(12) **PATENT**

(19) NO (11) **340554** (13) **B1**

NORWAY

(51) Int Cl.
F23C 7/06 (2006.01)
F23C 7/08 (2006.01)
F01K 25/14 (2006.01)
F01K 23/06 (2006.01)

Norwegian Industrial Property Office

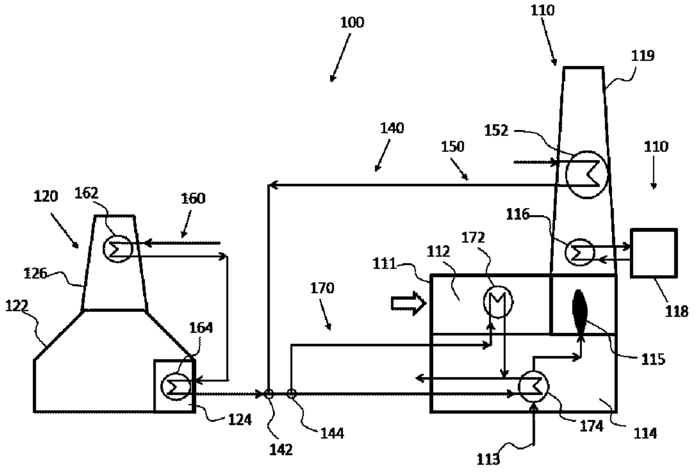
(21)	Application nr.	20150613	(86)	International Filing Date and Application Number
(22)	Date of Filing	2015.05.18	(85)	Date of Entry into National Phase
(24)	Date of Effect	2015.05.18	(30)	Priority
(41)	Publicly Available	2016.11.21		
(45)	Granted	2017.05.08		
(73)	Proprietor	Goodtech Recovery Technology AS, Per Krohgs vei 4, 1065 OSLO, Norge		
(72)	Inventor	Didier Ostorero, c/o Goodtech Recovery Technology AS, Per Krohgs vei 4, 1065 OSLO, Norge Veroslav Sedlak, c/o Goodtech Recovery Technology AS, Per Krohgs vei 4, 1065 OSLO, Norge		
(74)	Agent or Attorney	Acapo AS, Postboks 1880 Nordnes, 5817 BERGEN, Norge		

(54) Title **Heat recovery**

(56) References Cited:
WO 2012039624 A1
JP 10160112 A
JP 10318528 A
CN 103776026 A
US 4720968 A
WO 2013105867 A1
GB 2472849 A
WO 2013104885 A1

(57) Abstract

A system and a method for recovering waste heat from an industrial process in pre heating combustion air and fuel is provided. The present invention attains the above-described objective by a plurality of heat exchangers extracting heat from flue gas from a power plant and waste heat from an industrial process and transferring the extracted heat to air and optionally fuel entering said power plant.



Background of the Invention

Technical Field

The invention relates to heat recovery in general and more specifically a system and a method for recovering waste heat from an industrial process in pre heating combustion air and fuel.

Background Art

From prior art one should refer to general waste recovery technology wherein waste heat in a thermal power station in the flue is used to preheat air and/or fuel entering the thermal power station burner.

From prior art one should also refer to general waste recovery technology wherein waste heat in industrial processes such as aluminium electrolysis is recovered by heat exchangers and used for power generation, desalination and similar purposes.

At the same time such industrial processes, particularly electrochemical processes require large amounts of power and even with prior art the recovered power is low, complexities are high and temperature of the recovery system is low and thus overall efficiency is low. This also brings in associated problems such as pollution.

Disclosure of the Invention

Problems to be Solved by the Invention

Therefore, a main objective of the present invention is to provide a system and a method that overcomes the problems described above.

Means for Solving the Problems

The objective is achieved according to the invention by an apparatus for recovering waste heat as defined in the preamble of claim 1, having the features of the characterising portion of claim 1 and a method for recovering waste heat as defined in the preamble of claim 13, having the features of the characterising portion of claim 13.

