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(54) METHOD AND INSTALLATION FOR REMOVING DEPOSIT FROM EXTERNAL SURFACE OF A PIPE ARRAY OF A HEAT EXCHANGER

(57) The method for removing deposit from the external surface of a pipe array (20) of a heat exchanger comprises steps of defining a resonance frequency of said pipe array and applying first shaking force cycles to said pipe array at a frequency based on said resonance frequency. Said method further comprises steps of continuously measuring the response caused by said first shaking force cycles and continuously adjusting the frequency and/or amplitude of said first shaking force cycles based on the measured responses. The frequency and/or amplitude of the first shaking force cycles is adjusted to maximize the removal of the deposit from external surface of the pipe array.

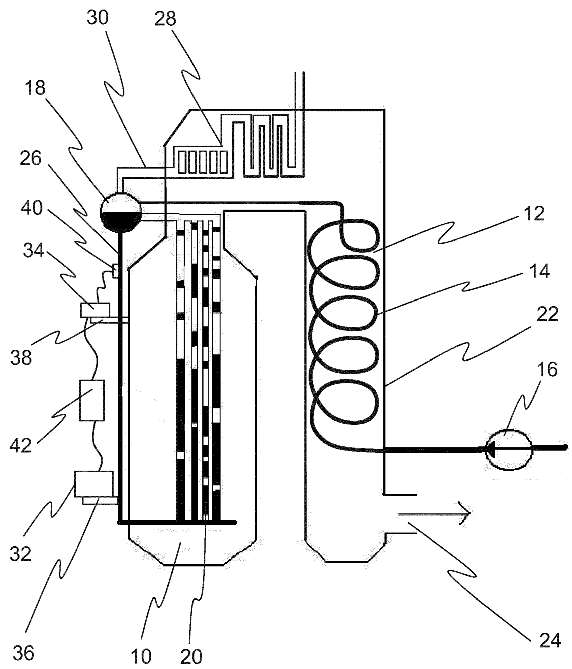

Fig. 1

EP 4 303 523 A1

Description

Technical Field

[0001] The invention relates to a method for removing deposit from the external surface of a pipe array of a heat exchanger comprising steps of defining a resonance frequency of said pipe array and applying first shaking force cycles to said pipe array at a frequency based on said resonance frequency. The method further relates to an installation for implementing in the method.

Background Art

[0002] Boiler plants are used to generate electricity by converting water into steam and conducting the steam through a turbine. The plant contains a furnace inside which fuel is burned to generate heat and a heat exchanger comprising a pipe array locating inside the furnace. Water is pumped through the pipe array whereby the hot gases inside the furnace raise the temperature of the pipe walls and the water running through the pipe array converting the water to steam. The boiler plan usually also contains an economizer to pre-heat the water before it enters into the furnace and a superheater for raising the temperature of the steam generated inside the furnace. When the boiler plant is in operation a substantial amount of dust, ash or other deposit carried by hot combustion gases is accumulated on the surfaces of the pipe array. To ensure satisfactory heat exchange between the hot gases and the water the pipes must be cleaned regularly.

[0003] Numerous methods and devices have been developed for shaking or rapping the pipe arrays with sufficient force to remove the dust, ash and deposit from the external pipe surfaces. Some of these methods and devices require application of excessively large forces to the pipe arrays which can damage them over a period on time, because the pipes must be cleaned relatively often.

[0004] Document US4018026 discloses a method for cleaning the gas-contacted surfaces of a tubular array of a power plant to dislodge solid deposit therefrom by applying a force in pulses to the tubular array at a frequency corresponding the resonance frequency or low fractional multiples of the resonance frequency of said tubular array. The resonance frequency is first calculated and this calculated frequency is slightly adjusted to achieve the largest amplitude of vibrations for the force applied. Although this method is workable, the cleaning effect of the method can still be improved.

[0005] An object of the invention is to provide method and installation for removing deposit form the external surface of pipe array of a heat exchanger having increased cleaning ability.

