(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 3 575 693 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
04.12.2019 Bulletin 2019/49

(21) Application number: **19177549.3**

(22) Date of filing: **30.05.2019**

(51) Int Cl.:
F24C 7/08 *(2006.01)*

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
KH MA MD TN

(30) Priority: **30.05.2018 IT 201800005863**

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(54) ELECTRIC OVEN AND METHOD OF OPERATION OF SUCH OVEN

(57) An electrical supplied oven comprising: a cooking cavity; an electric heating circuit associated with the cooking cavity and comprising a plurality of electric resistances, configured to heat the cooking cavity when supplied by electric current, and a plurality of switches configured for selectively isolating one or more resistances from the electric heating circuit; a first switch configured for selectively coupling each other a first and a second electric resistance of the electric heating circuit in series or in parallel; a control unit configured for controlling the switches according to a plurality of different selectable cooking programs; wherein the control unit is configured for performing a first cooking program, wherein only the first and the second resistance are supplied and the first switch is in a configuration for coupling each other in series the first and the second electric resistance.

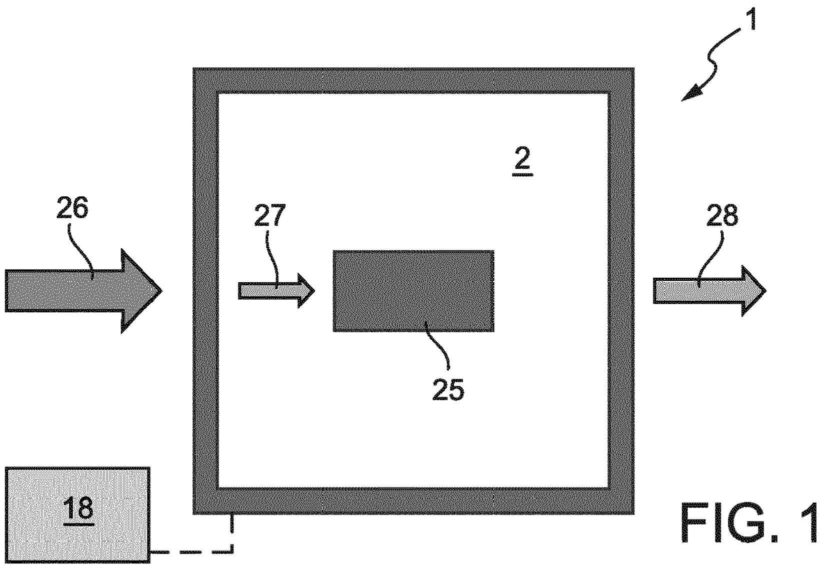

FIG. 1

EP 3 575 693 A1

Description

Cross-reference to related applications

[0001] This patent application claims priority from Italian patent application no. 102018000005863 filed on 30/05/2018.

Technical field

[0002] The technical field of application of the present invention relates to ovens, preferably domestic ovens, for the cooking of foods. More specifically, the technical field of the present invention relates to "electromechanically controlled" electrical supplied ovens, i.e. ovens provided with a cooking chamber or cavity in the walls of which electric resistances are embedded. As is known, once supplied by electric current, such resistances heat up and give off heat in the cooking cavity. For the purposes of the present invention, the term "oven" is understood to mean both built-in ovens and non-built-in ovens, i.e. free standing cookers, which are usually provided with an upper gas or induction cooking plane.

State of the art

[0003] Today, electrical supplied ovens for domestic use are commonplace. As said previously, such ovens comprise a cooking cavity or chamber delimited by a plurality of fixed walls and by a movable door, which selectively allows access to the cooking chamber, for the loading or removal of food and isolation of the cooking chamber, to create the correct cooking conditions. Every electrical supplied oven comprises an electric heating circuit provided with a plurality of resistances placed outside the cooking chamber, close to the walls thereof or embedded in the same. When supplied by electric current the resistances heat up and transfer heat to the food housed inside the cooking chamber. Parallel to the heating circuit, electrical supplied ovens also usually comprise a cooling circuit, for example, a cooling circuit provided with a fan. Such cooling circuit has the object of avoiding the excessive heating of the outer walls of the oven, whether it is built-in, to avoid damaging the recess, or not built-in, to prevent a user from touching the walls of the oven and burning himself/herself. Heating and cooling circuits are operable by users according to preset cooking programs and selectable as desired by special commands. A different actuation of the heating and cooling circuits corresponds to each cooking program. In fact, such heating and cooling circuits comprise switches or commutators, thermostats and timers capable of modifying the heating and cooling modes by isolating or supplying one or more electric resistances.

