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(54) **Continuous kiln**

(57) A continuous kiln (1) for products, having a duct (2') with at least one lateral wall (2); conveying means (3) for feeding the products inside the duct (2'); and a number of firing assemblies arranged successively along the duct (2') and having at least one burner (4; 400); respective exhaust means (5, 6, 8), for the exhaust gas of the burner (4; 400), arranged so that the exhaust gas flows crosswise to the travelling direction of the products along the duct (2'); at least one respective pressure sensor (120) inside the duct (2'); and respective combustion supporter supply means (40) connected to the pressure sensor (120) to adjust combustion supporter supply to the burner (4; 400) as a function of the pressure detected by the pressure sensor (120).

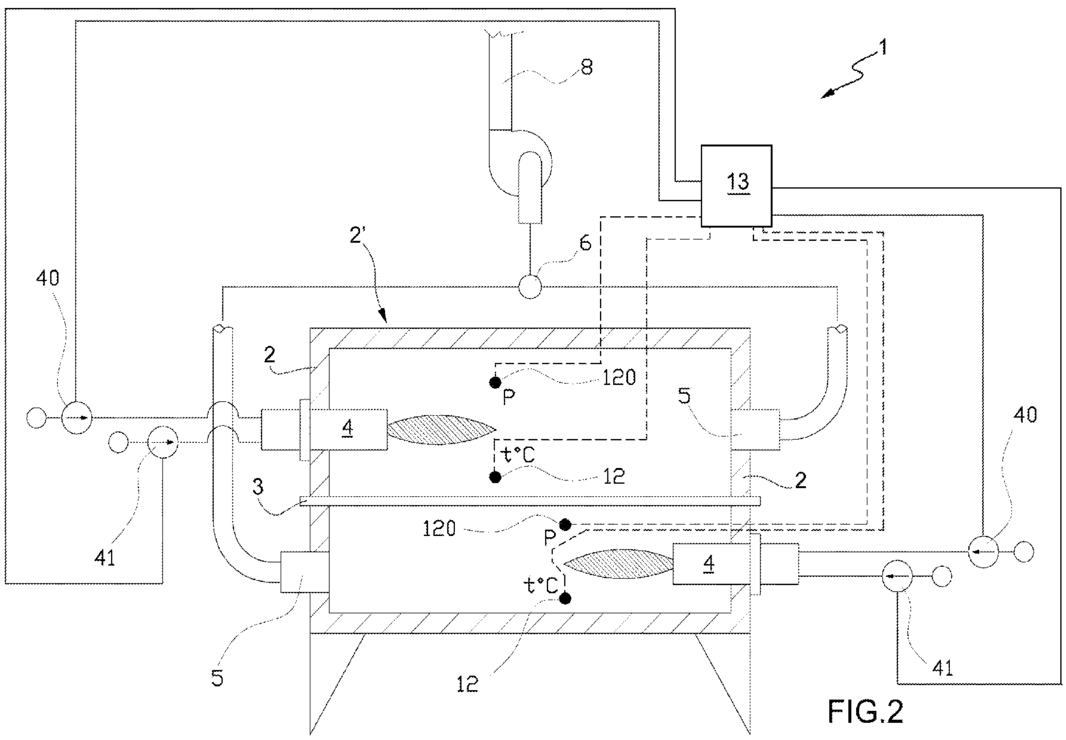

FIG.2

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Description

[0001] The present invention relates to a continuous kiln and a product firing method.

[0002] Kilns are known which comprise a rectangular-section duct fitted with burners for generating the necessary firing heat.

[0003] Kilns of this sort are used, for example, for firing ceramics, such as tiles, sanitary fixtures, bricks, etc.

[0004] The term "ceramics" is intended to mean, for example, products formed by compressing ceramic powder or cast from slip. Both may be glazed or not.

[0005] Inside the kiln, products such as tiles travel on a roller conveyor along the horizontal centreline of the kiln. Other types of products travel on carriages or plates moved appropriately along the kiln.

[0006] Burner and draught adjusting means establish a temperature pattern along the longitudinal axis of the kiln, which, depending on the travelling speed of the products, in turn defines a given product firing pattern.

[0007] The temperature pattern normally increases from the inlet of the kiln in the product travelling direction, and reaches a maximum (of over 900°C) along the half-way portion of the duct.

[0008] GB-A-1075596, for example, describes a kiln for ceramic products, comprising a duct; a conveyor belt for feeding the products inside the duct; and vertically oriented burner assemblies located on either side of the conveyor belt and defining firing chambers.

[0009] A major drawback of continuous kilns of the types described is the difficulty in regulating the temperature in the various firing chambers, which has a negative effect on operation of the kiln.

[0010] That is, the temperatures in the various sections of the kiln, from the product input section onwards, are inevitably conditioned by the temperature of the gas produced in the downstream and/or upstream sections. In kilns of the types described, a stream of hot gas forms inside the duct and accelerates gradually as it gets closer to the stack at the inlet of the duct, so that gas also migrates from a higher-pressure firing chamber to the adjacent chambers, thus contaminating the clean gas.

[0011] GB-A-2261059 describes a continuous kiln for products, comprising a duct; a conveyor belt for feeding the products inside the duct; adjacent burner assemblies defining sections of the kiln and fitted to the vertical longitudinal walls of the duct, both above and below the conveyor belt; and hot-gas exhaust openings, also formed in the vertical longitudinal walls of the duct and facing the burners. The burners and hot-gas exhaust openings are arranged to form a stream of hot gas flowing mainly parallel to the travelling direction of the products. For each section, the kiln also comprises a duct located at the top of the section and fitted with a damper for adjusting the pressure inside the section by, alternatively, feeding in or letting out air.

[0012] The device described in GB-A-2261059 clearly in no way serves to prevent gas flow between the various sections of the kiln. On the contrary, the layout of the burners and the damper would even appear to encourage mixing of the gas in adjacent sections.

[0013] JP-A-2009210194 describes a continuous kiln for products, comprising a duct; and a conveyor belt for feeding the products inside the duct. The kiln is divided into a number of (more specifically, seven) separate firing chambers, each equipped with burners and exhaust openings for the gas produced by the burners; and the pressure inside the duct differs from one firing chamber to another.

[0014] None of the above solutions ensures the exhaust gas in each firing chamber remains undisturbed, and therefore that no gas migrates from one firing chamber to another, thus making it impossible to achieve a temperature pattern with easily controllable, independent temperature gradient between one firing chamber and another.

[0015] Another, yet equally important, drawback involves purifying the exhaust gas.

[0016] As is known, contaminating substances are released at the various firing temperatures, and must be removed from the gas before it is exhausted into the atmosphere.

[0017] Though each is generated at a precise location or section of the kiln, depending on the temperature in the section, all the contaminating substances are present in the gas as a whole by the time it reaches the stack. This means all the gas must be subjected indiscriminately to a specific scrubbing process to remove each type of contaminating substance, thus greatly increasing the size of the scrubbing equipment and the running cost of the kiln.