[0006] The object of the invention is achieved with a method and installation which are characterized in what is disclosed in the independent patent claims. Some preferred embodiments of the invention are disclosed in the dependent claims.

Summary of the invention

[0007] The method according to the invention for removing deposit from the external surface of a pipe array of a heat exchanger comprises steps of defining a resonance frequency of said pipe array and applying first shaking force cycles to said pipe array at a frequency based on said resonance frequency. Said method further comprises steps of continuously measuring the response caused by said first shaking force cycles and continuously adjusting the frequency and/or amplitude of said first shaking force cycles based on the measured responses. The frequency and/or amplitude of the first shaking force cycle is adjusted to maximize the removal of the deposit from external surface of the pipe array. Preferably the measured response of the pipe array is the amplitude of frequency of the vibration caused by the shaking force cycle.

[0008] In a preferred embodiment of the method according to the invention defining said resonance frequency comprises steps of defining a default resonance frequency for said pipe array, selecting a frequency range having a lower value and an upper value, which lower value is lower than the default resonance frequency and which upper value is significantly higher than the default resonance frequency, defining a number of test frequencies between the lower value and upper value, applying test impulses at each test frequency to said pipe array and measuring the responses caused by said test impulses. From the test impulses causing high responses at least two resonance frequencies are identified and the first resonance frequency for the first shaking force cycles is selected from the group of identified resonance frequencies. The frequency of the first shaking force cycles is based on the selected first resonance frequency and it may be exactly or near the first resonance frequency. Alternatively, the frequency of first shaking force cycle may be at or near the low fractional multiples or multiples of the first resonance frequencies. If the shaking force cycle causes too high responses in the pipe array, which may damage the pipe array or structures around it, it is reasonable use frequencies, which are close but equal to the resonance frequency or any multiples of it.

[0009] It has been found, that in many cases the lowest resonance frequency is not the frequency causing the highest response, but higher resonance frequencies may cause higher amplitudes or vibrations, which remove deposit more efficiently. Therefore, by identifying and measuring responses of more than one resonance frequencies the most efficient resonance frequency can be found.

[0010] Another preferred embodiment of the method according to the invention further comprises steps of applying a second shaking force cycle to said pipe array at or near a second resonance frequency or at or near low fractional multiples or multiples of the second resonance frequency, which second resonance frequency is selected from the group of identified resonance frequencies. Said first shaking force cycle and said second shaking force cycle may be applied to said pipe array simultaneously. Alternatively, said first shaking force cycle and said second shaking force cycle may be applied to said pipe array sequentially.

[0011] Another preferred embodiment of the method according to the invention comprises running a calibration cycle between consecutive shaking force cycles. Said calibration cycle comprises steps of applying calibration impulses having altered frequencies to said pipe array, measuring the responses caused by each calibration impulse, identifying calibrated resonance frequencies from the calibration impulses causing high responses and selecting the frequencies of the following shaking force cycles based on said calibrated resonance frequencies. Thus, frequency of the following shaking force cycles may be exactly or near the calibrated resonance frequency or at or near the low fractional multiples or multiples of the calibrated resonance frequency.

[0012] In another preferred embodiment of the method according to the invention said first and second impulses and said first and second shaking force cycles are generated with same actuator.

[0013] In another preferred embodiment of the method according to the invention said first and second impulses are generated with an impact load applied directly to the pipe array. Alternatively, said first and second impulses are generated with an actuator indirectly connected to the pipe array.

[0014] In another preferred embodiment of the method according to the invention said response is measured with a measuring apparatus operating without mechanical connection to the pipe array. The measuring apparatus used in the method may comprise optical measuring instruments, such as laser, camera and/or optical distance sensor.

[0015] An installation according to the invention for removing deposit from the external surface of a pipe array of a heat exchanger comprises an actuator for applying first shaking force cycles to said pipe array. Said installation further comprises a measuring apparatus for measuring the response of said pipe array caused by said applied shaking force cycle and a control device configured to operate said measuring apparatus to continuously measure the response caused by said first shaking force cycles, to continuously adjust the frequency and/or amplitude of said first shaking force cycles of the actuator based on the measured responses and to operate the actuator to apply first shaking force cycles to said pipe array at the adjusted resonance frequency. The frequency and/or amplitude of the first shaking force cycle is adjusted to maximize the removal of the deposit from external surface of the pipe array.

