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(54) **METHOD AND DEVICE FOR ENERGY CONVERSION**

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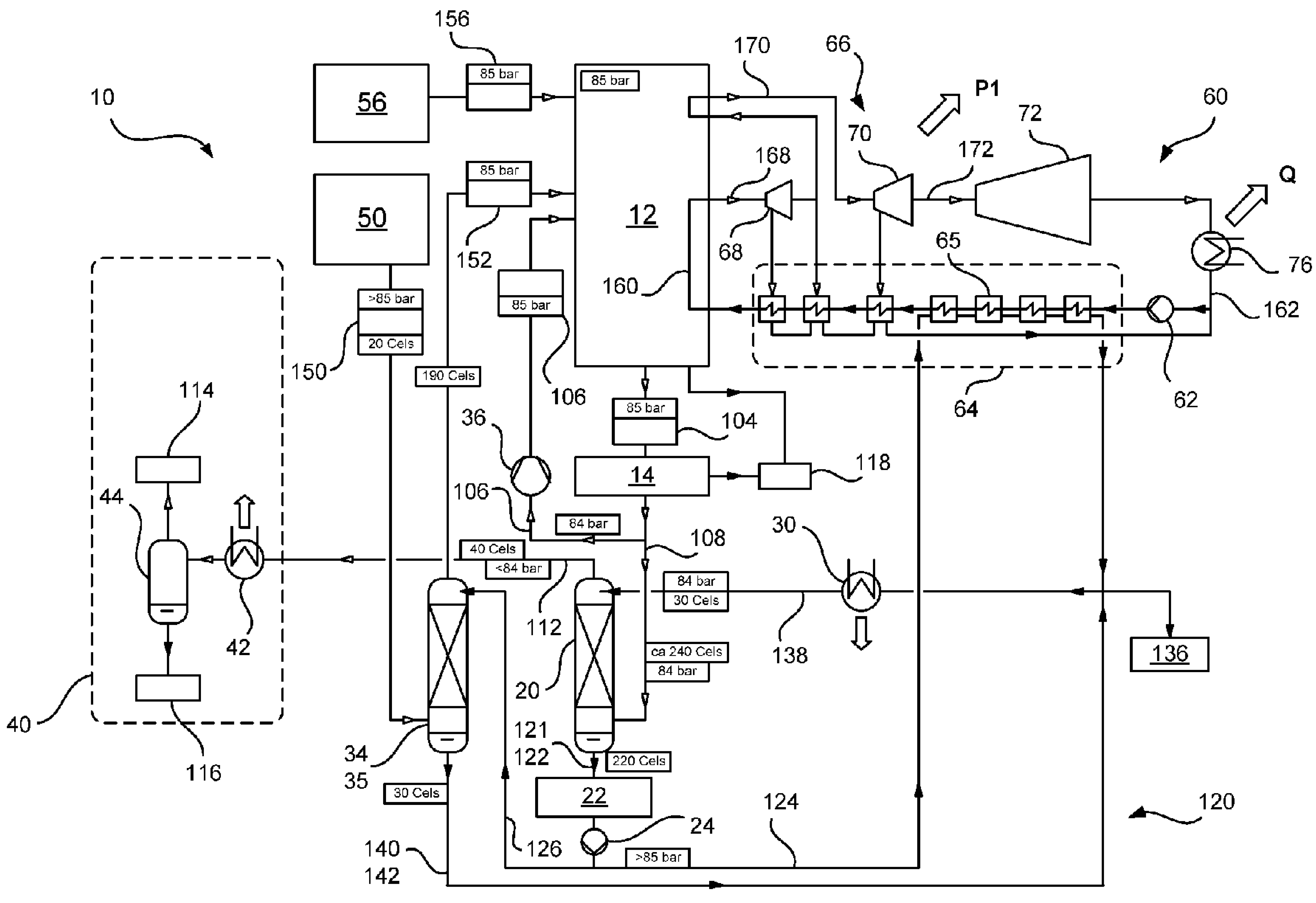
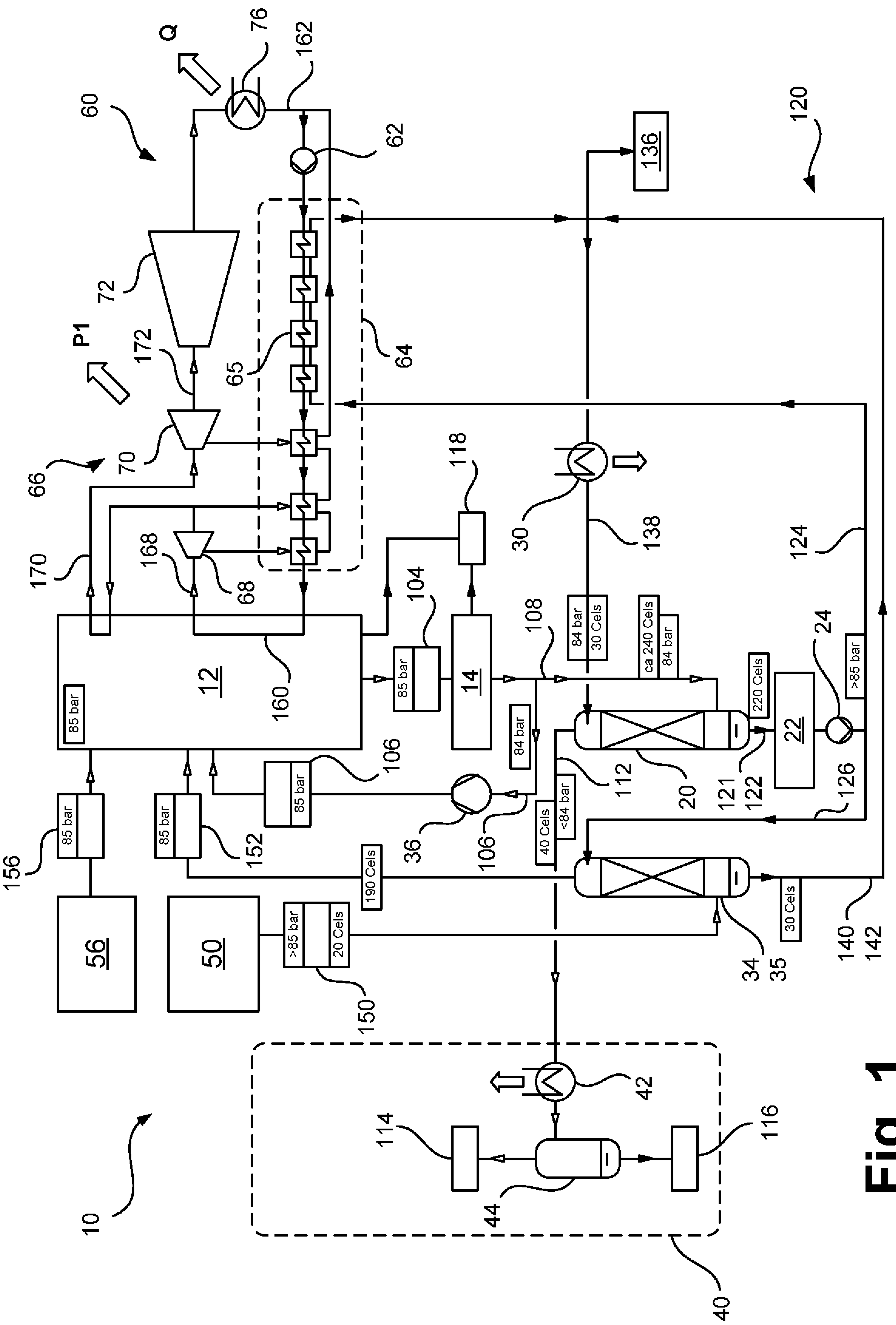
(57) **ABSTRACT**

A method and a device for conversion of energy are proposed, in which a hydrocarbon-containing energy source is burned in a combustion space (**12**) in an oxygen-enriched atmosphere and the generated heat is transmitted to a steam power plant circuit (**60**). Flue gas (**104**), which is formed in the combustion of the hydrocarbon-containing energy source, is cooled in a direct-contact cooler (**20**) in direct contact with a water-containing coolant flow (**138**).





