

(19)



(11)

EP 3 361 199 A1

(12)

EUROPEAN PATENT APPLICATION

(43) Date of publication:
15.08.2018 Bulletin 2018/33

(51) Int Cl.:
F27B 3/20 (2006.01) F27D 99/00 (2010.01)

(21) Application number: **17020049.7**

(22) Date of filing: **09.02.2017**

(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:
MA MD

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(54) METHOD AND SYSTEM FOR HEATING A FURNACE

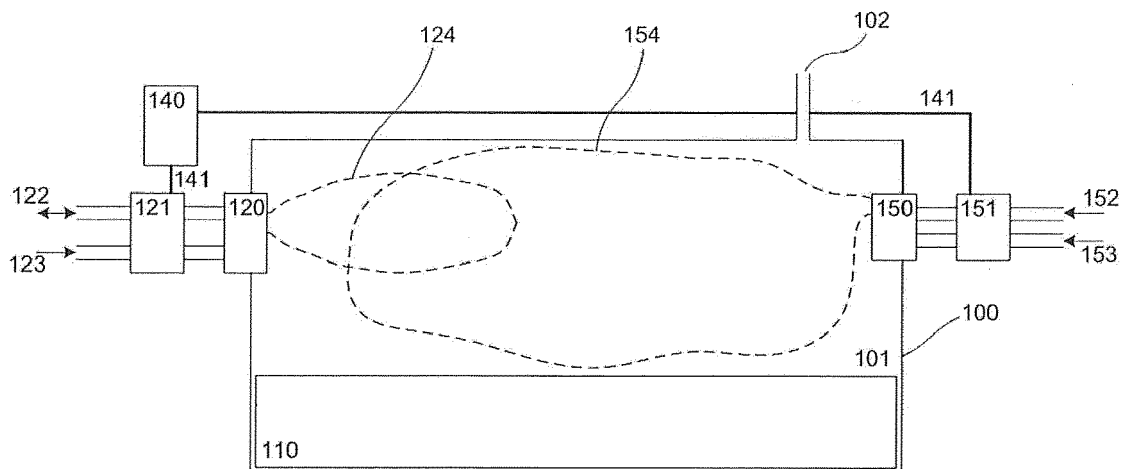
(57) Method for operating a melting furnace (100) for a metal material (110), which furnace (100) comprises a heated space (101) being heated by at least one pair of two alternately operated regenerative burners (120,130).

The invention is characterised in that the method comprises the steps

a) providing an additional burner (150) for heating the melting furnace (100), which additional burner (150) is arranged for heating the said space (101) by combusting

a fuel using an oxidant comprising at least 80% by weight oxygen; and

b) controlling the additional burner (150) in a manner which is time synchronized with the operation of the said pair of regenerative burners (120,130), so that the additional burner (150) is operated with a higher power during a transition period when none of the regenerative burners (120,130) of said pair is fired, as compared to during a firing period when one of the regenerative burners (120,130) of said pair is fired but not the other.



Figur 1

Description

[0001] The present invention relates to a method and a system for heating an industrial furnace, in particular for heating a furnace for melting of a metal material such as aluminium.

[0002] Today, regenerative burners are used for heating melting furnaces. Such burners typically operate alternately, such as in pairs. While a first burner is being fired, hot combustion products leave through a different, second burner, thereby heating material in the second burner. Thereafter, the process is reversed, so that the second burner is fired and delivers a fuel and/or oxidant which is preheated by said heated material. At the same time, the combustion products leave via the first burner, which is thereby heated. Thereafter, the process is reversed again, hence creating a periodically repeated process in which the thermal energy of the combustion products is used to preheat combustion gases.

[0003] Herein, the term "combustion gases" denote a fuel and/or an oxidant to be reacted in an exothermal reaction. "Combustion products" denote the reaction products of such exothermal reaction.

[0004] The use of such regenerative burners yields good efficiency in general. However, there is also a problem in that the heating power is reduced during the required transition time, during a switch between the first and the second burner, or vice versa. This leads to uneven heating temperatures with resulting quality problems and deteriorated efficiency.