[0016] In a preferred embodiment of the installation according to the invention said actuator comprises an electrical motor arranged to rotate a load, which load is configured to generate impulses to the pipe array and a frequency converter for steering the rotating speed of said electrical motor. The load may be configured to generate impulses directly to the pipe array or there may be a damping spacer between the load and the pipe array. Further, the load may be an unbalanced rotating disk, which is rotated by the motor of the actuator. This kind of actuator may be connected to the pipe array indirectly with fixing brackets, for example. The amount of unbalance can be adjusted by attaching additional weights to the rotating disk. Alternatively, said actuator may comprise an electrodynamic shaker, which produces vibration on the principle of magnetism. Further, the actuator may be a pneumatic and/or hydraulic vibrator.

[0017] In another preferred embodiment of the method according to the invention said measuring apparatus comprises an inductive sensor, a laser or a camera. Alternatively, the measuring apparatus may comprise sensors, such as vibration transducers or strain gauges, directly connected to the surface of the pipe array.

[0018] An advantage of the invention is, that it provides an effective and improved method to dislodge deposit from the external surface of the pipe array of a heat exchanger. In the invention the force applied to the piping system can be reduced without compromising the cleaning effect, whereby the stressing load induced to the pipe array is lower.

[0019] Another advantage of the invention is, that can implemented easily in existing heat exchangers for example in boiler plants.

Brief Description of the Drawings

[0020] In the following the invention will be described in detail, by way of examples, with reference to the accompanying drawings in which,

Fig. 1 depicts an example of boiler plant comprising a heat exchanger as a simplified cross-section.

Detailed Description

[0021] In figure 1 an example of a on a boiler plant as a simplified cross section is depicted. The boiler plant has a furnace 10 and heat exchanger comprising a pipe array 20 inside the furnace. The upper part of the furnace opens to into a smoke channel 22 on the side of the furnace. The smoke channel has an exit opening 24 in the lower end thereof. Inside the smoke channel there is an economizer comprising a helical feeding pipe 14 leading from a feeding water pump 16 to a steam chamber 18, which is connected with a connection pipe 26 to the bottom part of the pipe array inside the furnace. On the upper part of the furnace there is a superheater 28, which is connected to a steam chamber via a steam pipe 30.

[0022] When the boiler plant is in operation fuel is burned inside the furnace raising the temperature of the furnace 10 and the pipe array inside it. Hot smoke gases exit the furnace via smoke channel 22 and exit opening 24. Water is pumped with a feeding water pump 16 via feeding pipe 14 to the chamber 18. Inside the smoke channel the hot smoke gases warm the water flowing inside the feeding pipe, whereby the water entering the chamber has a temperature near boiling temperature of the water. The lower part of the chamber is filled with warm water and the upper part of the chamber is filled with steam. The water flows from the lower part of the chamber via connection pipe 26 to the pipe array 20 inside the furnace 10. Inside the pipe array the temperature of the water rises to a boiling temperature, and part of the water vaporises to steam, which rises upwards to the upper part of the chamber 18. Thus, the pipe array inside the furnace act as a vaporiser of the water. From the chamber steam flows via steam pipe 30 further into the superheater 28, wherein the temperature of the stems rises above the boiling temperature, i.e. the steam turns into a superheated steam, which is lead to a turbine to generate electricity.

[0023] The furnace and smoke channel contains hot combustion gases carrying ash, dust and other solid particles released and developed when fuel is burned inside the furnace. These solid particles create deposit on the external surface of the pipe array inside the furnace, superheater and smoke channel. For removing the deposit from the external surface of the pipe array the boiler plan is provided with an installation according to the invention.