[0004] With reference to such electrical supplied ovens, the present invention deals with the problem concerning how to reduce the required energy consumption and thus how to comprise at least a special cooking program for operating the oven, which has the object of requiring reduced energy with respect to the remaining programs already currently available. Clearly, such cooking program with low energy consumption, definable in such sense "ECO" program, must also be able to guarantee the required cooking. Potential greater duration in terms of time of such cooking program is widely compensated by the beneficial energy saving effect. Furthermore, as will be apparent in the description of the embodiment of the present invention, the increase in terms of time of such "ECO" cooking program in absolute values is absolutely sustainable and acceptable.

[0005] From a thermodynamic point of view, by analyzing the cooking of foods in the cooking chamber, the energy supplied for such purpose, i.e. the electric energy converted into heat by the resistances, is only partially transferred to the foods during cooking. In fact, there is always a part of the heat, which, instead of being transferred to the food, is transferred to the surrounding environment. Such portion of heat, which does not therefore fulfil the object of cooking the food, can be considered, to all intents and purposes "wasted" energy.

[0006] The above can be mathematically schematizable in the following formula:

$$E_s = E_L + E_W$$

In such formula E_s indicates the total input energy supplied, E_L indicates the energy transferred to the food (energy supplied to the load) and E_W indicates the energy wasted. Since for the purposes of heating the food for a determined cooking time, the value E_L is not modifiable, the only way of reducing E_s is by reducing the value of E_W. In detail, E_W can be mathematically schematizable in the following formula:

$$E_W = \dot{Q}_W * t_L$$

In such formula t_L indicates the delivery time for the desired cooking and $\dot{Q}_W$ indicates the thermal "power" wasted, i.e. the energy wasted in the unit of time. $\dot{Q}_W$ can, in turn, be expressed as the multiplication of three factors, i.e. ΔT, the logarithmic average of the difference in temperature between the cooking chamber and the surrounding environment, which absorbs the wasted energy, K, the thermal transfer coefficient, and S, a surface through which the thermal exchange takes place. Thus, in detail, E_W can be mathematically schematizable in the following formula:

$$E_W = K * S * \Delta T * t_L$$

Since S is a non-modifiable geometric value, in order to reduce E_W, it is necessary to act on the factors ΔT and K.

Description of the invention

[0007] Starting from such prior art and from the thermodynamic analysis provided, it is an object of the present invention to realize an oven capable of offering an innovative cooking cycle or program (definable ECO or LOW POWER ECO), wherein, with respect to the remaining cycles, a reduced quantity of energy is wasted. In detail, it is an object of the present invention to realize an oven capable of offering an innovative cooking cycle, wherein the factor $K^* \Delta T$ is optimized in order to reduce the quantity of energy wasted.

[0008] According to such objects, the present invention relates to an electrical supplied oven comprising:

- a cooking cavity for housing the food to be cooked;
- an electric heating circuit associated with a cooking cavity and comprising a plurality of electric resistances configured to heat the cooking cavity when supplied by electric current; the electric heating circuit further comprises a plurality of switches configured to selectively isolate one or more resistances from the current supply;
- a first switch configured for selectively coupling each other, in series or in parallel, a first and a second electric resistance of the electric heating circuit;
- a control unit configured to control the switches (or the electric heating circuit in general) according to a plurality of different pre-set cooking programs.