[0005] Also, during such a transition the furnace atmosphere turbulence decreases, which means that the convective heat transfer to the metal material fluctuates, which is not desired for similar reasons.

[0006] Especially for aluminium melting, there are further specific circumstances to take into consideration. For instance, the protective skim formed on the surface of the melt typically contains drops of pure aluminium, that risk oxidizing rapidly when subjected to too powerful heating, in turn leading to material quality deterioration.

[0007] WO 2016/070977 A1 discloses a solution based upon oxygen enrichment during the switch between different air burners in a similar setup.

[0008] US 2016/0348904 A1 discloses a method for improving internal flows in a regenerative burner-heated furnace, using an oxyfuel burner.

[0009] The present invention solves the above described problems, for many different metal materials but in particular for aluminium.

[0010] Hence, the invention relates to a method for operating a melting furnace for a metal material, which furnace comprises a heated space being heated by at least one pair of two alternately operated regenerative burners, which method is characterised in that the method comprises the steps a) providing an additional burner for heating the melting furnace, which additional burner is arranged for heating the said space by combusting a fuel using an oxidant comprising at least 80% by weight ox-

xygen; and b) controlling the additional burner in a manner which is time synchronized with the operation of the said pair of regenerative burners, so that the additional burner is operated with a higher power during a transition period when none of the regenerative burners of said pair is fired, as compared to during a firing period when one of the regenerative burners of said pair is fired but not the other.

[0011] Moreover, the invention relates to a system for heating a melting furnace for a metal material, which furnace comprises a heated space, which system comprises at least one pair of two regenerative burners, arranged to be fired alternately, which system is characterised in that the system further comprises an additional burner for heating the melting furnace, which additional burner is arranged for heating the said space by combusting a fuel using an oxidant comprising at least 80% by weight oxygen, and in that the system further comprises a control device arranged to control the additional burner in a manner which is time synchronized with the operation of the said pair of regenerative burners, so that the additional burner is operated with a higher power during a transition period when none of the regenerative burners of said pair is fired, as compared to during a firing period when one of the regenerative burners of said pair is fired but not the other.

[0012] In the following, the invention will be described in detail, with reference to exemplifying embodiments of the invention and to the enclosed drawings, wherein:

Figure 1 is a simplified top view of a furnace with a system according to the present invention;

Figure 2 is a simplified side view, using the same reference numerals, of the furnace and the system of Figure 1;

Figure 3 is a time chart showing a first exemplifying operation according to a method according to the present invention; and

Figure 4 is a time chart showing a second exemplifying operation according to a method according to the present invention.

[0013] Figures 1 and 2 show an industrial furnace 100, in which a system according to the invention has been installed. Preferably, such a system may be post-installed, in other words added to an existing furnace 100 with an existing regenerative burner-based heating system, yielding the advantages described herein for such an existing furnace. Such post-installation provides a very cost-efficient way of obtaining such advantages.

[0014] The furnace 100 comprises a heated space 101, which is heated by at least one pair of regenerative burners 120, 130 (see both Figure 1 and Figure 2). In the Figures, only one such pair is shown. However, it is realized that several such pairs can be used, working cooperatively in an analogous manner. It is even possible that more than two, such as three or more, regenerative burners are operated cooperatively and interchangingly

by taking turns being fired in various constellations. Hence, in general installed regenerative burners are operated alternately within one or several groups of burners, where the furnace 100 may comprise one or several such groups. 124, 134 denote respective flames from burners 120, 130.

[0015] In general, such regenerative burners operate alternately, so that during a firing period at least one of a group of regenerative burners is fired, providing a mixture of combustion gases for combustion and heating the space 101, while combustion products are evacuated through the non-firing burner or burners of the same and/or a different group. The evacuated combustion products, being hot, heat a suitable material body in the burner or burners through which they are evacuated.