A number of non-exhaustive embodiments, variants or alternatives of the invention are defined by the dependent claims.

The present invention attains the above-described objective by a plurality of heat exchangers extracting heat from flue gas from a power plant and waste heat from an industrial process and transferring the extracted heat to air and optionally fuel entering said power plant.

Effects of the Invention

The technical differences over prior art is that feed in the form of air and/or fuel to the burner in a thermal power plant is pre heated in a sequence that provides optimum use of waste heat and delivering maximum pre heating to the burner.

These effects provide in turn several further advantageous effects:

- it reduces fuel consumption and thus CO2 emission
- it simplifies energy recovery since steam raising is located in one place only
- it improves safety since steam is removed from certain industrial processes where water can cause explosion in liquid metal
- it makes it possible to increase burn temperature
- increased temperature increases Carnot cycle efficiency
- increased temperature allows for combusting and destroying harmful substances such as PCB

Brief Description of the Drawings

The above and further features of the invention are set forth with particularity in the appended claims and together with advantages thereof will become clearer from consideration of the following detailed description of an [exemplary] embodiment of the invention given with reference to the accompanying drawings.

The invention will be further described below in connection with exemplary embodiments which are schematically shown in the drawings, wherein:

Fig. 1 shows an embodiment with a parallel heating of air and fuel using heat in a flue and in an industrial process, and

Fig. 2 shows an embodiment with a series heating of air and fuel using heat in a flue and then in an industrial process.

Description of the Reference Signs

The following reference numbers and signs refer to the drawings:

100	Combined plant
110	Thermal power plant
111	Air inlet
112	Air pre-heater
113	Fuel inlet
114	Fuel pre-heater
115	Burner
116	Boiler
118	Turbine system
119	Flue
120	Industrial plant
122	Electrolysis cell
124	Sidelining
126	Exhaust conduit
140	Heat exchange circuit
142	Heat collection manifold
144	Heat distribution manifold
150	Flue gas circuit
152	Flue gas heat exchanger
160	Industrial plant circuit
162	Exhaust heat exchanger
164	Sidelining heat exchanger
170	Burner circuit
172	Burner air inlet heat exchanger
174	Burner fuel inlet heat exchanger

Detailed Description

Various aspects of the disclosure are described more fully hereinafter with reference to the accompanying drawings. This disclosure may, however, be embodied in many different forms and should not be construed as limited to any specific structure or function presented throughout this disclosure. Rather, these aspects are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the disclosure to those skilled in the art. Based on the teachings herein one skilled in the art should appreciate that the scope of the disclosure is intended to cover any aspect of the disclosure disclosed herein, whether implemented independently of or combined with any other aspect of the disclosure. For example, an apparatus may be implemented or a method may be practiced using any number of the aspects set forth herein. In addition, the scope of the disclosure is intended to cover such an apparatus or method which is practiced using other structure, functionality, or structure and functionality in addition to or other than the various aspects of the disclosure set forth herein. The scope of the invention is defined by the appended claims.

The invention will be further described in connection with exemplary embodiments which are schematically shown in the drawings, wherein Fig. 1 shows an embodiment with a heating of air and fuel using heat in a flue gas and in an industrial process.

Principles forming the basis of the invention

The underlying principle is that heat is recovered in a heat extraction circuit at different stages in a power station and/or in an industrial plant. Preferably the order of heat recovery is in increasing order of temperature. Heat recovered is then used to heat air and/or fuel entering a burner in the power station in a burner circuit.

Best Modes of Carrying Out the Invention

The embodiment of the apparatus according to the invention shown in Fig. 1 and 2 comprises a combined plant 100 comprising a thermal power plant 110 co located with an industrial plant 120 operating an industrial process. This is illustrated with an aluminium electrolysis cell 122 surrounded by a sidelining 124 that is cooled to prevent liquid metal from eroding and destroying the cell. Gases from the process leave through an exhaust conduit 126. Such gases typically comprise fluorides from the melt and carbon dioxide and carbon monoxide resulting from consumption of a carbon anode.

