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CA 2815785 C 2014/10/21

(11)(21) **2 815 785**

(12) **BREVET CANADIEN**
CANADIAN PATENT

(13) **C**

(22) **Date de dépôt/Filing Date:** 2011/04/15
(41) **Mise à la disp. pub./Open to Public Insp.:** 2012/10/15
(45) **Date de délivrance/Issue Date:** 2014/10/21
(62) **Demande originale/Original Application:** 2 737 410

(51) **Cl.Int./Int.Cl.** *B03B 9/02* (2006.01)
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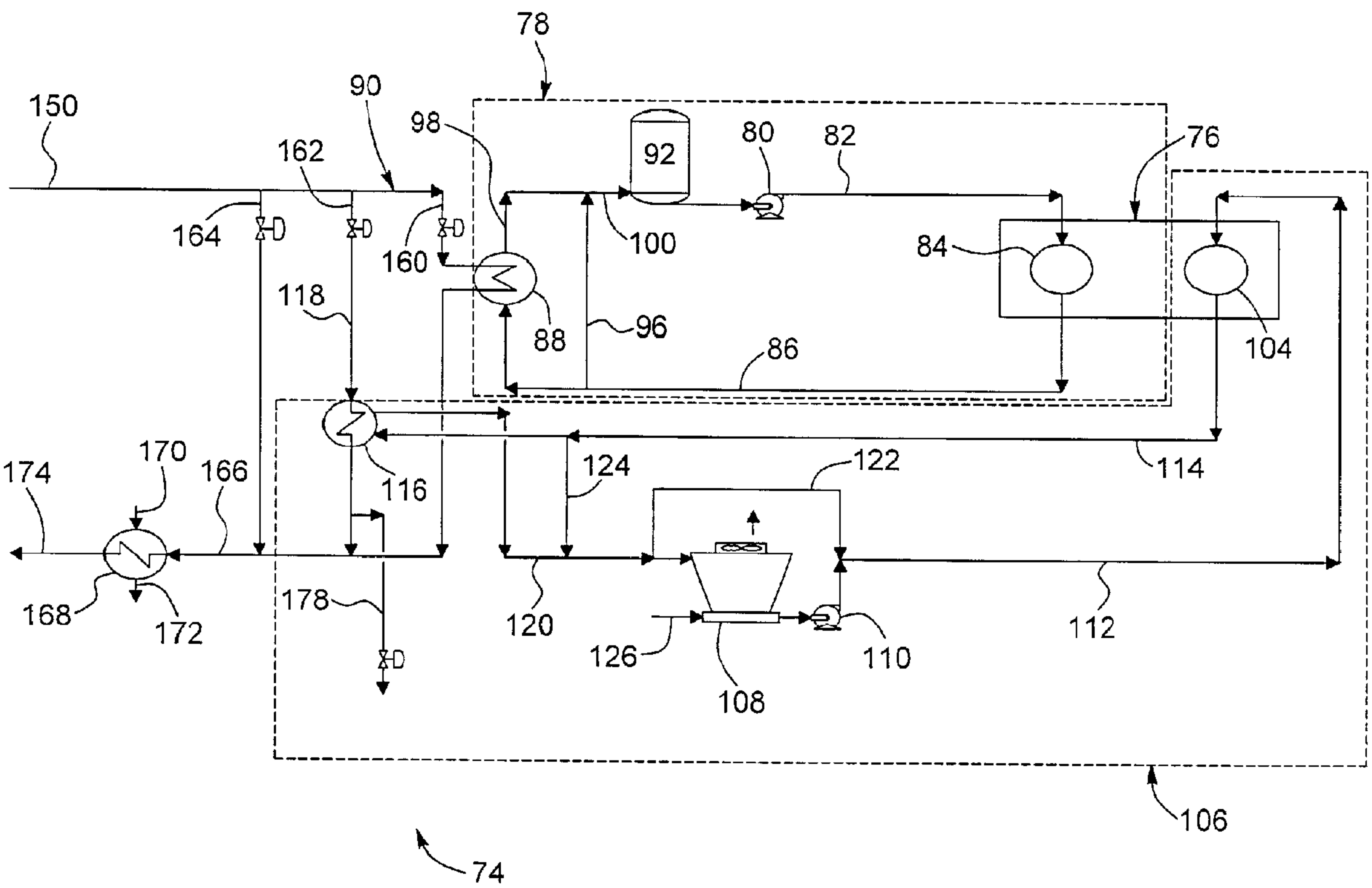
(54) **Titre : RECUPERATION DE CHALEUR DESTINEE A ETRE INTEGREE A UNE INSTALLATION DE TRAITEMENT DE MOUSSE DE BITUME COMPRENANT DES CIRCUITS EN BOUCLE A CIRCULATION THERMIQUE**

(54) **Title: HEAT RECOVERY FOR BITUMEN FROTH TREATMENT PLANT INTEGRATION WITH TEMPERATURE CIRCULATION LOOP CIRCUITS**



(57) **Abrégé/Abstract:**
A system for recovering heat from a bitumen froth treatment plant use temperature circulation loop circuits. The system has high temperature and low temperature cooling exchangers associated with the plant; the circulation loop circuits; and an oil sands process fluid line. The circuits include a high temperature circulation loop for circulating heat exchange media for recovering heat from the high temperature cooling exchangers to produce a heated media, and a low temperature circulation loop for circulating a cooling media for recovering heat from the low temperature cooling exchangers and producing a heated cooling media. The oil

(57) **Abrégé(suite)/Abstract(continued):**
sands process fluid line is in heat exchange connection with the high temperature circulation loop and the low temperature circulation loop, such that the heated media and the heated cooling media transfer heat to the oil sands process fluid to produce a heated process fluid.

ABSTRACT

A system for recovering heat from a bitumen froth treatment plant use temperature circulation loop circuits. The system has high temperature and low temperature cooling exchangers associated with the plant; the circulation loop circuits; and an oil sands process fluid line. The circuits include a high temperature circulation loop for circulating heat exchange media for recovering heat from the high temperature cooling exchangers to produce a heated media, and a low temperature circulation loop for circulating a cooling media for recovering heat from the low temperature cooling exchangers and producing a heated cooling media. The oil sands process fluid line is in heat exchange connection with the high temperature circulation loop and the low temperature circulation loop, such that the heated media and the heated cooling media transfer heat to the oil sands process fluid to produce a heated process fluid.

HEAT RECOVERY FOR BITUMEN FROTH TREATMENT PLANT INTEGRATION WITH TEMPERATURE CIRCULATION LOOP CIRCUITS

FIELD OF THE INVENTION

The present invention generally relates to the field of oil sands processing and in particular relates to heat exchange and recovery for bitumen froth treatment plants.

BACKGROUND

Known cooling systems in oil sands froth treatment process included open loop once-through cooling systems and conventional closed cooling water loop systems where process exchangers transfer heat to circulating cooling water which then recovers with heat exchangers higher grade heat to a recycling process water stream and then removes the low grade heat by evaporative cooling in a cooling tower.

Open loop cooling systems that transfer process heat directly have poor energy efficiency and are not environmentally acceptable. Within oil sand operations, bitumen extraction process requires significant volumes of hot process water at or around 80°C, some of the heat being largely recovered for recycling at temperatures ranging between 4°C to 30°C depending on factors such as season and pond size. This recycle water contains suspended solids, hydrocarbon e.g. bitumen, various salts e.g. chlorides and minerals that cycle up over time to reflect connate water contaminates in the ore body, and as exposed to atmosphere the water is saturated with both oxygen and carbon dioxide gases. Various oil sands operators have used this recycle water stream as cooling water with costly repercussions and drawbacks including: frequent need to clean fouled exchangers and to permit continuous exchanger cleaning have spare exchangers installed; upgrading of metallurgy to combat erosion and corrosion particularly in situations where the process cooling temperatures are above 60°C; frequent need to maintain exchanger velocities to control fouling; piping repairs on an on-going basis due to erosion and corrosion due to oxygen, chlorides and temperatures; and temperature limitations forcing supplementary heating of process water for extraction operations.

Oil sand operators have also used some conventional close loop cooling systems using cooling towers to reject heat by evaporative cooling with make-up water from the river. This option is not without challenges. For instance, the evaporative process causes minerals in make-up water to cycle up to saturation levels which if not managed will foul exchangers. The management involves blow down and make-up inventories together with chemical anti-scaling programs. Despite this water treatment and management, maximum cooling water temperatures are limited to levels similar to recycle water at about 65°C. In addition, the location of the cooling tower can create significant fog and ice safety issues. Consequently, towers are generally placed a significant distances from process unit and the interconnect supply and return pipelines are relatively costly and also often have diameters from 24 – 60 inches. Furthermore, the heat lost by evaporative cooling is not available for process use. In addition, blow down with concentrated minerals are disposed in tailing systems. Divalent ions, such as calcium ions, adversely affect bitumen extraction if not precipitated by carbon dioxide.

In addition, integrating froth treatment plant with other oil sands process operations in fraught with challenges due to differing operational and upset conditions.

In summary, known practices and techniques for heat exchange and cooling in this field experience various drawbacks and inefficiencies, and there is indeed a need for a technology that overcomes at least some of those drawbacks and inefficiencies.

SUMMARY OF THE INVENTION

The present invention responds to the above-mentioned need by providing a process and a system for heat removal and recovery from a froth treatment plant.

In one embodiment, the invention provides a system for recovering heat from a bitumen froth treatment plant. The system comprises a heat removal exchanger associated with the bitumen froth treatment plant and receiving a hot froth treatment process stream; a heat recovery exchanger; and a sealed closed-loop heat transfer circuit. The sealed closed-loop heat transfer circuit comprises piping for circulating a heat exchange media having uncontaminated and low fouling properties. The piping comprises a supply line for providing the heat exchange media to the heat removal exchanger to remove heat from the hot froth treatment process stream and produce a heated media; and a return line for providing the heated media from the heat removal exchanger to the heat recovery exchanger. The sealed closed-loop heat transfer circuit also comprises a pump for pressurizing and pumping the heat exchange media through the piping; and a pressure regulator in fluid communication with the piping for regulating pressure of the heat exchange media. The pump and the pressure regulator are configured to maintain the heat exchange media under pressure and in liquid phase within the piping. The system also comprises an oil sands process fluid line for supplying an oil sands process fluid to the heat recovery exchanger to allow the heated media to heat the oil sands process fluid, thereby producing a heated oil sands process fluid and a cooled heat exchange media for reuse in the heat removal exchanger.

In one aspect, the heat exchange media comprises demineralized water.

In another aspect, the heat exchange media comprises chemical additives to reduce fouling.

In another aspect, the heat exchange media is free of dissolved oxygen, suspended solids, scaling compounds and hydrocarbon contaminants therein.

In another aspect, the heat removal exchanger comprises a solvent condenser and the hot froth treatment process stream comprises a vapour phase solvent.

In another aspect, the solvent condenser comprises a plurality of solvent condensers.

In another aspect, the solvent condenser is associated with a solvent recovery unit.

In another aspect, the solvent condenser is configured such that the vapour phase solvent is condensed at a condensation temperature between about 65°C and about 130°C.

In another aspect, the solvent condenser is configured such that the heat exchange media is heated from an inlet temperature between about 25°C and about 40°C to an outlet temperature between about 80°C and about 120°C .

In another aspect, the heat recovery exchanger comprises a plurality of heat recovery exchangers.

In another aspect, the plurality of heat recovery exchangers comprises a first array of heat recovery exchangers arranged in series and a second array of heat recovery exchangers arranged in series.

In another aspect, the first and second arrays are arranged in parallel to each other.

In another aspect, the heat recovery exchangers are shell-and-tube type heat exchangers comprising tubes receiving the oil sands process fluid and a shell receiving the heated media.

In another aspect, the system comprises an in-line exchanger cleaning system associated with the shell-and-tube type heat exchangers.

In another aspect, the sealed closed-loop heat transfer circuit comprises a control device for controlling the temperature of the cooled heat exchange media to be consistent for reuse in the heat removal exchanger.

In another aspect, the control device comprises a bypass line for bypassing the heat recovery exchangers.

In another aspect, the pressure regulator comprises an expansion device.

In another aspect, the expansion device comprises an expansion tank.

In another aspect, the expansion tank is in fluid communication with the supply line of the piping.

In another aspect, the expansion tank is connected to the supply line upstream of the pump and downstream of the heat recovery exchanger.

In another aspect, the system comprises a balance line for providing fluid communication between the piping and the expansion tank.

In another aspect, the pump and the pressure regulator are configured to maintain the pressure of the heat exchange media above the pressure of the hot froth treatment process stream.

In another aspect, the pump and the pressure regulator are configured to maintain the pressure of the heat exchange media at least about 10% above the pressure of the hot froth treatment process stream.

In another aspect, the pump and the pressure regulator are configured to maintain the pressure of the heat exchange media between about 300 kPaa and about 800 kPaa.

In another aspect, the system also has a second heat removal exchanger associated with the bitumen froth treatment plant and receiving a second froth treatment process stream that is cooler than the hot froth treatment process stream; a second heat recovery exchanger; and a second heat transfer circuit for circulating a cooling media to the second heat removal exchanger to remove heat from the second froth treatment process stream and produce a heated cooling media and providing the same to the second the heat recovery exchanger.

In another aspect, the second heat removal exchanger comprises a low temperature solvent condenser and the second froth treatment process stream comprises a vapour phase solvent.

In another aspect, the low temperature solvent condenser comprises a plurality of low temperature solvent condensers.

In another aspect, the low temperature solvent condenser is associated with a tailings solvent recovery unit.

In another aspect, the low temperature solvent condenser is configured such that the vapour phase solvent is condensed at a condensation temperature between about 60°C and about 80°C.

In another aspect, the low temperature solvent condenser is configured such that the cooling media is heated from an inlet temperature between about 4°C and about 30°C to an outlet temperature between about 40°C and about 60°C.

In another aspect, the second heat recovery exchanger comprises a plurality of second heat recovery exchangers.

In another aspect, the plurality of second heat recovery exchangers comprises at least two in series.

In another aspect, the second heat recovery exchangers are shell-and-tube type heat exchangers comprising tubes receiving the oil sands process fluid and a shell receiving the heated cooling media.

In another aspect, the system comprises an in-line exchanger cleaning system associated with the shell-and-tube type heat exchangers.

In another aspect, the second heat recovery exchangers are plate and frame or spiral type heat exchangers.

In another aspect, the heat recovery exchanger and the second heat recovery exchanger are arranged in series to serially heat the oil sands process fluid.