Q
P1
85 bar
>85 bar
20 Cels
190 Cels
84 bar
30 Cels
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220 Cels
40 Cels
<84 bar
12
14
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156
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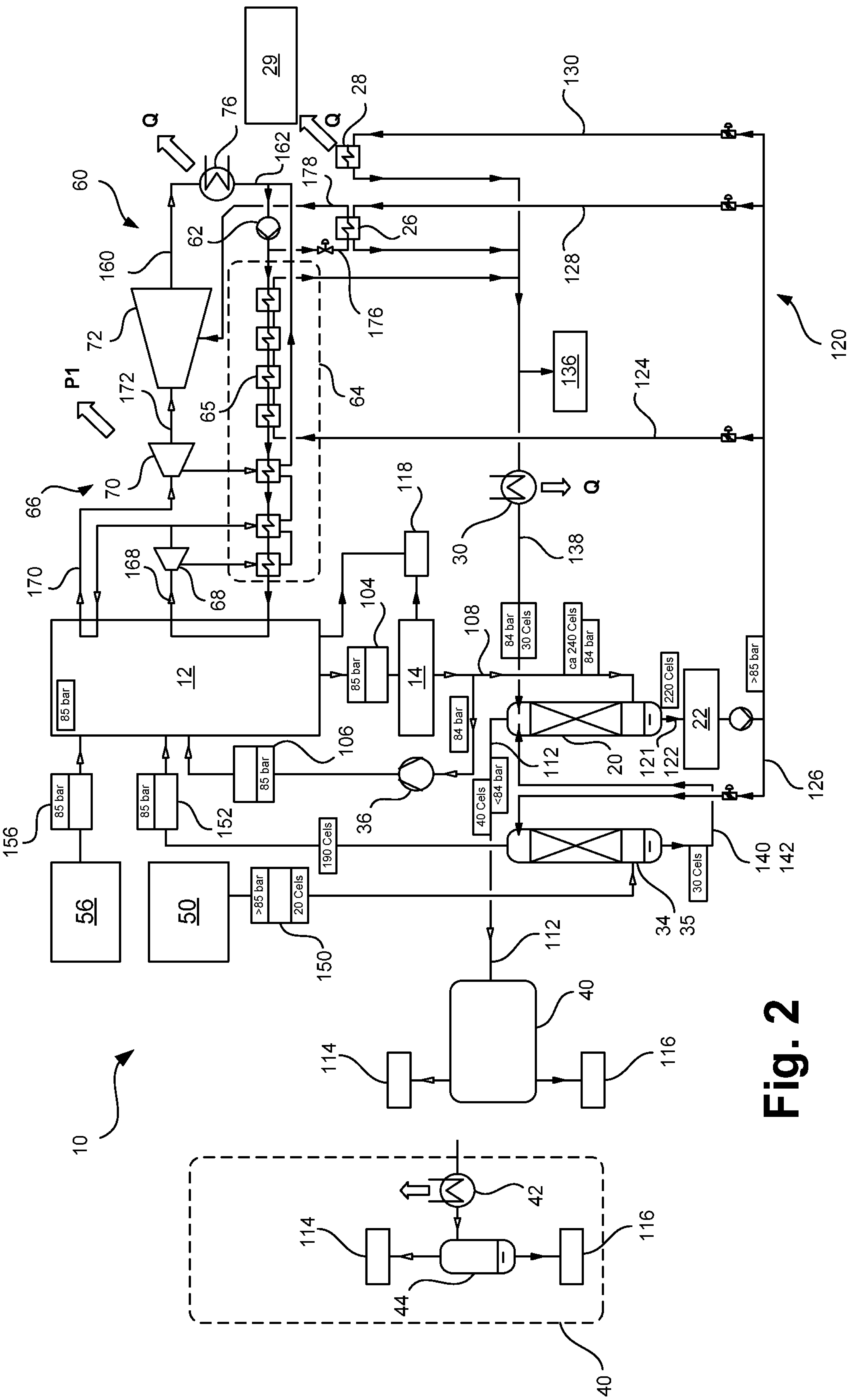
162
168
170
172

Fig. 1



29
28
130
Q
76
Q
162
178
60
26
62
160
128
176
72
P1
172
65
64
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136
124
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70
Q
30
118
168
170
68
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104
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84 bar
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85 bar
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84 bar
220 Cels
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>85 bar
112
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121
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106
85 bar
36
<84 bar
40 Cels
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85 bar
85 bar
152
190 Cels
140
142
30 Cels
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20 Cels
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40
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116
10
42
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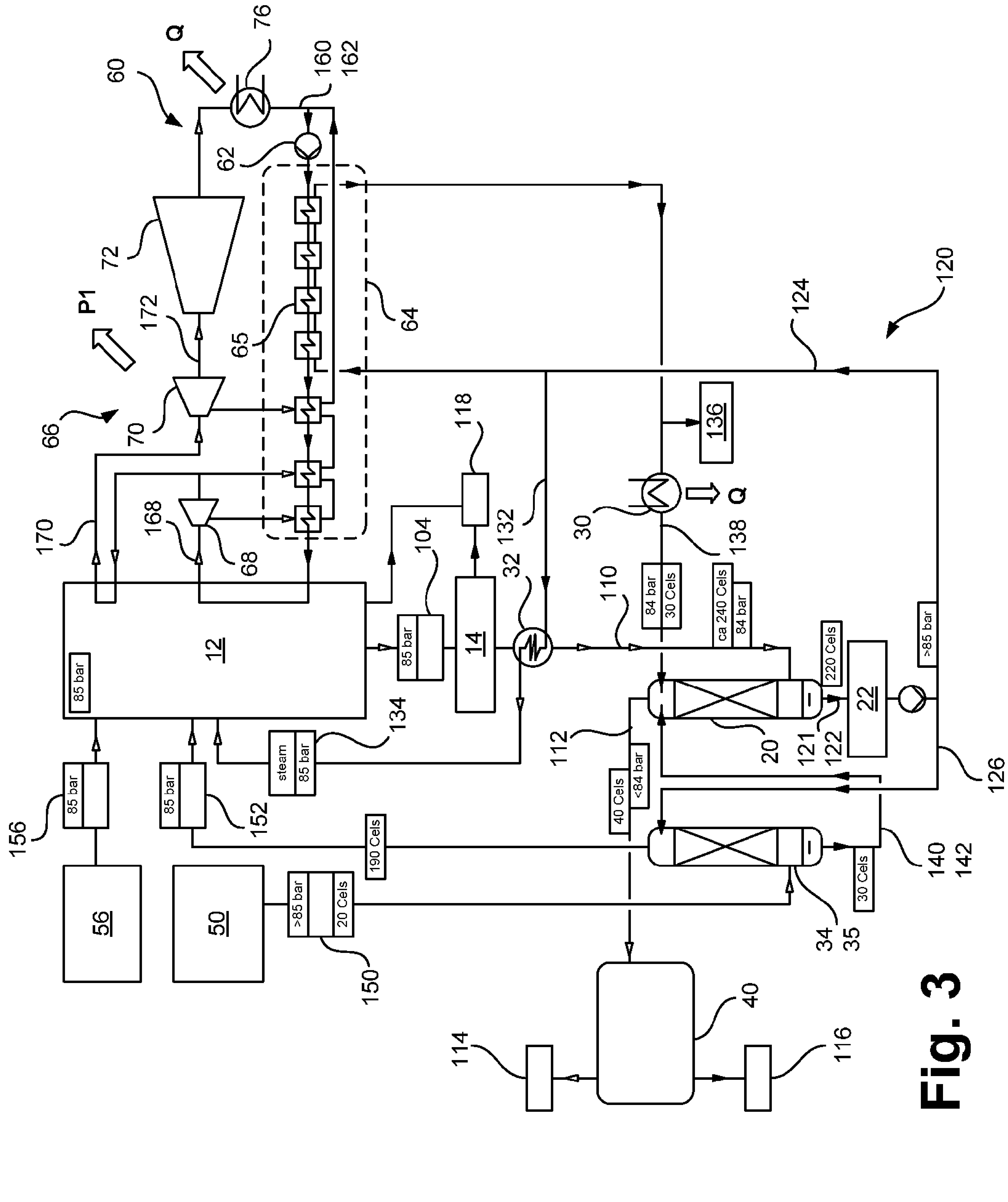
116
44
40