The thermal power plant 110 burns fuel from a fuel inlet 113 through a fuel pre-heater 114 wherein the fuel is burned in a burner 115 in air from an air inlet 111 through an air pre-heater 112. The burner heats a boiler 116 feeding a turbine system 118 with steam, preferably superheated steam. The boiler is a complex system of heat exchangers operating at different temperatures similar to what is known in prior art but adapted to handle the efficiency of the embodiments. The remaining heat then passes through the flue 119.

The industrial plant 120 can be any energy demanding process that generates a lot of waste heat. One such example is metal processing such as aluminium electrolysis. A plant typically comprises a plurality of electrolysis cells 122 but for simplicity a single electrolysis cell is shown. The cell is shown in simplified form with a sidelining 124 that is instrumental in containing liquid electrolyte including aluminium and is kept cooled to maintain a sidelayer, thus avoiding destruction of the electrolysis cell. Exhaust gases are ventilated through an exhaust conduit 126.

Many such plants require substantial amounts of power. In many cases aluminium plants were built next to major hydroelectric power stations. Where this is not possible dedicated thermal power plants have been co located with the aluminium plant. One such example is Quatalum, an aluminium smelter plant powered by a 1350 MW natural gas power plant.

Electricity from the thermal power plant is fed to the aluminium electrolysis cell (not shown). In addition the two are also connected by a heat exchanger circuit 140 comprising a flue gas circuit 150 and an industrial plant circuit 160 collecting heat from the processes. The heat is then brought into a burner circuit 170. The heat exchanger circuit uses a working medium for transferring heat.

The flue gas circuit 150 comprises a flue gas heat exchanger 152. The flue gas heat exchanger is able to raise the temperature of the working medium.

The industrial plant circuit 160 comprises an exhaust gas heat exchanger 162 and a sidelining heat exchanger 164. By passing the working medium first through the exhaust gas heat exchanger 162 and then the sidelining heat exchanger 164 the temperature of the working medium is able to absorb heat efficiently. Typically the temperature is raised to a temperature near the flue gas temperature and then to an even higher temperature in the next stage.

Fig. 1 shows a first embodiment where working fluid enters the flue gas circuit and the industrial plant circuit in parallel and the working medium of both branches are collected in a heat collection manifold 142. From there the working medium passes to a heat distribution manifold 144 to the burner circuit 170 where a first part passes working medium to a burner air inlet heat exchanger 172 heating air in the air pre-heater 112, and a second part passes working medium to a burner fuel inlet heat exchanger 174 heating fuel in the fuel pre-heater 114.

Fig. 2 shows a second embodiment where the working fluid enters the flue gas circuit and the industrial plant circuit in series. This provides a series heating of air in flue and then in an industrial process. A heat collection manifold is therefore not required. From there the working medium passes to a heat distribution manifold 144 to the burner circuit 170 where a first part passes working medium to a burner air inlet heat exchanger 172 heating air in the air pre-heater 112, and a second part passes working medium to a burner fuel inlet heat exchanger 174 heating fuel in the fuel pre-heater 114.

Using valves (not shown) it is possible to switch between the parallel heating shown in Fig. 1 and the series heating shown in Fig. 2.

If the temperature of the flue gas is too low to increase the efficiency of the thermal plant, the working medium will flow first through the exchanger in the flue gas (152) before flowing through the heat recovery heat exchangers in the industrial plant circuit (160), i.e series.

If the temperature of the flue gas is high enough to increase the efficiency of the thermal plant (compare to the series one), the parallel process will be used.

Alternative Embodiments

A number of variations on the above can be envisaged. For instance the burner circuit 170 can be changed.