In another aspect, the heat recovery exchanger and the second heat recovery exchanger are arranged in parallel for heating portions of the oil sands process fluid.

In another aspect, the system comprises a cooling tower coupled to the second heat transfer circuit for receiving the cooling media discharged from the second heat recovery exchanger and provide a cooled cooling media for reuse in the second heat removal exchanger.

In another aspect, the system comprises a sealed cooling tower coupled to the sealed closed-loop heat transfer circuit for trim cooling of the heat exchange media discharged from the heat recovery exchanger.

In another aspect, the sealed cooling tower comprises coiled tubing for carrying the heat exchange media and a cooling spray device for spraying cooling water into the coiled tubing to enable heat removal from the heat exchange media.

In another aspect, the sealed cooling tower is a WSAC™ cooling tower.

In another aspect, the system comprises a dump line in fluid communication with the oil sands process fluid line carrying the heated oil sands process fluid from the heat recovery exchangers, the dump line being configured to discard the heated oil sands process fluid.

In another aspect, the oil sands process fluid comprises recycle process water for reuse in an oil sands extraction operation.

In another aspect, the system comprises a trim heater for further heating the heated recycle process water prior to the oil sands extraction operation.

In another aspect, the froth treatment plant is a high temperature paraffinic froth treatment plant.

In another aspect, the high temperature paraffinic froth treatment plant is operated between about 70°C and about 120°C.

In another aspect, the froth treatment plant is a naphthenic froth treatment plant

The invention also provides a process for recovering heat from a bitumen froth treatment plant, the process comprising:

> providing sealed closed-loop heat transfer circuit for circulating a heat exchange media having low fouling properties;
>
> removing heat from a hot froth treatment stream into the heat exchange media to produce a heated media;
>
> transferring heat from the heated media to an oil sands process fluid to produce a heated oil sands process fluid and a cooled heat exchange media; and
>
> pressurizing and regulating pressure of the heat exchange media within the sealed closed-loop heat transfer circuit to maintain the heat exchange media under pressure and in liquid phase.

In one aspect of the process, the heat exchange media comprises demineralized water.

In another aspect, the heat exchange media comprises chemical additives to reduce fouling.

In another aspect, the heat exchange media is free of dissolved oxygen, suspended solids, scaling compounds and hydrocarbon contaminants therein.

In another aspect, the step of removing heat comprises condensing a vapour phase solvent as the hot froth treatment stream in a solvent condenser.

In another aspect, the solvent condenser comprises a plurality of solvent condensers.

In another aspect, the solvent condenser is associated with a solvent recovery unit of the bitumen froth treatment plant.

In another aspect, the process comprises condensing the vapour phase solvent at a condensation temperature between about 65°C and about 1130°C.

In another aspect, the process comprises heating the heat exchange media in the solvent condenser from an inlet temperature between about 25°C and about 40°C to an outlet temperature between about 80°C and about 120°C.

In another aspect, the step of transferring heat comprises using a plurality of heat recovery exchangers.

In another aspect, the plurality of heat recovery exchangers comprises a first array of heat recovery exchangers arranged in series and a second array of heat recovery exchangers arranged in series.

In another aspect, the first and second arrays are arranged in parallel to each other.

In another aspect, the heat recovery exchangers are shell-and-tube type heat exchangers comprising tubes receiving the oil sands process fluid and a shell receiving the heated media.

In another aspect, the process comprises in-line cleaning of the shell-and-tube type heat exchangers.

In another aspect, the array of heat recovery exchangers comprises plate and frame or spiral type heat exchangers.

In another aspect, the process comprises controlling the temperature of the cooled heat exchange media to be consistent for reuse in the step of removing heat.

In another aspect, the controlling is performed by a control device comprising a bypass line for partially bypassing the step of recovering heat.

In another aspect, the step of pressurizing and regulating pressure is performed by a pump and a pressure regulator.

In another aspect, the pressure regulator comprises an expansion device.

In another aspect, the expansion device comprises an expansion tank.

In another aspect, the expansion tank is in fluid communication with the cooled heat exchange media in the sealed closed-loop heat transfer circuit.

In another aspect, the pressure of the heat exchange media is maintained above the pressure of the process stream.

In another aspect, the pressure of the heat exchange media is maintained at least 10% above the pressure of the process stream.

In another aspect, the pressure of the heat exchange media is maintained between about 300 kPaa and about 800 kPaa.

In another aspect, the process comprises providing a second heat transfer circuit for circulating a cooling media; removing heat from a second froth treatment process stream that is cooler than the hot froth treatment process stream into the cooling media; and transferring heat from the heated cooling media to the oil sands process fluid.

In another aspect, the step of removing heat comprises condensing a second vapour phase solvent as the second froth treatment stream in a low temperature solvent condenser.

In another aspect, the low temperature solvent condenser comprises a plurality of low temperature solvent condensers.

In another aspect, the low temperature solvent condenser is associated with a tailings solvent recovery unit of the bitumen froth treatment plant.

In another aspect, the vapour phase solvent is condensed at a condensation temperature between about 60°C and about 80°C.

In another aspect, step of removing heat comprising heating the cooling media from an inlet temperature between about 4°C and about 30°C to an outlet temperature between about 40°C and about 60°C.

In another aspect, the step of transferring heat from the heated cooling media is performed in a second heat recovery exchanger.

In another aspect, the second heat recovery exchanger is a shell-and-tube type heat exchanger comprising tubes receiving the oil sands process fluid and a shell receiving the heated cooling media.

In another aspect, the process comprises serially heating the oil sands process fluid via the heated media and the heated cooling media.

In another aspect, the process comprises heating portions of the oil sands process fluid respectively via the heated media and the heated cooling media in parallel.

In another aspect, the process comprises a cooling tower coupled to the second heat transfer circuit for receiving the cooling media and providing a cooled cooling media for reuse in the step of removing heat from the second froth treatment process.

In another aspect, the process comprises trim cooling the heat exchange media using a sealed cooling tower coupled to the sealed closed-loop heat transfer circuit.

In another aspect, the sealed cooling tower comprises coiled tubing for carrying the heat exchange media and a cooling spray device for spraying cooling water into the coiled tubing to enable heat removal from the heat exchange media.

In another aspect, the sealed cooling tower is a WSAC™ cooling tower.

In another aspect, the process comprises dumping the heated oil sands process fluid in response to upset conditions in downstream application of the heated oil sands process fluid.

In another aspect, the oil sands process fluid comprises recycle process water for reuse in an oil sands extraction operation.

In another aspect, the process comprises trim heating the heated recycle process water prior to the oil sands extraction operation.

In another aspect, the froth treatment plant is a high temperature paraffinic froth treatment plant.

In another aspect, the high temperature paraffinic froth treatment plant is operated between about 70°C and about 120°C.

There is also provided a system for recovering heat from a bitumen froth treatment plant. The system comprises high and low temperature cooling exchangers associated with the bitumen froth treatment plant; a high temperature circulation loop for circulating heat exchange media for recovering heat from the high temperature cooling exchangers to produce a heated media; a low temperature circulation loop for circulating a cooling media for recovering heat from the low temperature cooling exchangers and producing a heated cooling media; and an oil sands process fluid line in heat exchange connection with at least one of the high temperature circulation loop and the low temperature circulation loop, such that at least one of the heated media and the heated cooling media transfer heat to the oil sands process fluid to produce a heated process fluid.

In one aspect, one of the at least one oil sands process fluid line is in heat exchange connection with both the high temperature and the low temperature circulation loops for receiving heat there-from.

In another aspect, the system comprises a high temperature heat exchanger connected to the high temperature circulation loop and the oil sands process fluid line.

In another aspect, the high temperature heat exchanger is a high temperature shell-and-tube exchanger comprising tubes in fluid communication with the oil sands process fluid line and a shell in fluid communication with the high temperature circulation loop for receiving the heated media.

In another aspect, the system comprises an in-line exchanger cleaning system associated with the high temperature shell-and-tube heat exchanger.

In another aspect, the system comprises a low temperature heat exchanger connected to the low temperature circulation loop and the oil sands process fluid line.

In another aspect, the low temperature heat exchanger is a low temperature shell-and-tube exchanger comprising tubes in fluid communication with the oil sands process fluid line and a shell in fluid communication with the low temperature heat recovery circulation loop for receiving the heated cooling media.

In another aspect, the system comprises an in-line exchanger cleaning system associated with the low temperature shell-and-tube type heat exchanger.

In another aspect, the low temperature heat exchanger and the high temperature heat exchanger are arranged in series for serially heating the oil sands process fluid.

In another aspect, the low temperature heat exchanger and the high temperature heat exchanger are arranged in parallel for heating portions of the oil sands process fluid.

In another aspect, the oil sands process fluid is recycle process water.

In another aspect, the system comprises a pipeline for supplying the heated recycle process water to an oil sands extraction operation.

In another aspect, the high temperature circulation loop is a sealed closed-loop circuit and comprises a pump and a pressure regulator for circulating the heat exchange media under pressure.

In another aspect, the pump and the pressure regulator are configured to maintain the pressure of the heat exchange media above the pressure of the hot froth treatment process stream.

In another aspect, the pump and the pressure regulator are configured to maintain the pressure of the heat exchange media at least about 10% above the pressure of the hot froth treatment process stream.

In another aspect, the pump and the pressure regulator are configured to maintain the pressure of the heat exchange media between about 300 kPaa and about 800 kPaa.

In another aspect, the heat exchange media comprises demineralized water.

In another aspect, the heat exchange media comprises chemical additives to reduce fouling.

In another aspect, the heat exchange media is free of dissolved oxygen, suspended solids, scaling compounds and bitumen therein.

In another aspect, the high temperature cooling exchangers comprise high temperature solvent condensers for condensing and removing heat from a vapour phase solvent.

In another aspect, the high temperature solvent condensers are associated with a solvent recovery unit of the bitumen froth treatment plant.

In another aspect, the high temperature solvent condensers are configured such that the vapour phase solvent is condensed at a condensation temperature between about 65°C and about 130°C.

In another aspect, the high temperature solvent condensers are configured such that the heat exchange media is heated from an inlet temperature between about

25°C and about 40°C to an outlet temperature between about 80°C and about 120°C.

In another aspect, the low temperature circulation loop is an open-loop circuit.

In another aspect, the cooling media comprises process water.

In another aspect, the low temperature circulation loop is a sealed closed-loop circuit.

In another aspect, the cooling media comprises demineralized water.

In another aspect, the cooling media comprises chemical additives to reduce fouling.

In another aspect, the cooling media is free of dissolved oxygen, suspended solids, scaling compounds and bitumen therein.

In another aspect, the set of high temperature cooling exchangers are associated with a froth separation unit (FSU), a solvent recovery unit (SRU) or a tailings solvent recovery unit (TSRU) or a combination thereof in the bitumen froth treatment plant.

In another aspect, the bitumen froth treatment plant is a high temperature paraffinic froth treatment plant.

In another aspect, the high temperature cooling exchangers are associated with the SRU.

In another aspect, the high temperature cooling exchangers are SRU solvent condensers.

There is also provided a process for recovering heat from a bitumen froth treatment plant using a sets of high and low temperature cooling exchangers.

There is also provided a process for recovering heat from a paraffinic froth treatment plant comprising:

providing a heat transfer circuit for circulating a heat exchange media;

removing heat from a froth treatment process stream into the heat exchange media to produce a heated exchange media;

pressurizing and regulating pressure of the heat exchange media within the heat transfer circuit to maintain the heat exchange media under pressure and in liquid phase; and

cooling at least a portion of the heated exchange media using a cooling tower to produce a cooled media.

In one aspect, the cooling water is a sealed cooling tower.

In another aspect, the sealed cooling tower comprises coiled tubing for carrying the heat exchange media and a cooling spray device for spraying cooling water into the coiled tubing to enable heat removal from the heat exchange media.

In another aspect, the sealed cooling tower is a WSAC™ cooling tower.

In another aspect, the froth treatment process stream is a stream of a solvent recovery unit (SRU) of the paraffinic froth treatment plant.

In another aspect, the froth treatment process stream is a stream of the tailings solvent recovery unit (TSRU) of the paraffinic froth treatment plant.

In another aspect, the process further comprises transferring heat from the heated exchange media to an oil sands process fluid to produce a heated oil sands process fluid, before the step of cooling.

In another aspect, the heated oil sands process fluid is supplied to an oil sands extraction operation.

There is also provided a process for integrating an oil sands extraction operation and a paraffinic froth treatment plant, comprising:

providing an oil sands process fluid line for supplying the process fluid to the oil sands extraction operation;

providing at least one dump line in fluid communication with the oil sands process fluid line;

providing a heat transfer circuit associated with the paraffinic froth treatment plant for circulating a heat exchange media and removing heat from the paraffinic froth treatment plant;

transferring heat from the heat exchange media to the oil sands process fluid to produce a heated oil sands process fluid; and

discarding at least a portion of the heated oil sands process fluid through the at least one dump line in response to upset conditions.

In one aspect, the discarding step comprises discarding a portion of the heated oil sands process fluid in response to upset conditions of the extraction operation.

In another aspect, the heated oil sands process fluid comprises hot process water.

In another aspect, the discarding step comprises feeding the hot process water back into a pond water inventory.

In another aspect, the discarding step comprises providing the hot process water to other parts of the oil sands operations or facilities for heat reutilization.

In another aspect, the discarding step comprises feeding a first portion of the heated oil sands process fluid into a utilities dump tank using a first dump line.

In another aspect, the discarding step comprises sending a second portion of the heated oil sands process fluid to a holding tank and discarding at least a part of the second portion of the heated oil sands process fluid through a holding tank dump line.

In another aspect, the holding tank dump line is associated with a level control device for controlling the level of the holding tank.

In another aspect, the discarded first and second portions of the heated oils sands process fluid are mixed and fed back into a pond inventory.

In another aspect, the upset conditions comprise startup, shutdown, turndown or maintenance of the extraction operation or paraffinic froth treatment plant.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig 1 is a process flow diagram of a heat removal and recovery system with a sealed closed loop cooling circuit and a tertiary cooling circuit according to an embodiment of the present invention.

Fig 2 is a process flow diagram of a heat removal and recovery system according to another embodiment of the present invention.

Fig 3 is a process flow diagram of an SRU including an example of condensing heat exchangers for use in connection with some embodiments of the present invention.

Fig 4 is a process flow diagram of a TSRU including an example of condensing heat exchangers for use in connection with some embodiments of the present invention.

