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(74) Agent: **CABINET PLASSERAUD**; 66, rue de la Chaussée d'Antin, 75440 Paris Cedex 09 (FR).

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(71) **Applicant:** BOOSTHEAT [FR/FR]; 41-47 boulevard Marcel Sembat, 69200 Villeurbanne (FR).

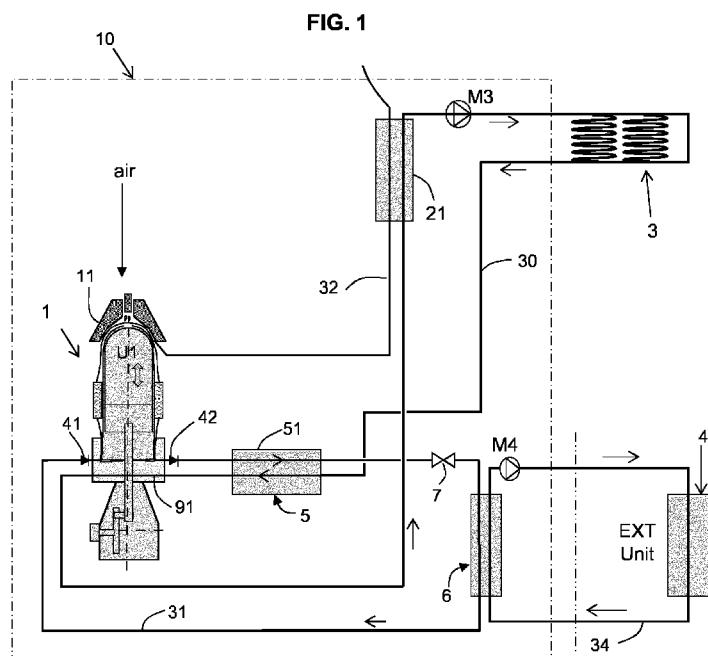
(72) **Inventor:** JOFFROY, Jean-Marc; Le Saoulas, 81500 Cabanes (FR).

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(54) Title: THERMODYNAMIC BOILER WITH THERMAL COMPRESSOR

(57) Abstract: A thermodynamic boiler for exchanging (providing or drawing) heat with a heating circuit (30), the boiler comprising a thermal compressor (1), the thermal compressor acting on a compressible fluid and comprising at least one compression stage with an alternating bi-directional piston (71) separating a first chamber (81) and a second chamber (82) and a first fuel burner (11) forming a heat source coupled to the first chamber, and using the heating circuit as a cold source coupled to the second chamber, the thermal compressor forming the compression function of a reversible heat pump type loop (31, 34),





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Thermodynamic boiler with thermal compressor

The present invention relates to heating systems that include devices known as boilers. The invention particularly relates to thermodynamic boilers benefitting 5 from a device called a heat pump (abbreviated "HP").

Context and Prior Art

Several technical solutions already exist for implementing a heat pump device in the context of a boiler.

First of all, the use of electric compressors to 10 compress and circulate a heat transfer working fluid is known. These compressors are also known as "electric HPs". However, the efficiency of these systems sharply decreases as the external temperature lowers, which in most cases leads to having a supplementary conventional fuel burner.

15 Gas engine heat pumps ("gas engine HP") are also known. This system involves the use of an internal combustion engine which is noisy and requires regular maintenance.

Adsorption/desorption gas heat pumps are also known, such as, for example, those using a water/ammonia or 20 water/zeolite pair, for example from document US 5729988-Tchernev. But these devices are complex and expensive; They also use materials that are potentially polluting or harmful.

In addition, it is generally preferable for this type 25 of boiler to be power adaptable and to also be designed to supply domestic hot water (known as "DHW").

In addition, most of the systems described above can generally be operated in reverse, in cooling mode.

Considering the aforementioned disadvantages, there is 30 a need to propose improved solutions for thermodynamic boiler systems with a heat pump effect.

For this purpose, a thermodynamic boiler is proposed for exchanging heat with at least one heating circuit, comprising a thermal compressor, the thermal compressor 35 acting on a compressible fluid and comprising at least one

compression stage with an alternating bi-directional piston separating a first chamber and a second chamber and a first fuel burner forming a heat source coupled to the first chamber, and using the heating circuit as a cold source 5 coupled to the second chamber, the thermal compressor forming the compression function of a reversible heat pump type loop, the first and second chambers being fluidly connected between each other through a **regenerator** with a to-and-fro fluid movement.

10 Through such provisions, the invention benefits from a direct transfer of heat between the burner and the working fluid to be compressed, the compressor is simple and compact, and the reversible heat pump type loop can be used either to provide heat to the heating circuit in heating 15 mode ("winter" mode), or in some cases to draw heat from the heating circuit in cooling mode ("summer" mode).

In addition, such a boiler requires very little maintenance and maintenance operations can be substantially spaced apart.

20 Note 1: Regarding the vocabulary used in the present document, it should be noted that heating circuit can be broadly interpreted as a circuit mainly for exchanging heat with an entity of interest, most often a premises, the objective being to heat or cool the entity of interest.

25 Note 2: In the abovementioned heat pump type loop, a compressible two-phase heat transfer fluid is used, and the invention benefits from an evaporation phenomenon on one exchanger and a condensation phenomenon on another exchanger.

30 According to a configuration, known as heating, the thermodynamic boiler supplies heat to the heating circuit ("heating" or "winter" mode), and the reversible heat pump type loop draws heat from an external unit.

Under these conditions, from the point of view of 35 thermal efficiency, all energy expended at the burner is

either used directly for compression or is distributed into the heating circuit. In addition, compression and the associated fluid circuit induce the drawing of "free" heat outside. Consequently, a very satisfactory performance 5 coefficient is obtained under these conditions.

In various embodiments of the invention, one may possibly also have recourse to one and/or the other of the following arrangements.

According to one aspect of the invention, the 10 thermodynamic boiler may comprise a supplementary device, the supplementary device comprising an auxiliary burner, distinct from the first burner, and a supplementary exchanger arranged on the heating circuit. The invention thus ensures, on the one hand, operation under very cold 15 external temperature conditions, or if the HP circuit is unavailable and, on the other hand, the passing of peak requirements, particularly for domestic hot water together with heating needs.

According to one aspect of the invention, the fuel is 20 advantageously gas. Advantageously either gas of fossil sources or bio gas is used.

According to one aspect of the invention, the compressible heat transfer fluid is CO₂; This is an available, non-polluting and safe fluid.

25 According to one aspect, a modulation unit and a motor (electromagnetic actuator linked to the piston movement) are advantageously provided to regulate (increase and/or decrease) the compressor rotation speed. Such power modulation enables an ideal compromise between comfort and 30 seasonal performance to be obtained, and maximizes the utilization rate of the HP.

According to one aspect, the heat pump type loop comprises two cascaded circuits, i.e., a compressible gas work circuit (31,1,5,7,6) and a glycol water circuit 35 (34,4,6); which enable a compressible gas work circuit to

be confined within a factory-sealed boiler assembly, which frees the plumber or installer from having to deal with the leakproofness of this circuit; this is in contrast to the glycol water circuit, which is easier to implement and can 5 be installed by the plumber.

According to one aspect, the compressor may comprise at least two compression stages in series, i.e., at least one second compression stage U2, in addition to the first U1. As a consequence, a CO₂ (R744) type fluid can be used, 10 with large excursions in pressure and CO₂ fluid temperatures adapted according to the temperatures of the water circuits to be heated. Good overall thermodynamic efficiency is thus obtained.

According to one aspect, the compressor may comprise 15 3 stages; As a consequence, the invention optimizes the spacing of pressure rises and the appropriateness of the CO₂ fluid temperatures adapted according to the temperatures of the water circuits to be heated and the thermal power to be delivered.

20 The stages are advantageously independent. This facilitates sizing and increases the modulation capabilities of each stage.

The thermodynamic boiler comprises an air preheater at the inlet of the first burner; heat is recovered from 25 the combustion fumes and is injected into the air bound for the burner; This improves the overall performance coefficient.