[0009] According to the main aspect of the invention, the control unit is configured to execute a first cooking program, definable as ECO program since it has the object of minimizing the waste of generated thermal energy, wherein only the first and the second resistance of the electric heating circuit are supplied and the first switch is in a configuration for coupling each other in series the first and the second electric resistance.

[0010] Advantageously, in this way, the power delivered by the heating circuit is far less than the power, which would be generated in the configuration, in which the first and the second resistance are in parallel. Such reduced power is physically concretized in a smaller logarithmic average of the difference in temperature between the cooking chamber on heating and the surrounding environment. In fact, since the heating occurs more slowly (with reduced power), the difference in temperature between the cooking chamber and the surrounding environment is always contained, minimizing the factor ΔT of the following formula, which describes the thermal energy wasted.

$$E_W = K * S * \Delta T * t_L$$

[0011] Clearly, the single absolute values of the first and second resistance are dimensioned so that in the configuration in parallel, they do not exceed the maximum power sustainable by domestic users (usually 3KW), while in the configuration in series, they offer a minimum power, which is nonetheless sufficient to reach the desired cooking.

[0012] Furthermore, the power delivered must take into account the volume of the cooking cavity. A numerical example of the aforesaid constraints will be provided in the description of the embodiment.

[0013] Preferably, the oven further comprises an electric cooling circuit comprising a fan configured to cool the environment outside the cooking chamber. Such fan has the object of keeping the built-in structure of the oven in such temperatures as not to compromise the recess or to prevent the outer walls of the oven from reaching dangerous temperatures for the user of the oven. In particular, according to the present invention, the cooling circuit comprises a first and a second branch for supplying the fan and a second switch configured for selectively activating the first or the second branch. According to the invention, the second branch is provided with a thermostat for controlling the activation of the fan only when a determined temperature threshold value has been reached. During execution of the first cooking program, the second switch is in a configuration so that the fan is supplied by the second branch of the cooling circuit and thus it is activated with a delay with respect to the start-up of the first cooking program and only when a temperature threshold value is reached in the cooking cavity.

[0014] Such delayed start-up of the cooling circuit allows a reduction in the thermal transfer coefficient factor, which is schematized as *K* in the following formula.

$$E_W = K * S * \Delta T * t_L$$

[0015] Thus, the delayed start-up of the fan of the cooling circuit, in conjunction with the delivery of energy terminates with low power, reached with the switching in series of the first and the second resistance, allows a reduction in the $K^* \Delta T$ ratio and consequently a reduction in the amount of energy wasted. In the description of an embodiment of the invention, a comparative numerical analysis will also be described between the execution (with the same oven and conditions) of the innovative first ECO program and another traditional cooking program.

[0016] Furthermore, again for the purposes of reducing the factor *K*, the second branch of the cooling circuit can further comprise a motor resistance in order to reduce the power available for the fan.

Description of one embodiment of the invention

[0017] Further features and advantages of the present invention will be apparent from the following description of a non-limiting embodiment thereof, with reference to the figures of the accompanying drawings, wherein:

- - figure 1 is a schematic view of an electrical supplied oven, wherein the energy flows are shown;
- - figure 2 is a schematic view of an embodiment of an electric circuit for the oven in figure 1, wherein the circuit is configured to execute an ECO cooking program with low wasted energy;
- - figure 3 is a view of a control table of the electric circuit, which summarizes a plurality of different selectable cooking programs;
- - figures 4 and 5 are comparative tables of energy consumptions obtained by means of the execution, in one same oven, of the ECO program and another program indicated in the diagram in figure 2.