Figs 5A, 5B and 5C, collectively referred to herein as Fig 5, is a process flow diagram of a heat removal and recovery system according to another embodiment of the present invention.

Figs 6A, 6B, 6C and 6D, collectively referred to herein as Fig 6, is a process flow diagram of a heat removal and recovery system according to another embodiment of the present invention.

DETAILED DESCRIPTION

In one aspect of the present invention, as illustrated in Figs 1, 2, 5 and 6, a heat removal and recovery system is provided to remove heat from a bitumen froth treatment plant and reuse the heat in an oil sands process fluid such as process water which is heated for extraction operations.

It is noted that a bitumen froth treatment plant preferably includes a froth settling unit (FSU), a solvent recovery unit (SRU) and a tailings solvent recovery unit (TSRU). The FSU receives bitumen froth and after addition of diluent solvent, such as paraffinic or naphthenic solvent, the diluted froth is separated into a high diluted bitumen component and an underflow solvent diluted tailings component. Depending on the particular solvent, solvent-to-bitumen ratio (S/B) and operating conditions used in the FSU, the high diluted bitumen component and the solvent diluted tailings component will have certain compositions and characteristics. The high diluted bitumen component is further treated in the SRU to remove solvent from the bitumen and produce recovered solvent for reuse in the FSU and bitumen for upgrading. The solvent diluted tailings component is further treated in the TSRU to recover solvent for reuse in the FSU and produce a solvent recovered tailings component which is sent to tailings ponds or further processing, as the case may be. In the overall froth treatment plant, each of the froth treatment units may include a number of vessels, heat exchangers and other processing equipment which operate at various conditions depending on the design and operation of the plant. For instance, the

FSU may include several sets of froth settling vessels arranged in series or in parallel or a combination of series and parallel. The heat from the bitumen froth treatment plant is removed from a so-called "hot froth treatment process stream" which should be considered as one or more of various different types of process streams that may be liquid, vapour, slurry or a mixture thereof; may contain various concentrations of solvent, hydrocarbons, water and/or mineral solids; may be associated with the FSU, SRU and/or TSRU; and may be in a naphthenic or paraffinic froth treatment plant.

Preferably, the froth treatment operation is a high temperature paraffinic froth treatment (PFT) process. The FSU preferably operates above about 70°C, and may be between about 70°C and about 120°C, between about 70°C and about 90°C, or between about 90°C and about 120°C.

The froth treatment plant includes heat transfer devices to heat, cool or condense various process streams. In particular, the heat transfer devices include cooling or condensing devices for removing heat from process streams.

Referring to Fig 3, an SRU 10 may include one or more flash vessels 12, 14 for recovering solvent from high diluted bitumen 16 derived from the froth separation vessels. The first flash vessel 12 produces a flashed solvent stream 18 and a partially solvent recovered bitumen stream 20. The flashed solvent stream 18 passes through a separator 22 and then is condensed in a first solvent condenser 24 to produce condensed solvent 26. The partially solvent recovered bitumen stream 20 is subjected to a second flash in flash vessel 14 to produce a second flashed solvent 28 and solvent recovered bitumen 30. The second flashed solvent 28 may be sent to a separator 32 and then to a second condenser 34 to produce a second condensed solvent stream 36, which may be combined with the first solvent stream 26 and reused in the froth treatment operation. The solvent recovered bitumen 30 may be further processed, for example in a bitumen fractionation column 38, which may receive other streams 40, 42 recovered from the SRU. The bitumen fractionation column 38 generates hot dry bitumen 44 as well as an overhead solvent 46 which is preferably condensed in a column condenser 48 to produce column recovered condensed solvent 50.

Referring to Fig 4, a TSRU 52 may include one of more flash or stripping vessels 54, 56 for recovering solvent from the solvent diluted tailings 58 derived from the froth separation vessels. The first stripping vessel 54 receives the solvent diluted tailings 58 and steam 60 and produces overhead flashed solvent 62 and an underflow of partially solvent recovered tailings 64, which is supplied to the second stripping vessel 56. The overhead flashed solvent 62 may be condensed by a first TSRU condenser 66 and then further processed. The partially solvent recovered tailings 64 is separated into a second overhead solvent 68 and an underflow of solvent recovered tailings 70. The second overhead solvent 68 is preferably condensed in a second TSRU condenser 72 and then further processed or separated to produce a recovered solvent for reuse in the froth treatment operation.

Referring to Figs 1, 2, 5 and 6, in one aspect of the present invention, the froth treatment plant comprises heat exchangers for cooling and/or condensing froth treatment streams and employs heat removal circuits for removing heat from the froth treatment streams and transferring the heat to another oil sands process fluid.

Referring in particular to Fig 1, in one aspect of the invention, there is a heat removal and recovery system 74 for removing heat from a froth treatment plant 76 and reusing it. It should be noted that the "heat removal and recovery system" may also be referred to herein using a variety of expressions such as a "heat recovery system", a "cooling system", "cooling circuit", "cooling loop", "heat recovery circuit", "heat transfer circuit" or other such variations. It should also be understood that while it may be referred to as a "cooling circuit" or "cooling system", the circuit may condense a froth treatment process stream such as flashed solvent at a constant temperature rather than actually lower the temperature of solvent stream. The invention provides various circuits that allow heat removal from a froth treatment plant for recovery and reuse in heating an oil sands processing stream such as process affected water for extraction operations.

In one aspect, the heat recovery system 74 includes a sealed closed-loop heat transfer system illustrated as within area 78 which includes a heat exchange media circulation pump 80 and supply piping 82 for circulating a heat exchange media through at least one froth treatment heat exchanger 84 which is preferably a high temperature cooling or condensing exchanger. The sealed closed-loop heat transfer system 78 also includes return piping 86 for returning heated media into heat recovery exchangers 88 where heat is transferred from the heated media to recycle process water circulated through a process water line 90 for example. As will be further described herein-below, the recycle process water is preferably heated for use in a bitumen ore extraction operation, for instance in a Clark Hot Water Extraction (CHWE) process to separate the bitumen from the ore and create an oil sands ore slurry.

In one aspect, the sealed closed-loop heat transfer system 78 can be viewed as a high temperature cooling circuit for recovering high grade heat from high temperature heat exchangers 84 in the froth treatment plant. For example, the high temperature heat exchangers may be condensing exchangers such as the SRU condensers 24, 34 and/or 48 illustrated in Fig 3. More regarding this high grade heat recovery will be discussed herein-below.

Referring to Fig 1, in one aspect, the high temperature cooling circuit 78 is pressurized, that is the cooling media which is circulated to remove heat from SRU condensing exchangers and provide heat to the recycled process water is maintained under pressure. The pressurized circulation loop configuration allows substantially avoiding static head requirements for the circulation pump while permitting heated cooling media to circulate. In one aspect, the cooling media in the circuit 78 is pressurized above the pressure of the process fluid being cooled or condensed in the high temperature heat exchangers 84. This enables several advantages. More particularly, if there is leakage between the cooling media and the process fluid, for instance due to damage to the exchanger walls, the higher pressure cooling media will leak into the process fluid line instead of the process fluid leaking into the cooling circuit. This allows improved leak detection since water based cooling media may be straightforwardly detected in solvent-based streams; preventing contamination of the cooling media with process fluid; and safeguarding against fouling within the cooling loop. In one preferred aspect, the cooling media pressure is maintained at least 10% above the pressure of the froth treatment process fluid. By maintaining the pressure of the heat exchange media above and preferably 10% above the pressure of the process fluid, e.g. solvent, helps prevent contamination of the cooling loop, since if there is a leak it will be from the cooling loop into the froth treatment process side. This is particularly advantageous since if the process stream leaks into the cooling system, exchangers can quickly foul and contaminant hydrocarbon phases can be detrimental and dangerous to cooling loop equipment such as cooling towers. On the other hand, water based cooling media can leak into the process side and be quickly detected using electrical based systems, since water conducts electricity and hydrocarbons do not.

In another aspect, the high temperature cooling circuit 78 also includes a pressure regulation device 92 which is preferably a pressure expansion tank or similar device. The pressurized expansion tank 92 is preferably provided and configured to allow for fluid expansion and some surge capacity within the cooling circuit 78. The pressure expansion tank 92 maintains the cooling loop system pressure and absorbs volume swings in the system due to thermal expansion and contraction of the cooling media. The circulation of cooling media is under pressure and maintained to avoid flashing of the media at the process cooling temperatures. The pressure expansion tank 92 helps maintain system pressure. In Figs 2, 5 and 6 the pressure expansion tank 92 is illustrated as being connected to the system via a balance line 94, but it may also be connected in-line and provides an amount of surge capacity for leaks. A reserve tank (not illustrated) may also be provided for inventorying the system during unit outages. The expansion device 92 and the reserve tank are preferably sized, designed and controlled in connection with the selected cooling media and the overall system operating conditions to achieve the desired pressurization and surge capacity. It is also noted that the expansion tank 92 may be located into the supply line 82 or the return line 86 of the cooling circuit 78, which may be chosen partially based on the layout of the SRU heat exchangers 84 for example. In addition, the pressure regulation device 92 may be a bladder tank separating gas blanket from the media or one with a gas blanket in direct contact with the fluid media, a low pressure tank or "surge tank" with pumps and pressure relief possibilities, or a pump and regulation valve combination, for example. The circulation pump 80 compensates for hydraulic loss and the pressure tank or other regulation device regulates pressure.

In another aspect, the high temperature cooling circuit 78 also includes a hot media bypass line 96 for bypassing the heat recovery exchangers 88. This hot media bypass line may be used for temperature control of the cooled heat transfer media 98 exiting the heat recovery exchangers 88 to produce a temperature controlled heat exchange media 100. Referring to Figs 5 and 6, there may be a temperature control device 102 including a valve and controller arrangement.

In one aspect, there are multiple cooling circuits such as the cooling circuit 78 illustrated in Fig 1 that are provided for recovering heat from froth treatment heat exchangers for reuse in heating process water for oil sands extraction operations or other purposes. It should be understood that each cooling circuit may be a sealed closed-loop circuit such circuit 78, coupled to a given set of froth treatment condensers and heat recovery exchangers.

In another aspect, referring to Figs 1 and 2, the froth treatment exchangers include high temperature cooling exchangers 84 and low temperature cooling exchangers 104. Preferably, there is a set of the high temperature cooling exchangers 84 and a set of the low temperature cooling exchangers 104. Each set of cooling exchangers may include exchangers associated with one or more of the froth treatment plant units such as the FSU, SRU and TSRU. Alternatively, each set of cooling exchangers may be associated with a corresponding one of the FSU, SRU or TSRU. The cooling exchangers are split into at least two sets by minimum cooling temperature needed. In one aspect, the set of high temperature cooling exchangers 84 is associated with the SRU, in particular with the condensers used to condense flashed overhead solvent, e.g. condensers 24, 34 and/or 48 illustrated in Fig 3. The high temperature condensing exchangers 84 may operate to handle about 70% to about 80% of the cooling heat load of the SRU.

Referring to Fig 1, in one optional aspect, the set of high temperature cooling exchangers 84 is associated with a sealed closed-loop cooling circuit 78 and the set of low temperature cooling exchangers 104 is associated with a separate cooling circuit which may be a closed loop or another type of cooling system.

The set of low temperature cooling exchangers 104 may be associated with the TSRU, in particular with the condensers used to condense flashed overhead solvent, e.g. condensers 66 and/or 72 illustrated in Fig 4. The TSRU condensers are often required to operate as low pressures and thus are low heat condensers and preferably associated with a low temperature cooling loop.

More regarding the high and low temperature heat exchangers will be discussed herein-below.

Referring back to Fig 1, a low temperature cooling circuit illustrated as within area 106 circulates from a cooling tower 108 which, with evaporative cooling, supplies cooling water at about 25°C in summer. Of course, it should be noted that the temperature of the cooling water that is supplied may vary depending on weather and environmental conditions as well as process operational requirements. A cooling water circulation pump 110 provides the hydraulic head required to overcome friction and static heads to distribute the cooling water via a supply header 112 to the low temperature cooling exchangers 104. In one aspect, the heat pick-up by an individual low temperature cooling exchanger 104 may be limited up to about 60°C as the temperature of the discharge cooling water, in order to minimize fouling potential due to water chemistry of the make-up water supply. The cooling water return line 114 may then return the heated cooling water to a low temperature heat recovery exchanger 116 that transfers heat from the heated cooling water to recycled process water 118. It should be understood that the heat transferred is affected seasonal factors. In summer, when recycle water temperatures are at or above 25°C, the cooling water with conventional exchangers used as the low temperature heat recovery exchanger 116 can achieve about 5°C approach temperatures and the remaining heat must be removed by the cooling tower 108. In winter, when recycle water temperatures are about 4°C, conventional exchangers used as the low temperature heat recovery exchanger 116 can achieve the 25°C cooling water circulation temperature; however, the cooling tower 108 is nevertheless preferably circulated to avoid damage due to ice formation.

Referring still to Fig 1, the cooled cooling water is supplied from the heat recovery exchanger 116 to the cooling tower 108 via a cool water line 120. In some embodiments, there may be additional bypass lines to enable advantageous control of the system. In one aspect, there is a cooling tower bypass line 122 so that a portion of the cooled cooling water 120 can bypass the cooling tower. This bypassing can simplify the setup to control temperature and optimize heat exchanger design and operation with a consistent inlet cooling water temperature. In addition, there may be cooling water connection line 124 connecting the return line 114 to the cool water line 120. These lines 122 and 124 can aid in temperature control of the cooling water supplied to the cooling tower and the lower temperature heat exchangers and can also facilitate maintenance, cleaning or replacement of exchangers, cooling tower, and other bypassed equipment. There is also a make-up water line 126 for providing make-up water to the system.

Referring to Figs 5 and 6, the high and low temperature heat exchanger circuits may be respectively associated with a set of high temperature heat exchangers and a set of low temperature heat exchangers. The high temperature set is illustrated as having two parallel banks each comprising six heat exchangers in series. It should note noted that many variations or alternative arrangements may be employed.

Regarding the cooling heat exchangers of the high and low temperature sets, they may be configured in shell-and-tube arrangements to achieve maximum heat recovery from the froth treatment plant units for transfer via the corresponding cooling loop to the recycle process water at the highest temperature. The preferred heat exchangers are able to achieve approach temperatures down to about 5°C. Shell-and-tube exchangers are preferred though plate exchangers which can achieve approach temperatures down to about 2°C may also be used and may even be advantageous, for instance for the low temperature heat recovery exchanger 116 shown in Fig 1.