[0018] Moreover, steam is generated in the various sections of the kiln during the firing process, and is discharged into the stack.

[0019] This steam must be prevented from condensing, in that it gives rise to acid liquids which, inside the kiln, are harmful to both the product and the structure of the kiln itself.

[0020] Steam is mainly generated in the lower-temperature, i.e. inlet, sections of the kiln, whereas, in the higher-temperature middle sections, the only water released is that forming part of the product material, and is released in smaller quantities than in the first few inlet sections of the kiln.

[0021] To prevent condensation, the gas temperatures must be kept high right up to the stack, thus increasing the running cost of the kiln.

[0022] It is an object of the present invention to provide a kiln and a firing method, designed to at least partly eliminate the above drawbacks.

[0023] According to the present invention, there are provided a kiln and a firing method, as claimed in the attached independent Claims, and preferably in one of the Claims depending directly or indirectly on the independent Claims.

[0024] Two preferred, non-limiting embodiments of the invention will be described by way of example with reference to the accompanying drawings, in which:

Figure 1 shows a vertical longitudinal section of a roller-type continuous kiln in accordance with a first embodiment of the invention;
Figure 2 shows a cross section along line II-II in Figure 1;
Figure 3 shows a horizontal section along line III-III in Figure 1, showing pressure adjustment inside the kiln;
Figure 4 shows a vertical longitudinal section of a roller-type continuous kiln in accordance with a second embodiment of the invention;
Figure 5 shows a cross section along line V-V in Figure 4;
Figure 6 shows a horizontal section along line VI-VI in Figure 4;
Figure 7 shows a firing graph achievable by the invention; the y axis shows temperature in °C, and the x axis the length of the kiln;
Figure 8 shows a cross section of a regenerative burner in Figure 4.

[0025] Number 1 in Figures 1 to 3 indicates as a whole a continuous kiln for products, comprising a duct 2', and a conveyor 3 for feeding the products inside duct 2'.

[0026] Conveyor 3 comprises a powered roller bed 3.

[0027] Duct 2' comprises two opposite, substantially vertical lateral walls 2.

[0028] Each lateral wall 2 of duct 2' is fitted, above and below conveyor 3, with two rows of gas or liquid fuel, e.g. CH_4, burners 4, each positioned so its combustion flame is directed crosswise to the travelling direction of the products along duct 2'. In the embodiments shown, each burner 4 is positioned so its combustion flame is directed horizontally.

[0029] Each burner 4 is associated with respective pneumatic means 40 (Figure 3) for supplying a combustion supporter (in particular, air) necessary to operate burner 4, and with a respective fuel supply pump 41.

[0030] The burners 4 above conveyor 3 on each lateral wall 2 are staggered with respect to the burners 4 below conveyor 3 on the same lateral wall 2, and with respect to the burners 4 on the opposite lateral wall 2. And, on either side of and on a level with each burner 4, exhaust openings 5 are formed for the exhaust gas generated by burners 4.

[0031] Each burner 4 and respective opening 5 are located on opposite lateral walls 2; and each opening 5 directly faces the corresponding burner 4 so the exhaust gas generated by the corresponding burner 4 flows crosswise to the travelling direction of the products along duct 2'.

[0032] Duct 2' is thus divided into a number of firing assemblies communicating with one another and each comprising a number of (in particular, three) burners 4 above and below conveyor 3. The firing assemblies are two or more in number, depending on the required performance of kiln 1.

[0033] If each firing assembly comprises three burners 4 (as in the example shown), two are located above and one below conveyor 3, or vice versa.

[0034] The burners 4 in each firing assembly may obviously be other than three in number.

[0035] The burners 4 in each firing assembly constitute an array of adjacent burners 4.

[0036] Kiln 1 described comprises partitions 11 extending between a top wall of duct 2' and conveyor 3, and between a bottom wall of duct 2' and conveyor 3, and which are sized to leave just enough space to let conveyor 3 and the products on it through.

[0037] In the example shown, partitions 11 are fixed, but may advantageously be movable to adapt the passage to the products travelling along duct 2'.

[0038] Each of the openings 5 in the same firing assembly communicates with a stack 6 comprising a suction fan 8.

[0039] Each stack 6 feeds the exhaust gas from duct 2' to scrubbing means for removing pollutants from the gas before it is exhausted to the outside.

[0040] Each firing assembly comprises at least one stack 6.

[0041] A stack 9 is located at the inlet of duct 2' to exhaust the gas produced by kiln 1, and comprises a suction fan 10.

[0042] Partitions 11 are preferably arranged to separate the firing assemblies.

[0043] At least one temperature sensor 12 and at least one pressure sensor 120 (Figure 2) are located inside each firing assembly. Temperature sensor 12 is located in the area inside duct 2' occupied by burner 4 or the array of adjacent burners 4.

[0044] Kiln 1 also comprises a control unit 13, which is connected to and supplied by pressure sensor 120 with pressure reading signals, and which controls the combustion supporter supply means (in particular, pneumatic means 40) to adjust combustion supporter supply to burner 4 as a function of the pressure detected by pressure sensor 120.

[0045] Control unit 13 is connected to and supplied by temperature sensor 12 with temperature reading signals, and controls the fuel supply means (in particular, pump 41) to adjust fuel supply to burner 4 as a function of the temperature detected by temperature sensor 12.

[0046] In actual use, pressure sensor 120 determines the current pressure value $P_{current}$ inside the firing assembly (either continuously or, alternatively, at predetermined intervals). The current pressure value $P_{current}$ is transmitted to control unit 13, which compares it with a reference pressure value P_{ref} established at the setup stage of kiln 1. In a preferred variation, reference pressure value P_{ref} is slightly higher than atmospheric pressure. More specifically, the pressure inside duct 2' is maintained between 101331 and 101334 Pa (P_{ref}).

[0047] If the absolute difference between the current pressure value $P_{current}$ and reference pressure value P_{ref} (e.g. 101332.5 Pa) exceeds a tolerance value TV (e.g. 0.5 Pa) also established at the setup stage, control unit 13 transmits a signal to an inverter, which accordingly controls pneumatic means 40, in particular by adjusting the motor speed of a respective suction fan. By so doing, the pressure in each firing assembly can be controlled independently of the adjacent firing assemblies, by increasing or reducing combustion supporter supply directly to each burner 4 as a function of current pressure value $P_{current}$.

[0048] In other words, by adjusting combustion supporter supply to each burner 4 as a function of the pressure of each firing assembly determined by respective pressure sensor 120, substantially even pressure can be maintained in duct 2'.

[0049] Control unit 13 is advantageously designed to adjust combustion supporter supply to each burner 4 as a function of the current pressure value $P_{current}$ detected by pressure sensor 120 of the relative firing assembly, so as to keep the pressure along duct 2' within a 9 Pa (in particular, 6 Pa) range on either side of reference pressure value P_{ref}. In some embodiments, the range is 3 Pa.