The thermodynamic boiler comprises a main exchanger (5) forming the essential thermal interface between the 30 compressible fluid circuit (31) and the heating circuit (30), and the compressor is cooled by the heating circuit return that first passes in at least one main exchanger 5, and then in the cold section of the thermal compressor; this is the best choice for good system performance and 35 efficiency.

Moreover, after cooling the compressor, the heating circuit return goes into the supplementary exchanger. In this way the heat supplied to the heating circuit is maximized.

5 The main exchanger comprises a high temperature "HT" exchanger and a low temperature "LT" exchanger; therefore heat can be supplied to two different heating circuits, one with a high mean temperature (coupled to the HT) and the other with a moderate high mean temperature (coupled to the
10 LT).

The thermodynamic boiler comprises a domestic hot water circuit; The boiler can thus fulfill all domestic boiler functions.

15 The domestic hot water is heated by means of the high temperature exchanger (50) which is arranged on the compressible fluid circuit directly at the outlet of the thermal compressor; This contributes to the priority given to domestic hot water.

20 According to one configuration, known as cooling, the thermodynamic boiler takes heat from the heating circuit 30, and delivers this heat either into the domestic hot water DHW circuit or into the external unit 4 (summer mode); Therefore the boiler can provide a cooling function, and also energy free domestic hot water.

25 Other aspects, objects and advantages of the invention will appear upon reading the following description of an embodiment of the invention, given by way of a non-limiting example. The invention will also be better understood in regard to the appended drawings in which:

30 - Figure 1 schematically represents a heating system comprising a boiler according to the invention,

- Figure 2 represents a system similar to Figure 1, the boiler being a hybrid and including a supplementary burner,

35 - Figure 3 represents a system similar to Figure 1, in which an air preheating exchanger is provided and the

boiler compressor comprises two compression stages,

- Figure 4 represents a system similar to Figure 3, in which the provision of domestic hot water is also ensured,

5 - Figure 5 represents a system similar to Figure 4, the boiler compressor comprising three compression stages,

- Figure 6 represents a stage in further detail, i.e., a compression unit used in the thermal compressor,

- Figure 7 represents the thermodynamic cycle in a stage,

10 - Figure 8 represents the central parts of a compressor in the three-stage configuration,

- Figure 9 represents a very general diagram of the use of a thermal compressor according to the invention in a reversible heat pump type loop, usable in heating and in 15 cooling modes.

In the various figures, the same references designate identical or similar elements.

20 Figure 1 shows an overview of a heating system typically provided to heat industrial premises or individual or collective housing. The heating system comprises a boiler **10** that will be described subsequently.

25 The system comprises a heating circuit marked **30**; As stated at the beginning, the term "*heating circuit*" does not preclude that this circuit takes heat; however in the first example as illustrated, the heating circuit comprises heat receiving entities **3** in the form of radiators/convectors **3** and/or underfloor heating, situated in the rooms of the premises to be heated.

30 There may be several heat receiving entities, for example one at low temperature (underfloor heating) and the other at higher temperature (convectors, domestic hot water). A circulator **M3** circulates water in the heating circuit **30**.

35 The case where one heat receiving entity is a pool or

greenhouse can also be considered. In addition, the heating system may be used in an industrial context with the heat receiving entity in the form of industrial process equipment.

5 Boiler **10** comprises a thermal compressor **1** which constitutes the motive power component of a heat pump circuit. In the example illustrated, only the external unit marked **4** is arranged outside the premises (building, housing, etc.). The rest of the main components are
10 arranged inside the premises, or even in the boiler **10** casing.

It is noted that in the figures, pipework is represented symbolically.

The heat pump device comprises, on the one hand, a
15 glycol water circuit **34** that circulates in the external unit **4**, and a working fluid circuit **31** which goes through compressor **1**. In the example illustrated, the working fluid is R744, otherwise known as CO₂, but another fluid with similar properties can be chosen. In order to distinguish
20 other fluids, the working fluid in circuit **31** will subsequently be called the "compressible" fluid, also known as refrigerant fluid in the art. This is opposed to the fluid that circulates outward in the external unit (circuit **34**) that is mainly water-based (glycol water) and also
25 opposed to the fluid that circulates in the heating circuit **30** already mentioned that is also mainly water-based, and therefore not compressible.

The various fluids used in circuits **31**, **31**, **34** are heat transfer fluids, whether compressible or not, they transfer
30 heat mainly from the external unit **4** to the receiving entities **3**, but also from burner **11** of the compressor to receiving entities **3**.

The cooling mode, also possible, will be described later.

35 It should be noted that external unit **4** can be an

aerothermal unit or a geothermal unit.

It is observed that capturing external heat by the heat pump effect uses two fluid circuits in series that are interfaced by exchanger **6**, also called interface exchanger **6**, which is preferably a cross flow exchanger. The glycol water circuit **34** comprises a circulator **M4**, recovers heat from external unit **4** and delivers this heat to interface exchanger **6**. It is noted that the compressible fluid circuit assembly **31**, i.e., the CO₂ assembly, is confined 10 inside boiler **10** which is prepared in a manufacturing plant; Only the glycol water circuit **34** must be applied by a professional onto the target installation.

In addition, the heat pump device comprises an expansion device **7**, known in itself, which plays the 15 opposite role of the compressor for pressure, and a main exchanger **5** that thermally couples the compressible fluid circuit at the compressor outlet with the heating circuit **30**. Main exchanger **5** is preferably configured to be a cross flow exchanger. Instead of a single exchanger **51** as 20 represented, the main exchanger may be constituted of several exchangers, either in parallel, or in series as will be seen later.

The compressible fluid circuit **31** contains fluid in two-phase form that recovers heat from interface exchanger **6** (the side called "evaporator" where the two-phase fluid passes from the liquid state to the vapor state) and 25 delivers this heat to the main exchanger **5** (the side called "condenser" where the two-phase fluid passes from the vapor state to the liquid state).

It is noted that the heating circuit return **30** first 30 passes through this main exchanger **5** and then is directed to the cold zone of the compressor at the location from which the heating circuit fluid cools the compressor 1.

It is noted that the burned gas outlet circuit (noted 35 **32**) of burner **11** passes to the inside of an exchanger **21**

coupled with the heating circuit, at the location of which the fumes give up their heat to the fluid of the main heating circuit **30**; Later we will see that this exchanger 21 can also be called in certain cases a "supplementary 5 exchanger" **21**.

The quantity of gas introduced and burned by burner 11 is controlled by a unit for regulating (not represented) the boiler.

Burner 11 is typically sized to be able to deliver up 10 to 6 kW; In practice when the compressor is operating, the regulation adjusts the power to between 2 kW and 6 kW.

More specifically for compressor 1, with reference to Figure 6, it is a thermal compressor known as a "regenerative" compressor with a heat provision zone (hot 15 zone), a cooling zone (cold zone), and a contained enclosure **8** that communicates with the outside thanks to 2 non-return valves, i.e., an inlet valve **41** (admission) and an outlet valve **42** (backflow).

In the example from Figure 1, there is only a single 20 compression stage noted **U1**.

In the contained enclosure **8**, the compressible fluid occupies a practically constant volume, and a displacer piston **71** is configured therein to alternatively displace, from top to bottom in the example illustrated, in order to 25 displace most of the volume of compressible fluid to the hot zone or to the cold zone. The piston is connected to a rod and crankshaft drive system in a self-driving system which will be seen later.

As represented in Figure 6, the compressor is 30 structured around an axial direction **X**, which is preferably disposed vertically, but another arrangement is not ruled out. Piston **71**, movably mounted in cylindrical liner **90**, can be displaced along this axis. Said piston separates first chamber **81** from second chamber **82**, these two chambers 35 being included in working enclosure **8** with the sum of their

volumes **V1+V2** being substantially constant. Piston 71 presents an upper portion in the form of a dome, for example hemispherical.