In one embodiment the burner circuit is a series connection between burner air inlet heat exchanger 172 and burner fuel inlet heat exchanger 174, in this order or opposite, optionally switchable between the two. In these embodiments a heat distribution manifold is not required.

It is also possible to heat only one of the air and the fuel.

In a variation of the parallel embodiment shown in Fig. 1 the exhaust gas of the industrial plant can be provided with a secondary circuit comprising further exhaust gas heat exchanger to recover heat remaining after passing through the exhaust gas heat exchanger 162. The heat in the secondary circuit can then be used to provide further pre heating of fuel or air.

The working medium can be a type of oil that can withstand the temperatures present in the industrial process. Alternatively air can be used and enter the air inlet, directly or via the burner circuit. While heat capacity of air is low it can be used to handle very high temperature stages without problems of fluids reaching due to high temperature.

Alternatively a fuel can be used as a working medium and enter the fuel inlet, directly or via the burner circuit. This can be beneficial for working temperature below the decomposition point for a fuel. One example is the use in the secondary circuit.

In certain industrial processes the exhaust gases comprise oxygen and/or flammable gases. For instances in the exhaust gas from aluminium electrolysis there is some CO present, a gas that is both flammable and also present a health risk. In one embodiment the exhaust gases are separated using membrane filters and combustible bases are fed into the burner 115 providing extra energy while rendering dangerous gases harmless.

Industrial Applicability

The invention according to the application finds use in co located systems comprising a power plant providing power to an industrial process. Alternatively energy could also be sent to the grid

Claims

1. A system for recovering waste heat from a combined plant (100) comprising a thermal power plant (110) and an industrial plant (120), the system comprising:

a heat exchanger circuit (140) having a working fluid, further comprising:

a heat extraction circuit comprising an industrial gas circuit (160) comprising at least one heat exchanger (162, 164) for extracting waste heat from the industrial plant (120), and

a burner circuit (170) comprising at least one heat exchanger (172, 174) for heating at least one from a group comprising air in an air pre-heater (112) heating air from an air inlet (111) and fuel in a fuel pre-heater (114) heating fuel from a fuel inlet (113) of the thermal power plant,

wherein the industrial plant is not a thermal power plant,

characterised in that the burner circuit uses heat extracted from the heat extraction circuit.

2. The system according to claim 1, wherein the heat extraction circuit further comprising a flue gas circuit (150) comprising a flue gas heat exchanger (152) for extracting waste heat from a flue gas in a flue (119) of the thermal power plant (110).

3. The system according to claim 2, further comprising a heat collection manifold (142) wherein the flue gas circuit (150) and the industrial gas circuit (160) are connected in parallel to the heat collection manifold.

4. The system according to claim 2, wherein the flue gas circuit (150) and the industrial gas circuit (160) are connected in series.

5. The system according to claim 1 or 2, further comprising a heat distribution manifold (144) wherein the burner air inlet heat exchanger (172) and burner fuel inlet heat exchanger (174) are connected in parallel to the heat distribution manifold.

6. The system according to claim 1 or 2, wherein the burner air inlet heat exchanger (172) and burner fuel inlet heat exchanger (174) are connected in series.

7. The system according to claim 1 or 2, wherein at least part of the exhaust gas in the exhaust conduit (126) is fed into the air inlet (111) of the thermal power plant (110).

8. The system according to claim 1 or 2, wherein the working fluid is air.

9. The system according to claim 8, wherein at least part of the working fluid is fed into the air inlet.

10. The system according to claim 1 or 2, wherein the working fluid is fuel.

11. The system according to claim 10, wherein at least part of the working fluid is fed into the fuel inlet.

12. The system according to claim 1 or 2 wherein the industrial plant comprises an aluminium electrolysis cell and wherein the industrial plant circuit (160) comprises an exhaust heat exchanger (162) and a sidelining heat exchanger (164).