In one aspect, the high temperature heat exchangers 84 may be selected, designed or operated such that solvent is condensed at a condensation temperature between about 65°C and about 130°C, preferably between about 80°C and about 100°C, while the heat exchange media is heated from an inlet temperature between about 25°C and about 40°C, preferably about 30°C, to an outlet temperature between about 80°C and about 120°C. It is also noted that individual condensers may operate as low as 65°C, while the aggregate of the set may operate between 80°C and 100°C. In another aspect, the low temperature heat exchangers 104 may be selected, designed or operated such that solvent is condensed at a condensation temperature between about 60°C and about 80°C, while the cooling water is heated from an inlet temperature between about 4°C and about 30°C, depending on seasonal conditions, to an outlet temperature between about 40°C and about 60°C, preferably about 45 °C.

Turning now to Figs 2 and 6, the low temperature cooling circuit may also be a sealed closed-loop circuit. In this embodiment, the low temperature cooling circuit preferably circulates a heat recovery medium similar to that for circuit 78 and includes a second expansion tank 128, a second pump 130 and sealed cooling tower 132. The sealed cooling tower may be a Wet Surface Air Cooler (WSAC™) or similar type cooling tower where heat exchange media to be cooled does not come into contact with the atmosphere or external cooling fluids, but rather is circulated within sealed coiled piping the exterior of which is sprayed with cooling water via a spray system 134. In particular, WSAC™ systems have re-circulated cooling water that cascades continuously over bundles of smooth tubes while air moves over the tube bundles in a downward direction that is concurrent with the cascading water. Heat is transferred by convection from the tube surfaces to the cascading cooling water and the flow of air mixes with the flow of cooling water, the flow of which is generally in the same downward direction. The cascade is at an equilibrium temperature as water evaporates to the air. The heat exchange media can thus be cooled indirectly by the sprayed or cascaded cooling water and can remain in the sealed closed-loop circuit without being contaminated or depressurized. Figs 2 and 6 illustrate a sealed cooling tower 132 having a make-up cooling water inlet 136 which provides make-up water into the bottom of the tower. The cooling water is pumped from the bottom of the cooling tower via a tower pump 138 to the spray system 134 which sprays cooling water onto sealed coiled piping 140 provided within the tower 132 and which contains the heat exchange media. There may also be a blowdown line 142 the flow of which is regulated by the tower pump 138 and a control device 144 shown in Fig 6. The sealed closed cooling tower may be used instead of a cooling tower with decks over which water or media flashes.

Referring to Fig 2, the second sealed closed-loop cooling circuit may also include a heated bypass line 146 including a bypass heat exchanger 148, for bypassing and heating the cooled cooling media exiting the second heat recovery exchanger 116 and recycling the heated media back upstream into the cooling water return line 114. This heated bypass line may be employed for providing additional heat to the process water, for temperature control purposes and/or allowing closed recirculation for upset conditions or maintenance of equipment when needed.

Referring now to Figs 1, 2, 5 and 6, the heat recovery and cooling circuits 78, 106 are preferably used to heat process water for use in oil sands extraction operations. In one aspect, cold process water 150 is provided via pipeline to at least one cooling circuit.

As shown in Figs 5 and 6, the cold process water 150 can be obtained from a pond inventory system 152 which includes a tailings and water pond 154 and a pumping reservoir system 156 which uses pumps 158 to supply the cold process water 150.

Referring to Figs 1, 2, 5 and 6, the cold process water may be heated by the heated media of the heat recovery and cooling circuits according to a variety of heat exchange configurations. In one embodiment, the cold process water may be split into multiple pipelines, such as a first process water line 160 which may be a high temperature line, a second process water line 162 which may be a low temperature line, and third process water line 164 which may be a bypass line that does not pass through any heat exchangers. As illustrated in the Figs, each of the lines 160, 162, 164 may split, bypass and/or pass through various heat exchangers and may also be controlled according to temperature and/or flow rate requirements.

The process water lines 160, 162, 164 preferably rejoin into a single hot process water line 166 containing heated process water for use in extraction operations.

Referring to Figs 1 and 2, the hot process water line 166 may pass through a final heat exchanger 168 which may use low pressure steam 170 to heat the process water to a final desired temperature, producing low pressure condensate 172 and a final hot process water stream 174. A bypass line 175 may be provided as its flow rate may be temperature controlled for obtaining the desired temperature at the outlet of the final heat exchanger 168. The final heat exchanger 166 may be located near consumers of heated process water to minimize heat losses during transmission.

Referring to Figs 2, 5 and 6, the process water lines may pass through other heat exchangers to optimally provide heat to the process water. For instance, there may be a condensate cooler or trim heater 176 to recover heat from steam condensed when heating process water in the final heat exchanger 168 downstream of the heat recovery heat exchanger 116.

In another aspect, one or more dump lines may be provided. Fig 1 shows a second process water dump line 178, Figs 2 and 5 show a common heated process water dump line 180 and Fig 6 shows an overall process water dump line 182. It should be noted that one or more of such dump lines may be used in connect with the process of the present invention. The dump lines may be designed and operated to enable several advantages. The low temperature process water dump line 178 allows disposing of lower temperature stream 162 compared to the high temperature stream 160, to meet the hydraulic and heat requirements of extraction without upsetting the froth treatment or wasting higher quality heat.

It is noted at this juncture that integration of a bitumen froth treatment plant and an oil sands extraction operation has a number of challenges related to coordinating the two operations during different operational conditions. For instance, both extraction and froth treatment experience a variety of upset conditions–startup, shutdown, turndown, maintenance, etc.–as well as normal processing conditions. The frequency, duration, location, magnitude and process-related implications of upset conditions vary significantly between extraction and froth treatment operations. Consequently, according to aspects of the present invention, the process is coordinated to overcome at least some of these challenges and mitigate inefficiencies and hazards associated with integration between extraction and froth treatment.

In one aspect, at least one process water dump line enables advantageous operational safety and efficiency of the froth treatment plant by adjusting to more frequent upset and downtimes of the extraction operation. More particularly, when the extraction operation experiences downtime–due to equipment failure, repair, relocation or temporary low quality or quantity oil sand ore, for example–it is advantageous not to reduce the cold process water supply for removing heat from the froth treatment operation via the heat recovery exchangers 84, 116, especially high temperature exchangers 84. The dump lines therefore enable the process water to recover heat from the froth treatment operation without interruption and then to bypass the extraction operation and be fed back into the pond water inventory or provided temporarily to other parts of the oil sands operations or facilities for heat reutilization. In one aspect, illustrated in Fig 6, there may be a utilities dump tank 184 into which the overall process water dump line 182 supplies at least a portion of the hot process water depending on extraction upset conditions. It should also be noted that the utility dump tank 184 could be a dump pond configured for the upset capacity. It should also be noted that a portion of the hot process water could be recycled back to mix with the cold process water 150 as long as excessive heat does not build up in the cooling system and the heat exchange between the cold process water and the heated media maintains sufficient efficiency. There is also a dump tank pump 185 for supplying the process water to a utilities dump header to return the process water to the pond inventory.

Referring to Fig 6, the final hot process water stream 174 may be fed to a holding tank 186 and a hot water supply pump 188 may supply the hot process water from the holding tank 186 to extraction operations 190, 192. There may also be a holding tank dump line 194 which is associated with a level control device for controlling the level of the holding tank 186.

In another aspect, illustrated in Fig 6, there is a hot process water delivery management system 196, which manages various process equipment and conditions. The hot process water delivery management system 196 may be programmed or operated to maintain stable operation and to adapt to upset conditions in extraction and also froth treatment as need be.

Turning now to Figs 1, 2, 5 and 6, in a preferred aspect of the present invention, the heat exchange media and cooling water of the two cooling circuits are each controlled and maintained at respective constant temperatures at the inlet to the high and low temperature heat exchangers respectively. If the heat exchange media temperature fluctuates excessively, then the cooling or condensing in the heat removal exchangers 84, 104 will be inconsistent resulting in downstream problems in the froth treatment plant. Fig 6 illustrates a possible temperature control setup 102 for maintaining a consistent temperature of the heat exchange media provided to the high temperature heat exchangers 84, as well as a second temperature control setup 198 for maintaining a consistent temperature of the second cooling circuit's heat exchange media provided to the low temperature heat exchangers 104. In addition, tight temperature control of the heat exchange media has the advantage of allowing smaller equipment design in the froth treatment plant since over-design for the sizing and number of equipment such as vessels and exchangers can be reduced. Furthermore, with a consistent supply temperature of the heat exchange media, the process can achieve consistent condensing or cooling of the solvent stream and avoid over-cooling which would require reheating the solvent for reuse in the froth treatment operation and thus cause inefficient energy use.

It should also be noted that although the illustrated embodiments show two heat transfer loops, there may be more than two loops associated with a corresponding set of condensers, heat recovery exchangers and trim cooling devices such as cooling towers. Alternatively, there may also be a single heat exchange loop combining the high and low temperature cooling circuits with appropriate piping, trim cooling devices, bypass lines, temperature and flow control devices and heat exchanger configurations.

Nevertheless, in a preferred embodiment of the present invention, there is at least a first sealed closed-loop heat transfer circuit coupled with the high temperature SRU condensers of a paraffinic froth treatment (PFT) plant. It should be noted that the SRU condensers may be operated at a variety of conditions, depending on sizing, economics and other design criteria. By way of example, the SRU solvent condensers may be operated at a pressure of about 500 kPaa and condense the solvent at a temperature of about 60°C; the SRU solvent condensers may alternatively be run at a pressure of about 200 kPaa and condense the solvent at a temperature in a range of 25°C to 40°C.

In one aspect, the present invention improves energy efficiency by minimizing requirements for transferring large flow rates of process water over long distances for use in extraction operations. In a high temperature PFT operation, for instance, the cooling duty is relatively fixed by design and for this fixed cooling load increasing the temperature of the process water reduces flow requirements for the final hot process water. Given that $Q = mC\Delta T$, an increase in ΔT for a same energy (Q) requirement corresponds to a decrease in mass flow rate (m) requirement. Since embodiments of the present invention allow the hot process water supplied to extraction to be at a higher temperature, the flow rate requirement is decreased, resulting in a corresponding decrease in equipment size and cost, e.g. reduced pipeline size, pump number, pump horse power requirements. This provides further design flexibility for smaller equipment resulting in significant cost savings. By way of example, in practice with a ΔT of about 30°C there may be as much as a 40% reduction in flow requirements for the same heat transfer, though this will depend on the configuration of the SRU. In one aspect, the high temperature process water is supplied to the extraction operation and before utilization it is combined with an amount of local cold process water (not illustrated) to achieve a desired temperature of the process water utilized in the given extraction unit.

In one aspect, the maximum temperature of the heat exchange media from a high temperature process exchanger may be limited by the selected heat exchange media and may approach up to about 120°C. The temperature of recycled process water will fluctuate to reflect the seasonal temperature variations of recycled process water. Preferably, the heat recovery exchangers recover the heat into the process water at the highest practical temperature and minimize trim heating demands. Optional heat transfer arrangements and trim heaters for the heating of recycled process water are further described herein and illustrated in the Figs.

It is noted that the heated cooling media and the heated cooling water may both transfer heat to the same stream of recycle process water, different streams of recycle process water or, alternatively, to other process streams in oil sands mining, extraction, in situ recovery or upgrading operations or a combination thereof. Heat requirements, pipeline infrastructure, proximity of the froth treatment plant and cooling loops to other process streams and economics in general are factors that will influence where the heat removed by the cooling loops will be transferred.

Referring to Figs 1, 2, 5 and 6, in one preferred aspect the heated cooling media and the heated cooling water transfer heat to recycle process water which is used in bitumen mining and extraction operations. As recycle process water has high fouling characteristics, the high and low temperature heat recovery exchangers 84 and 116 may each have spares installed to permit on-line cleaning. Isolation valves and associated systems for exchanger cleaning are not illustrated in detail but may be used in connection with various embodiments of the present invention.

In one non-illustrated embodiment, the low temperature heat recovery exchangers 116 may be configured to preheat the recycle water upstream of the high temperature heat recovery exchangers 84, thus being in a series configuration. This configuration may provide advantages such as reducing some seasonal variations due to recycle water temperatures.

The cold recycle process water may be split into multiple streams for low temperature heat exchange and high temperature heat exchange and the streams may be recombined for use in the same extraction operation, for example. Alternatively, each of the heated streams may be used for different applications, depending on their temperatures and flow rates.

Embodiments of the present invention provide a number of advantages, some of which will now be described. In general, the cooling system provides reliable recovery of high grade heat available from process exchangers that exceed the temperatures for heat recovery by regular closed-loop or open-loop cooling water systems.

The use of clean circulating heat exchange media, also referred to herein as "cooling media", permits additional and advanced process control options that are not available in conventional cooling water systems that employ unclean recycle waters.

In addition, the sealed closed-loop system is maintained under pressure to prevent liquid flashing and, as the static head up to the process exchangers–typically in the order of about 30 m to about 40 m–is recovered on the return side, the power required by the circulation pump is reduced to line and equipment pressure losses.

Furthermore, the circulating cooling media may be water or other heat transfer media and mixtures, which may be maintained in a clean state and may have with appropriate anti-fouling inhibiters suitable for operation conditions, thus improving the heat transfer efficiency and performance. Thus, the cooling media for the sealed closed-loop circuit is preferably selected as a non-fouling clean media avoiding the issues related to contaminated process water due to dissolved oxygen, suspended solids, scaling potential and bitumen fouling. This reduces fouling, scaling, erosion and corrosion in the sealed closed-loop circuit.

In addition, as the cooling system is sealed and pressurized, make-up requirements are only required in the rare case that leaks occur, which provides advantages over the conventional closed loop systems that require continuous make-up of treated water and blowdown of water with associated cost and environmental downsides.