[0050] More specifically, control unit 13 is connected to each pressure sensor 120 and is designed to control combustion supporter supply means 40 as a function of the pressure detected by each pressure sensor 120, so as to maintain pressure within a 1 Pa range along duct 2'.

[0051] Reference pressure value P_{ref} is the same for all the firing assemblies.

[0052] Control unit 13 is designed to adjust combustion supporter supply to each firing assembly (more specifically, to each burner 4) independently, as a function of the pressure detected by respective pressure sensor 120.

[0053] By adjusting the pressure gradient, substantially the same pressure, equal to reference pressure value P_{ref}, can be maintained in all the firing assemblies along duct 2', and fumes and/or gas can be prevented from migrating from a higher-pressure to adjacent lower-pressure firing assemblies.

[0054] Tests show that, when the pressure along duct 2' is substantially even (or within the above range), and exhaust gas flow is substantially crosswise to the travelling direction of the products along duct 2', there is a surprisingly big reduction in gas or fume flow along duct 2'.

[0055] In the same way, the temperature in the firing assemblies can be controlled as a function of a target firing pattern, as shown by way of example in Figure 7.

[0056] In actual use, temperature sensor 12 determines the current temperature value $T_{current}$ inside the firing assembly (either continuously or, alternatively, at predetermined intervals). The current temperature value $T_{current}$ is transmitted to control unit 13, which compares it with a target temperature value T_{i_tgt} established at the setup stage of kiln 1.

[0057] If the absolute difference between the current temperature value $T_{current}$ and target temperature value T_{i_tgt} exceeds a tolerance value TV' (e.g. 3°C, and advantageously 1°C) also established at the setup stage, control unit 13 transmits a signal to the fuel supply means (pump 41). The temperature in each firing assembly can be controlled independently of the adjacent firing assemblies, by increasing or reducing fuel supply directly to each burner 4 as a function of current temperature value $T_{current}$.

[0058] In other words, by adjusting fuel supply to each burner 4 as a function of the temperature of each firing assembly determined by respective temperature sensor 12, the target temperature can be maintained for each firing assembly.

[0059] Control unit 13 is advantageously designed to adjust fuel supply to each burner 4 as a function of the temperature detected by temperature sensor 12 of the relative firing assembly, so as to keep the temperature in the respective firing chamber within a 3°C (advantageously, 1°C) range on either side of target temperature value T_{i_tgt}.

[0060] Target temperature value T_{i_tgt} varies according to the firing assembly, and, in a preferred variation, increases from the inlet to the outlet firing assemblies.

[0061] More specifically, control unit 13 is designed to adjust fuel supply to each firing assembly (more specifically, to each burner 4) independently, as a function of the temperature detected by respective temperature sensor 12.

[0062] By reducing gas and/or fume flow between the various firing assemblies, the temperature in each firing assembly can be controlled extremely accurately, and is relatively unaffected by the temperature in the adjacent firing assembly/assemblies.

[0063] In alternative embodiments, there is one control unit 13 for the whole of kiln 1, or control unit 13 comprises a number of separate or connected central control units (or microprocessors). Some embodiments comprise a central control unit for each firing assembly. Others comprise two central control units for each firing assembly: one for controlling the fuel supply means (pump 41), and the other for controlling the combustion supporter supply means (pneumatic means 40). Other embodiments comprise a central control unit for each burner 4; in which case, the central control unit is connected to temperature and pressure sensors 12 and 120 of the relative firing assembly, and is designed to control the fuel supply means (pump 41) and combustion supporter supply means (pneumatic means 40) of respective burner 4.

[0064] Because each firing assembly has no other openings apart from opening 5 and the combustion supporter inlets for pneumatic means 40, the pressure in the firing assembly is not adjusted by injecting and discharging outside air, which would disturb the crosswise exhaust gas flow from each burner 4.

[0065] A second embodiment of the invention, shown in Figures 4 to 6, differs from the first by employing so-called heat-recovery or regenerative burners 400 instead of normal free-flame burners 4.

[0066] As is known, regenerative burners are widely used, by increasing efficiency and reducing fuel consumption.

[0067] As shown more clearly in Figure 8, regenerative burner 400 is a free-flame burner comprising fuel gas supply means 41 with a channel having an axis X. Burner 400 also comprises combustion supporter supply means 40 comprising a tubular (annular) conduit coaxial with axis X; and exhaust gas exhaust means comprising a tubular (annular) conduit coaxial with axis X and having an exhaust gas opening 5. It is important to note that, in this embodiment too, each opening 5 is located so that the exhaust gas from corresponding burner 400 flows crosswise to the travelling direction of the products along duct 2'.

[0068] Burner 400 is designed to draw in and use the combustion exhaust gas to preheat the combustion supporter. More specifically, the exhaust gas flow encounters the combustion supporter flowing in the opposite direction, and which is preheated, by drawing heat from the exhaust gas flow, before mixing with the fuel.

[0069] In Figures 4 to 6, the parts already described relative to the first embodiment are indicated using the same reference numbers.

[0070] In a preferred embodiment, kiln 1 has no stack 9 close to the inlet section of duct 2' to exhaust the gas produced by kiln 1.

[0071] Figure 7 shows a firing graph achievable by the invention in a kiln 1 with seven chambers between the inlet and outlet.

[0072] The left end of the firing graph indicates the inlet, and the right end the outlet of duct 2'.

[0073] Clearly, changes may be made to the invention as described without, however, departing from the scope defined in the accompanying Claims.

Claims

1. A continuous kiln (1) for products, comprising :

- a duct (2') having at least one lateral wall (2);
- conveying means (3) for feeding the products inside the duct (2'); and
- a number of firing assemblies arranged successively along the duct (2') and each comprising at least one burner (4; 400);

the continuous **kiln being characterized in that** each firing assembly comprises :

- respective exhaust means (5, 6, 8), for the exhaust gas of said burner (4; 400), arranged so that the exhaust gas from said burner (4; 400) flows crosswise to the travelling direction of the products along the duct (2');
- at least one respective pressure sensor (120) inside the duct (2'); and
- respective combustion supporter supply means (40) for supplying a combustion supporter to said burner (4; 400); the combustion supporter supply means (40) being connected to said pressure sensor (120) to adjust combustion supporter supply to said burner (4; 400) as a function of the pressure detected by the pressure sensor (120).

2. A continuous kiln as claimed in Claim 1, wherein each firing assembly comprises a respective temperature sensor (12) for determining the temperature at the firing assembly; and fuel supply means (41) for supplying fuel to the burner (4; 400), and which are connected to the temperature sensor (12) to adjust fuel supply as a function of the temperature detected by the temperature sensor (12).

3. A continuous kiln as claimed in one of the foregoing Claims, and comprising a control unit (13) connected to each pressure sensor (120) and designed to control the combustion supporter supply means (40) as a function of the pressure detected by each pressure sensor (120), to maintain pressure within a range of 3 Pa along the duct (2').

4. A continuous kiln as claimed in one of the foregoing Claims, wherein the exhaust means (5, 6, 8) of each firing assembly comprise at least one respective independent exhaust stack (6).