[0018] With reference to the aforesaid figures, figure 1 shows a schematic view of an oven 1 substantially limited to just the cooking chamber or cavity 2. As shown, food, schematized with reference 25, is housed inside this cooking chamber 2. The oven 1 is of the electric type, i.e. electric current is required to heat the food. In particular, the current is passed in an electric heating circuit provided with a plurality of electric resistances. As is known, the electric resistances heat up as the current passes and such heat is transferred to the cooking chamber in order to heat the food 25. As described in the introduction of the present description, only part of the electricity converted into heat by the resistances is transferred to the food 25 being cooked. In fact, there is always a part of the heat, which is transferred to the surrounding environment instead of being transferred to the food 25. Thus, such portion of heat does not fulfil the object of cooking the food and thus, this portion of heat can be considered to all intents and purposes "wasted" energy. The above is mathematically schematizable in the following formula:

$$E_s = E_L + E_W$$

In such formula E_s indicates the total input energy supplied, E_L indicates the energy transferred to the food (energy supplied to the load) and E_W indicates the energy wasted. In figure 1 reference 26 indicates the total energy supplied E_s ; reference 27 indicates the energy transferred to the food E_L while reference 28 indicates the energy wasted E_W.

[0019] Figure 2 shows a schematic view of an embodiment of the invention, i.e. an electric diagram, comprising a heating circuit 3, provided with a plurality of electric resistances 4-7 configured to heat the cooking chamber 2, and a cooling circuit 19 provided with a fan to cool the outer walls of the oven and/or the reception cavity walls of the cooking chamber 2. According to the example shown, the heating circuit 3 comprises a first 4, a second 5, a third 6 and a fourth resistance 7 respectively, which can be classified as sky resistance 4, circular resistance 5, grill resistance 6 and sole resistance 7. Both the configuration and the arrangement of such resistances are known to those skilled in the art and therefore such features will not be further described. The heating circuit 3 further comprises a plurality of switches 9-15 configured to selectively isolate one or the other resistance according to a plurality of pre-set cooking programs, selectable by the user. The table in figure 3 shows such plurality of cooking programs (A-I) wherein, a precise sequence of open or closed switches corresponds to each program. The switches indicated with X in the execution of the relative cooking program are understood to be closed and consequently allow the passage of electric current. In particular, according to the present invention, the heating circuit 3 comprises a first switch 16 configured for selectively placing the first 4 and the second resistance 5 between them, in series (when the switch 16 is closed), or in parallel. As is visible in the table in figure 3, such switch 16 is, in fact, only closed during the execution of the innovative ECO program of the present invention (program F in table in figure 3). Furthermore, during the execution of such program F, the other switches are controlled so as not to supply the remaining resistances. The effect of the execution of the program F is thus to bring the first 4 and the second resistance 5 in series, so as to generate on heating at low power, i.e. with reduced power with respect to the configuration with the first 4 and the second resistance 5 in parallel. In all the remaining cooking programs, the first 4 and the second resistance 5 are in parallel. For the sake of completeness, other components represented with references 29-34 are visible in the heating circuit 3 in figure 2. Such references refer to a fan 29 for ventilated cooking, a safety thermostat 30, an oven thermostat 31, an oven light 32, a warning light 33 and a programmable timer 34 respectively. Both the configuration and the arrangement of such components are known to experts skilled in the art and therefore, such features will not be further described.

[0020] As said previously, the electric diagram in figure 2 further comprises a cooling circuit 19 provided with a fan 20. As is visible, the cooling circuit 19 comprises two branches for supplying the fan, a first 21 and a second branch 22 respectively. A special switch 17 is present, which supplies the fan 20, when open, from the second branch 22. As can be seen in table in figure 3, the switch 17 is only open during the execution of the innovative ECO program indicated with F. In such conditions, the fan 20 is supplied along the branch 22, upstream of the fan, which comprises a thermostat 23 configured to delay the activation of the fan 20 until reaching a temperature threshold value. Without entering into the issue of the possible numerical value of such threshold and where the measurement point is located, certainly during the first steps of execution of the cooking program F, the fan is not in operation. Furthermore, between the thermostat 23 and the fan 20, the second branch 22 is provided with a motor resistance 24 so as to reduce the actuation power of the fan. As said previously, such delayed start-up of the cooling circuit allows a reduction in the transfer coefficient factor.