[0016] Then, during a transition period, the fired burner is switched off, and one or several burners through which the combustion products were evacuated are started up for firing. Since the evacuation and the firing involves a certain kinetic energy in the flowing gas mass, this transition is not instantaneous, but typically takes a number of seconds. Once finished, another firing period commences, involving a different one or several of the group of burners being fired, and combustion products are evacuated through the burner or burners that were originally not firing. Then, another transition period is commenced, and the process iterates repeatedly as long as heating of the space 101 is desired.

[0017] This way, the combustion gases are preheated by their flow through the heated burner material body, and thermal losses are kept to a minimum.

[0018] In the Figures, an exemplifying configuration is illustrated, in which preheated combustion primary oxidant is fed via lines 122, 132, which same line is used to evacuate combustion products when the burner 120, 130 in question is not fired. A primary fuel is fed via lines 123, 133. A control device 140 is used to achieve the regenerative operation, via control lines 141.

[0019] The furnace 100 also comprises a flue 102, arranged to evacuate excess gases.

[0020] According to the invention, a method for operating the melting furnace 100 comprises the step of providing, in addition to the existing burners 120, 130, an additional burner 150, also for heating the space 101 of the furnace 101, which additional burner is arranged for heating the said space 101 by combusting a fuel using a secondary oxidant comprising at least 80% by weight oxygen. More preferably, the secondary oxidant comprises at least 95% by weight oxygen, and is preferably industrially pure oxygen. The secondary oxidant is provided via a line 152, while the secondary fuel is provided via a line 153.

[0021] Then, the said method comprises the step of controlling the additional burner 150 in a manner which is time synchronized with the operation of the pair of regenerative burners 120, 130, so that the additional burner 150 is operated with a higher power during the above-described transition period, when none of the regenera-

tive burners 120, 130 of said pair is fired, as compared to during a firing period of the above-described type, when one of the regenerative burners 120, 130 of said pair is fired but not the other.

[0022] This way, the heating power of the furnace 100 space 101 as a whole can be made more even, which leads to more even quality in terms of end products, as well as to increased energy efficiency. Because of the high oxygen content of the secondary oxidant, the volume of additional combustion products resulting from the additional burner 150 is small, making it possible to evacuate the excess gases via the normal flue 102, which flue is typically not of high capacity in relation to the total furnace 100 capacity. This, in turn, makes it possible to install a system according to the invention with a minimum of modifications to an existing furnace 100.

[0023] Preferably, the furnace 100 is a melting furnace for a metal material 110, which preferably is selected from the group comprising aluminium, copper, iron and alloys thereof. However, according to a preferred embodiment, the metal material is aluminium. In particular for this material, the problem of excessive oxidation mentioned initially may be efficiently solved using the present invention, in particular when using the below described high secondary oxidant injection speeds.

[0024] In particular, the invention is useful for the melting of aluminium ingots and/or scraps, especially in a reverberatory furnace.

[0025] Preferably, the pair of regenerative burners 120, 130 are air burners. In other words, the primary oxidant is preferably air. The primary oxidant may also be oxygen-enriched air, or any other oxidant preferably comprising at the most 50% by weight oxygen. The primary fuel is preferably a gaseous fuel, but may also be a powder-form fuel, such as charcoal powder, or even a liquid fuel such as oil.

[0026] The additional burner 150 is preferably fed with a secondary fuel, such as a gaseous fuel, which is then preferably injected in a jet located at a distance of at least 5 cm from a jet of secondary oxidant, so that the secondary fuel and secondary oxidant jets do not mix until they have travelled some ways, such as at least 50 cm, out into the space 101 from the additional burner 150. Preferably, the said secondary fuel jet directed at an angle parallel to or divergent from the closest secondary oxidant. If there are several secondary fuel and/or oxidant jets, the corresponding preferably applies to such jets pairwise. This provides good results in terms of turbulence, convection and temperature evenness during operation of the additional burner 150.