Working enclosure **8** is structurally contained in an 5 assembly formed of a hot casing **96** and a cold cylinder head **95**, with the interposition of a thermal insulation ring **97**.

The first chamber **81**, also known as the "hot chamber," is arranged above the piston and is thermally coupled to a heat source **11** (a fuel burner 11) which supplies heat 10 directly to the gaseous fluid in the first chamber **81**. The first chamber is axisymmetric with a cylindrical portion of a diameter corresponding to the diameter **D1** of the piston and a hemispherical portion in the upper part, which comprises a central opening **83** for the inlet and outlet of 15 the compressible fluid. The heat source **11** forms a cap entirely surrounding the hot chamber **81**, with a burner injector **11a**.

The second chamber **82**, also known as the "cold chamber," is arranged below the piston and is thermally 20 coupled to a cold source (here the heating circuit **91** return) to thereby transfer heat from the compressible fluid to the heating circuit. The second chamber is cylindrical, with a diameter **D1**, and comprises several openings **84** circling around the axis, under the piston, for 25 the inlet and outlet of the compressible fluid.

A regenerative heat exchanger **19**, of the type conventionally used in thermodynamic machines of the Stirling engine type, is arranged around the wall of cylindrical liner **90**. This exchanger **19** (which will simply 30 be called "regenerator" below) comprises fluid channels with narrow cross sections and elements for storing thermal energy and/or a dense network of metal wires. This regenerator **19** is arranged mid-height between the upper end and the lower end of the enclosure and presents a hot side 35 **19a** towards the top and a cold side **19b** towards the bottom.

Inside the regenerator, a significant temperature gradient is observed between the hot side and the cold side, the hot side having a temperature close to the temperature of the burner cap, i.e., 700°C, the cold side 5 having a temperature close to the temperature of the heating circuit, i.e., a temperature of between 30°C and 70°C depending on the entity or entities present on the heating circuit.

An annular running gap **24** arranged against the inner 10 surface of the hot casing **96** connects opening **83** of the first chamber to the hot side **19a** of the regenerator.

Channels **25** in cylinder head **95** connect openings **84** of the second chamber to the cold side **19b** of the regenerator.

Therefore, when the piston moves up, the compressible 15 gas is dispelled from the first chamber **81** by running gap **24**, regenerator **19** and channels **25** in the direction of the second cold chamber **82**. Conversely, when the piston moves down, the compressible gas is dispelled from the second cold chamber **82** by channels **25**, regenerator **19** and running 20 gap **24**, in the direction of the first chamber **81**.

Stated otherwise the first and second chambers (81, 82) are fluidly connected between each other through the **regenerator** (19) with a to-and-fro fluid movement.

The operation of the compressor is ensured by the 25 alternating movement of the piston **71** between the bottom dead center **PMB** and the top dead center **PMH**, as well as by the action of a suction valve **41** on the inlet, and a backflow prevention valve **42** on the outlet. Different steps A, B, C, D, described below are represented in Figures 6 30 and 7.

Step A.

The piston, initially at the top, moves downward and the volume of the first chamber **81** increases while the volume of the second chamber **82** reduces. Because of this, 35 the fluid is pushed through the regenerator **19** from bottom

to top and is heated in the process. Pressure **Pw** simultaneously increases.

Step B.

When pressure **Pw** exceeds a certain value, the outlet valve **42** opens and pressure **Pw** settles at the compressed fluid discharge pressure **P2**, and fluid is expelled towards the outlet (the inlet valve **41** of course remains closed during this time). This continues until the piston reaches the bottom dead center.

10 Step C.

The piston now moves from the bottom upward and the volume of the second chamber increases while the volume of the first chamber decreases. Because of this, the fluid is pushed through the regenerator **19** from top downward and is cooled in the process. Pressure **Pw** simultaneously reduces. The outlet valve **42** closes when the upward movement begins.

Step D.

When pressure **Pw** drops below a certain value, the inlet valve **41** opens and pressure **Pw** settles at the fluid intake pressure **P1**, and fluid is drawn through the inlet (the outlet valve **42** of course remains closed during this time). This continues until the piston reaches the top dead center. The inlet valve **41** will close when the piston begins its descent.

25 Movements of the rod **18** are controlled by a self-driving device **14** acting on one end of the rod. This self-driving device comprises a flywheel **142**, a connecting rod **141** connected to said flywheel by a pivoting connection, for example a roller bearing **143**. The connecting rod is connected to the rod by another pivoting connection, for example a roller bearing **144**.

The auxiliary chamber **88** is filled with gaseous working fluid at a pressure noted **Pa**. When the device is in operation, the pressure **Pa** in the auxiliary chamber **88** 35 converges to an average pressure substantially equal to

half the sum of the mini **P1** and maxi **P2** pressures. In fact, due to the reduced functional clearance between ring **118** and rod **18**, in dynamic mode, this very slight leak does not affect operation and remains negligible.

5 When the flywheel rotates one turn, the piston sweeps a volume corresponding to the distance between the dead center and the bottom dead center, multiplied by the diameter **D1**.

10 The thermodynamic cycle, as represented in Figure 7, provides positive work to the self-driving device.

However, for the initial start-up and to regulate the rotation speed, an electrical motor **17** is coupled to flywheel **142**.

15 This motor can advantageously be housed in auxiliary chamber **88** or externally with a magnetic coupling to the wall.

20 Motor **17** is driven by a regulating unit, not represented in the figures; Controlling the motor enables the rotation speed of the flywheel to accelerate or decelerate, the thermal flows exchanged being practically proportional to the rotation speed of the flywheel. Thanks to motor **17**, the regulating unit can adjust the rotation speed typically between 100 rpm and 500 rpm, preferentially within the range [200 - 300 rpm].

25 It is also noted that motor 17 serves to start the self-driving device 14.

30 It is noted that piston 71 is not a power receiving piston (unlike an internal combustion engine or a conventional Stirling engine) but is simply a displacer piston; power is supplied in the form of increasing the working gas pressure.

35 It is noted that **V1 + V2 + Vchannel = Vtotal** if variations in the volume of rod 18 are eliminated, **V1** being the volume of the first chamber, **V2** being the volume of the second chamber and **Vchannel** being the volume of conduits

24, 25. Preferably, arrangements are made to have the smallest possible dead volume with conduits of narrow cross section, for example Vchannel < 10% of V1+V2 is obtained.

As illustrated in Figure 2, the boiler may 5 advantageously be a hybrid, i.e., it may contain an **auxiliary burner 20**, distinct from the first burner **11** and a **supplementary exchanger 21**. This auxiliary burner **20** will mainly be used in the event of operation in very cold external temperatures, and to pass the peak requirements 10 from the heating installation (this together with domestic hot water when it is present, see below).

The auxiliary burner **20** of the supplementary exchanger is generally dimensioned to have a heat output of around 20 kW, typically for an individual house, which is much higher 15 than the thermal power necessary for the compression function of the compressor as seen above.

More specifically, the regulating unit measures the external temperature, and various temperatures of the fluids in involved circuits (30, 31, 32, 34), to determine 20 the need to operate the supplementary burner **20**.

As already mentioned, the burned gas outlet circuit **32** of the first burner passes to the inside of supplementary exchanger **21**, at the location of which it gives up its heat to the fluid of the main heating circuit **30**.

25 It is noted that the fluid in heating circuit 30 receives its heat from main exchanger **5, 51** and from the cold part of the compressor (zone **91**) and finally from the combustion gases burned in the supplementary exchanger **21**. If auxiliary burner **20** is in operation, heat is also 30 provided directly from auxiliary burner 20.

Figure 3 illustrates two additional characteristics that may be present in the boiler of the invention.

First, **two compression stages**, in other words two compression units **U1, U2** are installed in series, one **U2** 35 after the other **U1**, each having its own burner **11, 12**.

