluid unless such limitations are clearly set forth in the appended claims.

[0086] The present application is generally directed to various heat recovery systems and methods for producing electrical and/or mechanical power from a heat source. The exemplary systems may include a heat exchanger, a turbine-generator set, a condenser heat exchanger, and a pump. The present invention is advantageous over conventional heat recovery systems and methods as it utilizes heat that would otherwise be rejected to the atmosphere to produce electricity and/or mechanical power, thus increasing process efficiency

[0087] Therefore, the present invention is well adapted to attain the ends and advantages mentioned as well as those that are inherent therein. The particular embodiments disclosed above are illustrative only, as the present invention may be modified and practiced in different but equivalent manners apparent to those skilled in the art having the benefit of the teachings herein. While numerous changes may be made by those skilled in the art, such changes are encompassed within the spirit of this invention as defined by the appended claims. Furthermore, no limitations are intended to the details of construction or design herein shown, other than as described in the claims below. It is therefore evident that the particular illustrative embodiments disclosed above may be altered or modified and all such variations are considered within the scope and spirit of the present invention. The terms in the claims have their plain, ordinary meaning unless otherwise explicitly and clearly defined by the patentee.

CLAIMS

What is claimed is:

1. A process for utilizing process heat by-product from refinery operations, comprising:
 - a first sub-process and a second sub-process, the first sub-process comprising the steps of:
 - a) directing process heat by-product from a refinery operation to a heater;
 - b) thermally contacting in said heater the process heat by-product with a working fluid to cool the process heat by-product to form a cooled by-product;
 - c) exhausting the cooled by-product to atmosphere;and the second sub-process comprising the steps of:
 - d) heating in said heater the working fluid to form a heated working fluid;
 - e) passing the heated working fluid through a turbine to form an expanded working fluid, wherein said passing of the heated working fluid through the turbine drives a generator for production of one of electricity and mechanical power;
 - f) passing the expanded working fluid through at least one heat exchanger to form a condensed working fluid; and
 - g) passing the condensed working fluid through at least one pump to form said working fluid;wherein the first and second sub-processes are linked via the heater, and wherein first and second sub-processes occur simultaneously.
2. The process of claim 1, wherein the at least one heat exchanger is selected from the group consisting of air-cooled condensers and water-cooled condensers.
3. The process of claim 1, wherein said process heat by-product comprises flue gas or waste heat from refinery operations.
4. The process of claim 1, wherein said process heat by-product comprises flue gas from a fluid catalytic cracking unit.

5. The process of claim 1, wherein said process heat by-product comprises heat by-product generated by

directing flue gas from a fluid catalytic cracking regenerator to a waste heat steam generator for generating steam,

passing said flue gas through an electrostatic precipitator to remove catalyst fines present in the flue gas, and

recovering the process heat by-product from the flue gas exiting the electrostatic precipitator.

6. The process of claim 1, wherein said process heat by-product comprises heat by-product generated by

directing a flue gas from a fluid catalytic cracking regenerator to a boiler, wherein the flue gas comprises carbon monoxide,

combusting the carbon monoxide in the boiler to generate steam,

passing the flue gas through an electrostatic precipitator to remove catalyst fines present in the flue gas, and

recovering the process heat by-product from the flue gas exiting the electrostatic precipitator.

7. The process of claim 1, wherein said process heat by-product comprises recovered heat from a high temperature reactor.

8. The process of claim 7, wherein the high temperature reactor is a fired heater or an incinerator.

9. The process of claim 7, wherein said heater is integral to a convection section of the high temperature reactor.

10. The process of claim 1, wherein the working fluid is selected from the group consisting of organic working fluids and refrigerants.

11. The process of claim 1, wherein the step of heating the working fluid to form the heated working fluid comprises vaporizing the working fluid.

12. The process of claim 1, wherein the step of heating the working fluid to form the heated working fluid comprises vaporizing the working fluid within a supercritical process.

13. A process for utilizing waste heat by-product, comprising:
a first sub-process and a second sub-process, the first sub-process comprising the steps of:

- a) directing waste heat by-product to a heater;
 - b) thermally contacting in said heater the waste heat by-product with a working fluid to cool the waste heat by-product to form a cooled by-product;
 - c) exhausting the cooled by-product to atmosphere;
- and the second sub-process comprising the steps of:
- d) heating in said heater the working fluid to form a heated working fluid;
 - e) passing the heated working fluid through a turbine to form an expanded working fluid, wherein said passing of the heated working fluid through the turbine drives a generator for production of one of electricity and mechanical power;
 - f) passing the expanded working fluid through at least one heat exchanger to form a condensed working fluid; and
 - g) passing the condensed working fluid through at least one pump to form said working fluid;

wherein the first and second sub-processes are linked via the heater, and wherein first and second sub-processes occur simultaneously.

14. The process of claim 13, wherein the at least one heat exchanger is selected from the group consisting of air-cooled condensers and water-cooled condensers.

15. The process of claim 13, further comprising the step of directing the cooled by-product to one of an incinerator, a scrubber, and a stack prior to exhausting the cooled by-product to the atmosphere.

16. The process of claim 13, wherein said waste heat by-product comprises waste heat from a steam generator.

17. The process of claim 13, wherein said waste heat by-product is generated by directing water into a steam generator,

heating the water with a heated air stream to form steam and the waste heat by-product.

18. The process of claim 17, further comprising the step of diverting a portion of the waste heat by-product through a diverter valve for discharging to atmosphere.

19. The process of claim 13, wherein said waste heat by-product comprises waste heat from a gas turbine.

20. The process of claim 13, wherein said waste heat by-product is generated by directing fuel into a gas turbine, and
combusting the fuel in the gas turbine to generate power and the waste heat by-product.

21. The process of claim 13, wherein the working fluid is selected from the group consisting of organic working fluids and refrigerants.

22. The process of claim 13, wherein the step of heating the working fluid to form the heated working fluid comprises vaporizing the working fluid.

23. The process of claim 13, wherein the step of heating the working fluid to form the heated working fluid comprises vaporizing the working fluid within a supercritical process.

24. A process for utilizing a heat by-product, comprising:
a first sub-process and a second sub-process, the first sub-process comprising the steps of:

- a) directing the heat by-product to a heater;
 - b) thermally contacting in said heater the heat by-product with a working fluid to cool the heat by-product to form a cooled by-product;
 - c) exhausting the cooled by-product to atmosphere;
- and the second sub-process comprising the steps of:
- d) heating in said heater the working fluid to form a heated working fluid;
 - e) passing the heated working fluid through a turbine to form an expanded working fluid, wherein said passing of the heated working fluid through the turbine powers a generator for production of one of electricity and mechanical power;

f) passing the expanded working fluid through at least one heat exchanger to form a condensed working fluid; and

g) passing the condensed working fluid through at least one pump to form said working fluid;

wherein the first and second sub-processes are linked via the heater, and wherein first and second sub-processes occur simultaneously.

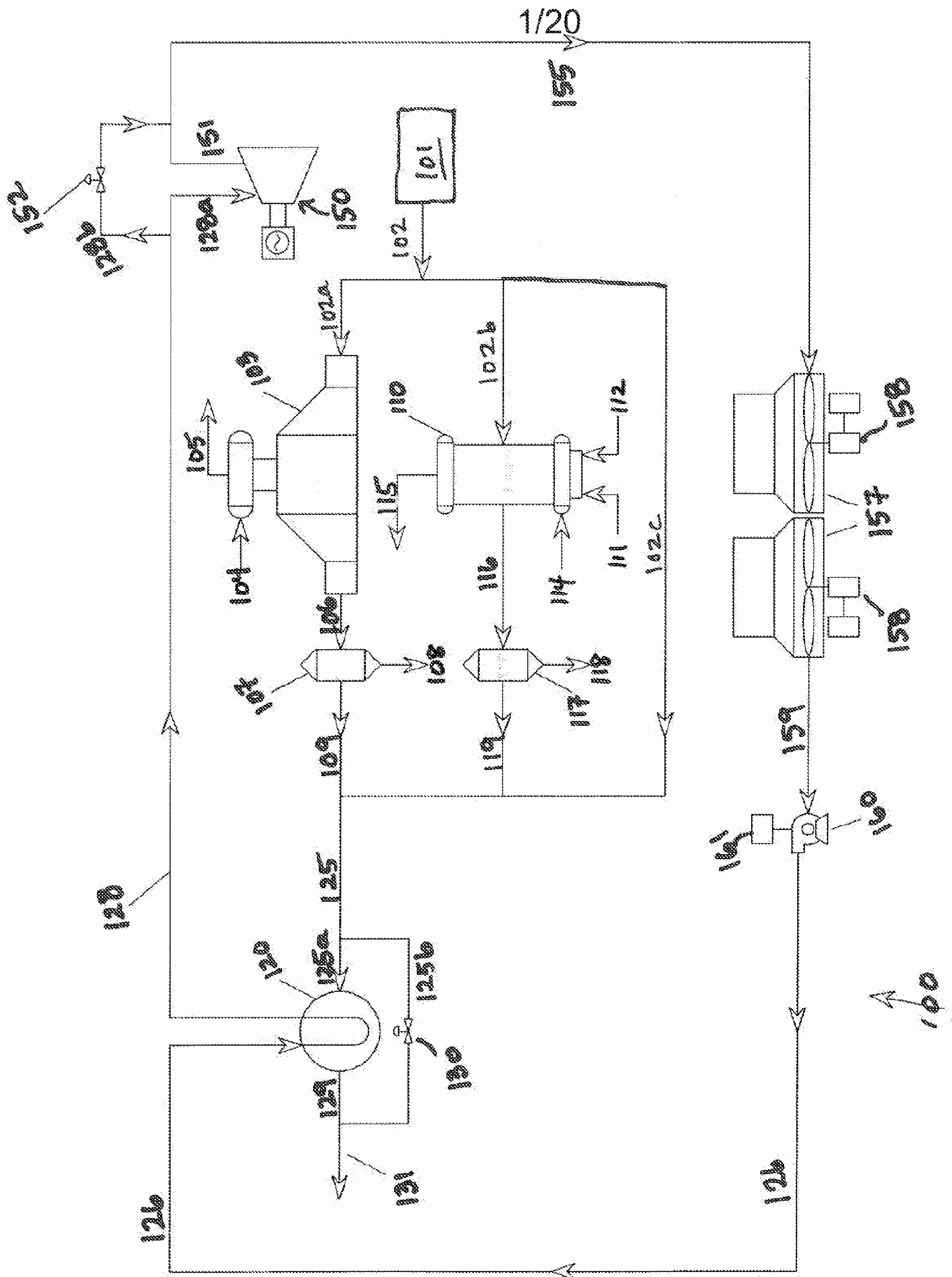
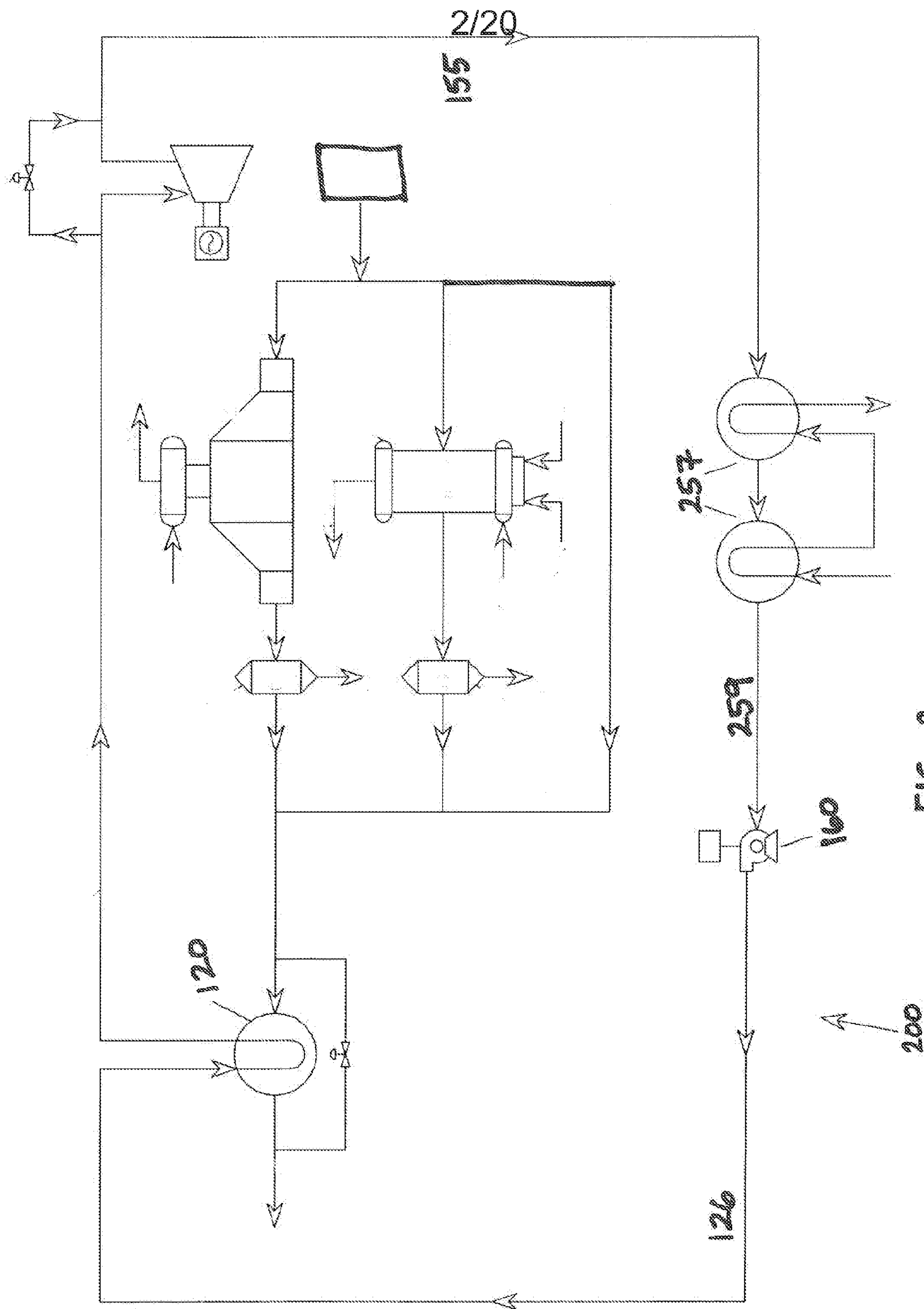