13. A method for recovering waste heat from a combined plant (100) according to claim 2 wherein the system is operated according to claim 3 when temperature of the flue gas in the flue (119) is above a threshold T_s, and operated according to claim 4 when temperature of the flue gas in the flue (119) is below a threshold T_p.

14. The method according to claim 13, wherein T_s is more than 150°C and T_p is less than 100°C.

Patentkrav

1. Et system for gjenvinning av spillvarme fra et kombinert anlegg (100) omfattende et varmekraftverk (110) og et industrianlegg (120), idet systemet omfatter:

en varmevekslerkrets (140) med et arbeidsmedium, videre omfattende:

en varmeekstraksjonskrets omfattende en industrigasskrets (160) omfattende minst én varmeveksler (162, 164) for å trekke ut spillvarme fra industrianlegget (120) og

en brennerkrets (170) omfattende minst én varmeveksler (172, 174) for å varme minst én fra gruppen omfattende luft i en luftforvarmer (112) som varmer luft fra et luftinntak (111) og brensel i en brenselsforvarmer (114) som varmer brensel fra et brenselsinntak (113) for varmekraftverket,

idet industrianlegget ikke er et varmekraftverk,

karakterisert ved at brennerkretsen benytter varme trukket ut fra varmeekstraksjonskretsen.

2. Systemet ifølge krav 1, idet varmeekstraksjonskretsen videre omfatter en røykgasskrets (150) som omfatter en røykgassvarmeveksler (152) for å trekke ut spillvarme fra røykgassen (119) i et røykrør.

3. Systemet ifølge krav 2, videre omfattende en varmesamlermanifold (142) idet røykgasskretsen (150) og industrigasskretsen (160) er koblet i parallell med varmesamlingsmanifolden.

4. Systemet ifølge krav 2, idet røykgasskretsen (150) og industrigasskretsen (160) er koblet i serie.

5. Systemet ifølge krav 1 eller 2, videre omfattende en varmefordelermanifold (144) idet luftinntaksvarmeveksleren (172) og brenselsinntaksvarmeveksleren (174) er koblet i parallell med varmefordelermanifolden.

6. Systemet ifølge krav 1 eller 2, idet luftinntaksvarmeveksleren (172) og brenselsinntaksvarmeveksleren (174) er koblet i serie.

7. Systemet ifølge krav 1 eller 2, idet minst deler av avløpsgassen i avløpsgassløpet (126) blir matet inn i luftinntaket (111) for varmekraftanlegget (110).

8. Systemet ifølge krav 1 eller 2, idet arbeidsmediet er luft.

9. Systemet ifølge krav 8, idet minst deler av arbeidsmediet blir matet inn i luftinntaket.

10. Systemet ifølge krav 1 eller 2, idet arbeidsmediet er brensel.

11. Systemet ifølge krav 10, idet minst deler av arbeidsmediet blir matet inn i brenselsinntaket.

12. Systemet ifølge krav 1 eller 2, idet industrianlegget omfatter en aluminiums-elektrolysecelle og idet industrianleggskretsen (160) omfatter en røykgassvarmeveksler (162) og en sidelagsvarmeveksler (164).

13. En fremgangsmåte for gjenvinning av spillvarme fra et kombinert anlegg (100) ifølge krav 2 idet systemet betjenes ifølge krav 3 når temperaturen til røykgassen i røykrøret (119) er over en terskel T_s, og betjenes ifølge krav 4 når temperaturen til røykgassen i røykrøret (119) er under en terskel T_p.