[0027] This is particularly true in, although not necessarily dependent upon, the preferred case in which the secondary oxidant is injected in a jet of very high velocity, such as preferably at least Mach 1, even more preferably at least Mach 1.5. Such high injection velocities of the secondary oxidant provide a very strong turbulence in the space 101, and a heavy dilution of the combustion gases and products therein, in effect providing a "flame-

less" combustion, wherein the flame 154 of the additional burner 150 substantially fills the entire space 101 above the material 110. This way, a very good convective heat transfer, as well as temperature homogeneity, is achieved throughout the transition period. This is true even with the small total volumes of added secondary oxidant needed when the secondary oxidant is of the above-described high-oxygen types.

[0028] Preferably, the said alternating operation of the regenerative burners 120, 130 is periodic, with transition periods of type described above between each regenerative burner 120, 130 switch. It is realized that there is at least one transition period between the firing of the first burner 120 and the firing of the second burner 130, and another transition period between the firing of the second burner 130 and the firing of the first burner 120, before a full cycle comes to a close. Then, it is preferred that the transition periods constitute between 5% and 20%, preferably about 10%, of the total time as seen over a whole regenerative burner pair 120, 130 alternating operation cycle.

[0029] In particular, it is preferred that each of the said transition periods is between 1 and 5 seconds, preferably about 2 seconds, of length. Similarly, it is preferred that each firing period is between 10 and 40 seconds, preferably between 15 and 30 seconds, preferably about 20 seconds, of length.

[0030] Even though a 2 second transition period does not seem that long, it has a quite noticeable impact on the thermal properties of the space 101, substantially not receiving any, or only a limited, thermal impulse from the burners 120, 130 during the transition period. In fact, it has turned out that improved end results and thermal efficiencies can be noted when using an additional burner 150 even for such short transition periods.

[0031] The maximum power of the one or several additional burners 150 arranged to compensate a certain set of regenerative burners 120, 130 is preferably between 10% and 50% of the total firing power of the compensated regenerative burners 120, 130 in question.

[0032] According to a preferred embodiment, the said synchronization is achieved by the control system 140, which is operative for controlling the additional burner 150, being arranged to respond to a control signal directed to at least one of the regenerative burners 120, 130. Hence, the present invention may be realized as a post-installation by modifying an existing control system 140 for the existing regenerative burners 120, 130, by adding a module controlling the additional burner 150, which added module may read or depend upon an existing control signal emitted from the existing control system 140. The added module may be installed by the existing control system 140, by the additional burner 150, or in any other convenient logical or spacial location.

[0033] The additional burner 150 may start upon the same signal that initiates the regenerative burner 120, 130 in question, and may end when the regenerative burner 120, 130 in question has reached full firing power

or after a predetermined time period.

[0034] Even though the additional burner 150, in simple implementations, may be operated using a strict on/off regulation, according to a very preferred embodiment, during the firing period the additional burner 150 is instead operated at a power which is not zero. Rather, during each firing period, the additional burner 150 power is reduced to a value which is smaller than a global maximum power value for the additional burner 150 during a transition period, preferably at least 10 times smaller than such a maximum value. Since the additional burner 150 is already fired during the firing period, but at a substantially lower power, it can be brought up to a desired transition period power very quickly, while still not adversely affecting the process during the firing period.

[0035] Figure 3 shows a first preferred embodiment of the control methodology of the additional burner 150, in which the additional burner 150 is operated according to a periodic regulation in which the additional burner 150 power is switched between a low P0 and a high P1 power, where the high power is used during the transition periods and the low power is used during the firing periods. Figure 3 also shows the firing patterns, as a function of the same time axis as used for the additional burner 150, of the regenerative burners 120, 130, as well as an exemplifying transitional period T and an exemplifying firing period F. As is clear from Figure 3, the additional burner 150 very rapidly, even substantially instantaneously (as compared to the more slowly changing power of the burners 120, 130), goes from low P0 to high P1 power, and vice versa. This provides for a simple yet efficient regulation regime.

[0036] However, Figure 4, which is similar to Figure 3, illustrates an alternative additional burner 150 regulation implementation. According to this regulation regime, during each transitional period, the additional burner 150 is operated at a power which first increases relatively rapidly, such as from P0 to P1, and thereafter decreases relatively slowly, such as from P1 back to P0, during one and the same transitional period. This way, and as illustrated in Figure 4, the varying power of the additional burner 150 can be designed to counteract the non-instantaneous power variations of the regenerative burners 120, 130, leading to a very even temperature homogeneity in the space 101 across time.