[0021] Finally, as confirmation of the effective efficacy of the present invention, figures 4 and 5 show comparative tables of the energy consumption according to the standard EN60350-1 on the same oven sample in two different cooking programs; the ECO program indicated with F in figure 3 and the Ring program indicated with I in figure 3 respectively. This comparative test shows that with the same EL (energy transferred to the load), the quantity ES (energy supplied to the appliance and thus wasted) is reduced by 20% (from 840Wh to 679Wh) even though the duration of the test has been extended from 44 to 56 minutes.

[0022] Clearly, also the dimensioning of the first and second resistance must take into account the fact that in the configuration in parallel, the maximum power sustainable by domestic users is not exceeded (usually 3KW), while in the configuration in series, a minimum power is offered, which is nonetheless sufficient for reaching the desired cooking.

[0023] Tests carried out by the Applicant have allowed the identification of the upper and lower threshold values of the ratio between the generated thermal power in KW and a factor dividing in dm^3 depending on the volume of the cooking cavity. Within such thresholds there is an appreciable energy saving without precluding the good result of the cooking. In the embodiment shown and in relation to the accompanying tables, such threshold values are schematizable in the following formula:

$$0{,}5 \leq \frac{\dot{P}_S}{0{,}0042 * V + 0{,}55} \leq 1{,}5$$

In such formula $\dot{P}_S$ indicates the electricity supplied in KW while V indicates the volume of the cooking cavity in dm^3.

[0024] Lastly, it is clear that modifications and variations may be made to the invention described herein without departing from the scope of the appended claims.

Claims

1. An electrical supplied oven (1) comprising:

   - a cooking cavity (2);
   - an electric heating circuit (3) associated with the cooking cavity and comprising a plurality of electric resistances (4, 5, 6, 7), configured to heat the cooking cavity (2) when supplied by electric current, and a plurality of switches (8-16) configured for selectively isolating one or more resistances (4, 5, 6, 7) from the electric heating circuit (3) ;
   - a first switch (16) configured for selectively coupling each other a first and a second electric resistance (4, 5) of the electric heating circuit (3) in series or in parallel;
   - a control unit (18) configured for controlling the switches (8-16) according to a plurality of different selectable cooking programs (A-I);

   wherein the control unit (18) is configured for performing a first cooking program (F), wherein only the first (4) and the second resistance (5) are supplied and the first switch (16) is in a configuration for coupling each other in series the first and the second electric resistance (4, 5).

2. The oven as claimed in claim 1, wherein during the execution of all remaining cooking programs (A-E, G-I) the first switch (16) is in a configuration for coupling each other in parallel the first and the second electric resistance (4, 5) .

3. The oven as claimed in claim 1 or 2, wherein the electric heating circuit (3) is configured so that, during the execution of the first cooking program (F), the ratio between the generated thermal power in KW and a factor dividing in dm3, depending on the volume of the cooking cavity (2), is comprised between a lower threshold value and an upper threshold value.

4. The oven as claimed in any one of the preceding claims, wherein the oven further comprises an electric cooling circuit (19) comprising a fan (20) configured for cooling the environment outside the cooking cavity (2), the cooling circuit (19) comprising a first (21) and a second branch (22) for supplying the fan (20) and a second switch (17) for selectively activating the first (21) or the second branch (22), the second branch (22) being provided with a thermostat (23) for controlling the activation of the fan (20) only when a temperature threshold value has been reached; wherein the control unit (18) is configured so that during the execution of the first cooking program (F), the second switch (17) is in a configuration so that the fan (20) is supplied by the second branch (22) of the electric cooling circuit (19).

5. The oven as claimed in claim 4, wherein during the execution of all remaining cooking programs (A-E, G-I), the second switch (17) is in a configuration so that the fan (20) is supplied by the first branch (21) of the cooling circuit (19).

6. The oven as claimed in claim 4 or 5, wherein the second branch (22) of the cooling circuit (19) further comprises a motor resistance (24).

7. A method for operating an electrical supplied oven, wherein the method comprises the steps of:

   a) providing an oven (1) as claimed in claim 1;
   b) supplying the electric heating circuit (3);

c) controlling the switches (8-16) for executing a first cooking program (F), wherein only the first and the second resistance (4, 5) are supplied and the first switch (16) is in a configuration so that the first and the second electric resistance (4, 5) are coupled in series.