14. Fremgangsmåte ifølge krav 13, der T_s er over 150°C and T_p er under 100°C.

1/2

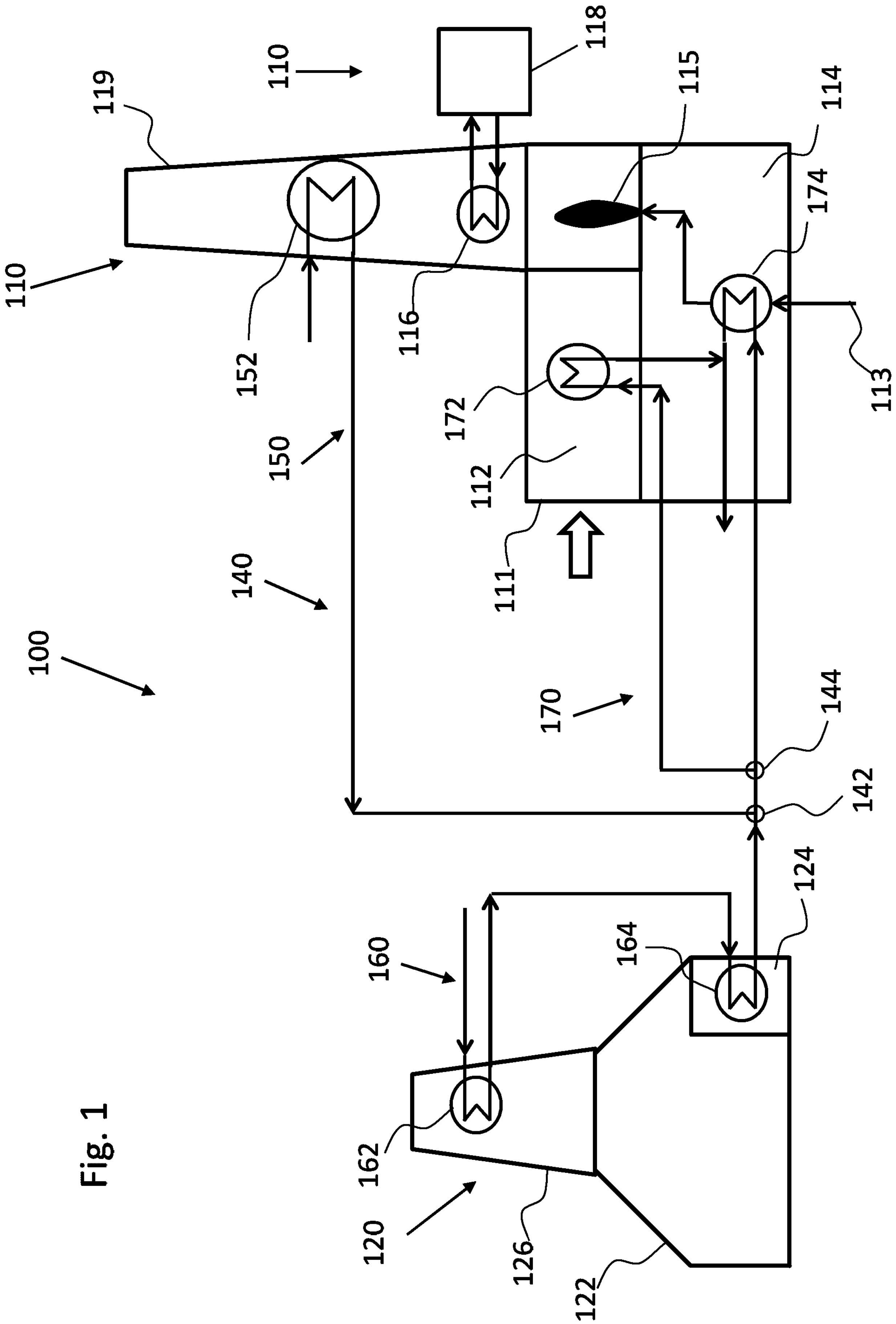

100
110
110
111
112
113
114
115
116
118
119
120
122
124
126
140
142
144
150
152
160
162
164
170
172
174