The second stage **U2** is similar or analogous on all points to the first stage **U1**; It comprises a burner **12**, at the location of which the combustion of gas mixed with entering air is produced, and a displacer piston **72** similar 5 to that of the first stage and whose movement and rotation speed are independent from the first. The sum of the power of the two burners **11, 12** can be dimensioned around 10 kW.

In practice, the outlet of the non-return valve **42** of the first stage is injected into the inlet non-return valve 10 **43** of the second stage. In an integrated version where the cold parts are shared, valves **42, 43** are combined. The outlet of the second stage **U2**, i.e., valve **44**, forms the outlet of compressor 1.

On the other hand, an air admission preheating 15 exchanger, marked **9**, can be provided, by which the invention benefits from the heat present in the exhaust exiting burners **11, 12** to preheat the cold air 35 flowing to the burner flames. Here preheating exchanger **9** is an air/air exchanger, known in itself, used with cross flows 20 in the example illustrated.

The air arriving in injector **11a** of burner **11** is thus at a temperature of between 100 °C and 300 °C.

Figure 4 illustrates, first, a main exchanger **5** formed by two serial (a characteristic that will be detailed 25 below) exchangers and another additional characteristic, i.e., the supply of domestic hot water (abbreviated "DHW"). A domestic hot water reserve tank **16**, known in itself and therefore not described in detail here, is provided. The water in this reserve tank is heated by the circulation of 30 fluid **36** when it passes in a DHW exchanger **15**.

A bypass branch **33** of the heating circuit **30** circulates in this DHW exchanger **15**. This bypass branch draws heat from a high temperature (HT) main exchanger marked **50** and transmits it to the domestic hot water in DHW exchanger **15**.

35 The flow of fluid that circulates in bypass branch **33**

can be controlled by a regulating valve **78** that is known in itself. This flow is determined in proportion to the needs of the system regulating the domestic hot water reserve tank.

5 Here main exchanger 5 comprises two exchangers arranged in series on CO₂ circuit 31: The "high" temperature exchanger **50** in which the bypass 33 configured to heat domestic hot water circulates, and the "low" temperature exchanger **51** that forms the main coupling of the CO₂ circuit 31 with the heating circuit 30. It is noted that 10 there can also be a combination of two exchangers (high and low) even without a domestic hot water circuit, for example if there are 2 heating receiver circuits, one low temperature and the other high temperature.

15 Typically, the mean temperature of the compressible fluid in high temperature exchanger 50 will be much higher than 100 °C, while the mean temperature of the compressible fluid in the low temperature exchanger 51 will be substantially lower than the outlet temperature of the high 20 temperature exchanger, most often lower than 150° or even preferentially lower than 100°.

Figure 5 illustrates an additional characteristic, i.e., a configuration of three compression stages, in other words three compression units **U1**, **U2**, **U3**.

25 The invention plans to have a burner **11** on the first stage and a burner **12** on the second stage and a third burner 13 on the third stage **U3**. Each stage is similar to that written on the subject of Figure 6. The sum of the power of the three burners 11, 12, 13 can be dimensioned 30 around 13kW or even 15kW.

Advantageously, the stages operate independently, the rotation speed can be different from one stage to another; The second and third stages respectively have pistons noted 72, 73.

35 It is noted that the heating circuit cools the three

cold zones of the compressors, by successive channels **93**, **92** and **91**.

The outlet of the first stage, i.e., valve **42** is connected to the inlet of the second stage, i.e., valve **43**.

5 The outlet of the second stage, i.e., valve **44** is connected to the inlet of the third stage, i.e., valve **45**. The outlet of valve **46** forms the general outlet of compressor 1.

Pressure staging can typically be as follows, the admission pressure of the first stage **U1** is on the order of

10 30 bar, the discharge pressure of the first stage (admission second stage) is on the order of 45 bar; the discharge pressure of the second stage **U2** (admission third stage) is on the order of 60 to 65 bar; The outlet of the third stage **U3** can be on the order of 90 bar.

15 It can be provided that the three cold zones of the three stages **U1** **U2** **U3** form a single part called a cold cylinder head such as that shown in dashed lines **95'** (Fig. 5).

Another optional characteristic of the boiler is 20 illustrated in Figure 5; A so-called de-icing exchanger marked **75** enables the glycol water circuit **34** to be directly coupled to the heating circuit **30**, without involving the compressible gas circuit **31**.

An auxiliary circuit **76** can be activated by a valve **74** 25 (manual or controllable) which activates this de-icing exchanger.

As its name indicates, this de-icing exchanger **75** is used to de-ice the external unit **4** by transferring heat from the heating circuit.

30 It is noted that this exchanger can also be used in certain cases for passive cooling, according to the same principle of transferring heat from the heating circuit to the external exchanger.

In general, it is noted that the fuel used in the 35 burner can be natural gas, or bio gas of plant or animal

origin, or light hydrocarbon compounds from industrial oil processing waste.

As illustrated in Figure 9, the thermal compressor **1** described above can be used within the context of the 5 diagrams from Figures 1 to 5, of course in a heating mode, but also conversely in a cooling mode.

In this case, in this cooling mode, heat will be drawn from heating circuit **30** (for example at the underfloor heating) and the heat drawn will be directed either to the 10 domestic hot water circuit **15, 16** or to the external unit **4**.

This result can be obtained by reversing the role of the evaporation and condensation exchangers **5', 6'** on the compressible gas loop **31**.

15 For reasons of clarity, four-way valve **77** that enables the fluid circulation directions to be reversed was not represented in Figures 1 to 5, but the principle is represented in Figure 9 where four-way valve **77** presents a normal position known as heating mode and a special 20 (reversed) position known as cooling mode.

When four-way valve **77** is in the normal position, the exchanger marked **6'** operates in condenser mode and the exchanger marked **5'** operates in evaporator mode.

25 Conversely, when valve **77** is in the reversed position, exchanger **5'** operates in condenser mode and the exchanger marked **6'** operates in evaporator mode.

In the boiler system, for reasons of clarity, certain components were not represented although they may also be present. In particular, these components are:

30 - expansion tanks on water circuits 34 30
- filling and drain cocks of the heating circuit
- filling and drain cocks of the CO₂ circuit
- various pressure gauges and temperature sensors
necessary for controlling the system by the
35 regulating unit

Summary of circuits

- 30: heating circuit
- 31: compressible CO₂ fluid
- 5 32: combustion fumes
- 33: bypass for DHW
- 34: glycol water (exchange with outside)
- 35: inlet of heated air
- 36: specific DHW circuit
- 10 76: de-icing bypass

CLAIMS

1. A **thermodynamic boiler** for exchanging heat with at least one **heating circuit** (30), the boiler comprising a thermal 5 compressor (1), the **thermal compressor** acting on a **compressible fluid** and comprising at least one **compression stage** with an alternating bi-directional **piston** separating a **first chamber** (81) and a **second chamber** (82) and a **first fuel burner** (11) forming a heat source coupled to the first 10 chamber, and using the heating circuit as a cold source coupled to the second chamber, the thermal compressor forming the compression function of a reversible heat pump type loop (31, 34), the first and second chambers (81, 82) being fluidly 15 connected between each other through a **regenerator** (19) with a to-and-fro fluid movement.
2. The thermodynamic boiler according to claim 1, in which the thermodynamic boiler supplies heat to the heating 20 circuit and the reversible heat pump type loop draws heat from an external unit (4) (winter mode).
3. The thermodynamic boiler according to claim 2, also comprising a **supplementary device** (2), the supplementary 25 device comprising an auxiliary burner (20), distinct from the first burner, and a **supplementary exchanger** (21) arranged on the heating circuit (30).
4. The thermodynamic boiler according to one of claims 1 to 30 3, in which the compressible fluid is **R744**.
5. The thermodynamic boiler according to one of claims 1 to 4, in which a **modulation unit and a motor** (17) are provided to regulate, i.e., increase and/or reduce the rotation 35 speed of the compressor.

6. The thermodynamic boiler according to one of claims 1 to 5, in which the heat pump type loop comprises **two cascaded circuits**, i.e., a compressible gas work circuit (31, 1, 5, 5 7, 6) and a glycol water circuit (34, 4, 6).