Fig. 1



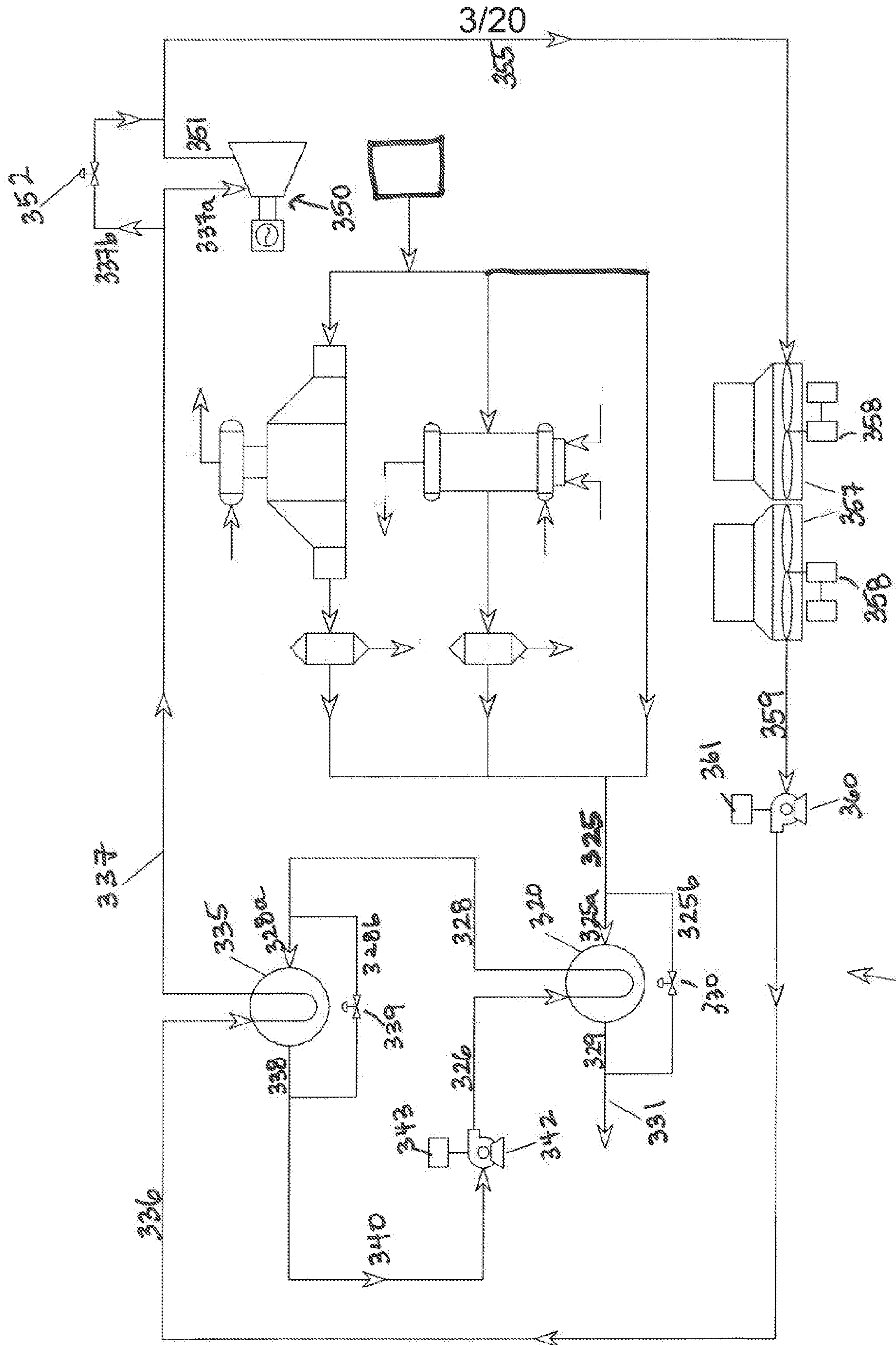


Fig. 3

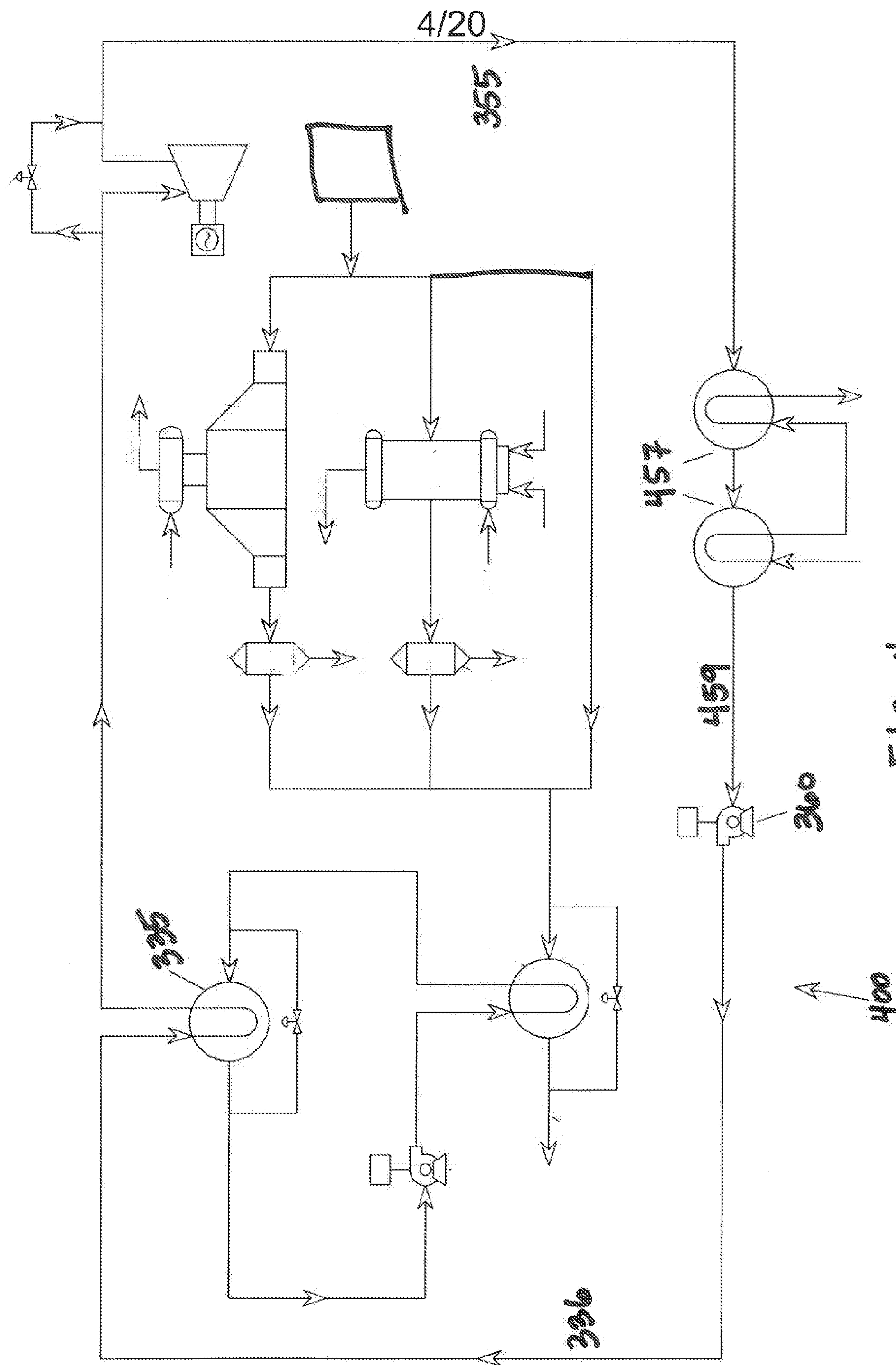


Fig. 4

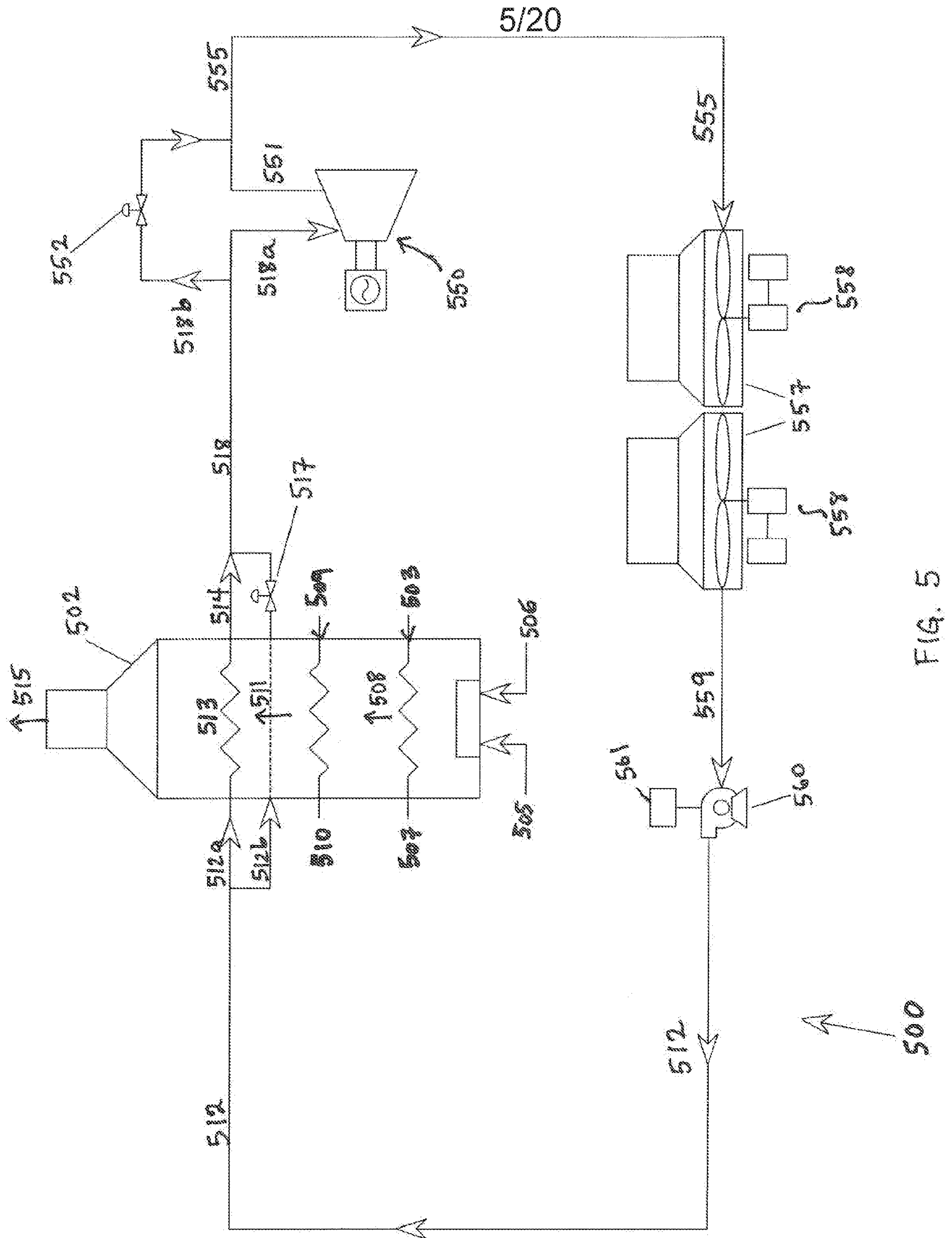