Furthermore, the cooling media in the sealed cooling loop is selected for low fouling and efficient heat transfer properties at high cooling temperatures which provides a number of functions. High temperature heat integration of the SRU with the froth treatment plant is enabled, with temperatures ranging between about 60°C and about 120°C or even higher temperatures. In addition, low fouling cooling media eliminates or greatly reduces the requirement of providing spare process heat exchangers or advanced and costly metallurgical solutions for corrosion and erosion resistance. By avoiding spares for online maintenance purposes, piping and valve arrangements can be simplified for increased efficiency. In addition, since in typical cooling loops fouling by cooling water limits velocity ranges for process control to the process side, by using clean non-fouling cooling media flow control can be provided from the cooling side of the exchangers allowing optimization to individual exchangers especially where multiple exchangers are used in parallel, as shown in Figs 5 and 6 for example. Due to the large flow rates in SRUs, multiple exchangers in parallel are common and often necessary. In addition, recovery of heat at higher temperatures increases reuse opportunities. In the case of oil sands operations, this minimizes trim heating requirements for hot process water used in bitumen extraction. In addition, design and maintenance of high heat recovery exchangers can focus on effective management of fouling due to the characteristics recycled process water. Since the cooling media passes through the shell side and the recycle process water passes through the tube side of the shell-and-tube heat exchangers and cleaning of tubes is generally easier than the shell side, using clean cooling media enhances cleaning and maintenance of the heat exchangers. It is also noted that cleaning systems exist for online cleaning of heat exchanger tubes and these may be used in connection with embodiments of the present invention for further enhancements.

In addition, the location of the high temperature heat exchangers may be adjacent or within given froth treatment plant units, e.g. the SRU. In one aspect, the high heat recovery exchangers are located close or within the SRU, which allows the supply and return pipeline lengths to be minimized relative to conventional cooling systems with towers. In another aspect, placement of the high heat recovery exchangers at grade with good access minimizes inefficiencies and difficulties related to accessibility for cleaning, which is particularly preferred when recycle process water has high fouling or frequent cleaning requirements.

In one aspect, the sealed closed-loop cooling system may be used in parallel with a conventional open- or closed-loop system such that the cooling systems service different sets of heat exchangers.

In another aspect, the cooling media for the high temperature closed cooling loop comprises or consists essentially of demineralized water. The cooling media may contain suitable chemical additives to enhance heat transfer or inhibit freezing during winter operations. Preferably, the composition of the cooling media is provided to limit exchanger fouling at the cooling conditions of process cooling exchangers.

In another aspect, sparing of the circulation pumps may be provided as the redundancy provides backup reliability for the system.

In another aspect, the split between high and low temperature process cooling exchangers increases the high grade heat recovery capability for reuse in the recycle process water system while reducing the need to spare exchangers for fouling by the clean cooling media.

In another optional aspect, the cooling media recovers heat from an SRU condensing exchanger and the heated media then transfers its heat to another stream within the froth treatment plant, e.g. in the FSU, the TSRU or another stream in the SRU itself, if need during particular operational conditions. The maximizing of heat recovery and reuse for other process purposes minimizes heat derived from combustion of fuel gas or hydrocarbons and greenhouse gas emissions with associated carbon credits for reduced emissions.

In another aspect, a high temperature PFT complex may have associated coolers to cool process streams during plant outages and these intermittent streams may be on the low temperature loop.

In another aspect, the froth treatment complex may use a naphtha solvent as diluent in lieu of paraffinic solvent with closed loop closing systems optimally cooling and condensing recovered naphtha diluent in diluent recovery plants or naphtha recovery plants.

In another aspect, while Fig 1 illustrates a case in which there are two cooling loops, there may also be intermediate loops that are separate, linked or temporarily integrated with one or both of the cooling loops. Some intermediate loop integration with the other loops may allow streams or portions thereof to be withdrawn, added, exchanged between loops or recirculated in a variety of ways.

There are still other advantages of using embodiments of the sealed closed-loop cooling system of the present invention. Carbon steel materials may be used throughout the system, giving lower capital expenditure for the many heat exchangers in froth treatment operations. The system enables significantly lower maintenance costs. In addition, using two cooling circuits, such as sealed closed-loop circuit 78 and the "tertiary cooling circuit" 106 illustrated in Fig 1, enables advantageous recovery of high grade heat while ensuring additional recovery of low grade heat and facilitates achieving the desired cooling of TSRU and SRU condensers. Furthermore, duplex heat exchangers may be replaced with carbon steel, resulting in significant capital cost reduction. The number of spare exchangers can also be reduced, further decreasing capital costs. The spare exchangers required may be based on clean service fouling factors, for example. In some case, it may be preferred to run a single cooling loop during summer peak periods, e.g. about two months of the year, with adjustments in froth treatment such as TSRU second stage and chiller capacity being performed as required. It should also be understood that there are significant operating expenditure savings with the sealed closed-loop heat recovery system.

Finally, it should be understood that the present invention is not limited to the particular embodiments and aspects described and illustrated herein.

CLAIMS

1 . A system for recovering heat from a bitumen froth treatment plant, the system comprising:

high and low temperature cooling exchangers associated with the bitumen froth treatment plant;

a high temperature circulation loop for circulating a heat exchange media and recovering heat from the high temperature cooling exchangers to produce a heated media;

a low temperature circulation loop for circulating a cooling media and recovering heat from the low temperature cooling exchangers to produce a heated cooling media; and

an oil sands process fluid line in heat exchange connection with at least one of the high temperature circulation loop and the low temperature circulation loop;

wherein at least one of the heated media and the heated cooling media transfer heat to the oil sands process fluid to produce a heated process fluid.

2 . The system of claim 1, wherein the oil sands process fluid line is in heat exchange connection with both the high temperature and low temperature circulation loops for receiving heat there-from.

3 . The system of claim 2, comprising a high temperature heat exchanger connected to the high temperature circulation loop and the oil sands process fluid line.

4 . The system of claim 3, wherein the high temperature heat exchanger is a high temperature shell-and-tube exchanger comprising tubes in fluid communication with the oil sands process fluid line and a shell in fluid communication with the high temperature circulation loop for receiving the heated media.

5 . The system of claims 4, comprising an in-line exchanger cleaning system associated with the high temperature shell-and-tube heat exchanger.

6 . The system of any one of claims 2 to 5, comprising a low temperature heat exchanger connected to the low temperature circulation loop and the oil sands process fluid line.

7 . The system of claim 6, wherein the low temperature heat exchanger is a low temperature shell-and-tube exchanger comprising tubes in fluid communication with the oil sands process fluid line and a shell in fluid communication with the low temperature circulation loop for receiving the heated cooling media.

8 . The system of claims 7, comprising an in-line exchanger cleaning system associated with the low temperature shell-and-tube type heat exchanger.

9 . The system of claim 7 or 8, wherein the low temperature heat exchanger and the high temperature heat exchanger are arranged in series for serially heating the oil sands process fluid.

10 . The system of claim 7 or 8, wherein the low temperature heat exchanger and the high temperature heat exchanger are arranged in parallel for heating portions of the oil sands process fluid.

11 . The system of any one of claims 1 to 10, wherein the oil sands process fluid is recycle process water.

12 . The system of claim 11, comprising a pipeline for supplying the heated recycle process water to an oil sands extraction operation.

13 . The system of any one of claims 1 to 12, wherein the high temperature circulation loop is a sealed closed-loop circuit and comprises a pump and a pressure regulator for circulating the heat exchange media under pressure.

14 . The system of any one of claims 1 to 13, wherein the pump and the pressure regulator are configured to maintain the pressure of the heat exchange media above the pressure of the hot froth treatment process stream.

15 . The system of any one of claims 1 to 14, wherein the pump and the pressure regulator are configured to maintain the pressure of the heat exchange media at least about 10% above the pressure of the hot froth treatment process stream.

16 . The system of any one of claims 1 to 15, wherein the pump and the pressure regulator are configured to maintain the pressure of the heat exchange media between about 300 kPaa and about 800 kPaa.

17 . The system of any one of claims 1 to 16, wherein the heat exchange media comprises demineralized water.

18 . The system of any one of claims 1 to 17, wherein the heat exchange media comprises chemical additives to reduce fouling.

19 . The system of any one of claims 1 to 18, wherein the heat exchange media is free of dissolved oxygen, suspended solids, scaling compounds and bitumen.

20 . The system of any one of claims 1 to 19, wherein the high temperature cooling exchangers comprise high temperature solvent condensers for condensing and removing heat from a vapour phase solvent.

21 . The system of claim 20, wherein the high temperature solvent condensers are associated with a solvent recovery unit of the bitumen froth treatment plant.

22 . The system of claim 20 or 21, wherein the high temperature solvent condensers are configured such that the vapour phase solvent is condensed at a condensation temperature between about 65°C and about 130°C.

23 . The system of any one of claims 20 to 22, wherein the high temperature solvent condensers are configured such that the heat exchange media is heated from an inlet temperature between about 25°C and about 40°C to an outlet temperature between about 80°C and about 120°C.

24 . The system of any one of claims 1 to 23, wherein the low temperature circulation loop is an open-loop circuit.

25 . The system of claim 24, wherein the cooling media comprises process water.

26 . The system of any one of claims 1 to 23, wherein the low temperature circulation loop is a sealed closed-loop circuit.

27 . The system of claim 26, wherein the cooling media comprises demineralized water.

28 . The system of any one of claims 26 or 27, wherein the cooling media comprises chemical additives to reduce fouling.

29 . The system of any one of claims 26 to 28, wherein the cooling media is free of dissolved oxygen, suspended solids, scaling compounds and bitumen.

30 . The system of any one of claims 1 to 29, wherein the high temperature cooling exchangers are associated with a froth separation unit (FSU), a solvent recovery unit (SRU) or a tailings solvent recovery unit (TSRU) or a combination thereof in the bitumen froth treatment plant.

31 . The system of claim 30, wherein the bitumen froth treatment plant is a high temperature paraffinic froth treatment plant.

32 . The system of claim 31, wherein the high temperature cooling exchangers are associated with the SRU.

33 . The system of claim 32, wherein the high temperature cooling exchangers are SRU solvent condensers.

34 . A process for recovering heat from a paraffinic froth treatment plant comprising:

providing a heat transfer circuit for circulating a heat exchange media;

removing heat from a froth treatment process stream into the heat exchange media to produce a heated exchange media;

pressurizing and regulating pressure of the heat exchange media within the heat transfer circuit to maintain the heat exchange media under pressure and in liquid phase; and

cooling at least a portion of the heated exchange media using a cooling tower to produce a cooled media.

35 . The process of claim 34, wherein the cooling water is a sealed cooling tower.

36 . The process of claim 35, wherein the sealed cooling tower comprises coiled tubing for carrying the heat exchange media and a cooling spray device for spraying cooling water into the coiled tubing to enable heat removal from the heat exchange media.

37 . The process of claim 35 or 36, wherein the sealed cooling tower is a WSAC™ cooling tower.

38 . The process of any one of claims 34 to 37, wherein the froth treatment process stream is a stream of a solvent recovery unit (SRU) of the paraffinic froth treatment plant.

39 . The process of any one of claims 34 to 38, wherein the froth treatment process stream is a stream of the tailings solvent recovery unit (TSRU) of the paraffinic froth treatment plant.

40 . The process of claim 38 or 39, further comprising transferring heat from the heated exchange media to an oil sands process fluid to produce a heated oil sands process fluid, before the step of cooling.

41 . The process of claim 40, wherein the heated oil sands process fluid is supplied to an oil sands extraction operation.

42 . A process for integrating an oil sands extraction operation and a paraffinic froth treatment plant, comprising:

providing an oil sands process fluid line for supplying the process fluid to the oil sands extraction operation;

providing at least one dump line in fluid communication with the oil sands process fluid line;

providing a heat transfer circuit associated with the paraffinic froth treatment plant for circulating a heat exchange media and removing heat from the paraffinic froth treatment plant;

transferring heat from the heat exchange media to the oil sands process fluid to produce a heated oil sands process fluid; and

discarding at least a portion of the heated oil sands process fluid through the at least one dump line in response to upset conditions.

43 . The process of claim 42, wherein the discarding step comprises discarding a portion of the heated oil sands process fluid in response to upset conditions of the extraction operation.

44 . The process of claim 42 or 43, wherein the heated oil sands process fluid comprises hot process water.

45 . The process of claim 44, wherein the discarding step comprises feeding the hot process water back into a pond water inventory.

46 . The process of claim 44, wherein the discarding step comprises providing the hot process water to other parts of the oil sands operations or facilities for heat reutilization.

47 . The process of any one of claims 42 to 44, wherein the discarding step comprises feeding a first portion of the heated oil sands process fluid into a utilities dump tank using a first dump line.

48 . The process of claim 47, wherein the discarding step comprises sending a second portion of the heated oil sands process fluid to a holding tank and discarding at least a part of the second portion of the heated oil sands process fluid through a holding tank dump line.

49 . The process of claim 48, wherein the holding tank dump line is associated with a level control device for controlling the level of the holding tank.

50 . The process of claim 48 or 49, wherein the discarded first and second portions of the heated oils sands process fluid are mixed and fed back into a pond inventory.

51 . The process of any one of claims 42 to 50, wherein the upset conditions comprise startup, shutdown, turndown or maintenance of the extraction operation or paraffinic froth treatment plant.