5. A continuous kiln as claimed in one of the foregoing Claims, wherein the burners (400) are regenerative or heat-recovery burners.

6. A continuous kiln as claimed in one of the foregoing Claims, and comprising at least one partition (11) located between two adjacent firing assemblies and designed to permit passage of the products and to prevent exhaust gas flow between the adjacent firing assemblies.

7. A continuous kiln as claimed in one of the foregoing Claims, wherein the burner (4; 400) is fitted to the lateral wall (2) of the duct (2'), so that its combustion flame is directed crosswise to the travelling direction of the products.

8. A continuous kiln as claimed in one of the foregoing Claims, wherein each firing assembly comprises a number of burners (4; 400) located on opposite sides of the product conveying means (3).

9. A continuous kiln as claimed in one of the foregoing Claims, wherein the exhaust means (5, 6, 8) of each firing assembly comprise a respective exhaust gas scrubber.

10. A continuous kiln as claimed in one of the foregoing Claims, wherein the duct (2') has no openings other than an inlet opening, an outlet opening, and the openings required by the exhaust means (5, 6, 8), by the combustion supporter and fuel supply means (40, 41), and eventually by a further exhaust stack (9).

11. A method of firing a product, the method comprising the steps of :

- feeding the product into a continuous kiln (1);
- conveying the product inside a duct (2') to fire the product; and
- removing the product once it has been fed through the duct (2');

the method being **characterized in that** the continuous kiln (1) is as claimed in one of Claims 1 to 10; and the method comprises a step of adjusting the pressure of each firing assembly, and in the course of which combustion supporter supply to each burner (4; 400) of the firing assembly is adjusted as a function of the pressure of the firing assembly detected by the respective pressure sensor (120).

12. A method as claimed in Claim 11, wherein the step of adjusting the pressure of each firing assembly comprises the substeps of :

- determining, by means of the pressure sensor (120), the current pressure value ($P_{current}$) inside the duct (2') at the firing assembly;
- calculating the difference between the current pressure value ($P_{current}$) and a reference pressure value (P_{ref}); and
- adjusting combustion supporter supply to each burner (4; 400) independently of the other firing assembly/assemblies and as a function of the difference between the current pressure value ($P_{current}$) and the reference pressure value (P_{ref}).

13. A method as claimed in Claim 12, wherein the step of adjusting pressure comprises adjusting combustion supporter supply to each burner (4; 400) when the absolute difference between the current pressure value ($P_{current}$) and the reference pressure value (P_{ref}) exceeds a given first tolerance value (TV).

14. A method as claimed in one of Claims 11 to 13, wherein the step of adjusting pressure is performed independently for each firing assembly, so as to keep the pressure of each firing assembly within a 3 Pa (more specifically, 1 Pa) range with respect to a reference pressure value (P_{ref}) common to all the firing assemblies.

15. A method as claimed in one of Claims 11 to 14, and comprising a step of adjusting the temperature of each firing assembly, and in the course of which fuel supply to each burner (4; 400) of the firing assembly is adjusted as a function of the temperature of the firing assembly detected by the respective temperature sensor (12).

16. A method as claimed in Claim 15, and comprising, for each firing assembly, the further steps of :

- establishing, at a preliminary setup stage, a target temperature value (T_{i_tgt}) to be maintained in the firing assembly to achieve a given firing pattern;
- determining the current temperature value ($T_{current}$) by means of the respective temperature sensor (12);
- calculating the difference between the current temperature value ($T_{current}$) and the target temperature value (T_{i_tgt}); and
- adjusting fuel supply to each burner (4; 400) as a function of the difference between the current temperature value ($T_{current}$) and the target temperature value (T_{i_tgt}).