Fig. 2


60
Q
76
160
162
62
72
P1
172
65
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66
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168
68
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12
85 bar
104
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132
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110
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138
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124
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85 bar
156
85 bar
152
85 bar
40 Cels
<84 bar
190 Cels
140
142
30 Cels
34
35
56
50
>85 bar
20 Cels
150
40
114
116

Fig. 3

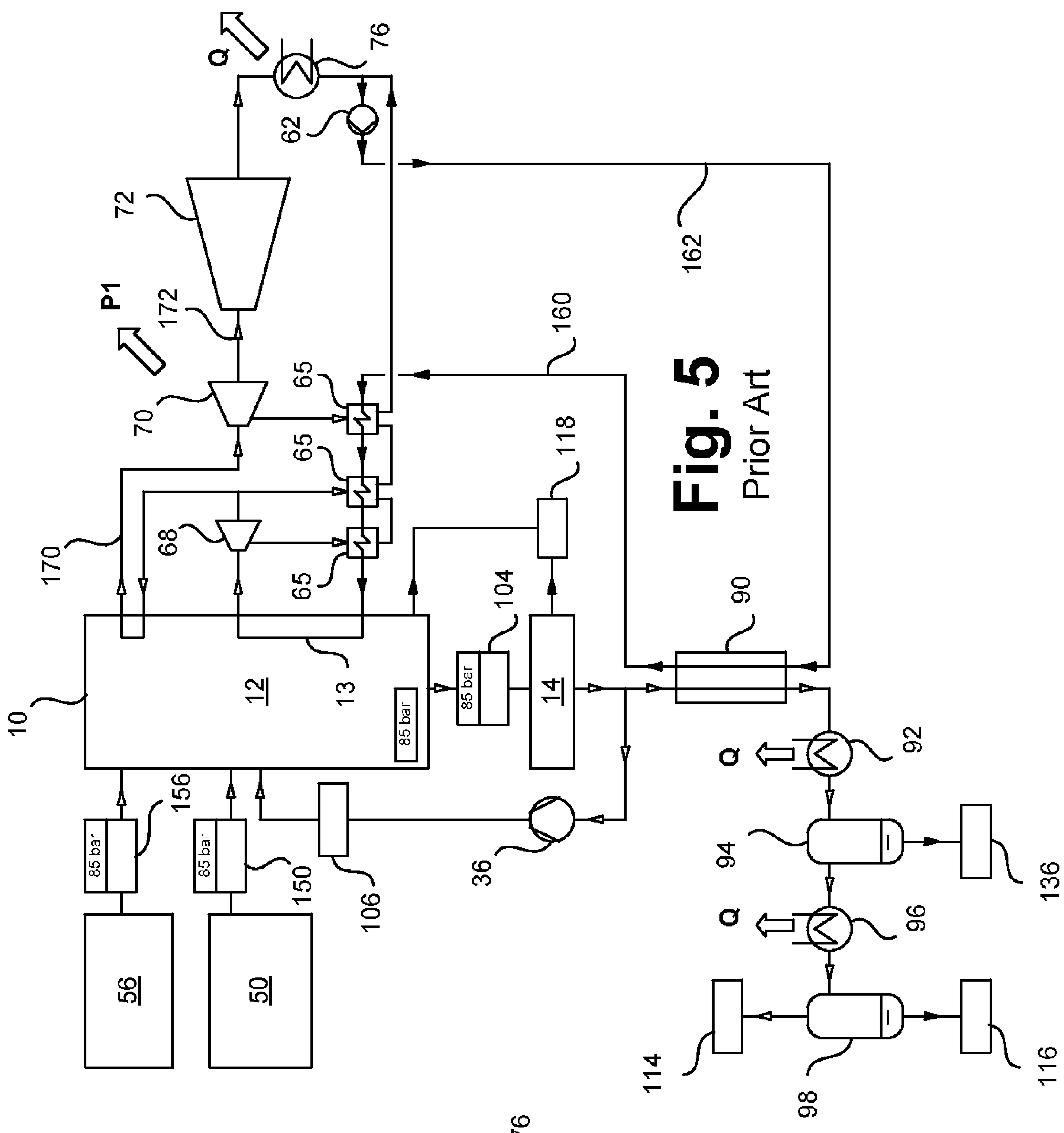

Fig. 5
Prior Art

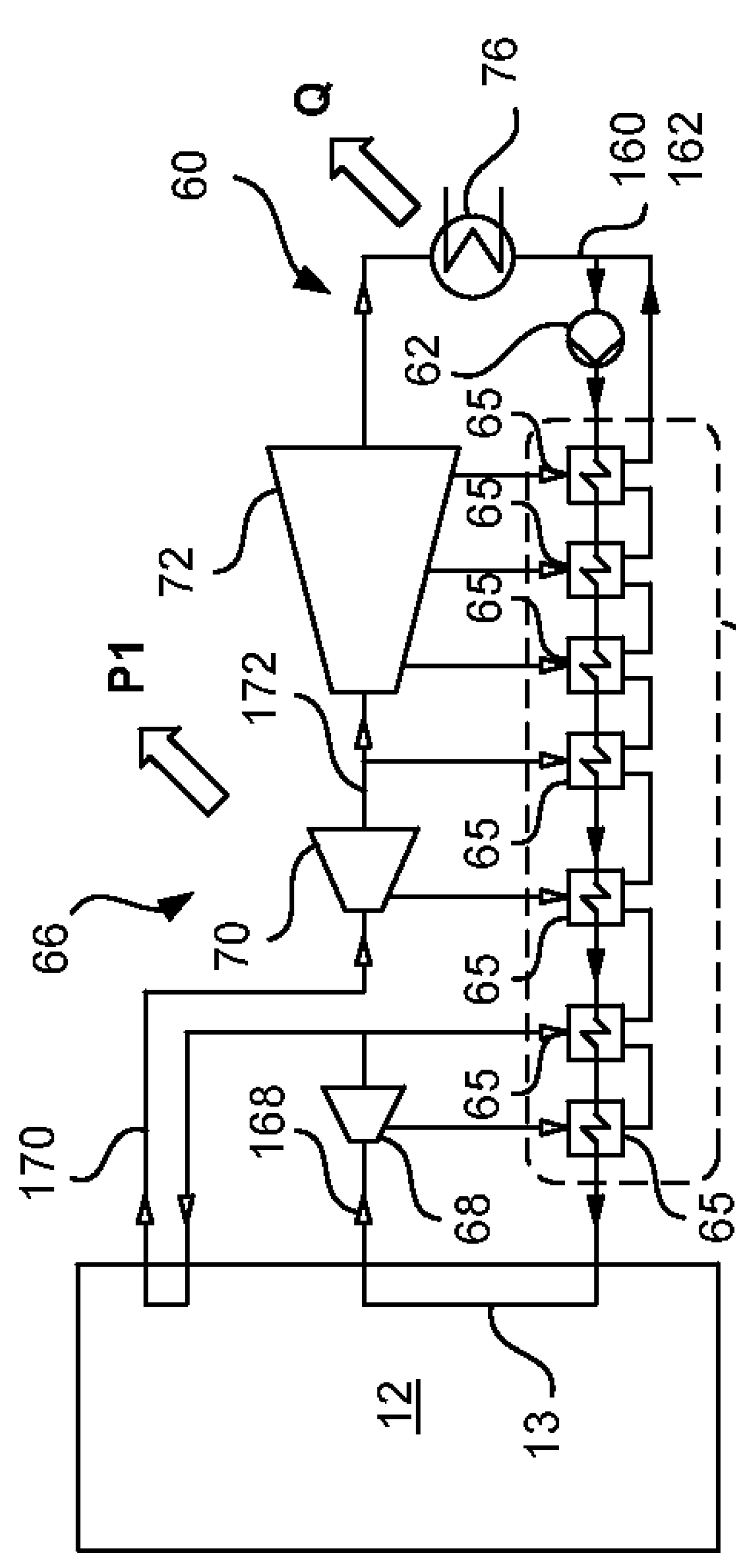

Fig. 4
Proir Art

METHOD AND DEVICE FOR ENERGY CONVERSION

FIELD OF THE INVENTION

[0001] The invention relates to a method for conversion of energy in which a hydrocarbon-containing energy source is burned in a combustion space in an oxygen-enriched atmosphere and the generated heat is transmitted to a steam power plant circuit.

[0002] Furthermore, the invention relates to an apparatus or device for conversion of energy with a combustion space for combustion of a hydrocarbon-containing energy source in an oxygen-enriched atmosphere and a steam power plant circuit that is energy-coupled to the combustion space for use of the heat that has been generated in the combustion space.

BACKGROUND OF THE INVENTION

[0003] So-called oxyfuel power plant methods are known. In them, a hydrocarbon-containing energy source is burned not in a normal air atmosphere, but rather in an oxygen-enriched atmosphere or even in almost pure oxygen. A flue gas that is formed during combustion then consists mainly of carbon dioxide (CO_2) and water vapor in the ideal case.

[0004] Therefore, the method is suitable especially as an energy conversion method in combination with separation of carbon dioxide. As a result of the flue gas consisting mainly of carbon dioxide and water vapor, the carbon dioxide can be separated comparatively easily from the flue gas by first of all the water vapor being condensed and the remaining gas then being separated into a carbon dioxide portion and a residual gas portion that may be present. The separated carbon dioxide can be, for example, forced into the ground or intercalated therein (so-called “carbon capture and storage” method, CCS). Thus, it does not end up in the earth’s atmosphere. Carbon dioxide is made responsible for a considerable portion of global warming.

[0005] One disadvantage of the known oxyfuel method consists in that the flue gas is present at relatively low temperatures so that the condensation of water out of the flue gas takes place at relatively low temperatures (less than 150° C.). Due to the low temperature, the energy content of this heat, therefore the usable portion of the heat, is relatively low. The condensation energy is therefore generally discarded, i.e., released to cooling water without energy use. This leads to degraded process efficiency.

[0006] For improved use of the waste heat of the flue gas, especially of the condensation energy of the water in the flue gas, an oxyfuel power plant method is also known in which both the energy source and also the oxygen are compressed and at pressures in the range of roughly 50 bar are delivered into the combustion space. Combustion then takes place at a correspondingly high pressure, and the flue gas is present at the outlet from the combustion space likewise at a high pressure.