8. The method as claimed in claim 7, wherein the method comprises the steps of:

d) providing an oven (1) as claimed in claim 4;
e) supplying the electric cooling circuit (19);
f) controlling the second switch (17) so that during the execution of the first cooking program (F), the fan (20) is supplied by the second branch (22) of the electric cooling circuit (19).

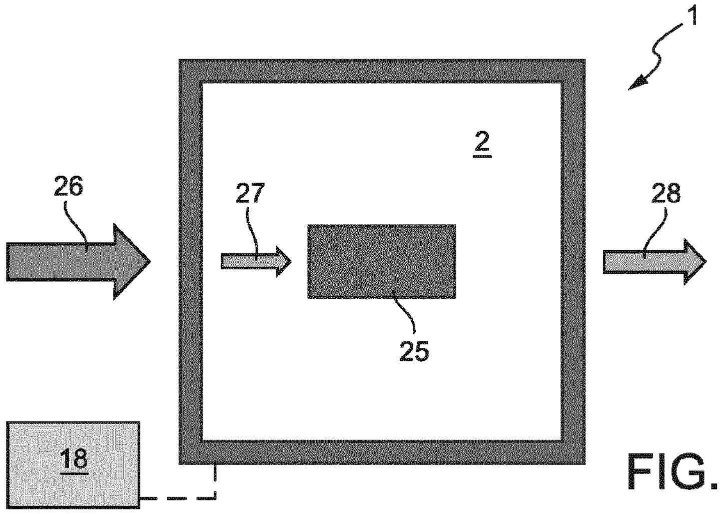

FIG. 1

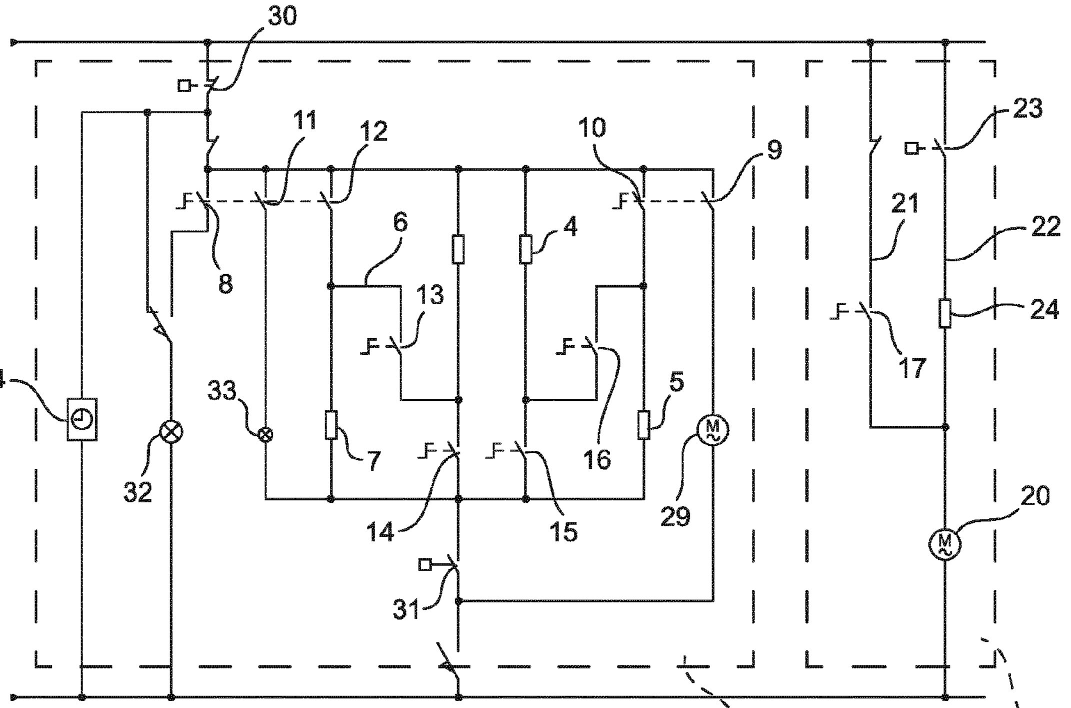

FIG. 2

POS	8	9	10	11	12	13	14	15	16	17
A										
B	●			●	●			●		●
C	●			●			●	●		●
D	●			●	●					●
E	●	●	●	●		●				●
F		●		●					●	
G	●	●		●	●			●		●
H	●	●		●			●	●		●
I	●	●	●	●						●