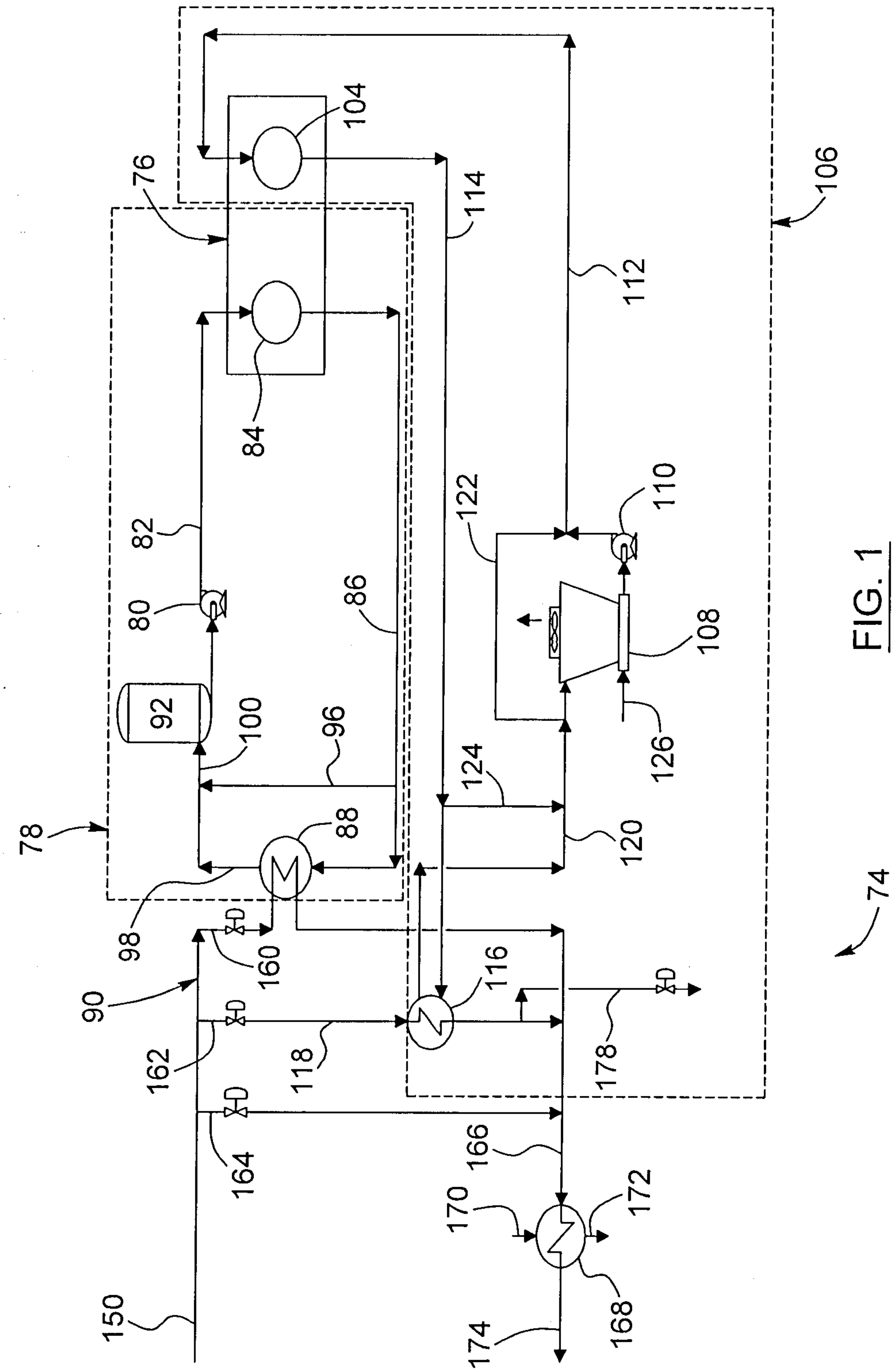

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FIG. 1

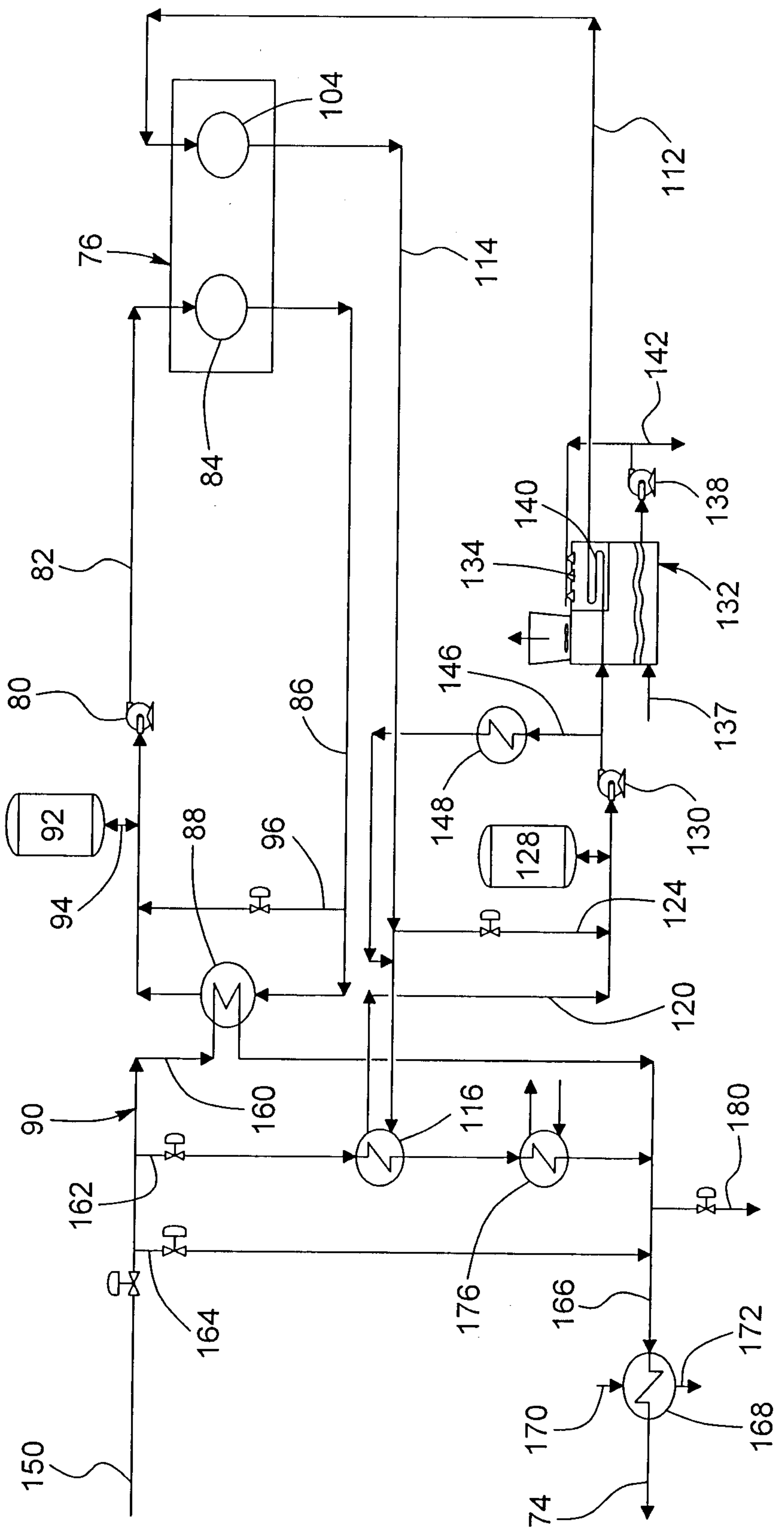
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FIG. 2

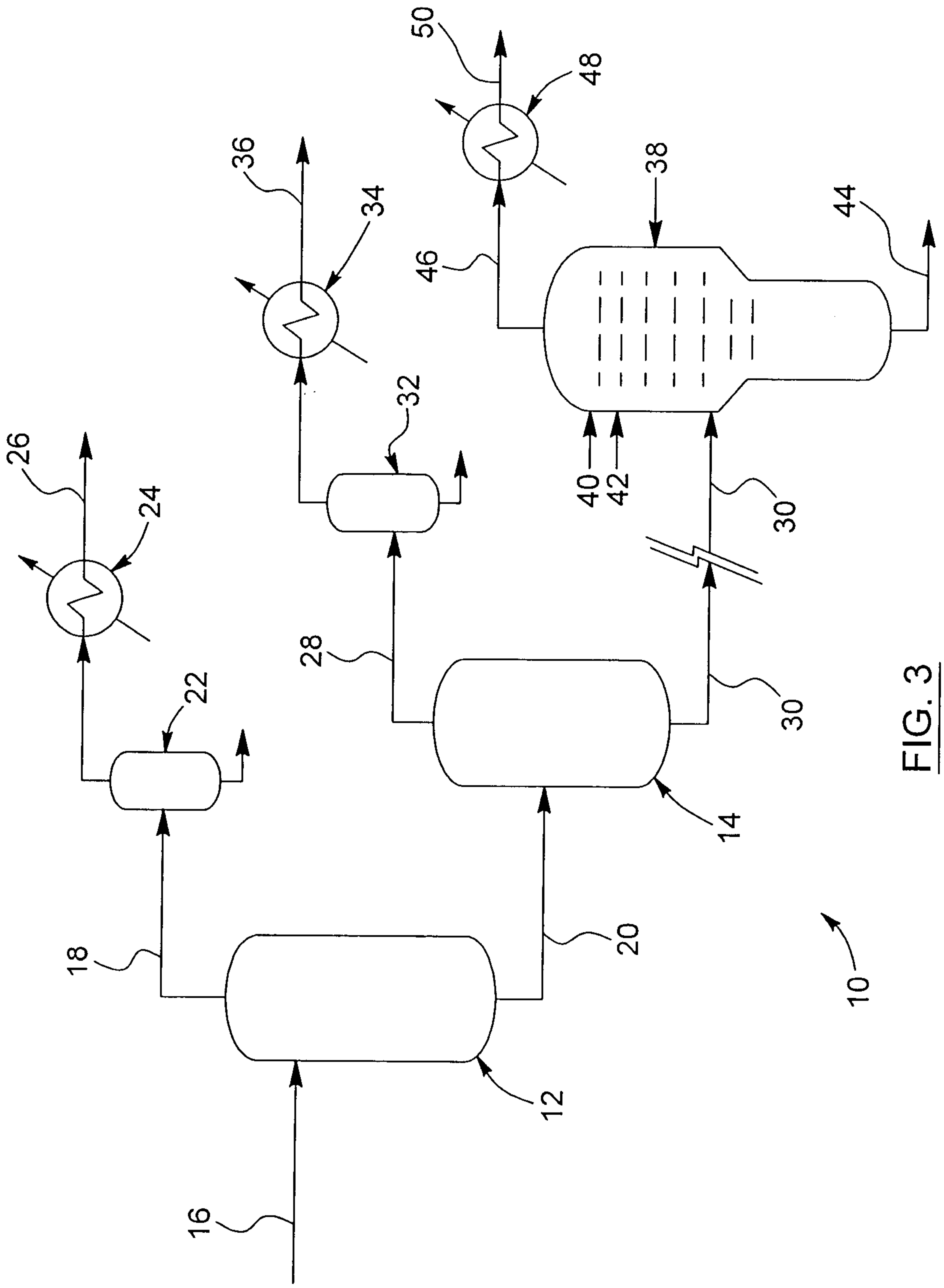


FIG. 3

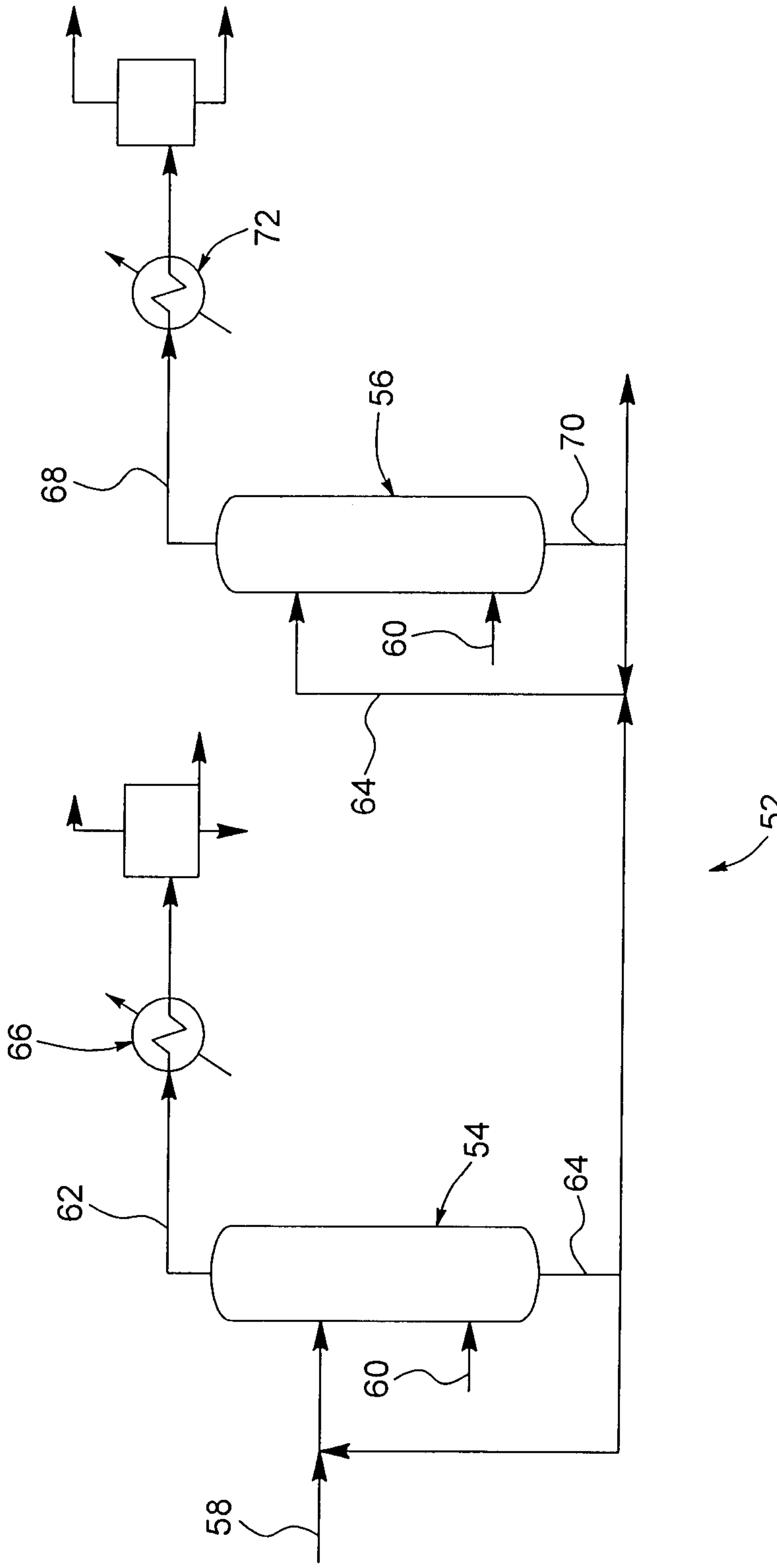
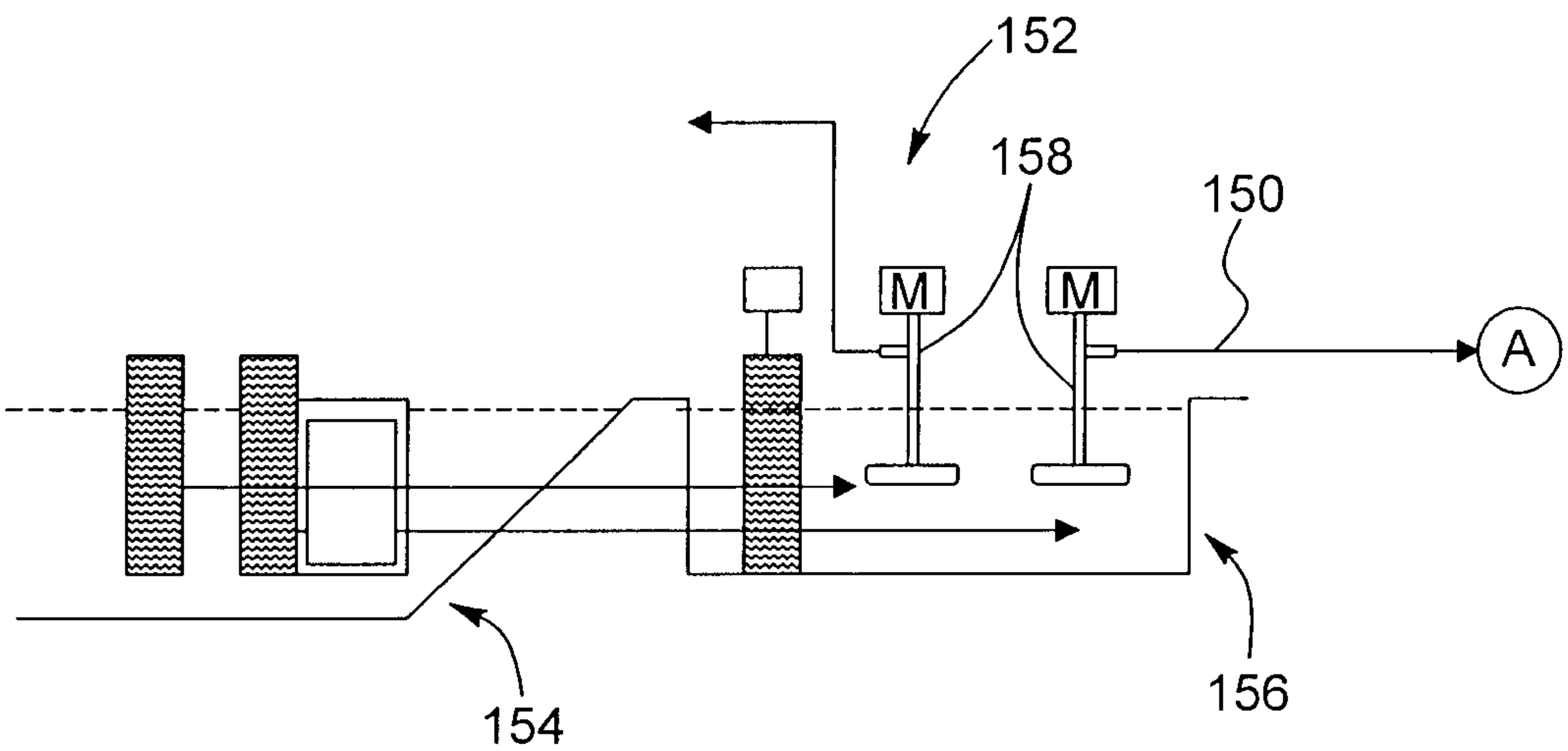