[0007] One advantage of this method is that the entire flue gas path, i.e., the path from the outlet from the combustion space up to condensation of the flue gas, can be designed in a much more compact manner due to the reduced volume. Another advantage consists in that the flue gas dew point, i.e., the temperature at which condensation of the flue gas begins, is much higher compared to the low-pressure oxyfuel method. Consequently, the condensation energy is also present at high temperatures so that the energy content of this energy is greater.

[0008] By integration of this heat or energy into the steam power plant circuit, for example by use of the energy for preheating a working fluid of the steam power plant circuit, generally feed water, the total efficiency of the system, which can also be called a power plant, can be improved.

[0009] In a known method, the water vapor of the flue gas is condensed in a heat exchanger (flue gas condensation heat exchanger) in counterflow to the feed water of the steam power plant circuit for use of the energy of the flue gas, whereby the feed water is preheated.

[0010] Preheating the feed water makes it possible to reduce the number of conventionally undertaken taps (side streams from the steam turbine unit of the steam power plant) as well as the amount of the tapped steam from the turbines for feed-water preheating, especially in the medium-pressure and low-pressure range. The turbines can thus generate more electrical or mechanical power.

[0011] One problem in this use of the energy of the flue gas, however, consists in that in reality, the flue gas, in contrast to the idealized model, contains not only carbon dioxide and water, but also a plurality of other components, such as, for example, sulfur oxides and nitrogen oxides that are soluble in water. In addition, with rising pressure, the solubility of carbon dioxide in water rises. These above-mentioned substances constitute strong acids, dissolved in water.

[0012] Due to the high pressures, the high temperatures, a large amount of heat to be transferred, and the acid water solution, the demands on the flue gas condensation heat exchanger are high. These demands can so far be managed only with a very high technical effort that is associated with correspondingly high costs.

[0013] Another disadvantage of the known approach consists in that the available condensation heat of the flue gas is greater than the heat that is required for heating the feed water. The condensation heat can therefore not be completely integrated into the method and used so that the theoretical potential for improvement that exists cannot be completely exhausted.

[0014] The use of the condensation energy of the flue gas of an oxyfuel process for feed-water preheating is described in U.S. Pat. No. 6,918,253 B2 and U.S. Pat. No. 6,196,000 B1.

SUMMARY OF THE INVENTION

[0015] Therefore, an object of the invention is to provide a method and a device or apparatus for conversion of energy that are especially economical and that enable especially energy-efficient and cost-efficient use of the flue gas exhaust heat of an oxyfuel power plant process.

[0016] Upon further study of the specification and appended claims, other objects, aspects and advantages of the invention will become apparent.