7. The thermodynamic boiler according to one of claims 1 to 6, in which the compressor comprises at least **two compression stages** in series, i.e., a second compression 10 stage (U2).

8. The thermodynamic boiler according to claim 7, with **three stages** (U1, U2, U3).

15 9. The thermodynamic boiler according to one of claims 7 or 8, in which the **stages** are **independent**.

10. The thermodynamic boiler according to one of claims 1 to 9, comprising an **air preheater** (9) at the inlet to at 20 least the first burner.

11. The thermodynamic boiler according to one of claims 1 to 10, comprising a **main exchanger** (5) forming the essential thermal interface between the compressible fluid 25 circuit (31) and the heating circuit (30), and the compressor is cooled by the heating circuit return that first passes in at least the main exchanger (5), and then in the cold section of the thermal compressor.

30 12. The thermodynamic boiler according to one of claims 1 to 11, in which the heating circuit return passes, after cooling the compressor, into the supplementary exchanger (21).

35 13. The thermodynamic boiler according to claim 11, in

which the main exchanger (5) comprises a **high temperature** exchanger (50) and a **low temperature** exchanger (51).

14. The thermodynamic boiler according to one of claims 1
5 to 13, comprising a **domestic hot water circuit** (15, 16).

15. The thermodynamic boiler according to claim 13 and
claim 14, in which the domestic hot water (33) is heated by
means of the high temperature exchanger (50) which is
10 arranged on the compressible fluid circuit directly at the
outlet of the thermal compressor (1).

16. The thermodynamic boiler according to claim 14, in
which the thermodynamic boiler takes heat from the heating
15 circuit (30), and delivers this heat either into the
domestic hot water DHW circuit or into the external unit
(4), to provide a cooling function.