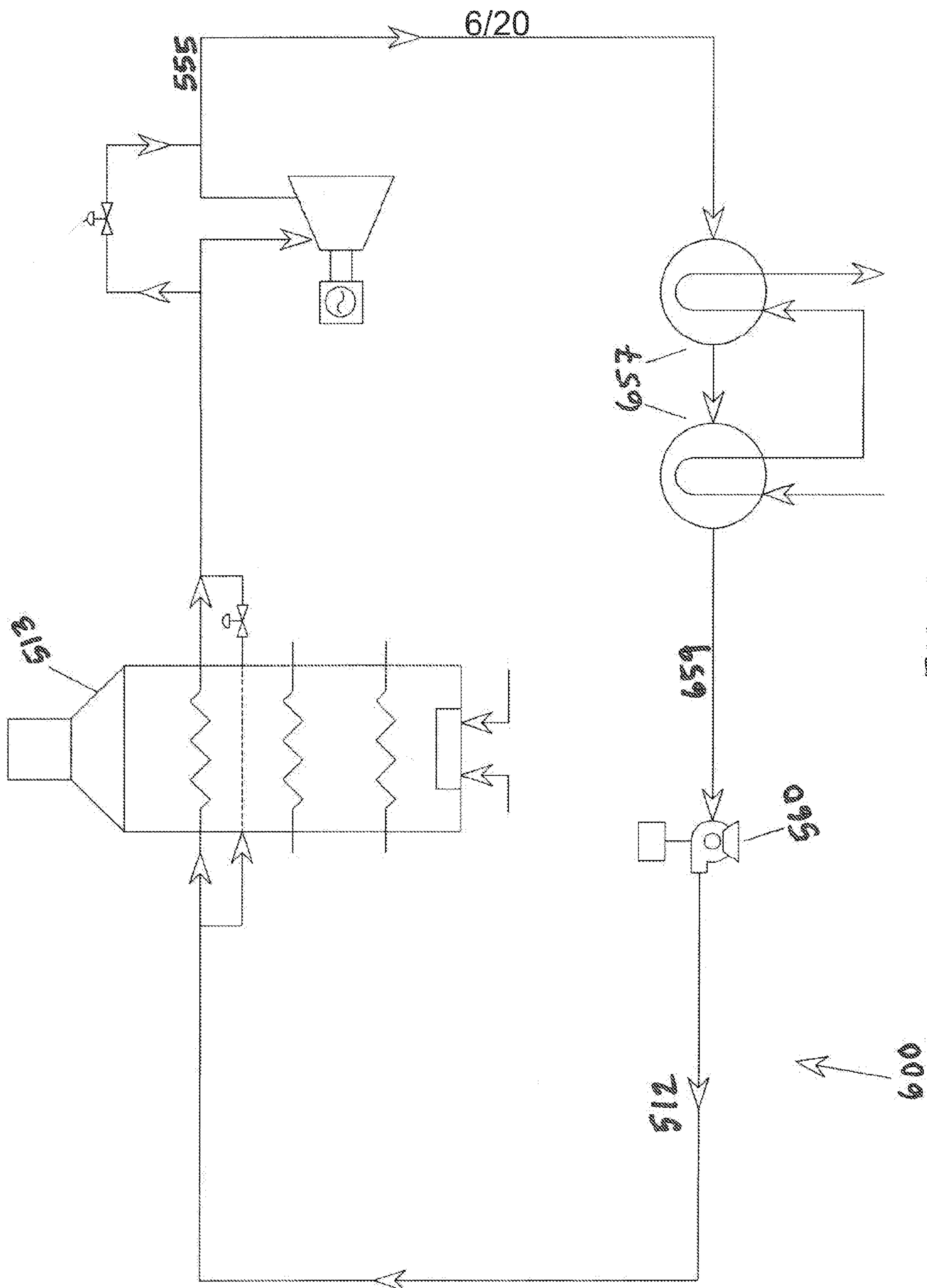


FIG. 5



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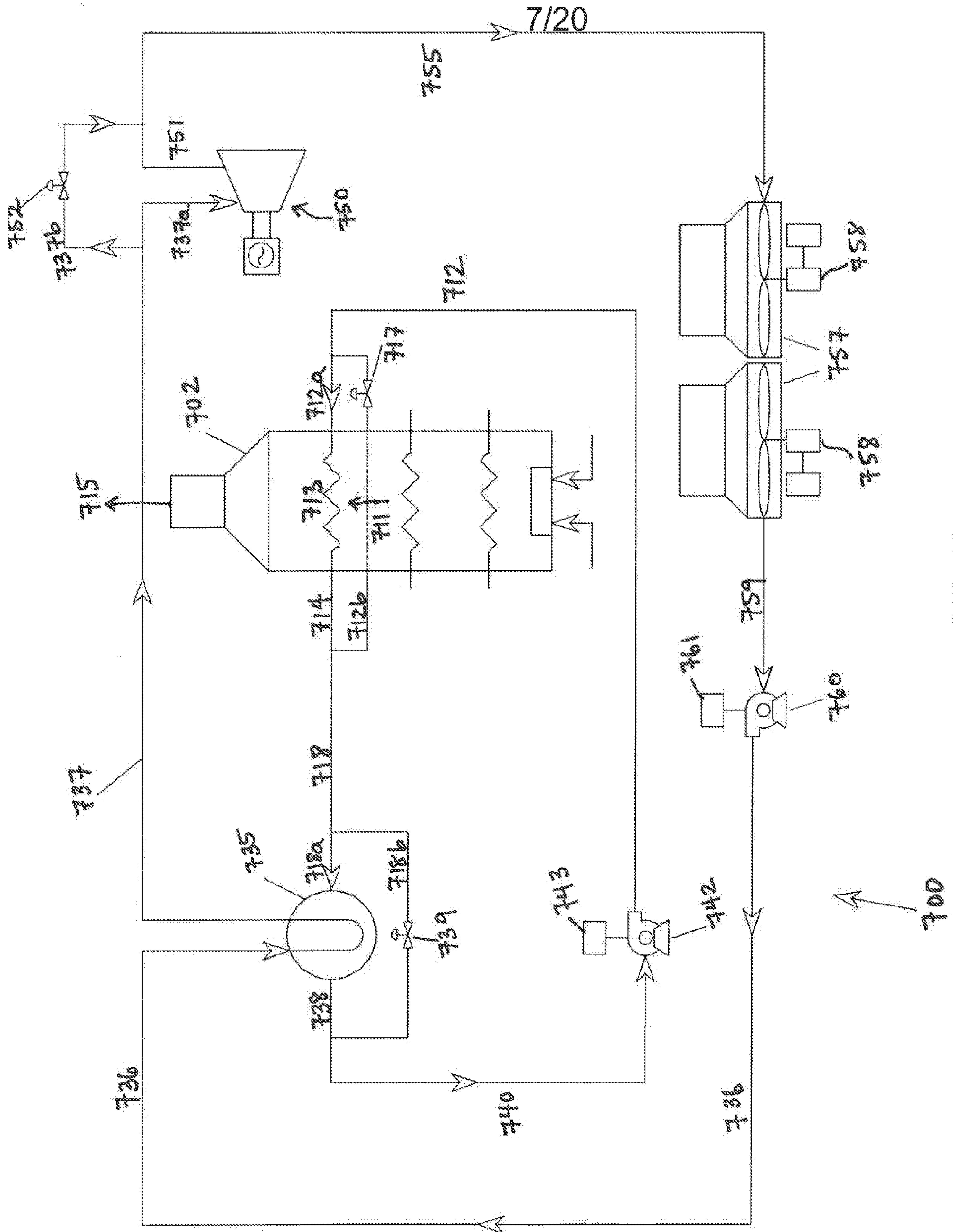