[0017] These objects are achieved according to the invention by a method for conversion of energy, in which a hydrocarbon-containing energy source is burned in a combustion space in an oxygen-enriched atmosphere and the generated heat is transmitted to a steam power plant circuit, wherein flue gas, formed in the combustion of the hydrocarbon-containing energy source, is cooled in a direct-contact cooler in direct contact with a water-containing coolant flow. These objects are also achieved according to the invention by an apparatus with a combustion space for combustion of a hydrocarbon-containing energy source in an oxygen-enriched atmosphere and a steam power plant circuit, which is energy-coupled to the combustion space for use of heat generated in the combustion space, wherein a direct-contact cooler is connected downstream from the combustion space and in which cooler a flue gas, formed in the combustion of the hydrocarbon-containing energy source, can be cooled in direct contact with a water-containing coolant flow. Preferred configurations of the invention are given in the following description.

[0018] The method is characterized according to the invention in that the flue gas that is formed in the combustion of the hydrocarbon-containing energy source is cooled in a direct-contact cooler in direct contact with a water-containing coolant flow.

[0019] With respect to the device, it is provided according to the invention that a direct-contact cooler is connected downstream from the combustion space and in it a flue gas that is formed in the combustion of the hydrocarbon-containing energy source can be cooled in direct contact with a water-containing coolant flow.

[0020] One advantage of the method according to the invention and of the device according to the invention is that the transport of heat and mass in a direct-contact apparatus is much more intense than in a heat exchanger with flows separated by substance. The heat transfer or heat exchange therefore proceeds more efficiently so that less surface is needed; this leads to a considerable cost reduction.

[0021] Another advantage of the flue gas making direct contact with the water-containing coolant consists in that flue gas washing takes place by the liquid water, and in the washing, at least some of the water vapor is condensed and washed out of the flue gas. In the direct-contact cooler, therefore, separation of substances takes place. The cooled gas flow that is leaving the direct-contact cooler contains a smaller portion of water than the hot flue gas flow that is entering the direct-contact cooler. Preferably, the cooled gas flow already contains a relatively pure carbon dioxide, together with gaseous impurities that may be present and a preferably small portion of water vapor. In the direct-contact cooler, in one advantageous configuration of the invention, an at least partial, preferably extensive, separation of the water portion from the flue gas can be undertaken.

[0022] One basic idea of the invention can be seen in dissipating the condensation heat of the flue gas, not directly to the working fluid (feed water) of the steam power plant circuit, but rather to a coolant flow that is then used as a heat transfer medium. The heat is transferred to the coolant flow in this case in the flue gas making direct contact with the cold liquid flow, which is enriched in this connection with water from the flue gas. The usable heat of the flue gas is therefore released to a heat transfer medium that can then relay or distribute the heat to one or optionally several consumers. This enables especially efficient and flexible use of the condensation heat of the flue gas.

[0023] The energy coupling of the combustion space to the steam power plant circuit is implemented especially by routing the working fluid through the combustion space, especially in pipelines. Vaporization and optionally superheating of the working fluid take place in the pipelines.

[0024] Preferably, the water-containing coolant flow that is fed directly into the direct-contact cooler is a water-rich flow or one consisting largely of water, for example with a water portion of at least 80 or 90%. By way of simplification, the coolant flow is therefore water. The flue gas is condensed in direct contact with the water flow and optionally cooled. The coolant flow can be especially a circulated flow that contains water that has been condensed from the flue gas or at least largely consists of it. The coolant flow can therefore contain impurities or components of the flue gas that dissolve in water.

[0025] The flue gas flow is preferably fed into the direct-contact cooler in a lower region and is routed in counterflow to the coolant that is preferably fed into an upper region of the direct-contact cooler and trickles down into the direct-contact cooler. To make available intensive contact of the gas with the liquid, the direct-contact cooler contains preferably fillings or packings. With respect to the high temperatures and pressures, the use of ceramic and/or metal fillings or packings is preferred (e.g., random packings such as Raschig rings, Pall rings, and Berl saddles, and structured packings such as Koch-Sulzer packing, Intalox packing, or Mellapak, as well as combination of random and structured packings).

[0026] The energy source (fuel, propellant) can be a solid, liquid and/or gaseous feedstock. To make available the condensation heat at a temperature level that can be used technically more efficiently, it is preferred according to the invention that the combustion of the hydrocarbon-containing energy source in the combustion space, which can also be called the combustion chamber, takes place at a pressure above atmospheric pressure. The flue gas thus likewise has an elevated pressure and a corresponding dew point (dew point temperature).

[0027] A preferred pressure range for the combustion of the energy source is 5 to 100 bar (abs.), in another configuration 40 to 100 bar (abs.). In particular, it is preferred that the combustion of the hydrocarbon-containing energy source in the combustion space takes place at at least 8 bar (abs.), preferably at least 10 bar (abs.). In another configuration, it is preferred that the combustion of the hydrocarbon-containing energy source in the combustion space takes place at at least 40 bar (abs.), preferably at least 80 bar (abs.). Depending on the specific flue gas composition, the dew point of the flue gas, for example at a flue gas pressure of 80 bar, is in a range above 200° C.

[0028] Accordingly, it is preferred that a liquid flow that has been withdrawn from the direct-contact cooler be used as a heat transfer medium for energy use. The flow can be cooled especially in at least one heat exchanger for energy use. The fluid flow withdrawn from the direct-contact cooler is preferably essentially water that may contain dissolved substances such as sulfur oxides, nitrogen oxides or carbon dioxide.

[0029] To increase the efficiency of the power plant process, it is especially preferred that at least one part of the liquid flow withdrawn from the direct-contact cooler be used to preheat a working fluid of the steam power plant circuit.

[0030] The steam power plant circuit in the fundamentally known manner is a circuit with a working fluid that can be vaporized for conversion of heat into mechanical work (energy). To generate the mechanical energy, the vaporous working fluid is expanded in a steam turbine (Rankine process). The steam turbine is coupled to a generator for generating a flow. The working fluid is brought to a high pressure by means of a pump. The pressurized working fluid is then vaporized by supplying heat and superheated, and it is expanded to a low pressure in the steam turbine. After condensation in a condenser, the fluid is brought again to high pressure. For vaporization and superheating, the working fluid is conventionally routed in pipelines through the combustion space. The final temperature can be in the range from roughly 500° C. to 700° C., especially roughly 600° C., depending on the specific design. Preferably, the working fluid is water that is also called feed water.

[0031] Preferably, prior to vaporization and superheating of the working fluid, preheating takes place to increase the efficiency of energy conversion. The preheating of the working fluid that can be called especially feed-water preheating takes place by heat transfer from the liquid flow from the direct-contact cooler to the working fluid of the steam power plant circuit. The liquid flow that has been withdrawn from the direct-contact cooler is cooled in doing so and heats the working fluid (feed water).

[0032] Advantageously, the preheating of the working fluid takes place in at least one liquid-liquid heat exchanger. The liquid-liquid heat exchanger is preferably a water-water heat exchanger with feed water on one side and the water flow that has been withdrawn from the direct-contact cooler on the other side. Feed-water preheating of the steam power plant circuit can take place in this way in conventional water-water heat exchangers and thus can be implemented economically and with relatively low hardware cost. Preferably, the feed-water preheating takes place in counterflow to the liquid flow that has been withdrawn from the direct-contact cooler.