[0024] The installation comprises an actuator 32 for applying shaking force cycles, i.e series on impulses, to said pipe array and measuring apparatus 34 for measuring the response caused by said applied shaking force cycles. The load may be configured to generate force cycles directly to the pipe array via a connecting piece or they may be damping spacer between the load and the pipe array. The actuator may be electrodynamical vibrator and the load may be steered with an amplifier. Further, the actuator may be a pneumatic or hydraulic shaker.

[0025] Preferably the actuator 32 comprises an electrical motor arranged to rotate a striking load, which load is configured to generate force cycles to the pipe array and a frequency converter for steering the rotating speed of said electrical motor. With the frequency converter the frequency and torsional moment of the motor can be changed. The load may be an unbalanced rotating disk, which is rotated by the motor of the actuator. The amount of unbalance can be adjusted by attaching additional weights to the rotating disk near the periphery of the disk. The disks may have threaded holes, into which holes additional weight can be attached by screwing. Alternatively, the actuator may comprise a hammering device, which is rotated by said electrical motor.

[0026] In a preferred embodiment of the installation according to the invention the actuator comprises electrodynamic shaker, which produces vibration on the principle of magnetism. The operation principle of these kind of actuators is well known and therefore it is not explained here in detailed manner.

[0027] The location of the actuator in the boiler plant can be chosen. The only requirement is that the impulses generated by the actuator must be able to transmit to pipe array causing the pipe to vibrate. The actuator may be connected to the pipe array 20 indirectly with a bracket 36 attached to the connecting pipe as in fig. 1. The bracket has a first end connected to the connecting pipe 16 outside the furnace. The actuator may generate force cycles to the bracket or/to the connection pipe. In both cases the force cycles transmit to the pipe array inside the furnace and make the pipe array to vibrate at the natural frequency i.e. the resonance frequency of the pipe array.

[0028] In the invention the response caused by the applied force cycles is measured by a measuring apparatus 34 resting on a support 38 connected to the wall of the furnace. The response is easiest to measure directly from the pipe array 20 with sensors 40 belonging to the measuring apparatus, which sensors are indirectly connected to the external surface of the pipe array for example via a metal bar, which is attached to the pipe array by welding. In fig. 1 the sensor 40 is attached to the external surface of connection pipe 26. The sensor may be a vibration sensor, strain gauge, transitional sensor or optical sensor. The response may be measured from any suitable location of the pipe array either by using only one sensor or by using numerous sensors placed in different locations. It may be possible to measure the response indirectly from the structures connected to the piper pipe array. The response can be measured from the movement of the pipe array using distance sensors, such as inductive sensors. Further, optical measuring apparatus operating without mechanical connection to the pipe array, such as laser devices and cameras, may be used.

[0029] The installation further comprises a control device 42 connected to the measuring apparatus 34 and to the actuator 32 by cables or by wireless connection. The control device is configured operate the actuator to run force cycles continuously or periodically. The duration of the force cycles can be chosen, for example each force cycle may last 30 seconds. Between the consecutive force cycles there may be a pause, which may last several seconds, minutes, hours or even days depending on the cleaning necessity of the pipe array. The control device continuously receives measurement data from the measuring apparatus, calculates the response caused by the force cycles and continuously adjust the frequency and/or amplitude of the following shaking force cycles generated by the actuator 32 to maximize the removal of the deposit from external surface of the pipe array.

[0030] In the method according to the invention the resonance frequency of the pipe array is determined. This determination is done by first defining a default resonance frequency by numerical calculation, for example. Then a frequency range having a lower value and an upper value is selected, which lower value is lower than the default resonance frequency and which upper value is significantly higher than the default resonance frequency. The selected frequency range is tested by applying test impulses to the pipe array. The test impulses having a starting frequency value and a number on sequential frequencies with incremental changes to the previous frequency value go through the whole frequency range and the responses caused by the test impulses are measured. The test impulses are generated by the actuator 32, which is operated by the control device 42 either manually or preferably automatically. The test frequencies and the responses measured by the measuring apparatus 34 are recorded to the control device or to a separate measuring unit. The test impulses may start from the lower frequency value proceeding towards the upper value or from the upper frequency value proceeding towards the lower value. Further, the starting frequency value may be any intermediate value between the upper and lower values.