FIG. 7

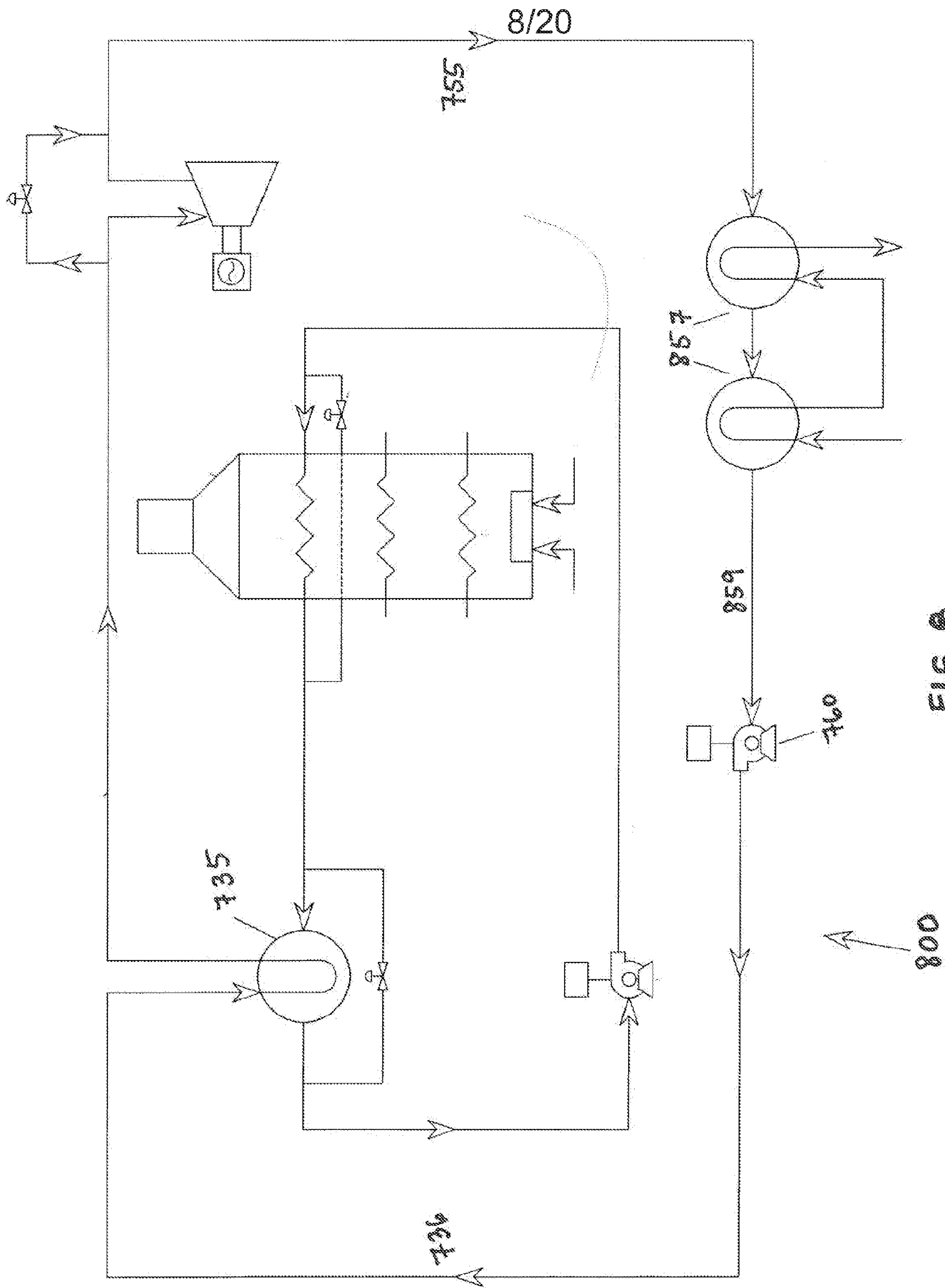


FIG. 8

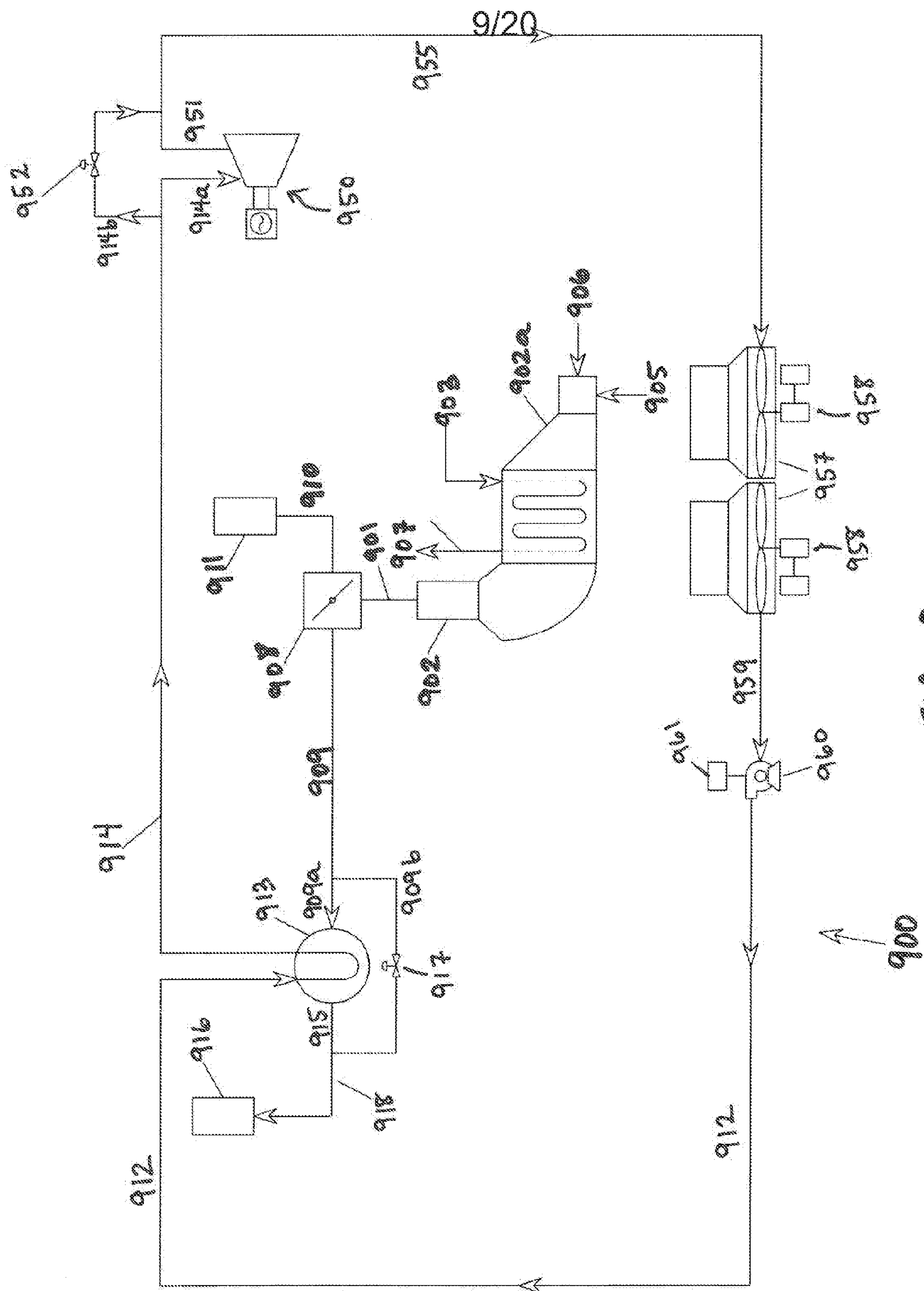
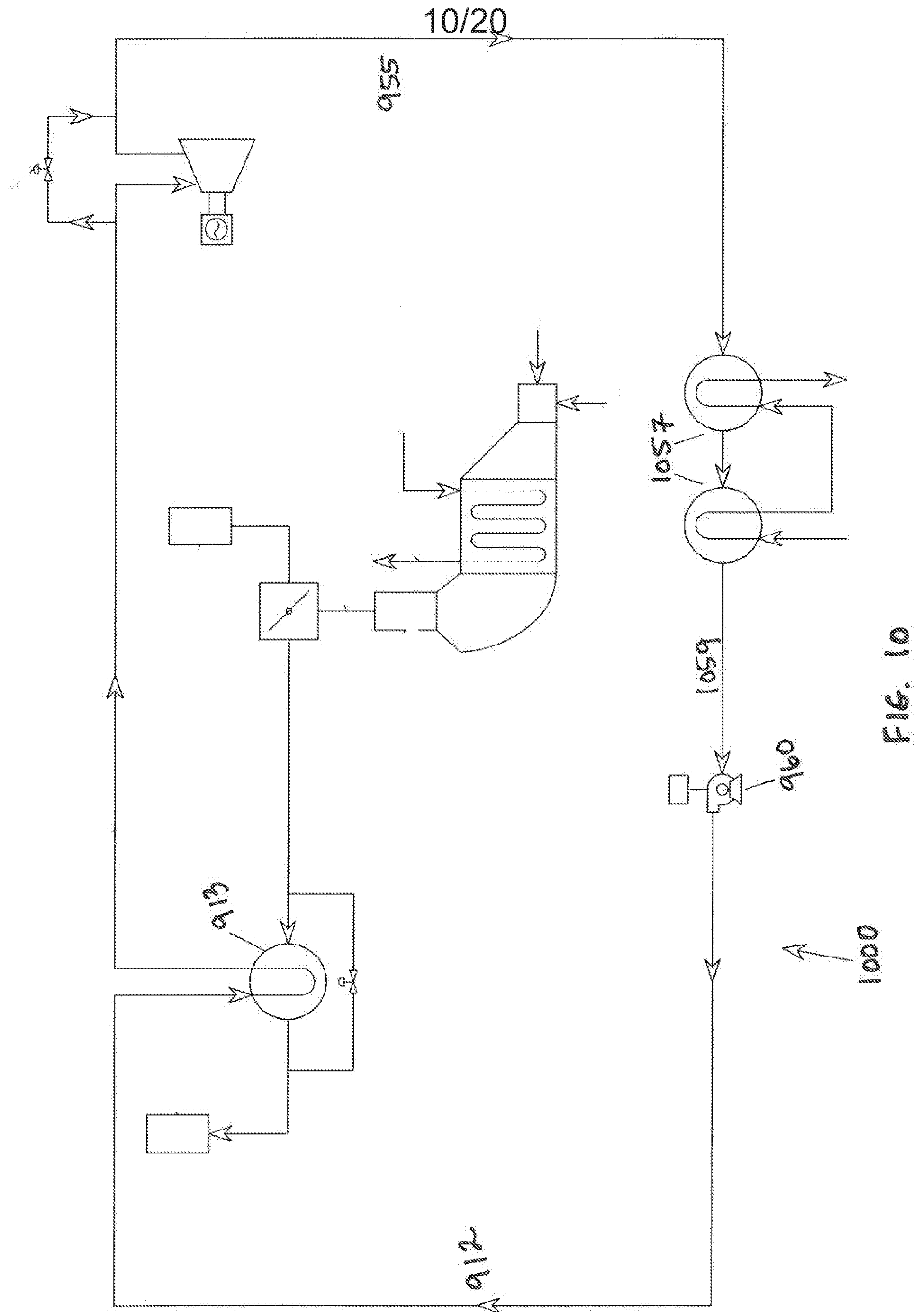