[0033] Alternatively or in addition to the heating of the working fluid, at least one part of the liquid flow withdrawn from the direct-contact cooler can be used to vaporize the working fluid of the steam power plant circuit. The vaporized and optionally (slightly) superheated working fluid can then be fed into a low-pressure turbine part of the steam turbine and thus can increase the output of the steam turbine. This steam feed can be usefully regarded as negative steam removal.

[0034] Another preferred possibility of the use of the energy of the flue gas consists in that at least one part of the liquid flow that has been withdrawn from the direct-contact cooler is used in an oxygen preheater for preheating an oxygen flow. An oxygen flow here is defined as a flow that contains at least one oxygen portion that is larger than the oxygen portion in the ambient air. For example, it can be a flow with an oxygen portion of at least 80%, preferably roughly 97%. The oxygen flow is fed into the combustion space for preparing the oxygen-enriched atmosphere in which the combustion of the energy source takes place. The preheating of the oxygen before being fed into the combustion space leads to an improvement of the efficiency of the overall process.

[0035] Within the scope of this invention, an oxygen-enriched atmosphere is defined as an atmosphere that contains a larger oxygen portion than ambient air. Preferably, the oxygen portion in an oxygen-enriched atmosphere is at least 80%, preferably roughly 97%.

[0036] The flow of oxygen can be efficiently heated or preheated in that the oxygen flow is heated in a direct-contact heat exchanger (direct-contact heater) in direct contact with the liquid flow withdrawn from the direct-contact cooler or a part of it. In this case, it can be provided in particular that the gaseous oxygen flow is fed underneath into the direct-contact heat exchanger and is routed in counterflow to the liquid that is fed preferably in an upper region and trickles down into the direct-contact heat exchanger. The direct-contact heat exchanger preferably has a packing or filling for making available an intensive gas-liquid contact. The preheating of the oxygen by direct contact with a condensed water fraction from the flue gas ensures especially efficient heat transport so that compared to a conventional heat exchanger, a smaller surface is required.

[0037] Preferably, a liquid flow withdrawn from the oxygen preheater is at least partially returned as a coolant flow to the direct-contact cooler. This flow is a water-rich flow or one consisting largely of water. The return of this water flow to the direct-contact cooler for condensing or cooling the flue gas can take place either directly or via another heat exchanger, for example a cooling water heat exchanger.

[0038] It is especially preferred according to the invention that a liquid flow that has been withdrawn from the direct-contact cooler be returned after cooling at least partially as a coolant flow to the direct-contact cooler. The coolant flow is therefore circulated, it being heated as the water portion of the flue gas is received in the direct-contact cooler, cooled with the release of heat to the heat consumer, and fed again into the direct-contact cooler. As a result of receiving water and optionally other components from the flue gas flow, a partial flow that contains essentially water is transferred out to equalize the material balance.

[0039] To protect the apparatus and lines of the water circuit, for example against corrosion, preferably the liquid flow that has been withdrawn from the direct-contact cooler is delivered to a water-treatment apparatus. In the water-treatment apparatus, the water conditioning takes place that, for example, can include the setting of a pH value and/or the addition of anti-corrosion agents.

[0040] One preferred measure for setting, especially reducing, the combustion temperature in the combustion space is the return of a part of the flue gas to the combustion space. To do this, some of the flue gas is branched off preferably upstream from the direct-contact cooler and returned to the combustion space via a fan.

[0041] Another possibility for influencing the combustion temperature in the combustion space is to return part of the liquid flow that has been withdrawn from the direct-contact cooler to the combustion space. The liquid flow that contains largely water and thus can be called a water flow can either be delivered as liquid into the combustion space or at least partially vaporized beforehand in a heat exchanger and then at least partially in vapor form delivered into the combustion space. In the case of prior vaporization, it is preferred that the liquid flow or water flow be heated or vaporized against flue gas from the combustion space. The heat exchanger that is intended for this purpose is installed in the flue gas path preferably upstream from or in front of the direct-contact cooler.

BRIEF DESCRIPTION OF THE DRAWINGS

[0042] The invention as well as additional details of the invention are explained in more detail below using preferred embodiments that are shown in the attached schematic figures, wherein:

[0043] FIG. **1** shows a process diagram of one embodiment of a method according to the invention and a corresponding device;

[0044] FIG. **2** shows a process diagram of one embodiment of a method according to the invention and a corresponding device;

[0045] FIG. **3** shows a process diagram of one embodiment of a method according to the invention and a corresponding device;

[0046] FIG. **4** shows a process diagram of a steam power plant circuit according to the state of the art; and

[0047] FIG. **5** shows a process diagram of an oxyfuel process according to the state of the art.

DETAILED DESCRIPTION

[0048] First of all, a conventional steam power process as well as a known oxyfuel method are described using FIGS. **4** and **5**.

[0049] In a conventional steam power process, a working fluid **160**, which is conventionally water (feed water **162**), is circulated. A steam power plant circuit **60** (Rankine cycle) comprises a feed-water pump **62**, a feed-water preheating part **64**, a steam turbine unit **66**, and a condenser **76**. The steam turbine unit **66**, as shown in the figures, can comprise several parts, for example a high-pressure part **68**, a medium-pressure part **70**, and a low-pressure part **72** that can consist of independent turbines in each case. The corresponding turbines (high-pressure turbine, medium-pressure turbine, and low-pressure turbine) can each have several expansion stages (impellers).

[0050] The working fluid **160** or feed water **162** is brought to a high pressure level by means of the feed-water pump **62** that can have several pump units with different pressure stages. Depending on the design, this can be in the range of 300 bar. The feed water **162** is preheated in the feed-water preheating part **64** and then routed in pipelines **13** through a combustion space **12**, in which an energy source (fuel) is burned. In the combustion space **12**, the feed water is further heated, vaporized and superheated.

[0051] The resulting high-pressure steam **168** is expanded in the steam turbine unit **66**. The expansion takes place preferably in several stages, first the superheated high-pressure steam **168** being expanded in the high-pressure part **68** of the steam turbine unit **66** and afterwards again routed through the combustion space **12** and again superheated or superheated further. Afterwards, the steam as medium-pressure steam **170** is expanded in the medium-pressure part **70** and as low-pressure steam **172** in the low-pressure part **72** and then is condensed in the condenser **76**.

[0052] To preheat the feed water **162**, a series of heat exchangers **65** is used. The feed water **162** is heated by steam that is removed at suitable sites of the turbine unit **66**. These steam removals reduce the amount of steam in the turbines so that the total output is reduced.

[0053] FIG. **5** shows a known method for conversion of energy. A device **10** for conversion of energy comprises a combustion space **12**, in which a hydrocarbon-containing energy source is burned in an oxygen atmosphere. The energy source as a fuel flow **156** from a fuel preparation unit **56** is fed into the combustion space **12**. To prepare the oxygen atmosphere, an oxygen-enriched flow that is called the oxygen flow **150** is supplied from an air-separation apparatus **50**.

[0054] The energy source is burned in the combustion space **12** and the heat that forms in doing so is transferred via pipelines **13** to a steam power plant circuit **60**. The feed water **162** is preheated in a first step in a counterflow heat exchanger **90** in counterflow to condensing flue gas **104**. The counterflow heat exchanger **90** is exposed to especially high loads due to the prevailing temperatures and the material composition of the flue gas **104**.

[0055] Further feed-water preheating takes place in heat exchangers **65** by removing steam from the steam turbine unit **66**.