FIG. 3

Heating function:	Forced air heating "if"					Low power ECO mode 720W				nominal temperature rise:		155 K			
bricks								measured		room	oven temperature				
no.	dry weight m_d (g)	wet weight m_w (g)	absorbed water Δm (g)	end cooking weight (informative) (g)	weight loss (informative) (g)	start temperatures thermocouple no. 1 (°C)	start temperatures thermocouple no. 2 (°C)	energy consumption E_k (kWh)	time t_k (min)	average ambient temp. (°C)	nominal value ΔT^{if} (K)	real value (°C)	real value Δtif (K)	setting T_{ks}^{if} (°C)	temperature difference $\Delta T_{k,setting}^{if}$ (K)
84	920	1945	1025	1829	116	4,6	4,7	0,677	55,0	23,0	***135±10***	159	136	160	1
82	922	1963	1041	1846	117	5,0	4,8	0,685	57,0	24,0	***155±10***	183	159	180	-3
89	926	1947	1021	1836	111	4,8	4,9	0,676	55,0	23,0	***175±10***	200	177	200	0
Results at ΔT_0 =	**155 K**			**S * ΔT_0 + B**			**Slope S**		**Intercept B**		**Standard deviation σ**			**$\Delta T_{setting}^{if}$ ≤ 20 K**	
Energy (linear regression)			(kWh)	**0,679**			-0,00001		0,68051		**0,008**			**-0,7**	
Time (linear regression)			(min)	**55,7**			0,00		55,05		**1,95**			**o.k.**	

FIG. 4

Heating function:	Forced air heating "if"					Ring Heating mode 2000W				nominal temperature rise:		155 K			
bricks								measured		room	oven temperature				
no.	dry weight m_d (g)	wet weight m_w (g)	absorbed water Δm (g)	end cooking weight (informative) (g)	weight loss (informative) (g)	start temperatures thermocouple no. 1 (°C)	start temperatures thermocouple no. 2 (°C)	energy consumption E_k (kWh)	time t_k (min)	average ambient temp. (°C)	nominal value ΔT^{if} (K)	real value (°C)	real value Δtif (K)	setting T_{ks}^{if} (°C)	temperature difference $\Delta T_{k,setting}^{if}$ (K)
85	911	1993	1082	1839	154	5,8	5,7	0,789	46,0	24,0	***135±10***	162	138	160	-2
76	923	1954	1031	1791	163	5,4	5,4	0,850	43,0	23,0	***155±10***	182	159	180	-2
85	911	1989	1078	1809	180	5,2	5,2	0,910	41,0	23,0	***175±10***	200	177	200	0
Results at ΔT_0 =	**155 K**			**S * ΔT_0 + B**			**Slope S**		**Intercept B**		**Standard deviation σ**			**$\Delta T_{setting}^{if}$ ≤ 20 K**	
Energy (linear regression)			(kWh)	**0,840**			0,00310		0,36032		**0,004**			**-1,3**	
Time (linear regression)			(min)	**43,7**			-0,13		63,65		**0,30**			**o.k.**	

FIG. 5

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EUROPEAN SEARCH REPORT

Application Number
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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
The Hague	19 September 2019	Fest, Gilles

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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A : technological background
O : non-written disclosure
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T : theory or principle underlying the invention
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& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

page 1 of 2

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EUROPEAN SEARCH REPORT

Application Number
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The present search report has been drawn up for all claims

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page 2 of 2

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO.

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