FIG. 1

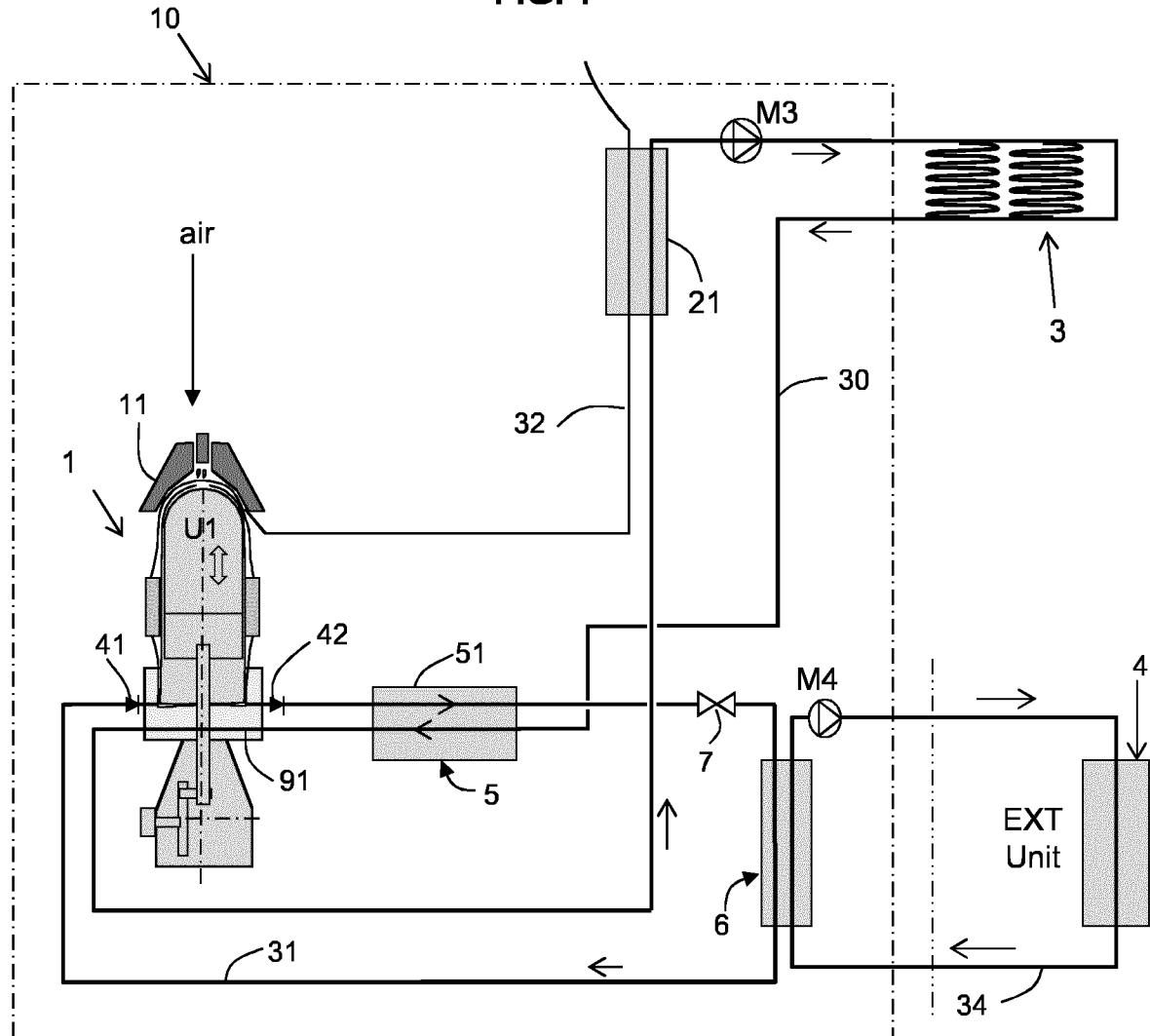


FIG. 2

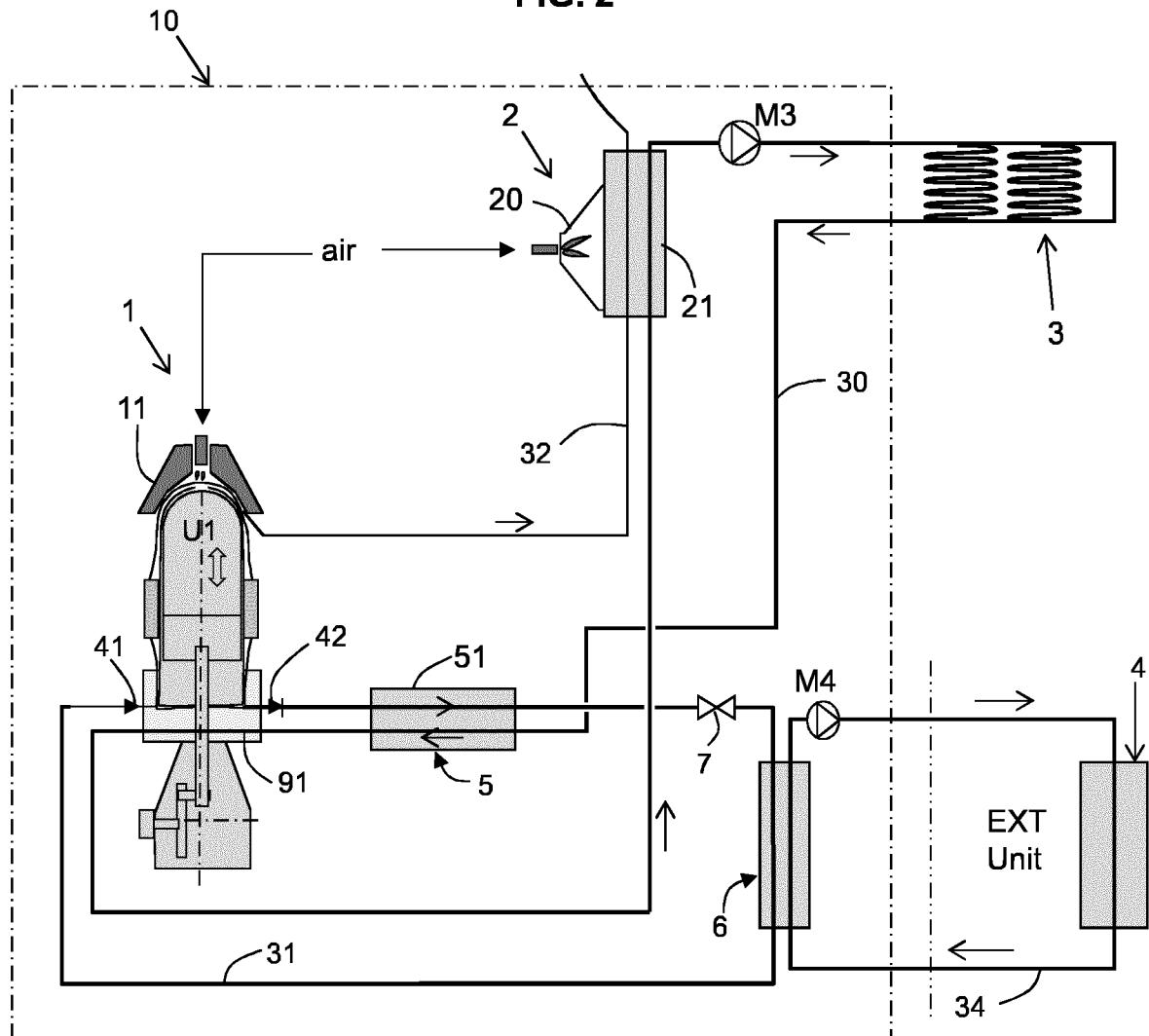


FIG. 3

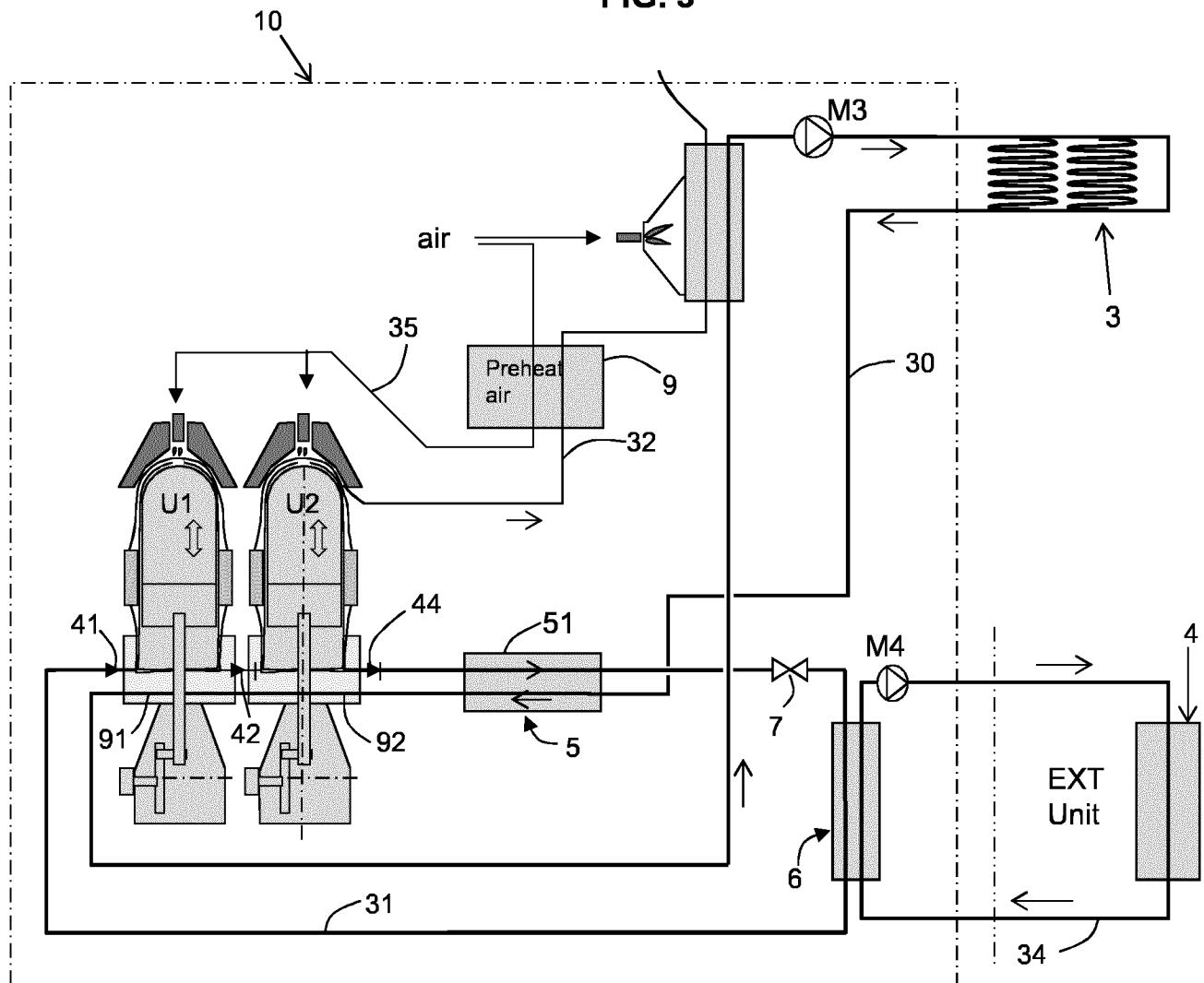


FIG. 4

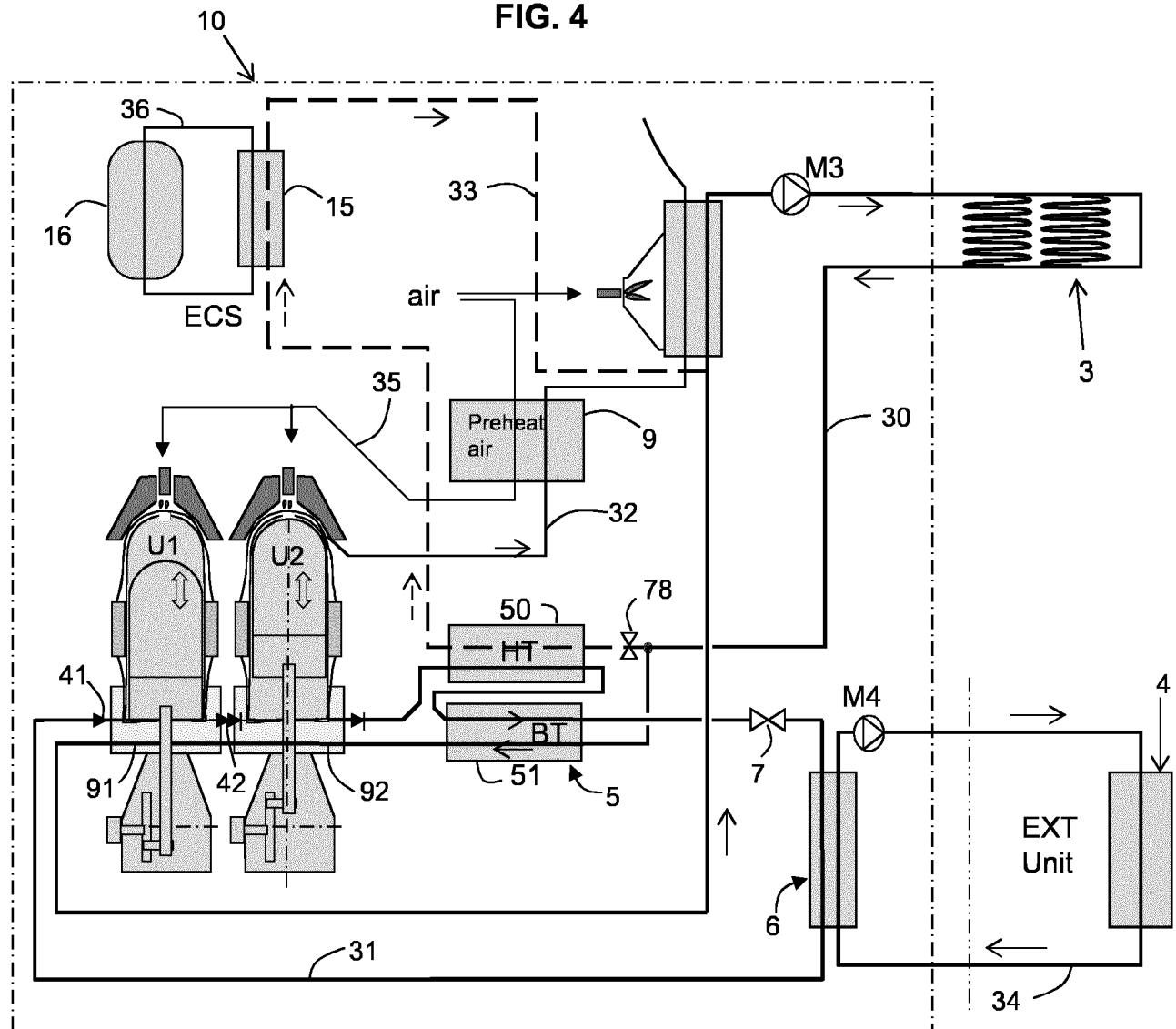


FIG. 5

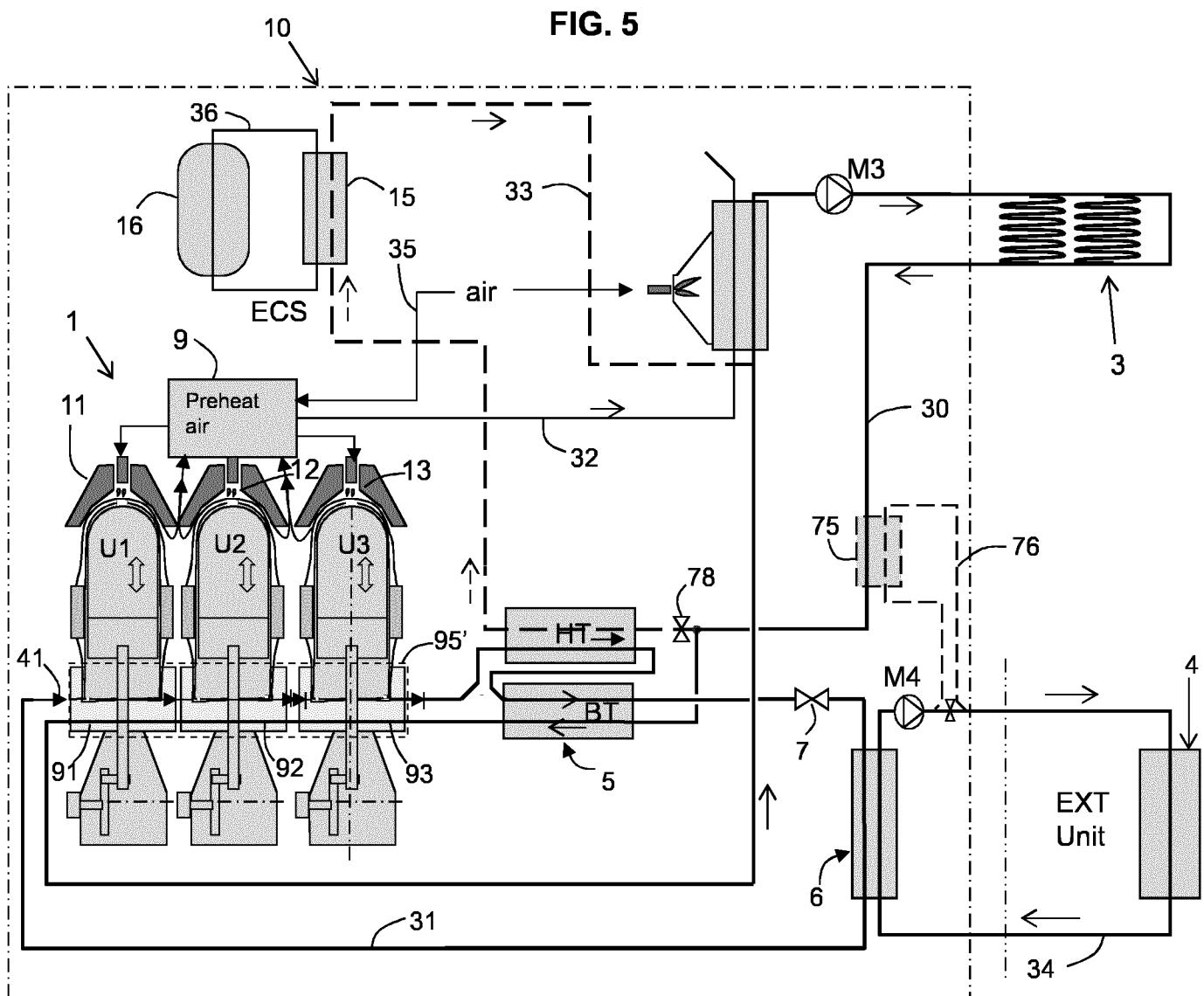


FIG. 6

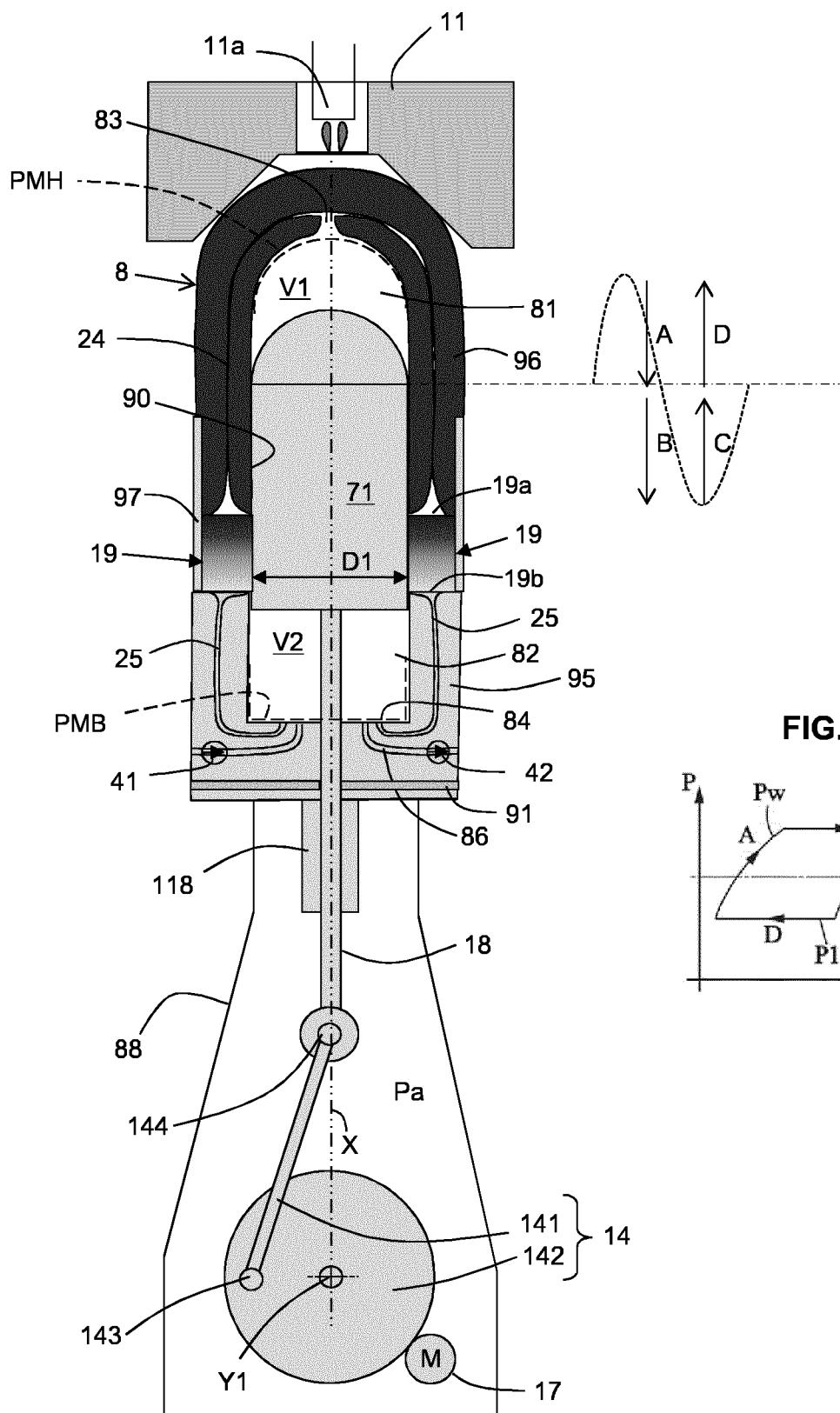


FIG. 7

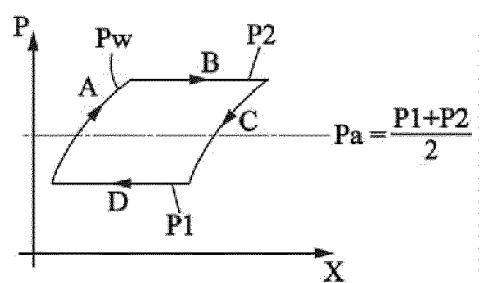


FIG. 8

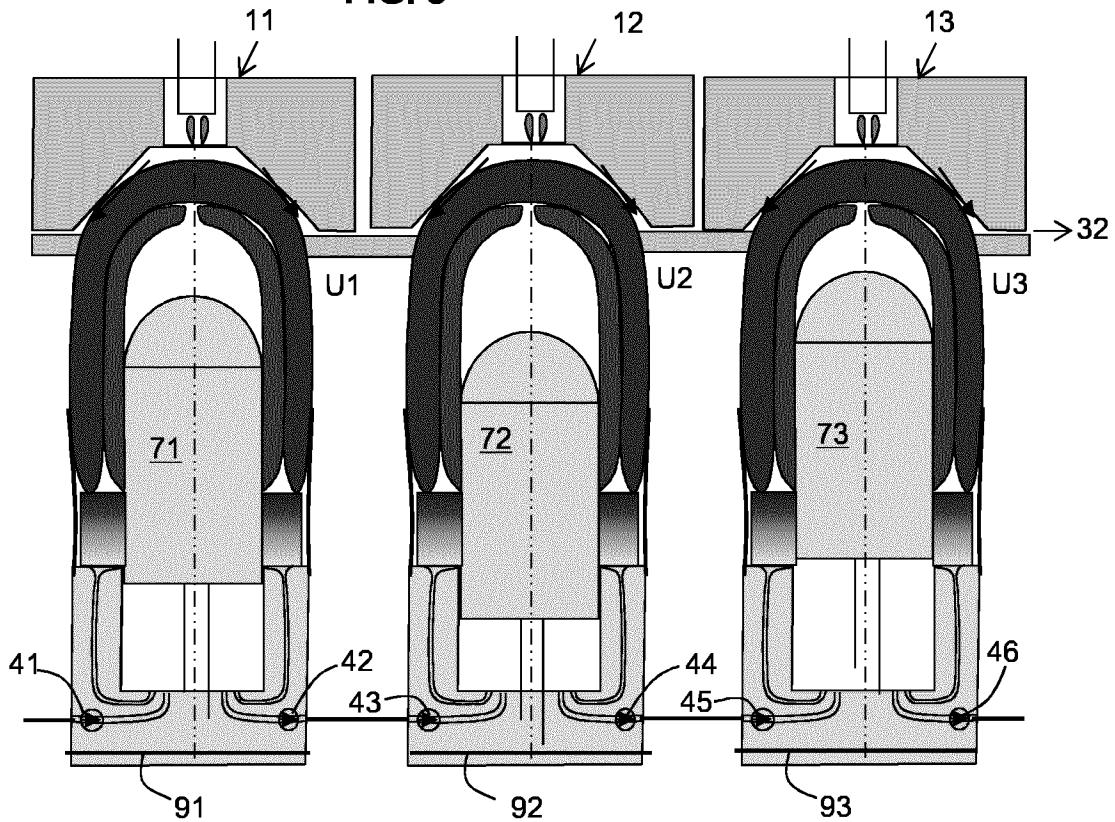
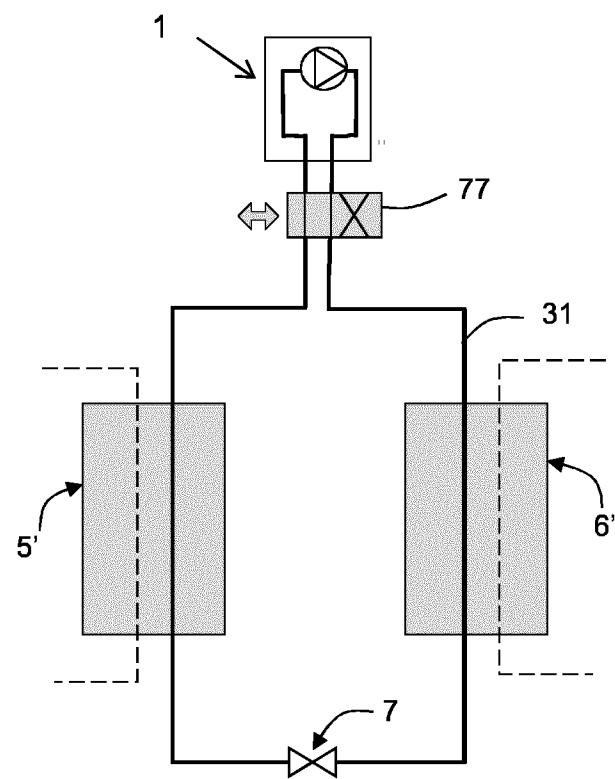


FIG. 9



INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2016/075271

A. CLASSIFICATION OF SUBJECT MATTER				
INV.	F24H9/00	F24D11/02	F24D17/02	F25B1/10
	F25B9/14	F25B27/00	F04B25/00	F04B35/00

ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F24H F24D F02G F25B F04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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X	