17. A method as claimed in one of Claims 11 to 16, wherein the product is a ceramic product.

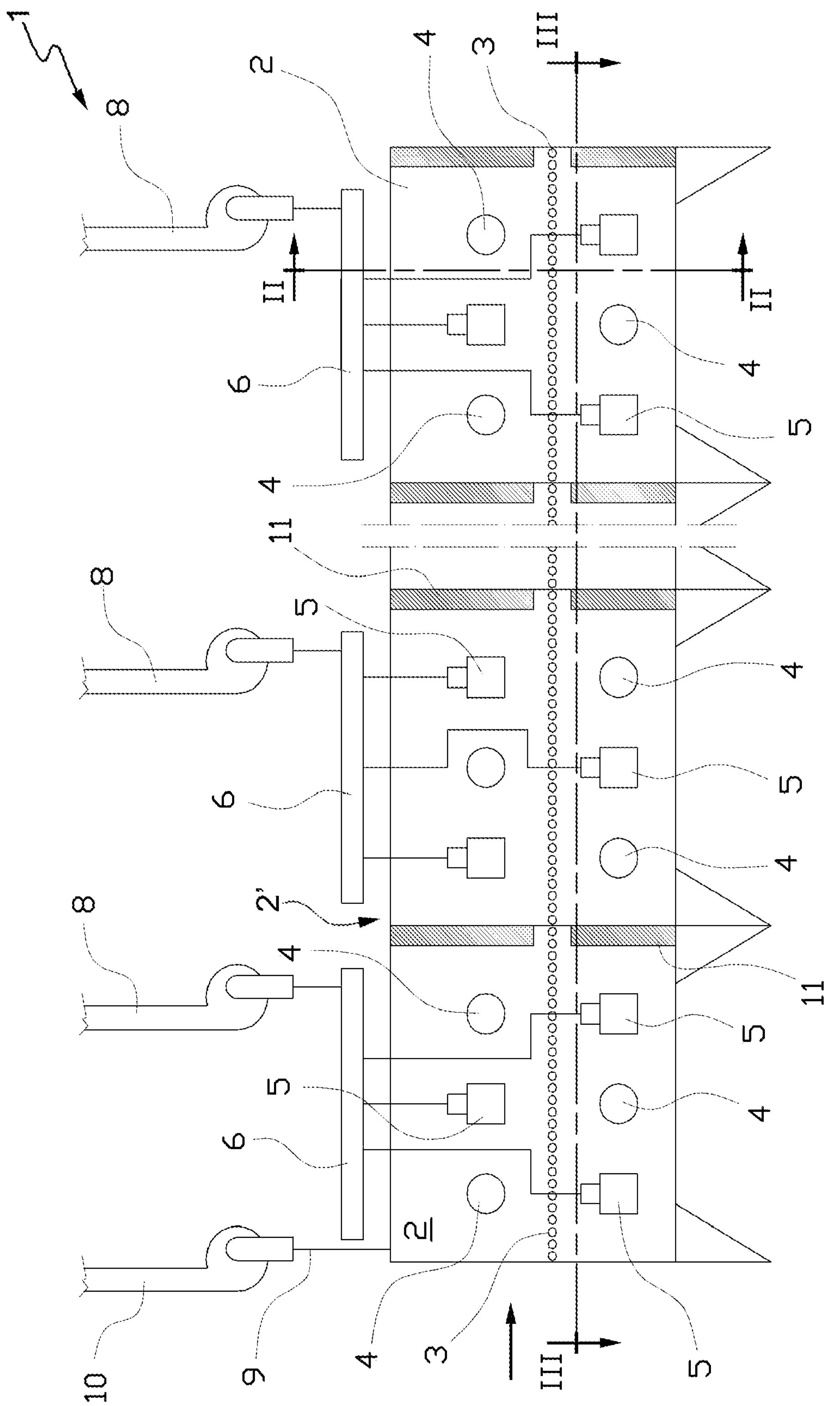

FIG.1

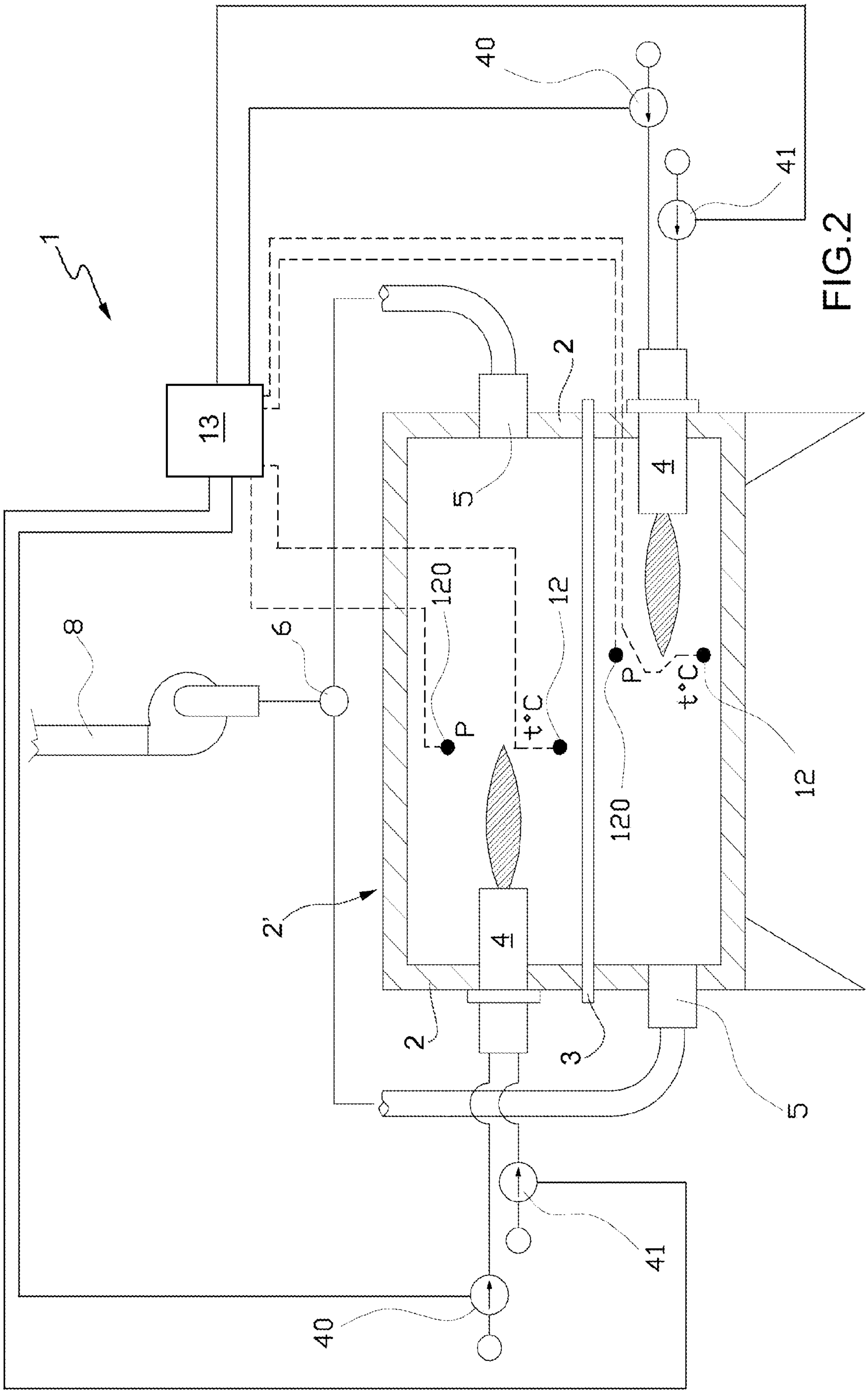