[0031] Once the whole frequency range has been inspected, the control device or separate measuring unit identifies the test impulses causing highest responses. Preferably at least two resonance frequencies are identified and the resonance frequency for the first shaking force cycles is selected from the group of identified resonance frequencies. It has been found, that in many cases the lowest resonance frequency is not the frequency causing the highest response, but higher resonance frequencies may cause higher amplitudes, frequencies or shapes of vibrations, which remove deposit more efficiently. Therefore, by identifying more than one resonance frequency the most efficient resonance frequency can be found. After the first resonance frequency is selected, the actuator adjusts the actuator to generate force cycles at or near this frequency or at or near the low fractional multiple or multiple of this frequency.

[0032] During operation of the power plant the amount of deposit on the external surface of the pipe array usually changes, whereby the resonance frequency may also chance. Therefore, in the method according to the invention the response caused by said first shaking force cycles is continuously measured and the frequency and/or amplitude of the first shaking force cycles generated by the actuator are continuously adjusted based on the measured responses. The frequency and/or amplitude of the first shaking force cycles is adjusted to maximize the removal of the deposit from external surface of the pipe array.

[0033] In has been found, that different kind of deposit may require shaking forces having different frequencies. Thus, the removal of the deposit may be enhanced by using more shaking force cycles having different frequencies. Therefore, in method according to the invention second shaking force cycles may be applied to said pipe array at or near the second resonance frequency or at or near the low fractional multiple of multiples of this second resonance frequency, which second resonance frequency is selected from the group of previously identified resonance frequencies. Said first shaking force cycle and said second shaking force cycle may be applied to said pipe array simultaneously or sequentially.

[0034] The resonance frequency of the pipe array may chance during operation of the boiler plant for example because of accumulation of deposit on the external surfaces of the pipes or because on loosening of the support structures of the pipe array. Therefore, between consecutive shaking force cycles a calibration cycle may be run. This calibration cycle comprises steps of applying calibration impulses to said pipe array, the calibration impulses having frequencies, which are slightly different than the resonance frequencies. The responses caused by calibration impulses are compared and calibrated resonance frequencies are identified from the calibration impulses causing highest responses. In the following shaking force cycles calibrated resonance frequencies are used. The installation may run the calibration cycle automatically or guided by an operation person.

[0035] The installation according to the invention detects if the amplitude and/or frequency of the response suddenly chances. This kind of chance may be an indication of malfunction or breaking of a device belonging to the installation or deterioration or failure in the pipe array. In this situation the installation may run a calibration cycle and/or send an incident report to monitoring personnel in a remote location.

[0036] The operation of the installation may be monitored and checked through remote connection utilizing local network or modems. The operation history of the installation may be recorded and stored to a local server or to a cloud server for later inspection and use. Storing information to a cloud server makes possible to use different algorithms, machine learning and AI (Artificial Intelligence) to optimize the operation of the installation. The installation may contain its own input/output devices, such as a keyboard and a display, or it can be connected to the operating system of the boiler plant through a suitable interface device. The control device, measuring apparatus and interface device may send different calculated characteristics, such as amplitude response to the operating system of the boiler plant with analogous or digital messages. This makes possible to monitor the operation on the installation from the monitoring room of the boiler plant.

[0037] In the explanation above the heat exchanger is arranged into a boiler plant producing steam. The invention is not limited to be used only in boiler plants, but in can be used in any plant or factory comprising a heat exchanger with a pipe array, which is susceptible to accumulation of deposit on the external surface thereof.

[0038] Some preferred embodiments of the invention has been disclosed above. The invention is not limited to the solutions explained above, but the invention can be applied in different ways within the limits set by the patent claims.