WO 2012/107480 A1 (BOOSTHEAT [FR]; JOFFROY JEAN-MARC [FR]) 16 August 2012 (2012-08-16) pages 3-18; figures 1-8 -----	1-14,16
A	WO 2014/023586 A1 (BOOSTHEAT [FR]) 13 February 2014 (2014-02-13) pages 2-22; figures 1-12 -----	15 1,2, 4-11,14, 16
A	DE 10 2011 118042 A1 (BLZ GEOTECHNIK GMBH [DE]) 16 May 2013 (2013-05-16) paragraphs [0011] - [0013], [0027] - [0037], [0041], [0042]; figures 1-11 -----	1-16
A	US 2 157 229 A (VANNEVAR BUSH) 9 May 1939 (1939-05-09) pages 1-3; figures 1-9 ----- -/-	1-16

Further documents are listed in the continuation of Box C.

See patent family annex.

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"O" document referring to an oral disclosure, use, exhibition or other means

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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Date of the actual completion of the international search	Date of mailing of the international search report
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12 January 2017

19/01/2017

Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer
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Schwaiger, Bernd

INTERNATIONAL SEARCH REPORTInternational application No
PCT/EP2016/075271

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	EP 2 273 203 A2 (BOSCH GMBH ROBERT [DE]) 12 January 2011 (2011-01-12) pages 4, 5; figures 1-4 -----	1-16

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Information on patent family members

International application No

PCT/EP2016/075271

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