FIG. 9



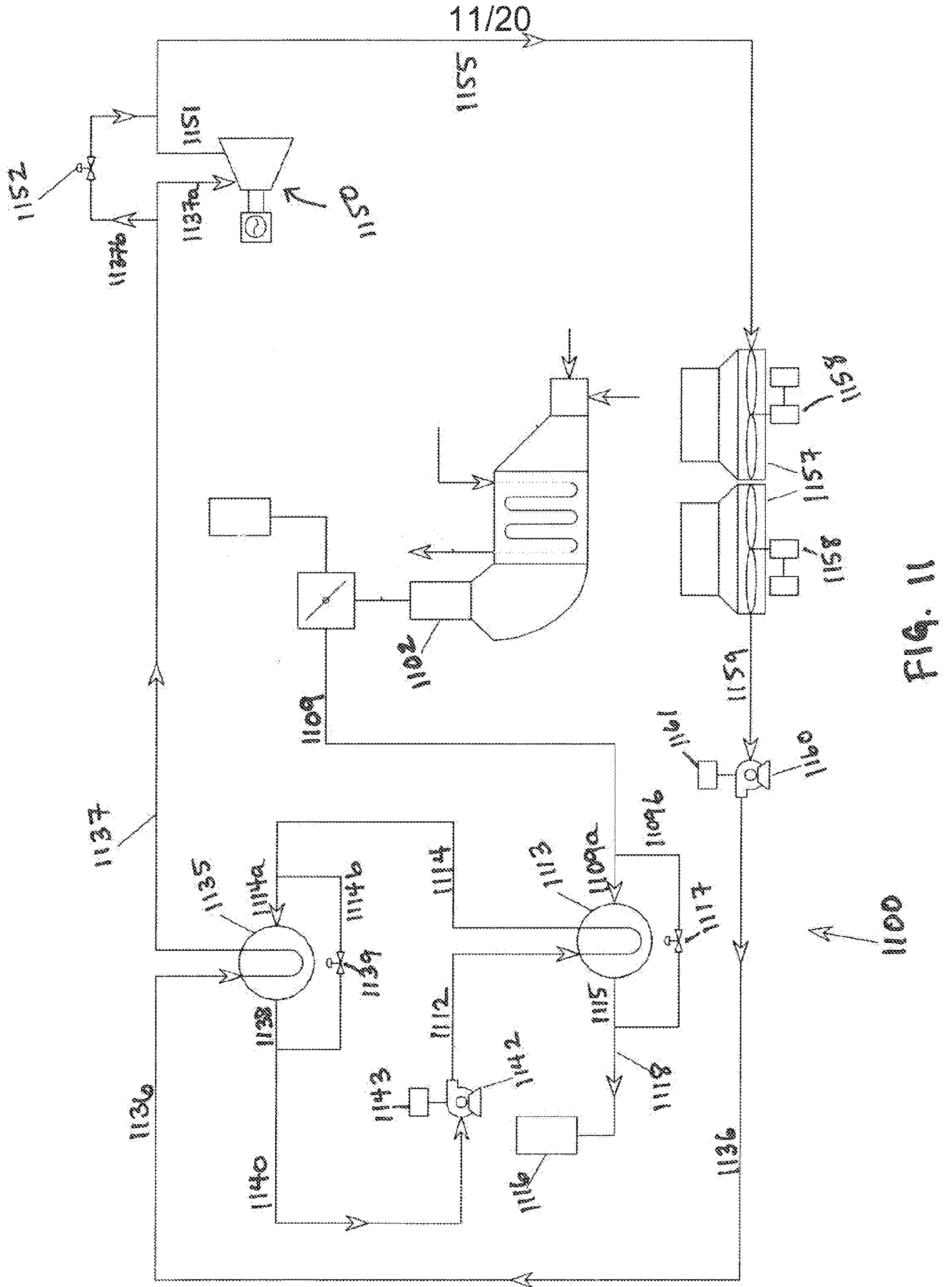
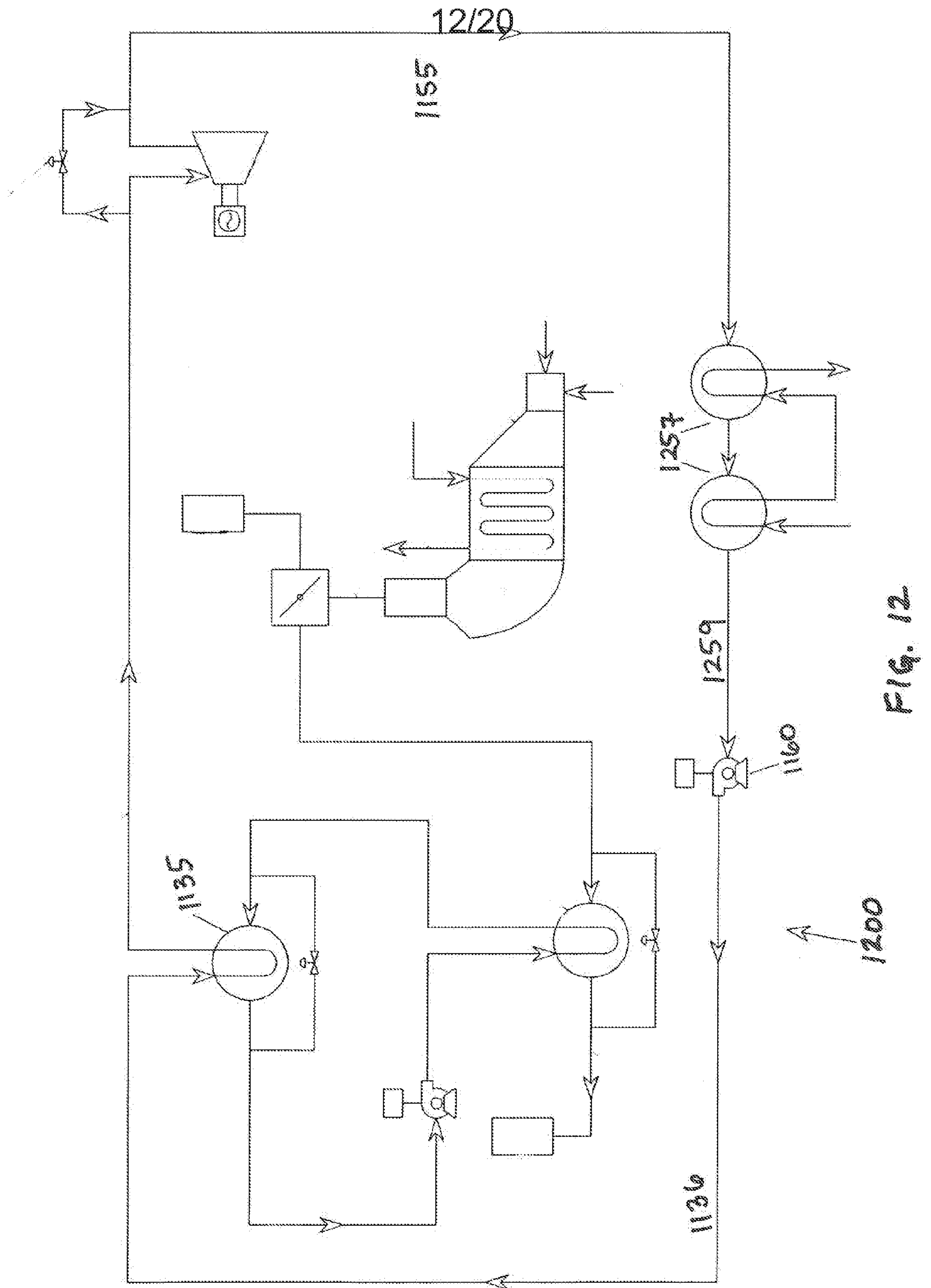