[0037] In addition to improving the temperature homogeneity and providing the other advantages described above, the additional burner 150 may also be used as a range extender for the total furnace 100 power capacity. Hence, according to a preferred embodiment, the method of the invention further comprises the step of using the additional burner 150, in addition to the regenerative burners 120, 130, to temporarily increase the maximum power of the furnace 100. This may, for instance, be the case during startup of the furnace 100 or in connection to charging of more metal material.

[0038] A system according to the invention comprises, according to a first aspect, both the additional burner 150,

the regenerative burners 120, 130 as well as the control system.

[0039] According to an alternative aspect, a system according to the invention comprises the additional burner 150 and that part of the control system 140 which is operative for controlling the additional burner 150. This alternative aspect is particularly suitable for post-installations as described above.

[0040] Above, preferred embodiments have been described. However, it is apparent to the skilled person that many modifications can be made to the disclosed embodiments without departing from the basic idea of the invention.

[0041] For instance, there may be more additional burners installed than the one additional burner 150 shown.

[0042] Also, the furnace 100 is shown in a very simplified way. It may comprise many different features that are as such conventional, such as various baffles, constrictions or gas passages; additional heating arrangements; doors; transport devices, and so forth.

[0043] In general, everything which is said above regarding the method according to the present invention is equally applicable to the system according to the present invention, and vice versa.

[0044] Hence, the invention is not limited to the described embodiments, but can be varied within the scope of the enclosed claims.

Claims

1. Method for operating a melting furnace (100) for a metal material (110), which furnace (100) comprises a heated space (101) being heated by at least one pair of two alternately operated regenerative burners (120,130), **characterised in that** the method comprises the steps

a) providing an additional burner (150) for heating the melting furnace (100), which additional burner (150) is arranged for heating the said space (101) by combusting a fuel using an oxidant comprising at least 80% by weight oxygen; and

b) controlling the additional burner (150) in a manner which is time synchronized with the operation of the said pair of regenerative burners (120,130), so that the additional burner (150) is operated with a higher power during a transition period when none of the regenerative burners (120,130) of said pair is fired, as compared to during a firing period when one of the regenerative burners (120,130) of said pair is fired but not the other.

2. Method according to claim 1, **characterised in that** the metal material (110) is selected from the group

comprising aluminium, copper, iron and alloys thereof, and is preferably aluminium.

3. Method according to claim 1 or 2, **characterised in that** the pair of regenerative burners (120,130) are air burners.
4. Method according to any one of the preceding claims, **characterised in that** said alternating operation of the said regenerative burners (120,130) is periodic, with transition periods of said type between each regenerative burner (120,130) switch, and **in that** said transition periods constitute between 5% and 20% of the total time as seen over a whole regenerative burner (120,130) pair alternating operation cycle.
5. Method according to claim 4, **characterised in that** each of the said transition periods is between 1 and 5 seconds, preferably about 2 seconds.
6. Method according to claim 4 or 5, **characterised in that** each firing period is between 10 and 40 seconds, preferably between 15 and 30 seconds, preferably about 20 seconds.
7. Method according to any one of the preceding claims, **characterised in that** said synchronization is achieved by a control system (140) for the additional burner (150) being arranged to respond to a control signal directed to at least one of the regenerative burners (120,130).
8. Method according to any one of the preceding claims, **characterised in that**, during the said firing period, the additional burner (150) is operated at a power which is not zero.
9. Method according to any one of the preceding claims, **characterised in that**, during the said transitional period, the additional burner (150) is operated at a power which first increases relatively rapidly, and thereafter decreases relatively slowly, during one and the same transitional period.
10. Method according to any one of the preceding claims, **characterised in that** said oxidant, during the transitional period, is injected into the heated space (101) at a velocity of at least Mach 1.
11. Method according to any one of the preceding claims, **characterised in that** the method further comprises the step of using the additional burner (150), in addition to the regenerative burners (120,130), to temporarily increase the maximum power of the furnace.
12. System for heating a melting furnace (100) for a met-