Reference Signs:

[0039]

10 furnace
12 economizer
14 feeding pipe
16 water pump
18 steam chamber
20 pipe array
22 smoke channel
24 exit opening
26 connecting pipe
28 superheater
30 steam pipe
32 actuator
34 measuring apparatus
36 bracket
38 support
40 sensor
42 control device

Claims

1. A method for removing deposit from the external surface of a pipe array (20) of a heat exchanger comprising steps of

- defining a resonance frequency of said pipe array (20)
- applying first shaking force cycles to said pipe array (20) at a frequency based on said resonance frequency

characterizing in that said method further comprises steps of

- continuously measuring the response caused by said first shaking force cycles and
- continuously adjusting the frequency and/ or amplitude of said first shaking force cycles based on the measured responses.

2. The method according to claim 1, **characterized in that**, defining said resonance frequency comprises steps of

- defining a default resonance frequency for said pipe array (20)
- selecting a frequency range having a lower value and an upper value, which lower value is lower than the default resonance frequency and which upper value is significantly higher than the default resonance frequency
- defining a number of test frequencies between the lower value and upper value
- applying test impulses at each test frequency to said pipe array (20)
- measuring the responses caused by said test impulses
- identifying at least two resonance frequencies from the test impulses causing high responses and
- selecting the first resonance frequency for the first shaking force cycles from the group of identified resonance frequencies.

3. The method according to claim 2, **characterized in that**, said method further comprises steps of

- applying a second shaking force cycle to said pipe array at or near a second resonance frequency or at or near low fractional multiples or multiples of the second resonance frequency, which second resonance frequency is selected from the group of identified resonance frequencies.

4. The method according to claim 3, **characterized in that**, said first shaking force cycle and said second shaking force cycle are applied to said pipe array (20) simultaneously.

5. The method according to claim 3, **characterized in that**, said first shaking force cycle and said second shaking force cycle are applied to said pipe array (20) sequentially.

6. The method according to any of the claims 1 to 5, **characterized in that**, said method further comprises running a calibration cycle between consecutive shaking force cycles, which calibration cycle comprises steps of

- applying calibration impulses having altered frequencies to said pipe array
- measuring the responses caused by each calibration impulse
- identifying calibrated resonance frequencies from the calibration impulses causing high responses and
- selecting the frequencies of the following shaking force cycles based on said calibrated resonance frequencies.

7. The method according to any of the claims 1 to 6, **characterized in that**, said first and second impulses and said first and second shaking force cycles are generated with same actuator (32).

8. The method according to any of the claims 1 to 7, **characterized in that**, said first and second impulses are generated with an impact load applied directly to the pipe array (20).

9. The method according to any of the claims 1 to 8, **characterized in that**, said first and second impulses are generated with an actuator (32) indirectly connected to the pipe array (20).

10. The method according to any of the claims 1 to 8, **characterized in that**, said response is measured with a measuring apparatus (34) operating without mechanical connection to the pipe array (20).

11. The method according to any of the claims 1 to 2, **characterized in that**, the measured response is the amplitude or frequency of vibration of the pipe array (20).

12. An installation for removing deposit from the external surface of a pipe array (20) of a heat exchanger comprising

- an actuator (32) for applying first shaking force cycles to said pipe array (20) and **characterizing in** said installation further comprises
- a measuring apparatus (34) for measuring the response of said pipe array (20) caused by said applied shaking force cycle and
- a control device (42) configured
- to operate said measuring apparatus (34) to continuously measure the response caused by said first shaking force cycles
- to continuously adjust the frequency and/or amplitude of said first shaking force cycles of the actuator (32) based on the measured responses and
- to operate the actuator (32) to apply first shaking force cycles to said pipe array (20) at the adjusted resonance frequency.

13. The installation according to claim 12, **characterized in that**, said actuator (32) comprises an electrical motor arranged to rotate a load, which load is configured to generate impulses to the pipe array (20) and a frequency converter for steering the rotating speed of said electrical motor.

14. The installation according to claim 12, **characterized in that**, said actuator (32) comprises electrodynamic shaker, which produces vibration on the principle of magnetism.

15. The installation according any of the claims 12 to 14, **characterized in that**, said measuring apparatus (34) comprises an inductive sensor, a laser or a camera.