FIG. 11



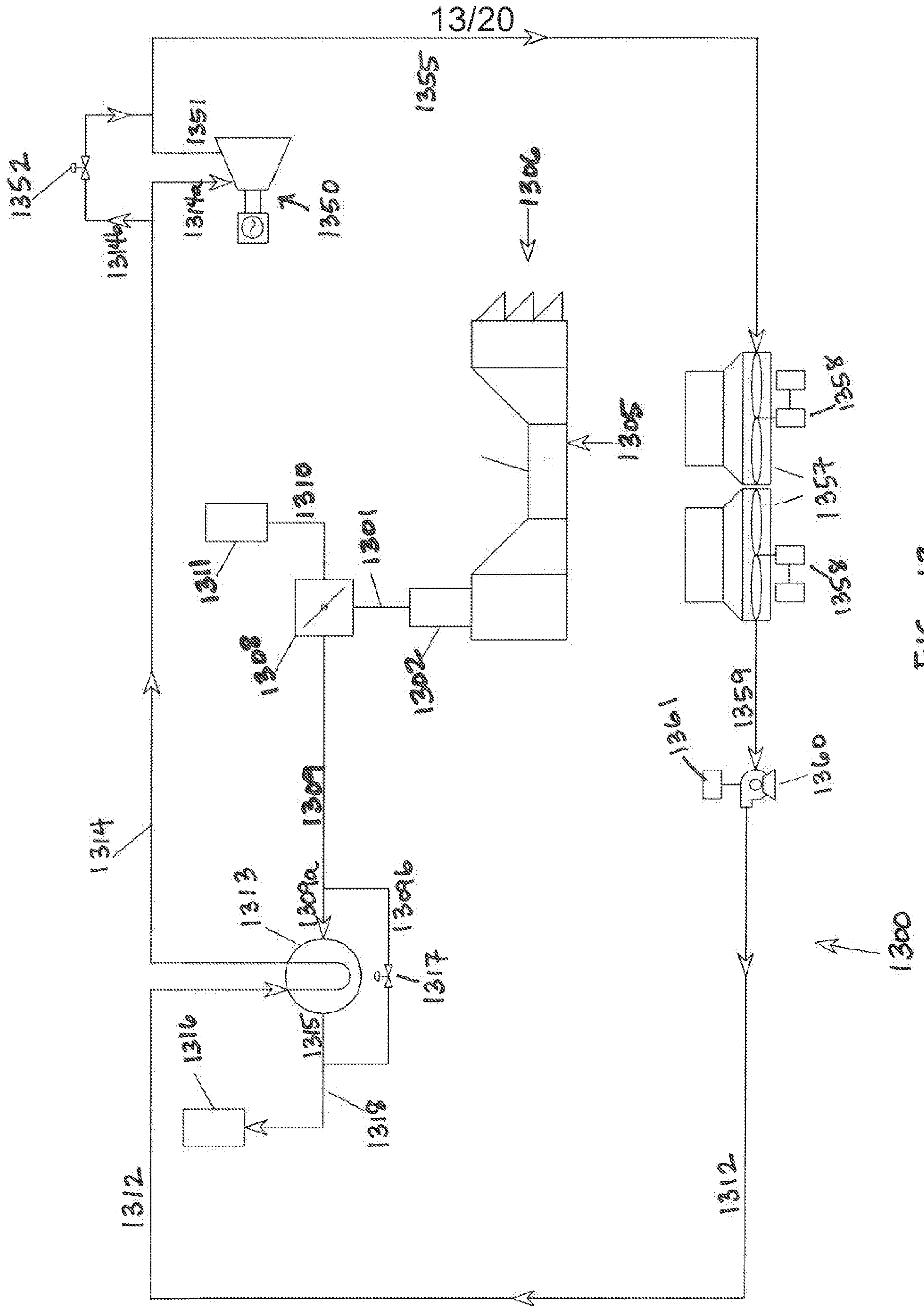
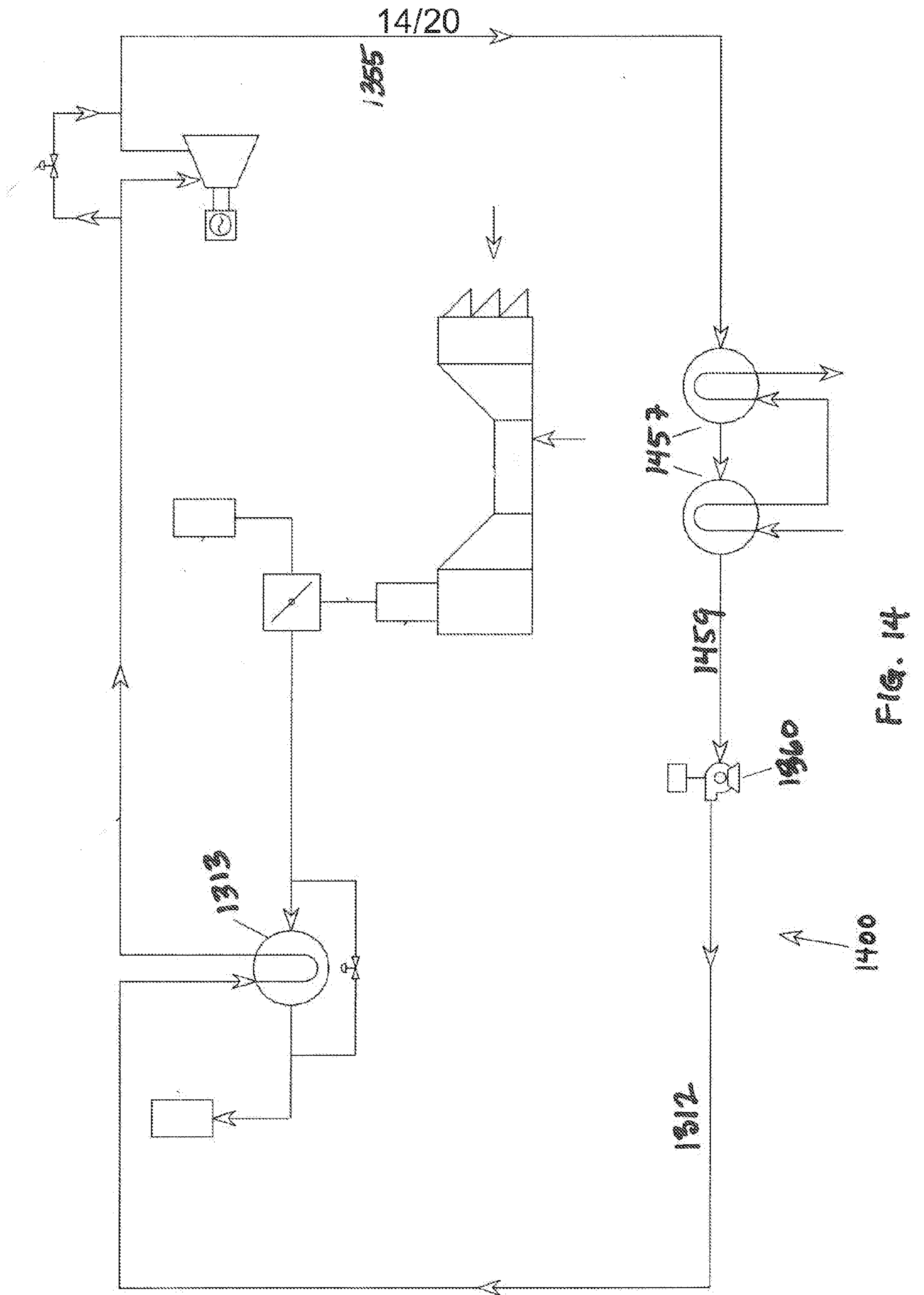