al material, which furnace (100) comprises a heated space (101), which system comprises at least one pair of two regenerative burners (120,130), arranged to be fired alternately, **characterised in that** the system further comprises an additional burner (150) for heating the melting furnace (100), which additional burner (150) is arranged for heating the said space (101) by combusting a fuel using an oxidant comprising at least 80% by weight oxygen, and **in that** the system further comprises a control device (140) arranged to control the additional burner (150) in a manner which is time synchronized with the operation of the said pair of regenerative burners (120,130), so that the additional burner (150) is operated with a higher power during a transition period when none of the regenerative burners (120,130) of said pair is fired, as compared to during a firing period when one of the regenerative burners (120,130) of said pair is fired but not the other.

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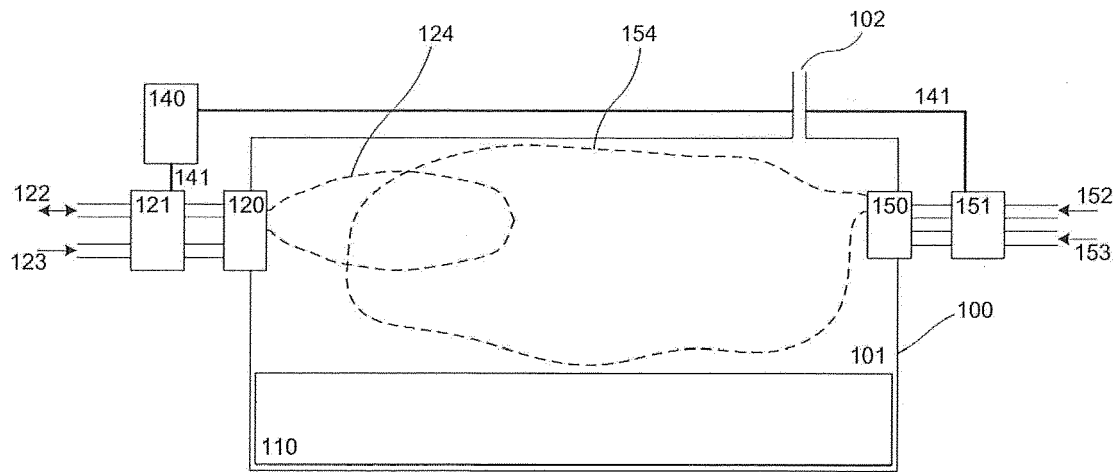
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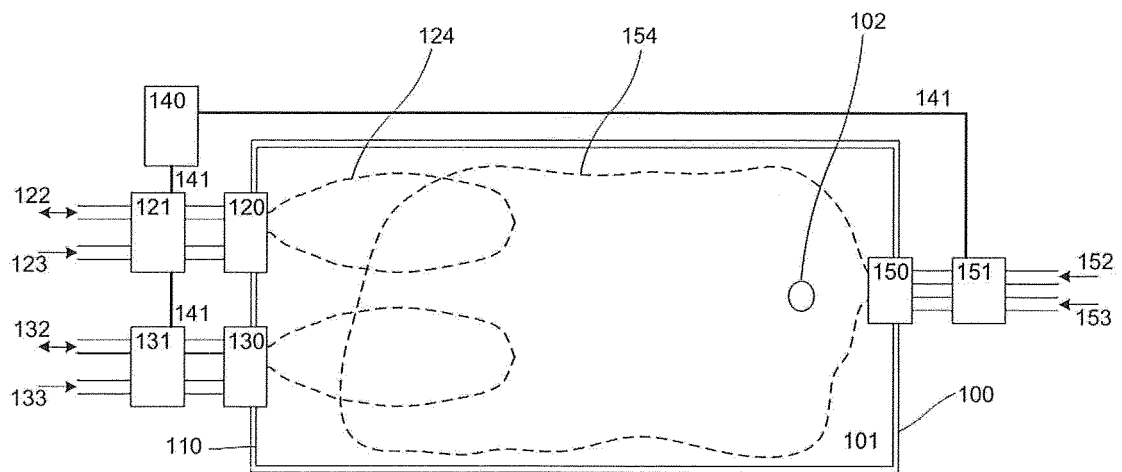
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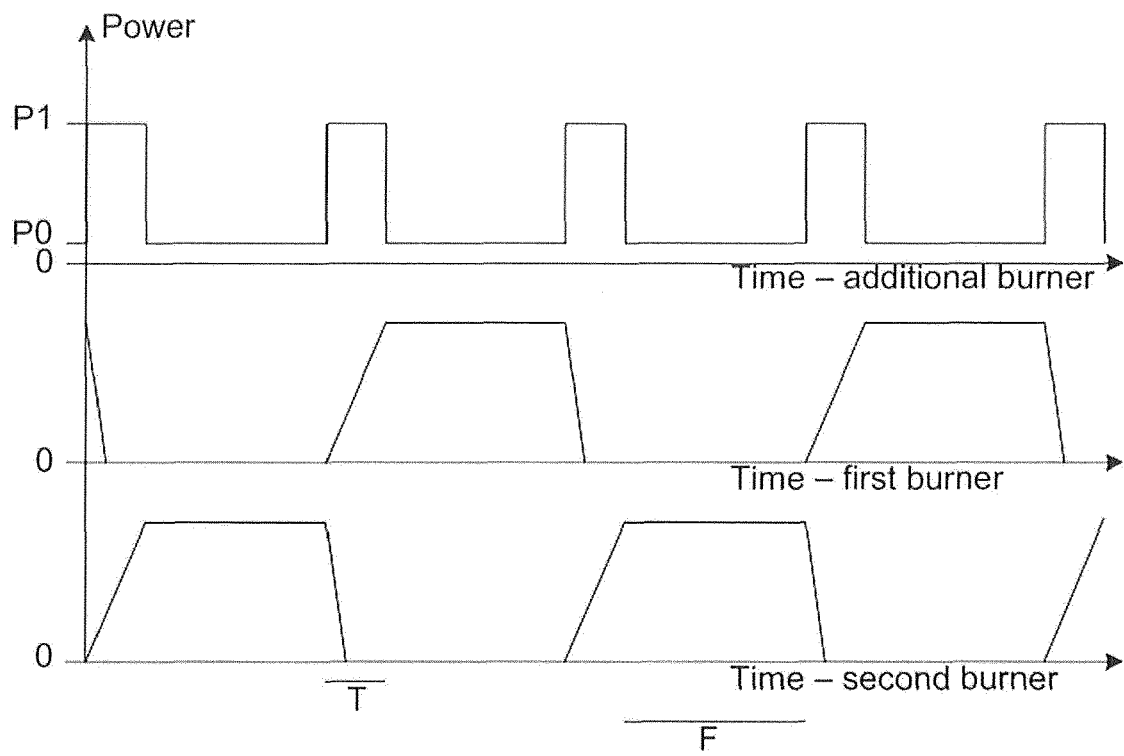
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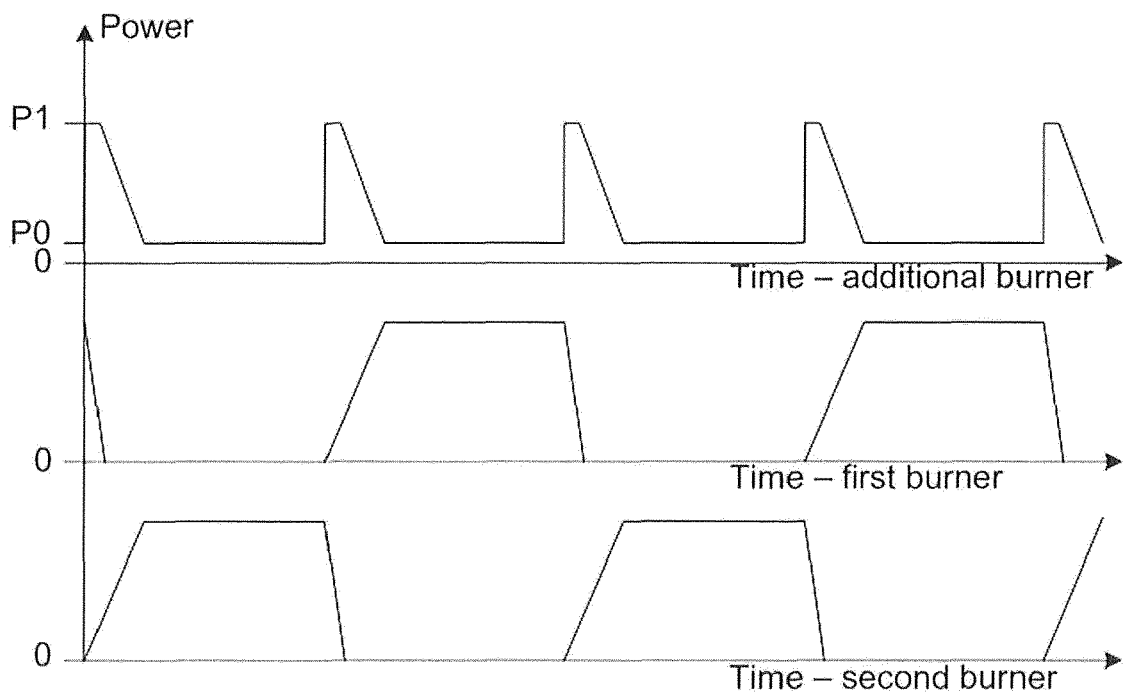
Figur 1