Fig. 1

2/2

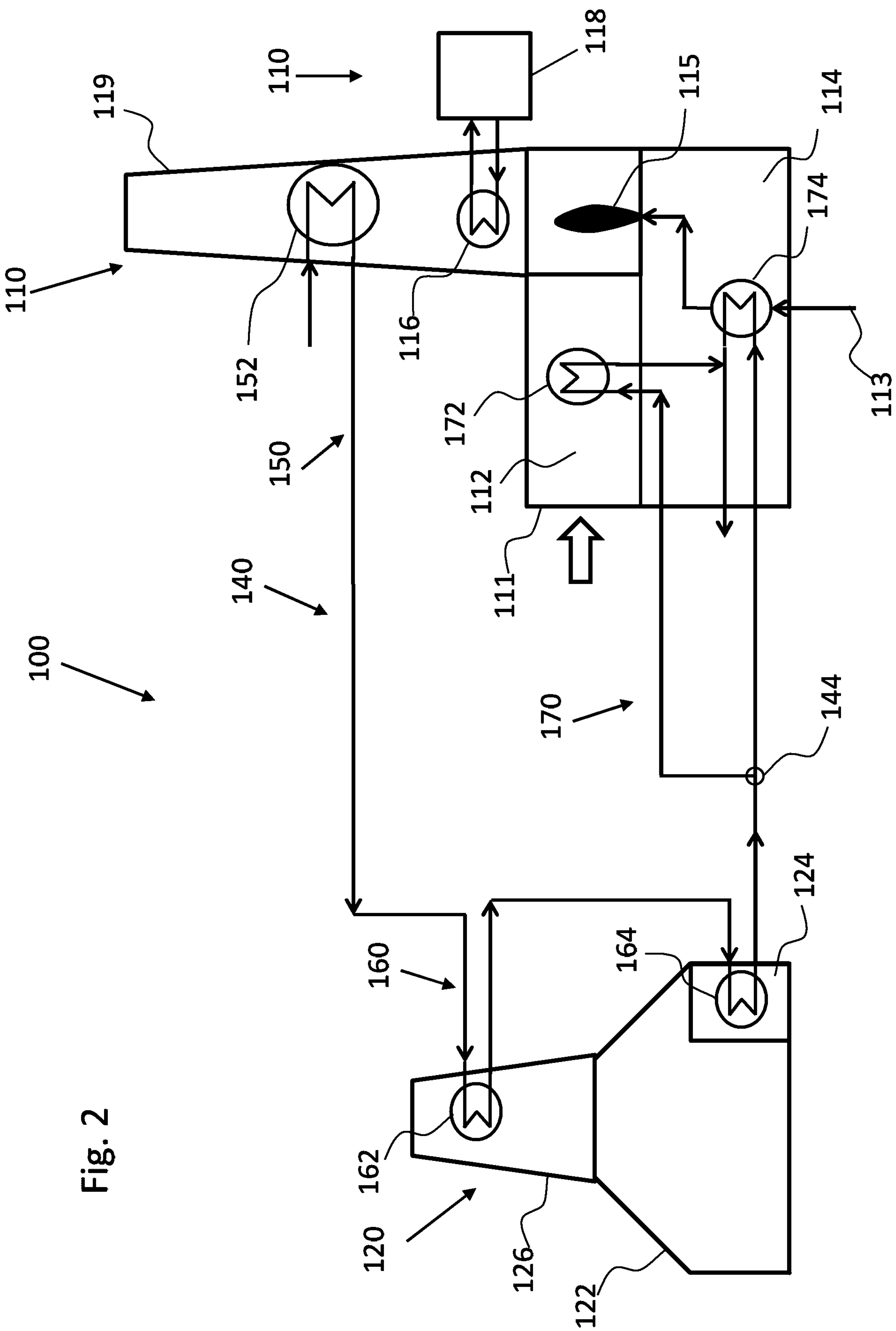

100
110
110
111
112
113
114
115
116
118
119
120
122
124
126
140
144
150
152
160
162
164
170
172
174

Fig. 2