FIG. 13



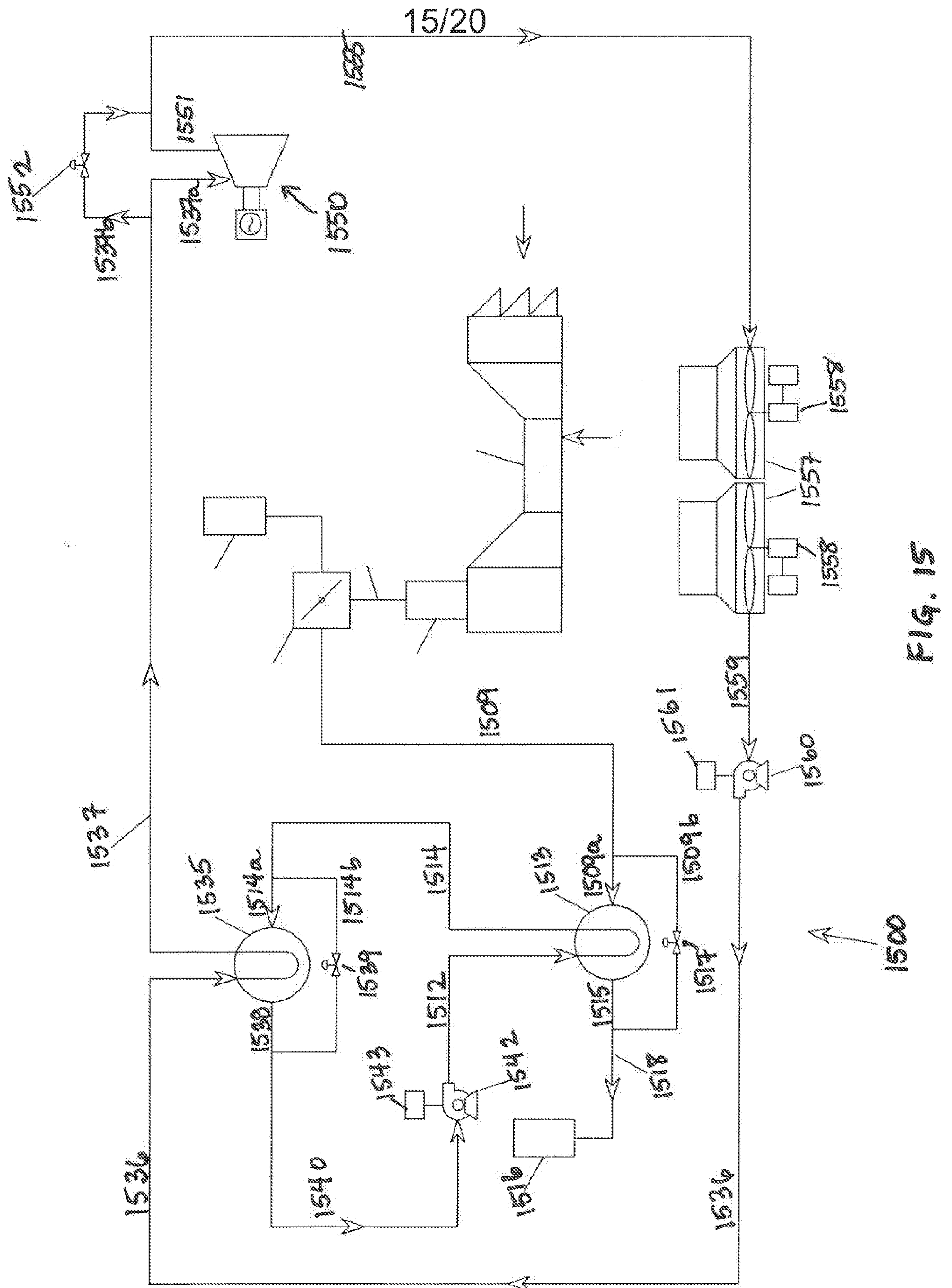


Fig. 15

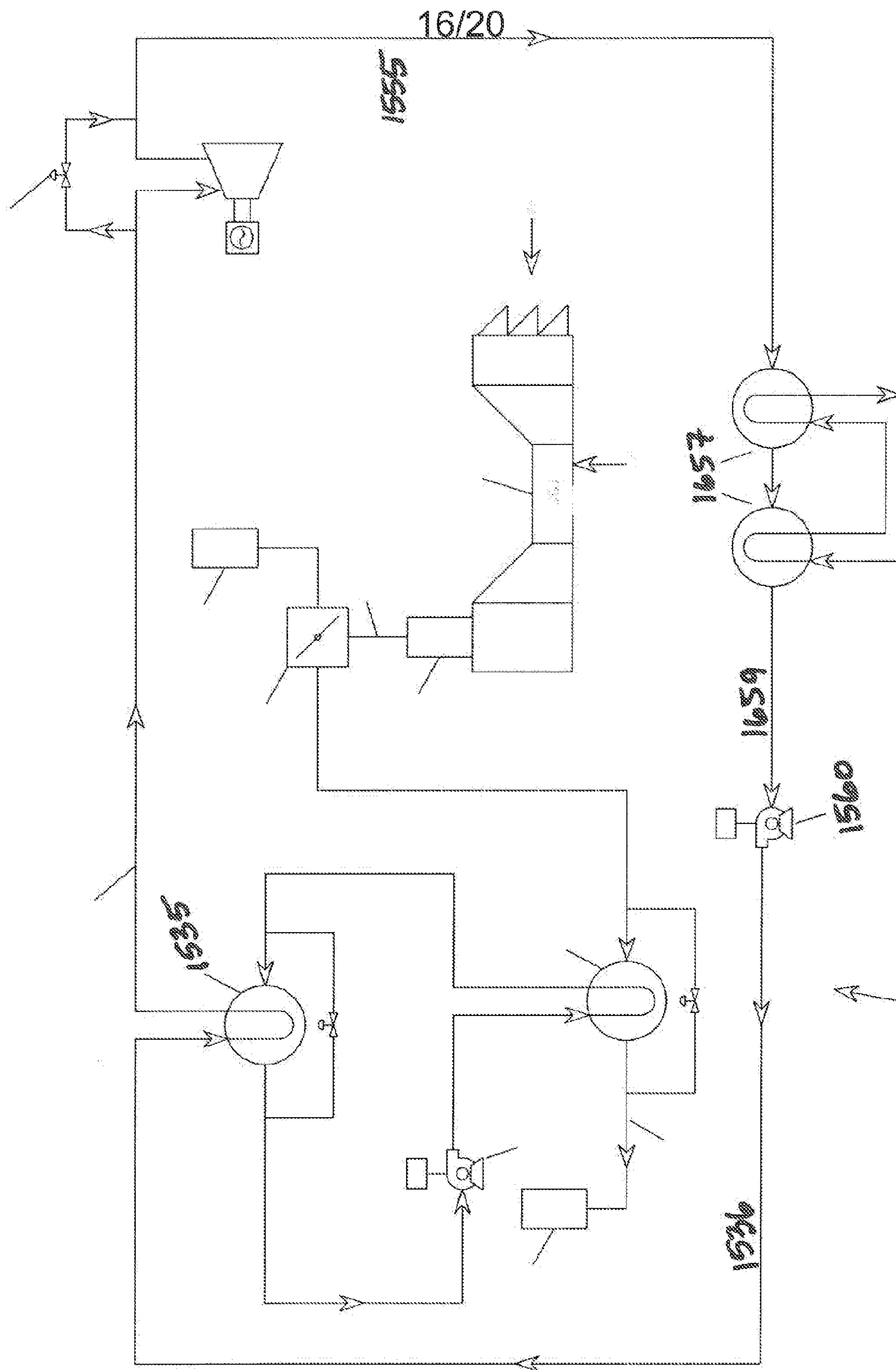
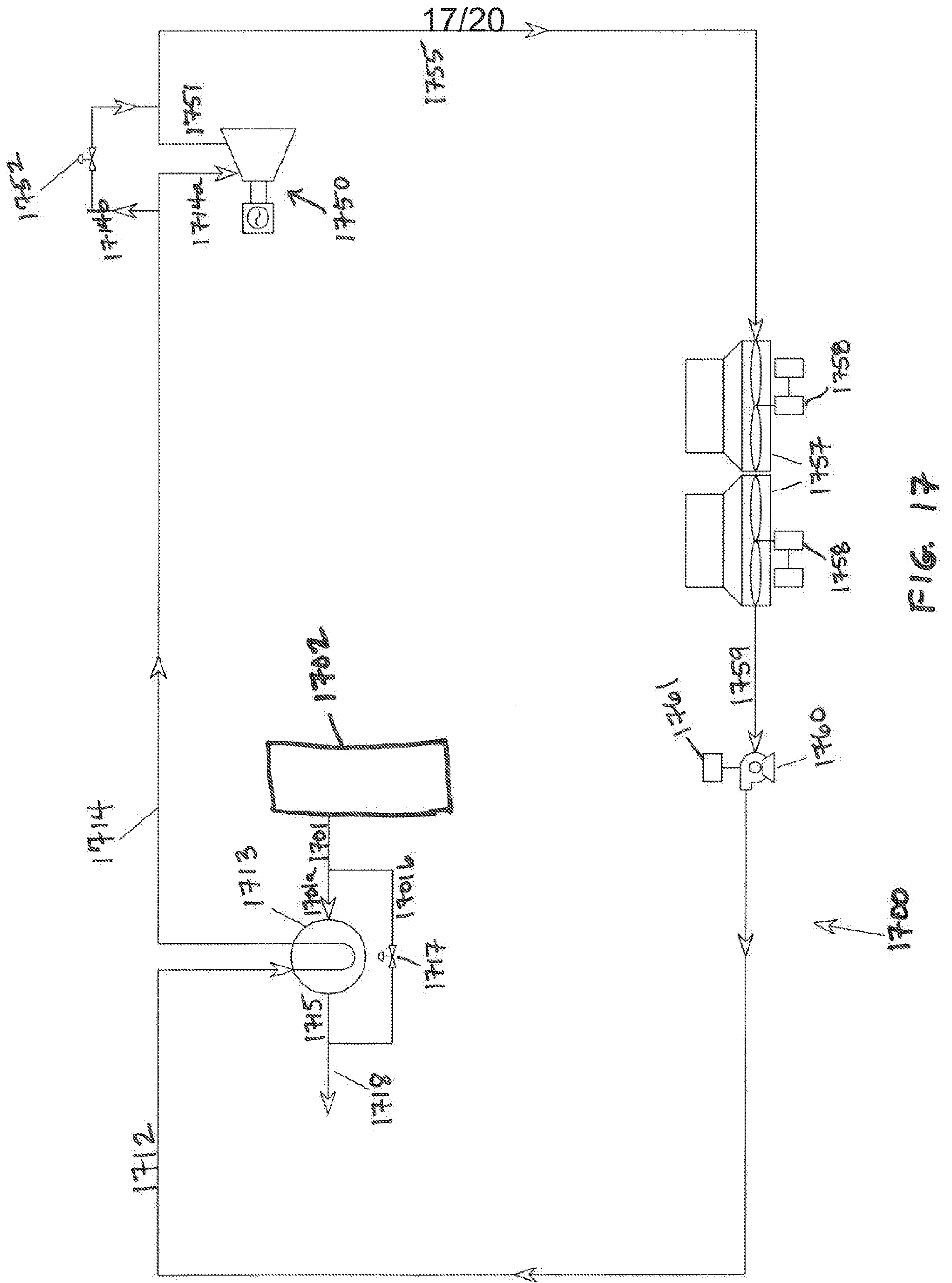
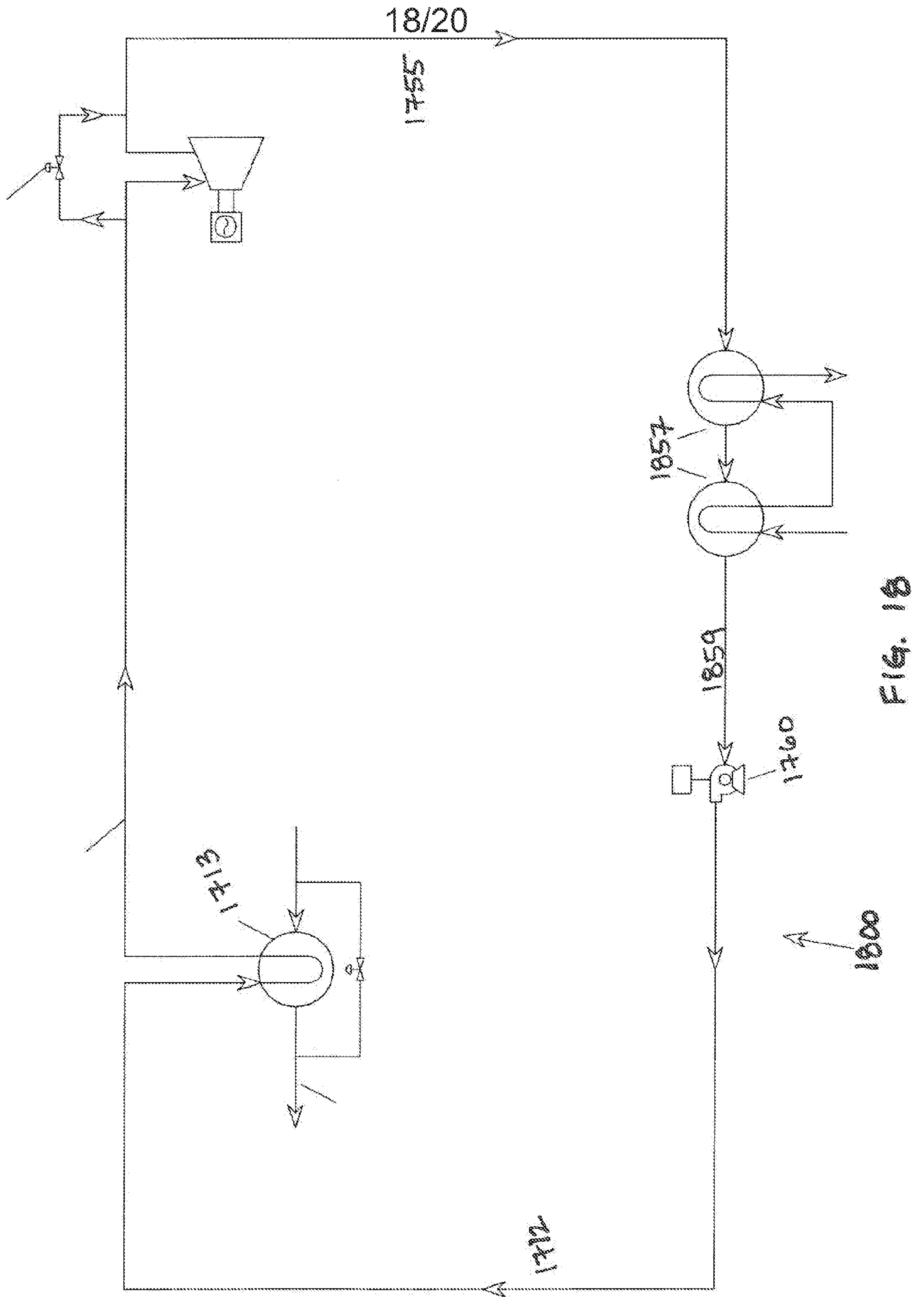