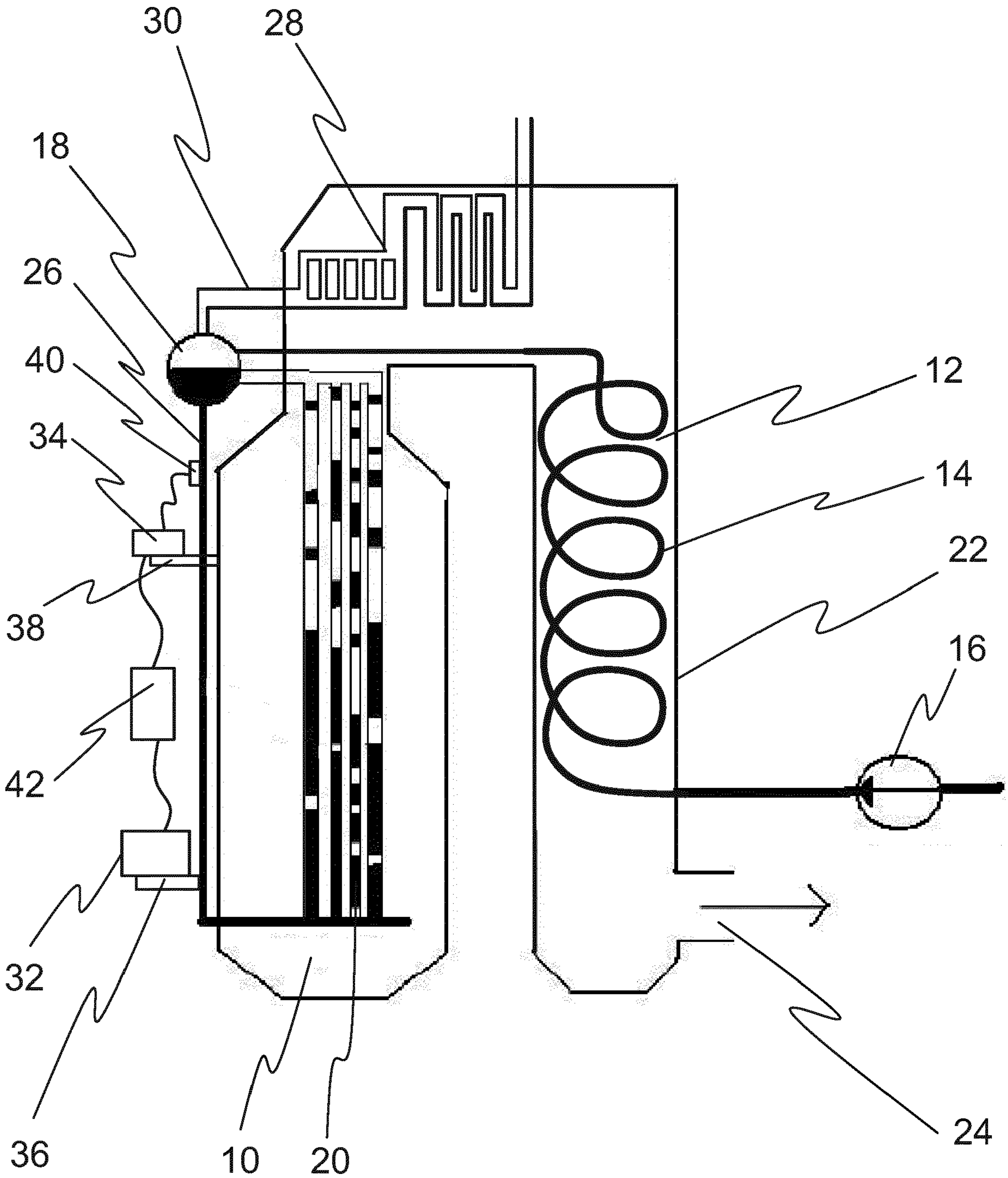

Fig. 1

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EUROPEAN SEARCH REPORT

Application Number
EP 22 18 3746

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The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	2 December 2022	Vassoille, Bruno

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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