FIG. 4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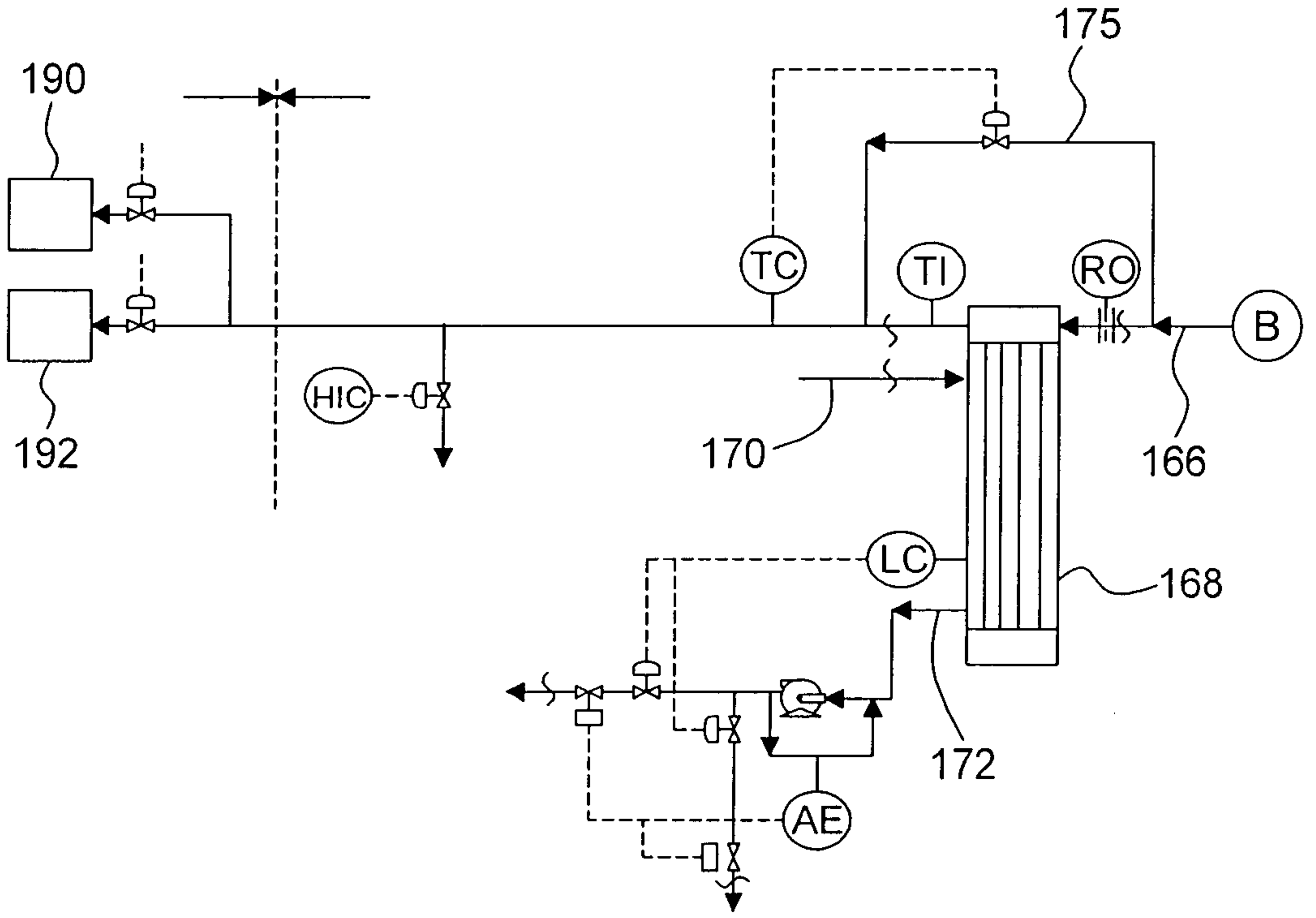
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FIG. 5A

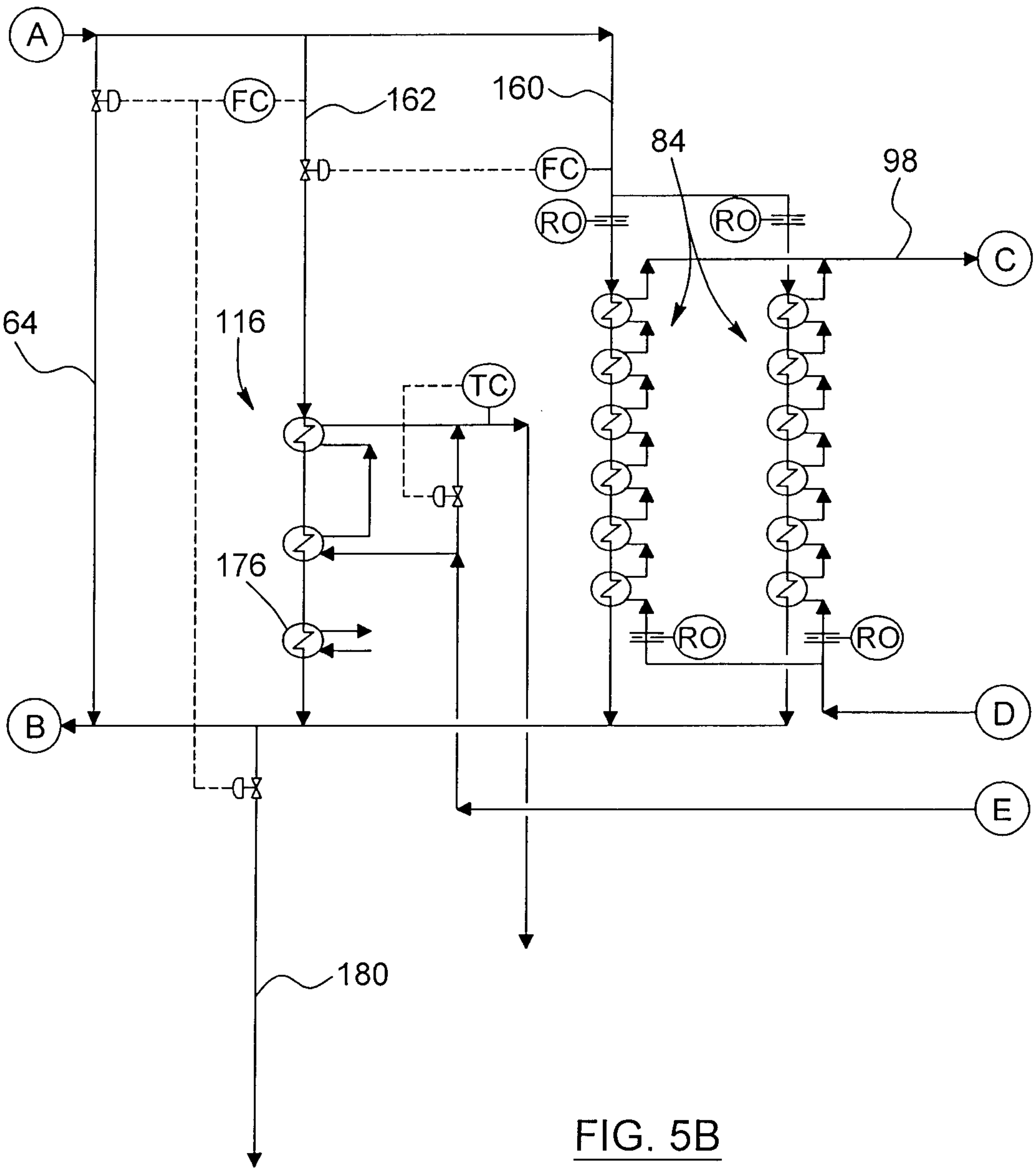

FIG. 5B

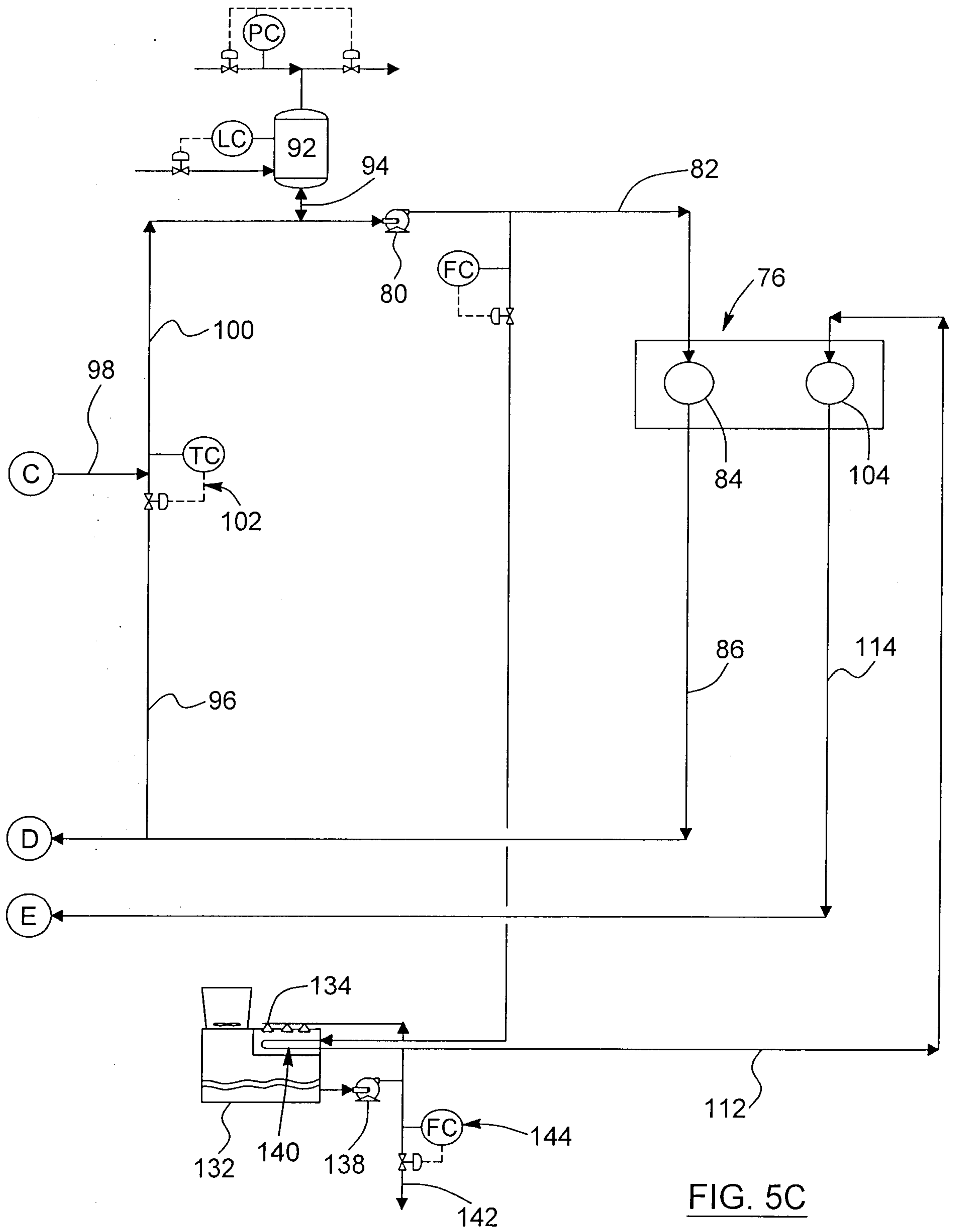
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FIG. 5C