Fig. 16





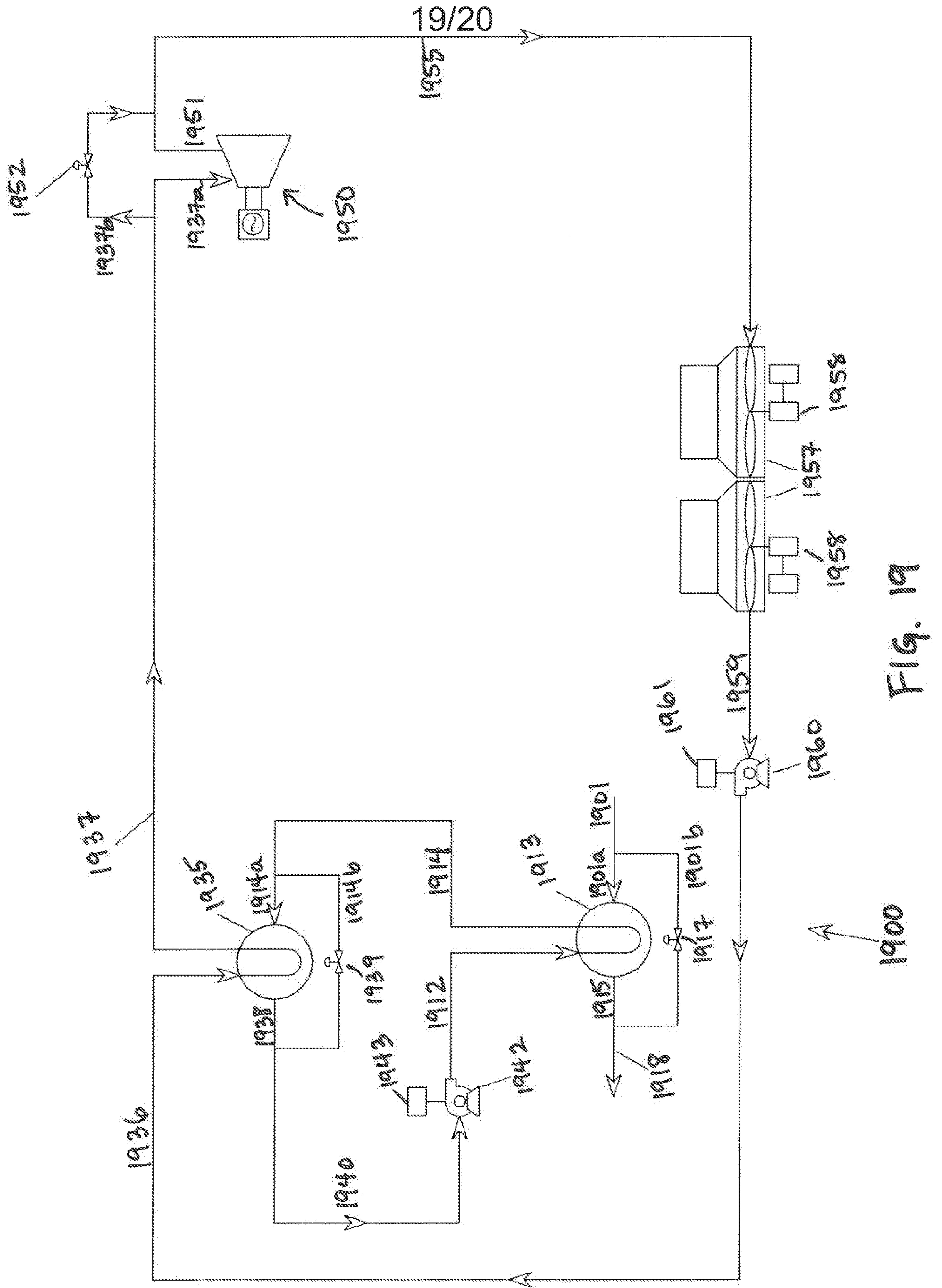
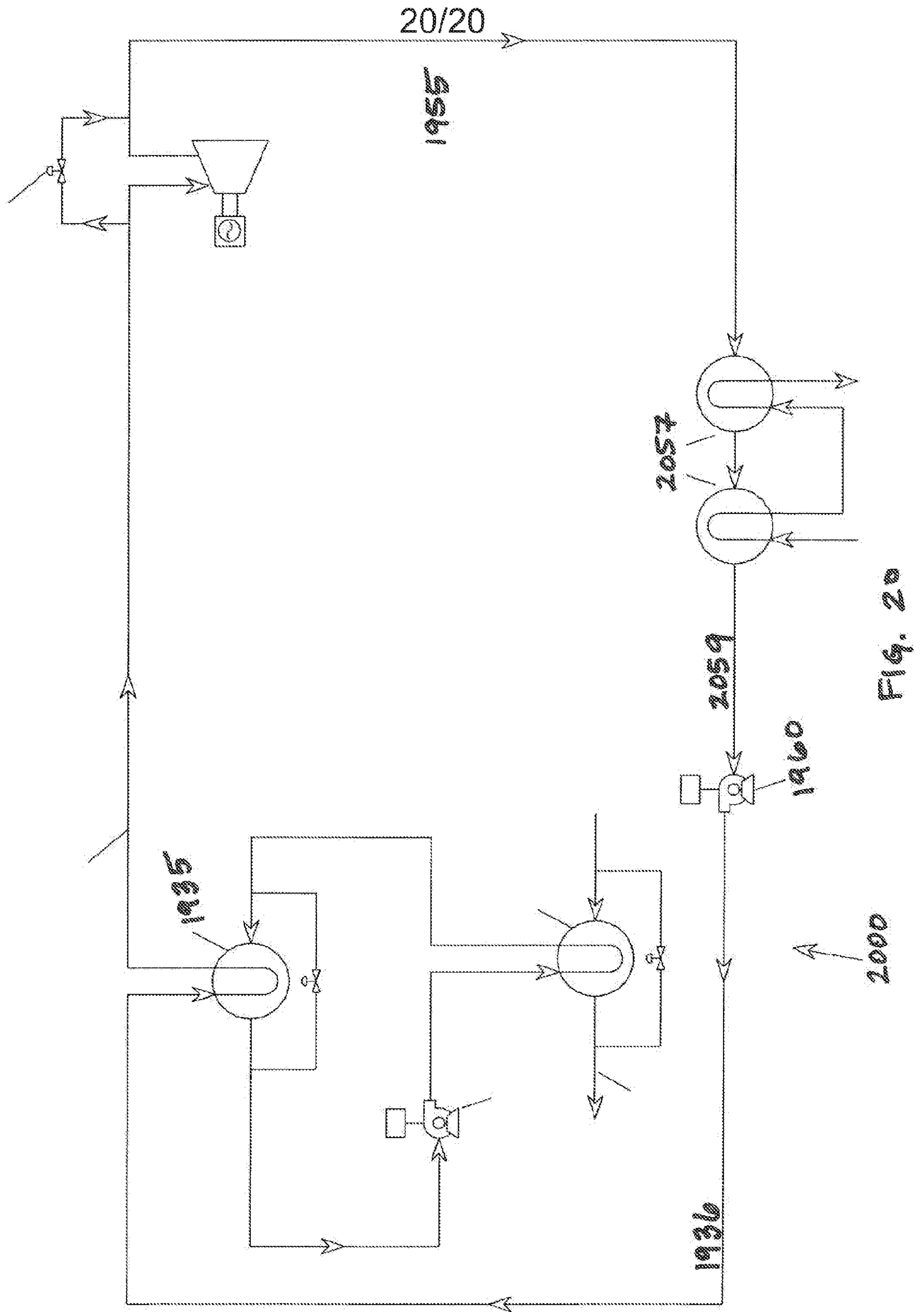


Fig. 19



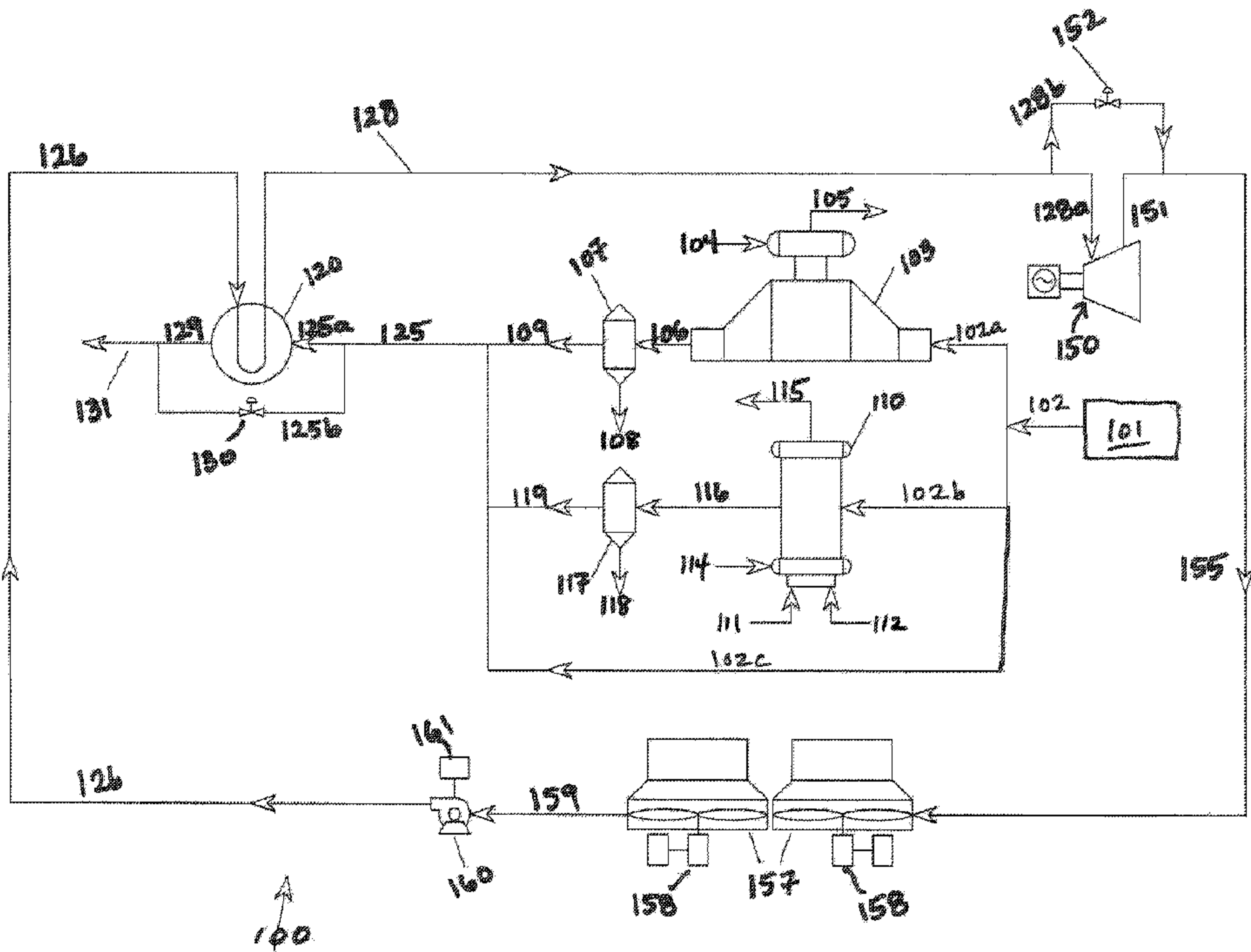


FIG. 1