FIG.2

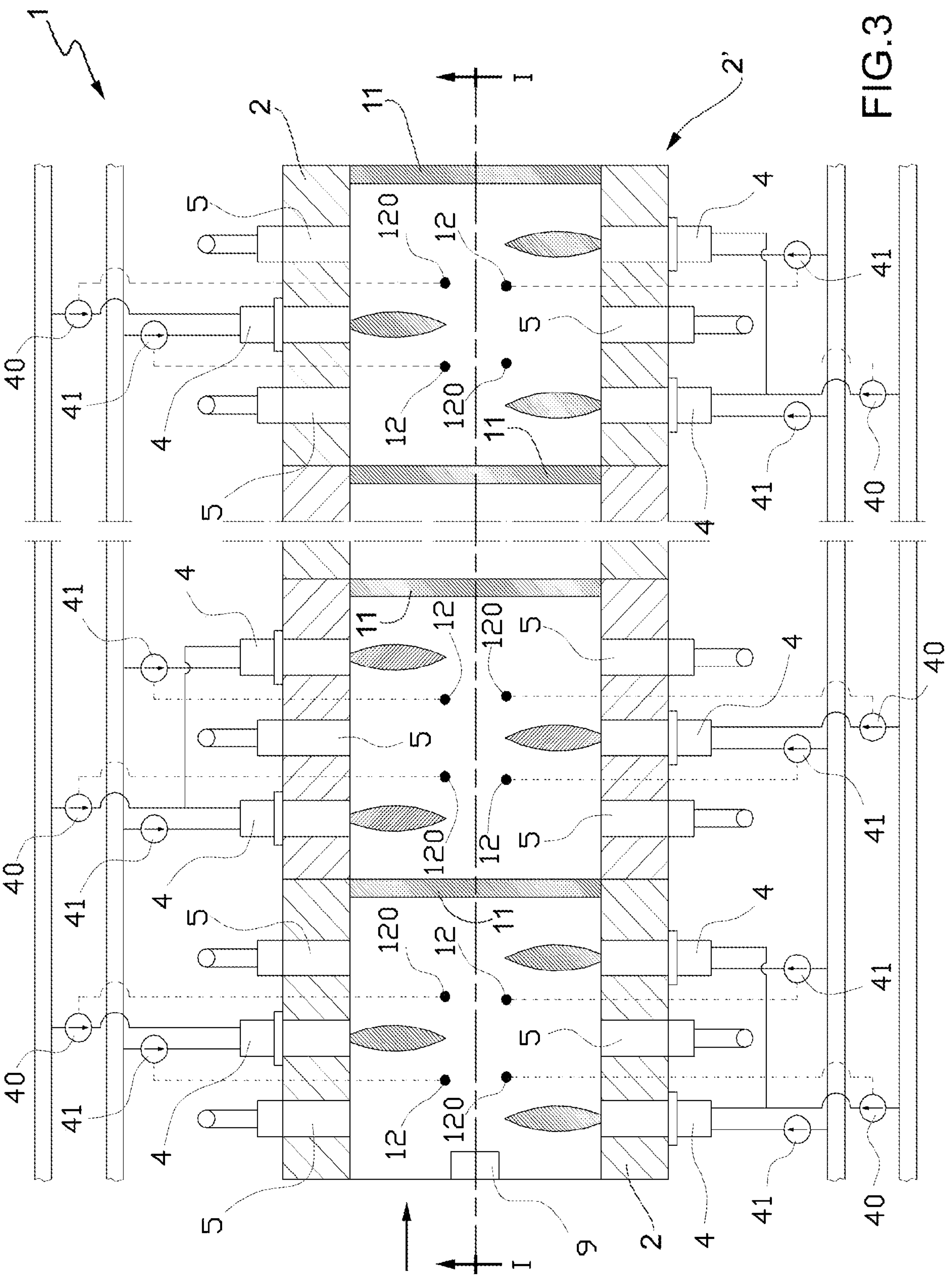

FIG.3

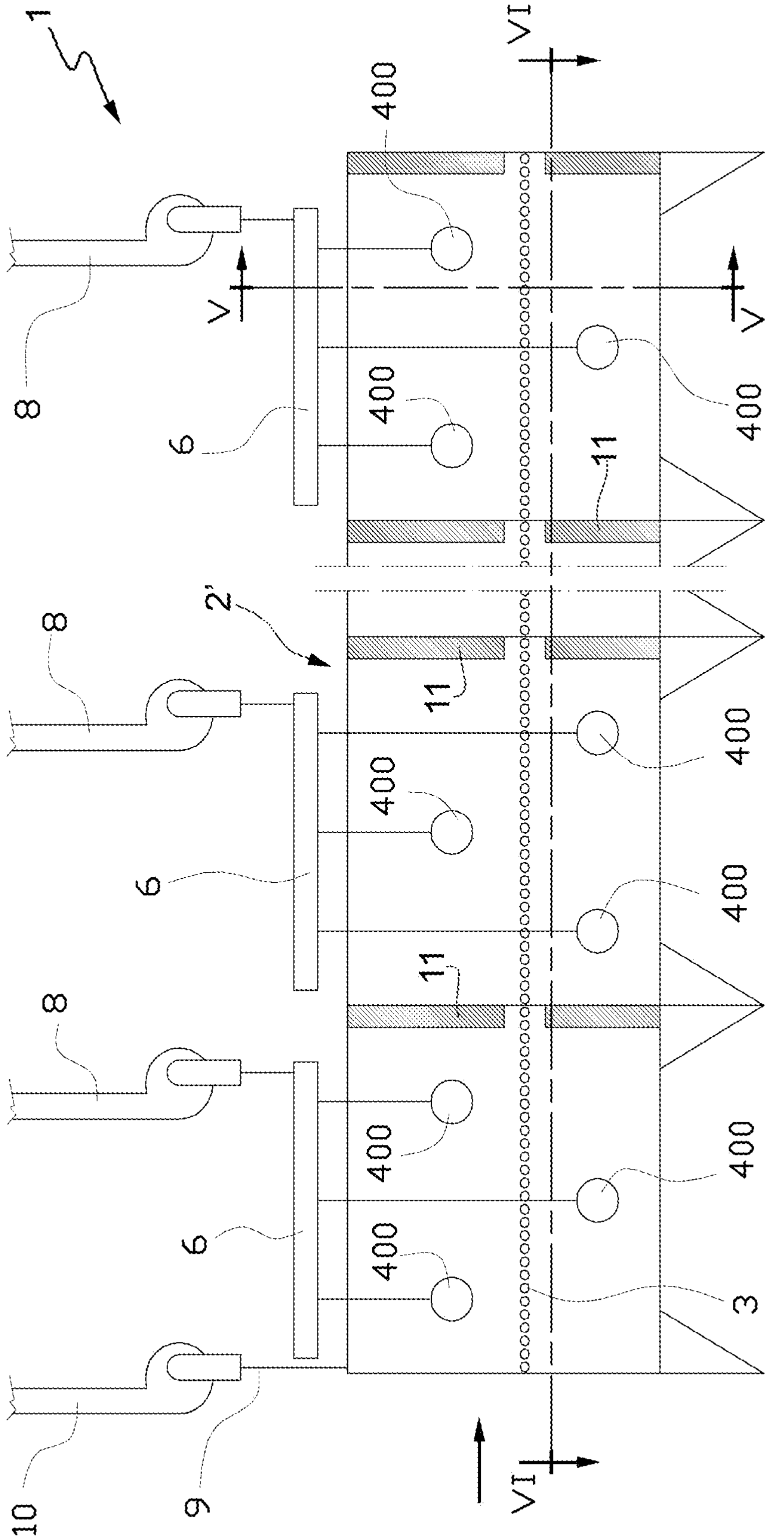
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FIG.4