[0056] Before delivery of the flue gas **104**, solid particles are separated in a particle separation apparatus **14** and withdrawn as ash **118**. Some of the flue gas flow is returned to the combustion space **12** as a partial flow **106** by means of a fan **36**.

[0057] In a flue gas cooler **92**, the flue gas is further cooled. Water that has condensed out as a water product flow **136** is withdrawn from a water-separation tank **94**. After liquefaction of the carbon dioxide in a CO_2 condenser **96**, a liquid CO_2 product flow **116** and a gaseous residual gas flow **114** are withdrawn from a CO_2-separation tank **98**.

[0058] FIGS. **1** to **3** show preferred configurations of a system or device **10** according to the invention for conversion of energy. For better understanding and for showing possible operating points, in this case exemplary process parameters are given. The latter can also be regarded as mean values of a parameter range that is defined preferably by a deviation up and down from the indicated mean value of 10% or 20%. Identical, equivalently-acting or similar components or flows are identified with the same reference numbers in all figures. To the extent the device and the method correspond to those of FIGS. **4** and **5**, reference is made to the embodiments there to avoid repetition.

[0059] A first preferred embodiment of the invention is shown in FIG. **1**. The device **10** for energy conversion comprises a combustion space **12**, in which a hydrocarbon-containing energy source is burned in an oxygen-enriched atmosphere. The energy source as a fuel flow **156** is supplied from a fuel preparation unit **56** (fuel system). The heat that forms is transferred to a steam power plant circuit **60** for producing mechanical energy in a turbine system.

[0060] To prepare the oxygen atmosphere, an oxygen-enriched flow that is called the oxygen flow **150** is produced in an air-separation apparatus **50**. The oxygen flow **150** exists at a pressure above a combustion space pressure. The pressure can be, for example, at least 80 bar. The temperature at the outlet of the air-separation apparatus **50** can be, for example, roughly the ambient temperature, i.e., roughly 20° C.

[0061] Before delivery into the combustion space **12**, the oxygen flow **150** is preheated in an oxygen preheater **35** that is a direct-contact heat exchanger **34** in the illustrated embodiment. The oxygen flow **152** that has been preheated preferably to roughly 180° C. to 200° C. is delivered into the combustion space **12**.

[0062] A flue gas **104** (flue gas flow) that is formed by combustion leaves the combustion space **12** and is supplied to a particle separation apparatus **14** for separation of solid particles. The separated solid particles together with a solid flow are withdrawn from the combustion space **12** as ash **118**. After the particle separation apparatus **14**, the flue gas flow is divided into a first partial flow **106** that is returned to the combustion space **12** and a second partial flow **108**. To return the partial flow **106** to the combustion space **12**, there is, for example, a fan **36**.

[0063] The second partial flow **108** is routed into a direct-contact cooler **20** for cooling and partial condensation. The direct-contact cooler **20** can have a tank or a column. The tank or the column can contain fillings and/or structured packings.

[0064] The partial flow **108** of the flue gas is fed into a lower region of the direct-contact cooler **20** and rises in counterflow to a coolant that is trickling down. The coolant is a water-rich liquid flow **121** that has been withdrawn from the bottom of the direct-contact cooler **20**. This liquid flow **121**, which can also be called a water flow **122**, flue gas condensation flow or bottom flow is fed at least partially after cooling as a coolant flow **138** into an upper region of the direct-contact cooler **20** and thus is circulated (water circuit **120**).

[0065] In the direct-contact cooler **20**, cooling and partial liquefaction of the flue gas **104** or of the partial flow **108** take place. Due to the direct contact with the coolant flow **138** (water flow), a predominant part of the water vapor condenses out of the flue gas **104**. Therefore, the water or water vapor is depleted. The cooled flue gas flow **112** leaves the direct-contact cooler **20** and is supplied to a CO_2 separation unit **40**. There, the flue gas flow **112** is separated into a liquid CO_2 product flow **116**, which contains primarily carbon dioxide, and a gaseous residual gas flow **114**. The CO_2 separation unit **40** has a CO_2 condenser **42** and a gas-liquid separating tank **44**. Optionally, aftertreatment steps, for example further cleaning of the CO_2 flow, can also take place.

[0066] The aforementioned liquid water flow **122** is withdrawn from the bottom of the direct-contact cooler **20**. The temperature of the water flow **122** corresponds to the dew point of the flue gas at a given pressure and a given flue gas composition. The water flow **122** is first chemically conditioned in a water-treatment apparatus **22** and then cooled in a series of heat exchangers in order to be supplied again afterwards as a coolant flow **138** at least in part to the direct-contact cooler **20**.

[0067] The circulation of the water flow **122** takes place by means of a pump **24** that can have several pump units. The water flow **122** is divided into at least two partial flows that are supplied to different heat users.

[0068] According to the configuration of FIG. **1**, a first partial flow **124** is used for feed-water preheating of the steam power plant circuit **60**. A second partial flow **126** is used to preheat the oxygen flow **150**.

[0069] To preheat the feed water **162**, the partial flow **124** is routed in one or more heat exchangers **65** of the feed-water preheating part **64** in counterflow to the feed water **162** and in doing so is cooled. The heat transfer takes place in liquid-liquid heat exchangers with flows that are separated by material. In addition, in other heat exchangers **65**, the feed water can be preheated by removing steam from the turbine unit **66**.

[0070] The partial flow **126** is fed into the direct-contact heat exchanger **34** in an upper region and flows down into the heat exchanger. The oxygen flow **150** (gas) to be heated is supplied to the direct-contact heat exchanger **34** in a lower region and rises into the heat exchanger.

[0071] A liquid flow **140** that can also be called a bottom flow **142** is withdrawn from the bottom of the direct-contact heat exchanger **34**. This flow that contains essentially water is combined with a return flow from the heat exchangers **65** and further cooled in a water cooler **30** against cooling water. The cooled flow is delivered again as a coolant flow **138** to the direct-contact cooler **20**. A water product flow **136** is withdrawn from the water circuit **120**.

[0072] FIG. **2** shows other possible uses of the thermal energy of the water flow **122** that has been withdrawn from the direct-contact cooler **20**. Here, a partial flow **128** is routed to a heat exchanger (boiler make-up evaporator **26**) in which one part **176** of the feed water **162** is evaporated. The evaporated feed water (water vapor **178**) is supplied to the low-pressure part **72** of the steam turbine unit **66** and increases the mass flow there.

[0073] Another partial flow **130** is routed to a heat exchanger unit **28**, in which heat is released to an external heat consumer **29**, for example an adjacent power plant installation.

[0074] Instead of a return via the water cooler **30**, the bottom flow **142** (water flow) that has been withdrawn from the direct-contact heat exchanger **34** can also be fed directly, i.e., without intermediate cooling, into the direct-contact cooler **20**, as shown in FIG. **2**. In this connection, the bottom flow **142** is fed overhead into the direct-contact cooler **20**.

[0075] The version according to FIG. **3** differs from the above-described version by a return of a water flow or water vapor flow into the combustion space **12**. To return water to the combustion space **12**, a partial flow **132** of the bottom flow is branched out from the direct-contact cooler **20**. The latter can be fed hot either directly into the combustion space **12**—as shown in FIG. **2**—or can be evaporated beforehand. The partial flow **132** is evaporated here in a water evaporator **32** against hot flue gas and is routed as a water vapor return flow **134** into the combustion space **12**. The water evaporator **32** in the flue gas route is located upstream from the direct-contact cooler **20**. A precooled flue gas flow **110** that emerges from the water evaporator **32** is fed into the direct-contact cooler **20**.