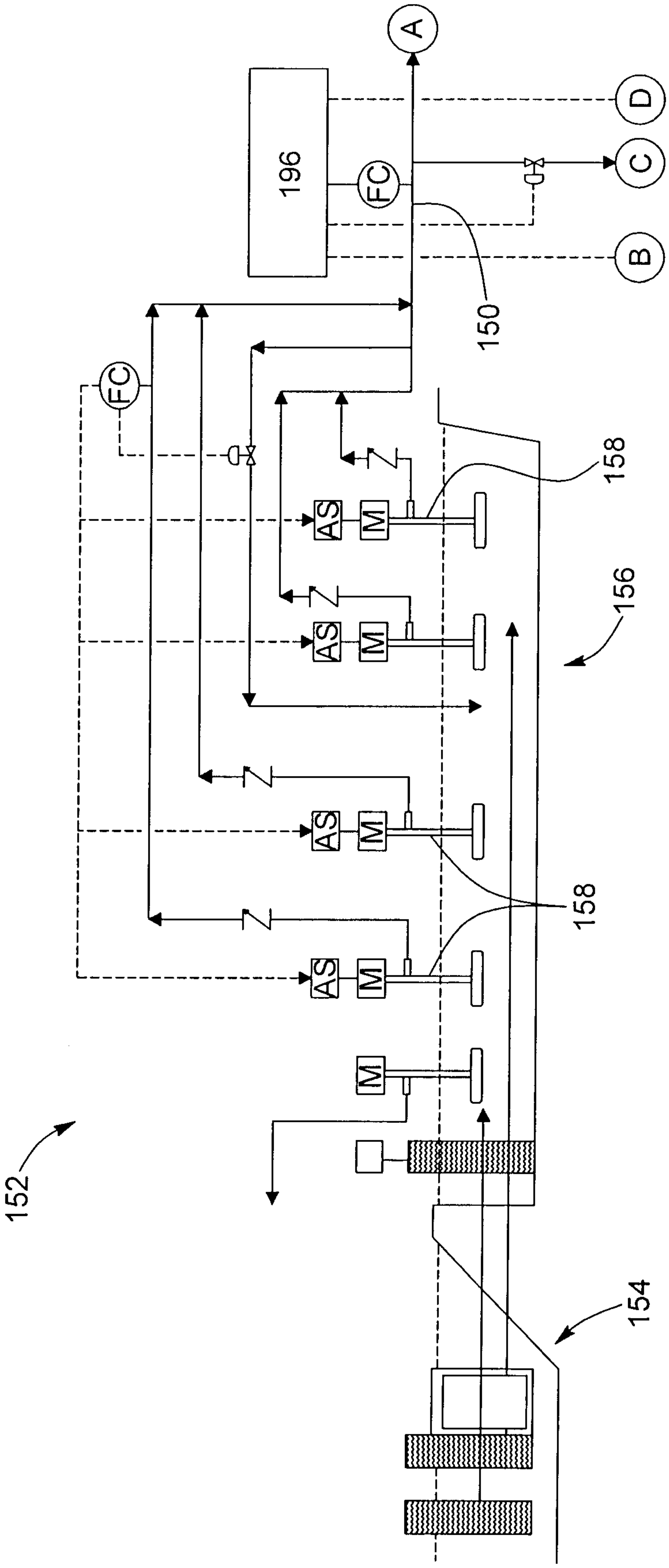

FIG. 6A

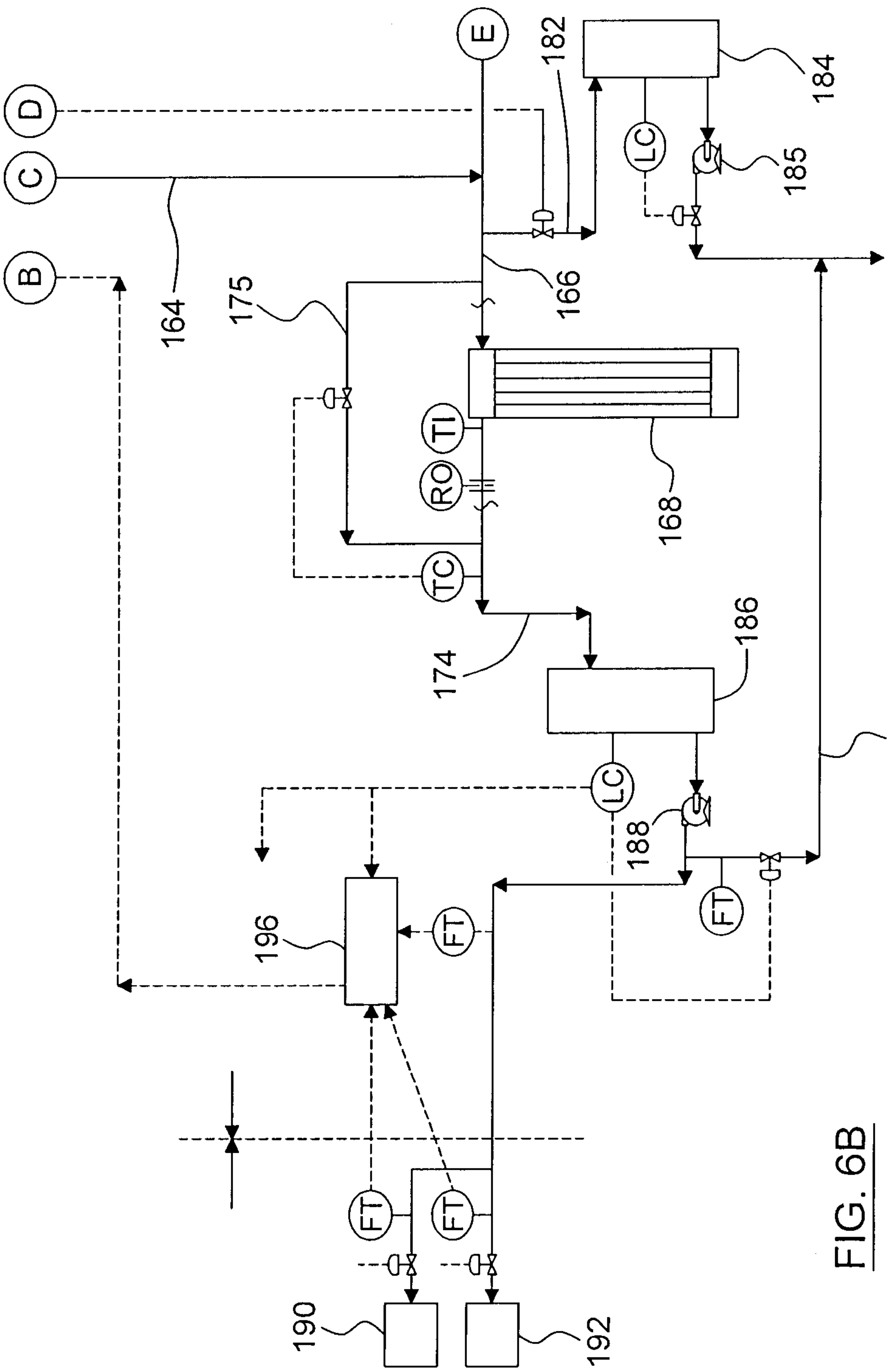
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FIG. 6B

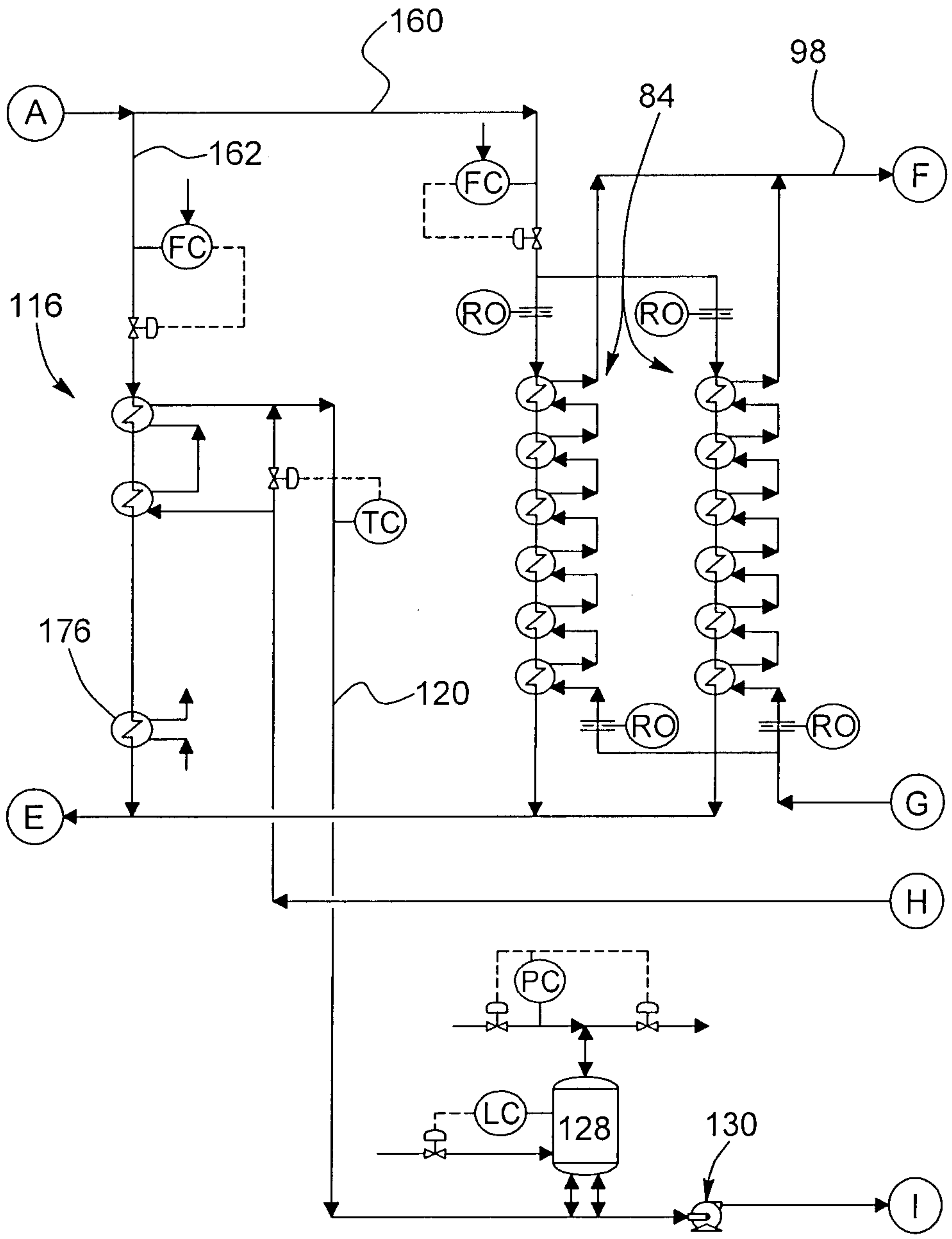

FIG. 6C

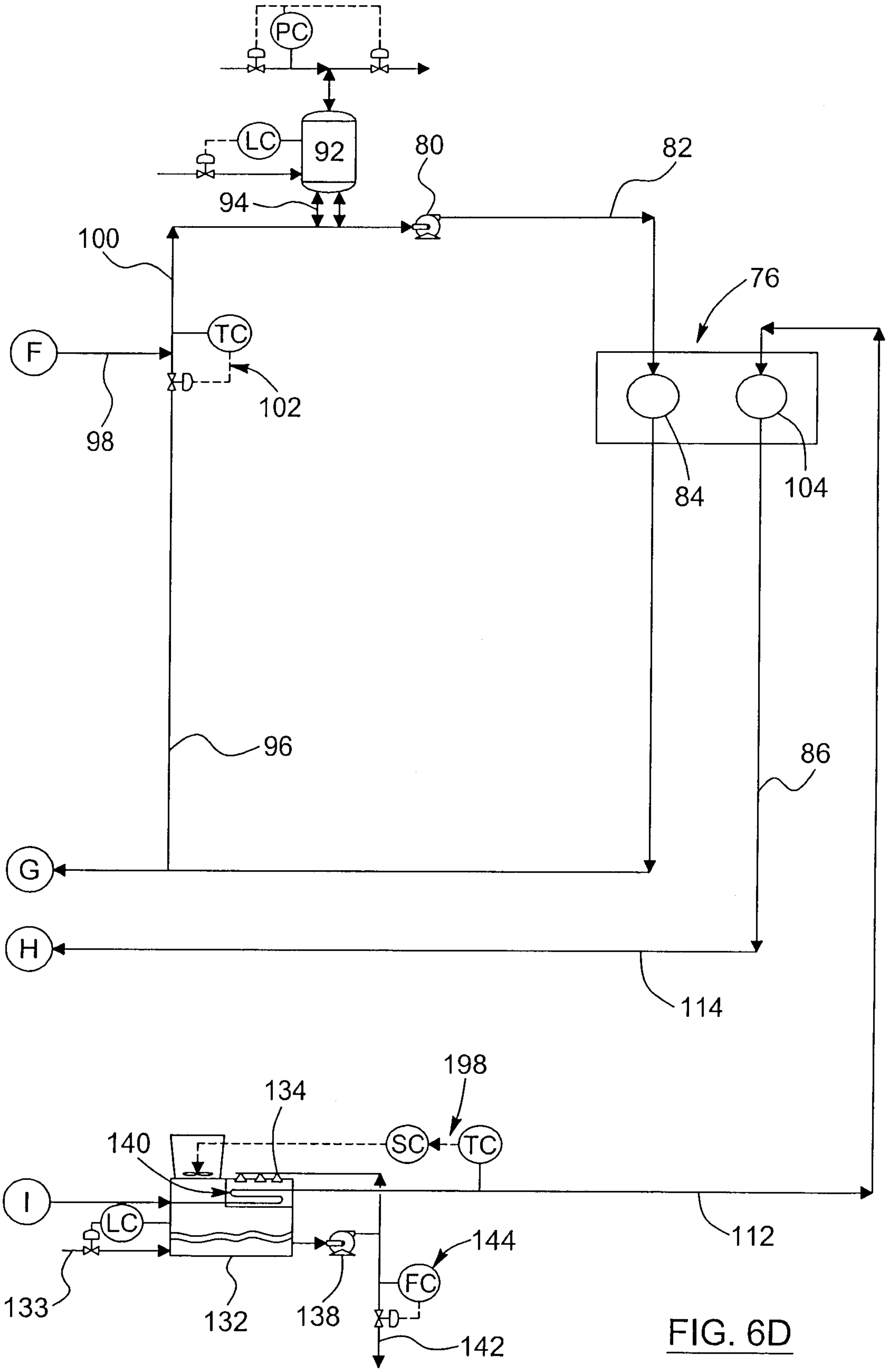
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FIG. 6D


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