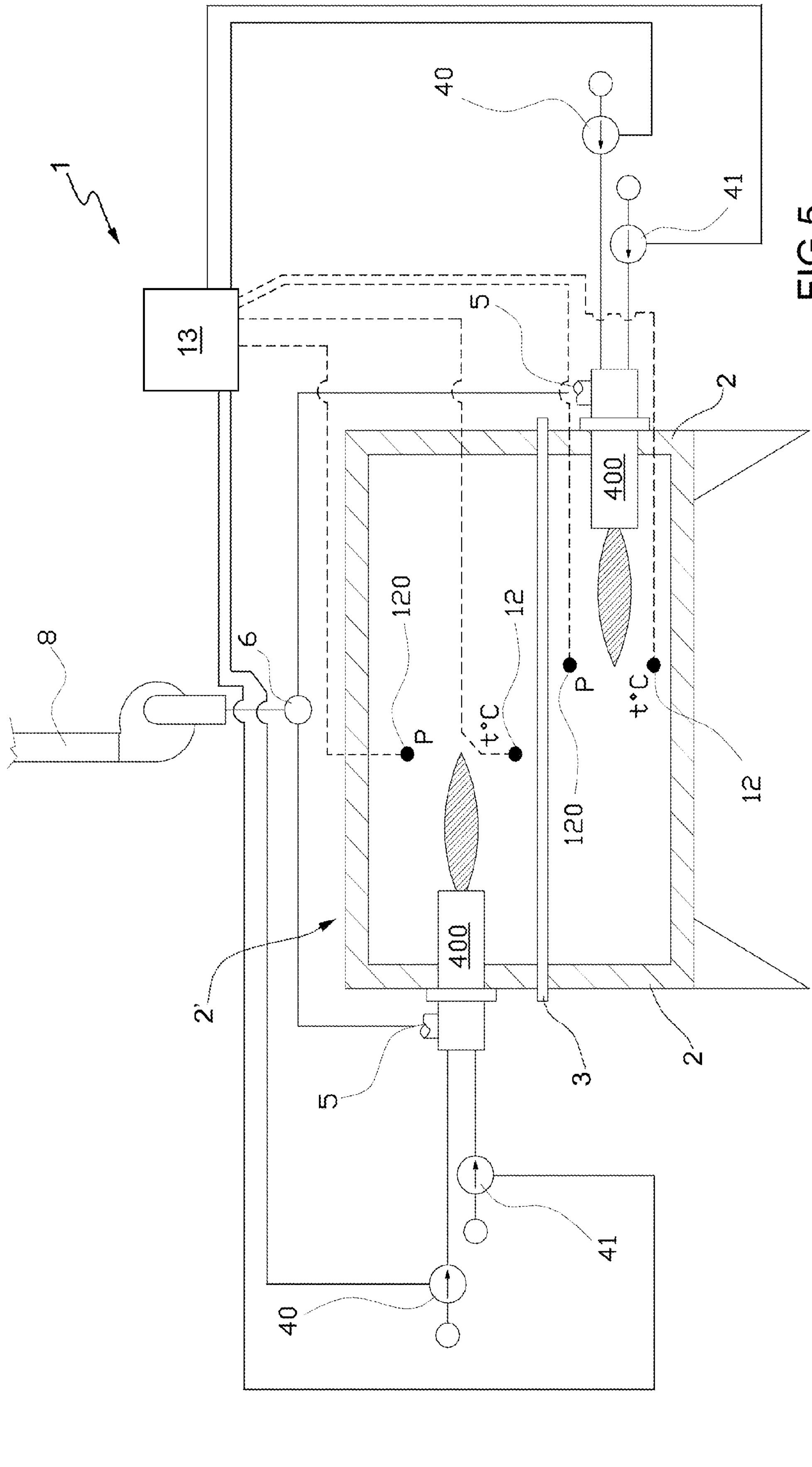

FIG.5

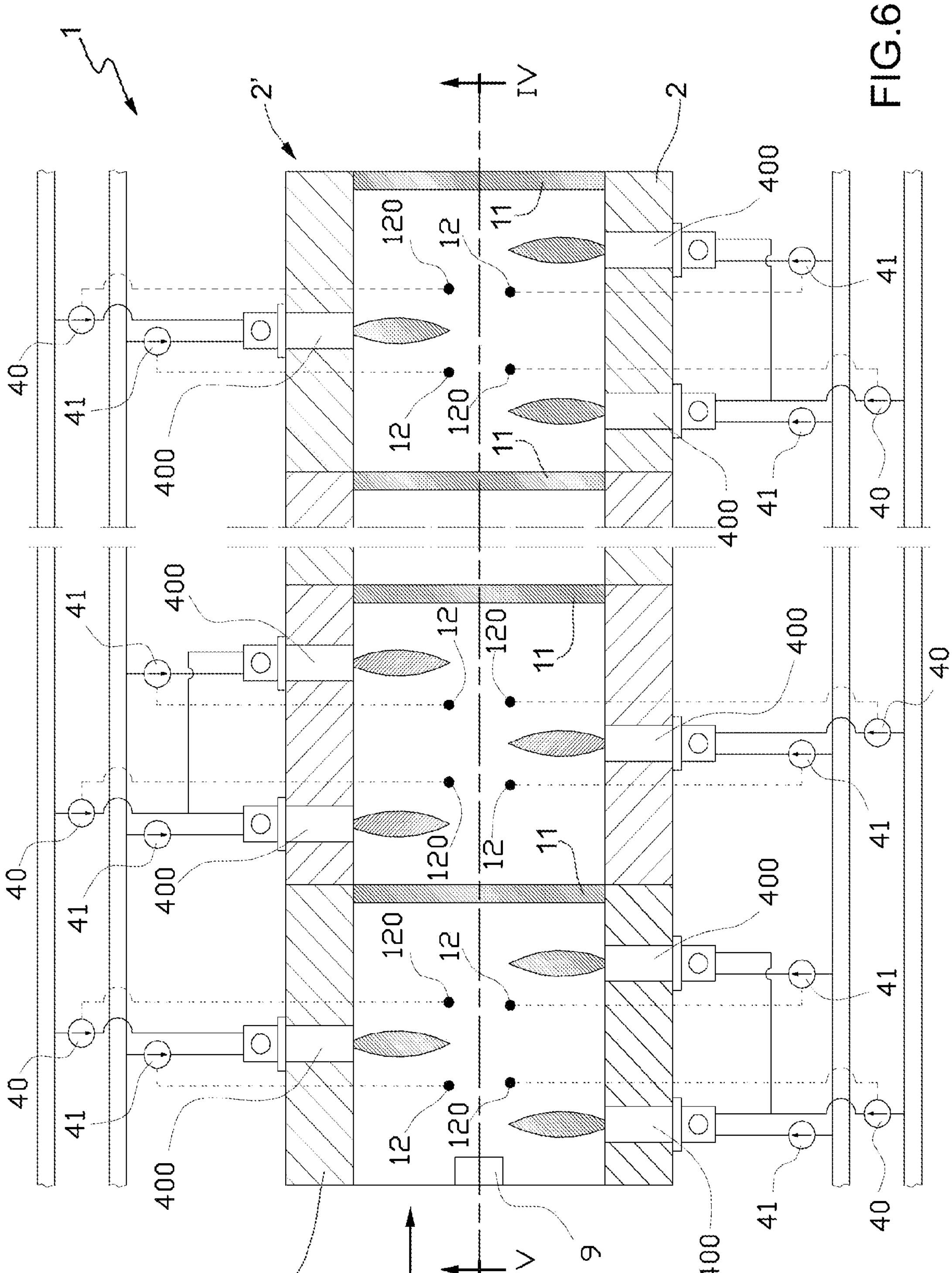

FIG.6

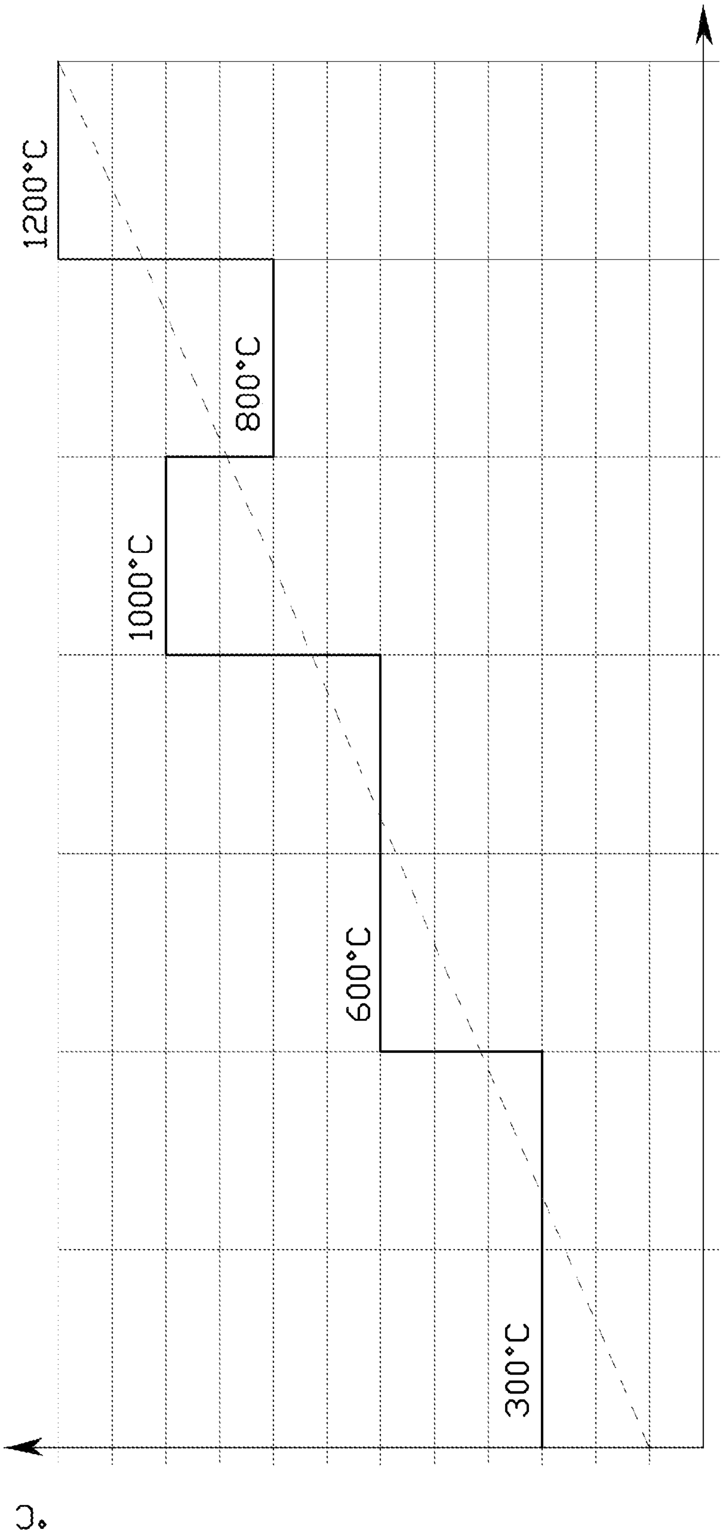

FIG.7

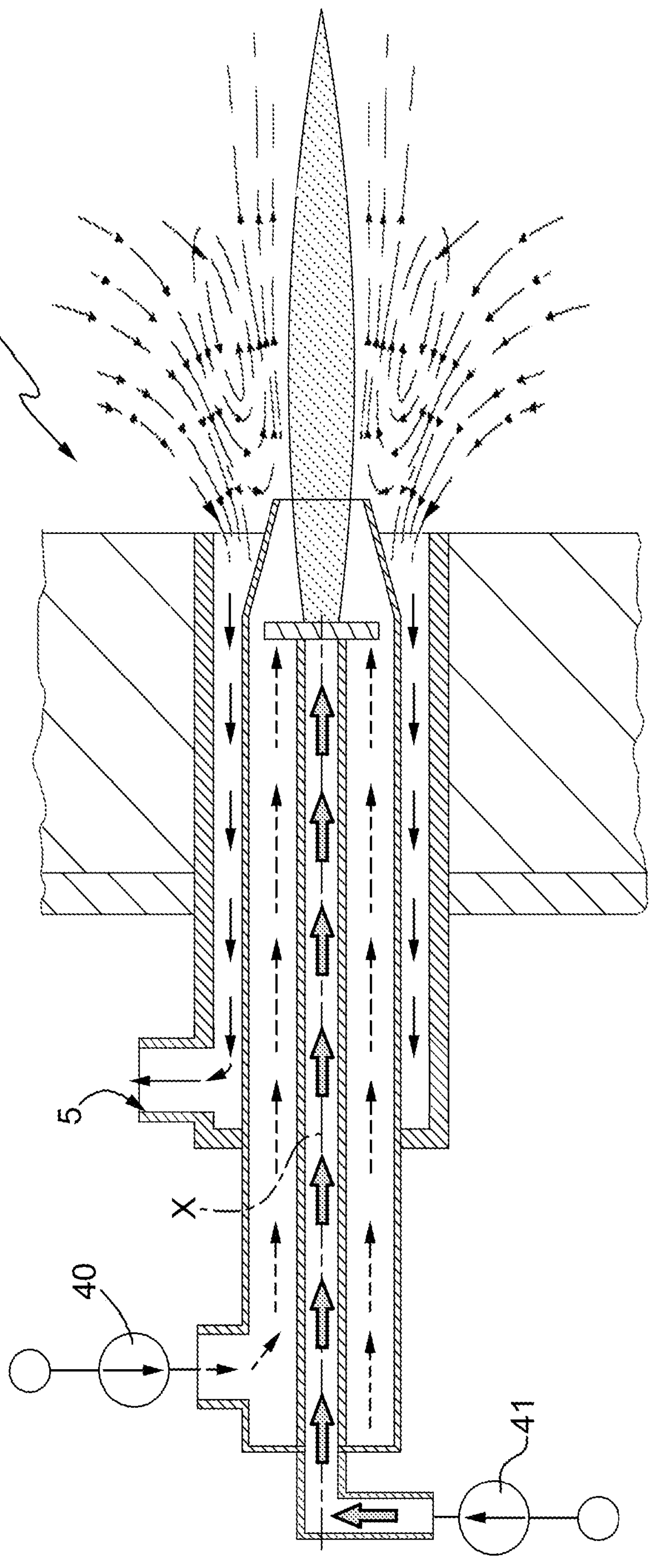

FIG.8

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EUROPEAN SEARCH REPORT

Application Number
EP 10 17 0548

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	GB 1 075 596 A (BOYD COLUMBUS MILLER) 12 July 1967 (1967-07-12) * figures 1-3 * -----	1-17	INV. F27B9/02 F27B9/10 F27B9/30 F27B9/40
A	GB 2 261 059 A (NIPPON FURNACE KOGYO KK [JP]; NIPPON KOKAN KK [JP]) 5 May 1993 (1993-05-05) * abstract * * See "Summary of the invention".figure 3 * -----	1-17	
X,P	JP 2009 210194 A (TDK CORP) 17 September 2009 (2009-09-17) * figures 1-3 * -----	1-17	

TECHNICAL FIELDS SEARCHED (IPC)
F27B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	31 August 2010	Gimeno-Fabra, Lluis

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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3

EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 10 17 0548

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31-08-2010

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

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