[0076] Without further elaboration, it is believed that one skilled in the art can, using the preceding description, utilize the present invention to its fullest extent. The preceding preferred specific embodiments are, therefore, to be construed as merely illustrative, and not limitative of the remainder of the disclosure in any way whatsoever.

[0077] The preceding examples can be repeated with similar success by substituting the generically or specifically described reactants and/or operating conditions of this invention for those used in the preceding examples.

[0078] From the foregoing description, one skilled in the art can easily ascertain the essential characteristics of this invention and, without departing from the spirit and scope thereof, can make various changes and modifications of the invention to adapt it to various usages and conditions.

[0079] The entire disclosures of all applications, patents and publications, cited herein and of corresponding German patent application DE 10 2012 013 414.2, filed Jul. 5, 2012, are incorporated by reference herein.

REFERENCE NUMBER LIST

[0080] **10** Device for conversion of energy
[0081] **12** Combustion space
[0082] **13** Pipeline
[0083] **14** Particle separation apparatus
[0084] **20** Direct-contact cooler
[0085] **22** Water-treatment apparatus
[0086] **24** Pump
[0087] **26** Boiler make-up evaporator
[0088] **28** Heat exchanger unit
[0089] **29** External heat consumer
[0090] **30** Water cooler
[0091] **32** Water evaporator
[0092] **34** Direct-contact heat exchanger
[0093] **35** Oxygen preheater
[0094] **36** Fan
[0095] **40** CO_2 separation unit
[0096] **42** CO_2 condenser
[0097] **44** Gas-liquid-separating tank
[0098] **50** Air-separation apparatus

[0099] **56** Fuel preparation unit
[0100] **60** Steam power plant circuit
[0101] **62** Feed-water pump
[0102] **64** Feed-water preheating part
[0103] **65** Heat exchanger
[0104] **66** Steam turbine unit
[0105] **68** High-pressure part
[0106] **70** Medium-pressure part
[0107] **72** Low-pressure part
[0108] **76** Condenser
[0109] **90** Counterflow heat exchanger
[0110] **92** Flue gas cooler
[0111] **94** Water-separation tank
[0112] **96** CO_2 condenser
[0113] **98** CO_2-separation tank
[0114] **104** Flue gas
[0115] **106** First partial flow
[0116] **108** Second partial flow
[0117] **110** Precooled flue gas flow
[0118] **112** Cooled flue gas flow
[0119] **114** Residual gas flow
[0120] **116** CO_2 product flow
[0121] **118** Ash
[0122] **120** Water circuit
[0123] **121** Liquid flow
[0124] **122** Water flow
[0125] **124** Partial flow for feed-water preheating
[0126] **126** Partial flow for oxygen preheating
[0127] **128** Partial flow to boiler make-up evaporator
[0128] **130** Partial flow to heat exchanger unit
[0129] **132** Partial flow to water evaporator
[0130] **134** Water vapor return flow
[0131] **136** Water product flow
[0132] **138** Coolant flow
[0133] **140** Liquid flow
[0134] **142** Bottom flow
[0135] **150** Oxygen flow
[0136] **152** Preheated oxygen flow
[0137] **156** Fuel flow
[0138] **160** Working fluid
[0139] **162** Feed water
[0140] **168** High-pressure steam
[0141] **170** Medium-pressure steam
[0142] **172** Low-pressure steam
[0143] **176** Part of the feed water to the boiler make-up evaporator
[0144] **178** Water vapor

1. A method for conversion of energy comprising:

burning a hydrocarbon-containing energy source in a combustion space (**12**) in an oxygen-enriched atmosphere to generate heat; transmitting the generated heat to a steam power plant circuit (**60**); and cooling flue gas (**104**), formed in the combustion of the hydrocarbon-containing energy source, in a direct-contact cooler (**20**) in direct contact with a water-containing coolant flow (**138**).

2. The method according to claim **1**, wherein the combustion of the hydrocarbon-containing energy source in the combustion space (**12**) takes place at a pressure above atmospheric pressure.

3. The method according to claim **1**, wherein the combustion of the hydrocarbon-containing energy source in the combustion space (**12**) is performed at at least 8 bar (abs.).

4. The method according to claim **3**, wherein the combustion of the hydrocarbon-containing energy source in the combustion space (**12**) is performed at at least 10 bar (abs.).

5. The method according to claim **3**, wherein the combustion of the hydrocarbon-containing energy source in the combustion space (**12**) is performed at at least 40 bar (abs.).

6. The method according to claim **3**, wherein the combustion of the hydrocarbon-containing energy source in the combustion space (**12**) is performed at at least 80 bar (abs.).

7. The method according to claim **1**, wherein a liquid flow (**121**), withdrawn from the direct-contact cooler (**20**), is used as a heat transfer medium for energy use.

8. The method according to claim **1**, wherein at least one part of a liquid flow (**121**), withdrawn from the direct-contact cooler (**20**), is used to preheat a working fluid (**160**) of the steam power plant circuit (**60**).

9. The method according to claim **1**, wherein a working fluid is used to transmitting the heat generated in the combustion space (**12**) to the steam power plant circuit (**60**), and the working fluid is preheated in at least one liquid-liquid heat exchanger.

10. The method according to claim **1**, wherein a working fluid is used to transmitting the heat generated in the combustion space (**12**) to the steam power plant circuit (**60**), and at least one part of a liquid flow (**121**), withdrawn from the direct-contact cooler (**20**), is used to evaporate the working fluid (**160**) of the steam power plant circuit (**60**).

11. The method according to claim **1**, wherein at least one part of the liquid flow (**121**), withdrawn from the direct-contact cooler (**20**), is used in an oxygen preheater (**35**) for preheating an oxygen flow (**150**).

12. The method according to claim **11**, wherein the oxygen flow (**150**) is heated in a direct-contact heat exchanger (**34**) in direct contact with the part of the liquid flow (**121**) that has been withdrawn from the direct-contact cooler (**20**).

13. The method according to claim **11**, wherein a liquid flow (**140**), withdrawn from the oxygen preheater (**35**), is at least partially returned as a coolant flow into the direct-contact cooler (**20**).

14. The method according to claim **1**, wherein a liquid flow (**121**), withdrawn from the direct-contact cooler (**20**), after cooling is at least partially returned as a coolant flow (**138**) into the direct-contact cooler (**20**).

15. The method according to claim **1**, wherein a liquid flow (**121**), withdrawn from the direct-contact cooler (**20**), is supplied to a water-treatment apparatus (**22**).

16. The method according to claim **1**, wherein one part of the flue gas (**104**) is returned into the combustion space (**12**).

17. The method according to claim **1**, wherein one part of a liquid flow (**121**), withdrawn from the direct-contact cooler (**20**), is returned into the combustion space (**12**).

18. An apparatus for conversion of energy by the method according to claim **1**, said apparatus comprising:

a combustion space (**12**) for the combustion of a hydrocarbon-containing energy source in an oxygen-enriched atmosphere; a steam power plant circuit (**60**), which is energy-coupled to the combustion space (**12**) for use of heat that has been generated in the combustion space (**12**); and a direct-contact cooler (**20**) connected downstream from the combustion space (**12**) wherein a flue gas (**104**), formed in the combustion of the hydrocarbon-containing energy source, can be cooled in direct contact with a water-containing coolant flow (**138**).

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