Figur 2



Figur 3



Figur 4



EUROPEAN SEARCH REPORT

Application Number
EP 17 02 0049

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DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	GB 2 525 942 A (LINDE AG [DE]) 11 November 2015 (2015-11-11)	12	INV. F27B3/20 F27D99/00
Y	* paragraphs [0022], [0024], [0025], [0026], [0042], [0043], [0047], [0048], [0050]; claims 1,4-7; figures 1,2 *	1-11	
X	US 2007/006681 A1 (ROBERTSON THOMAS F [US] ET AL) 11 January 2007 (2007-01-11)	12	
Y	* paragraphs [0002], [0011], [0012], [0015] - [0018], [0019] - [0021]; claims 1,6; figures 1,2 *	1-11	
Y	US 2013/091898 A1 (MIETH RAINER [DE] ET AL) 18 April 2013 (2013-04-18) * paragraph [0056]; claims 1-8; figures 1-3 *	1	
Y	US 2010/291493 A1 (JARRY LUC [US]) 18 November 2010 (2010-11-18) * paragraphs [0011], [0023] - [0028] *	1	TECHNICAL FIELDS SEARCHED (IPC)
A	EP 3 098 512 A1 (AIR PROD & CHEM [US]) 30 November 2016 (2016-11-30) * the whole document *	1-12	F27B F27D
A	WO 2016/168099 A1 (PRAXIR TECH INC [US]) 20 October 2016 (2016-10-20) * the whole document *	1-12	
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 3 August 2017	Examiner Gavriliu, Alexandru
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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ON EUROPEAN PATENT APPLICATION NO.**

EP 17 02 0049

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This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
GB 2525942 A	11-11-2015	NONE	
US 2007006681 A1	11-01-2007	EP 1960559 A2	27-08-2008
		US 2007006681 A1	11-01-2007
		US 2008191396 A1	14-08-2008
		US 2009020051 A1	22-01-2009
		WO 2007008420 A2	18-01-2007
US 2013091898 A1	18-04-2013	BR 102012008250 A2	04-06-2013
		CN 102730937 A	17-10-2012
		KR 20120115158 A	17-10-2012
		US 2013091898 A1	18-04-2013
		US 2013180289 A1	18-07-2013
US 2010291493 A1	18-11-2010	BR PI0615084 A2	03-05-2011
		CA 2619681 A1	01-03-2007
		CN 101253367 A	27-08-2008
		EP 1920192 A1	14-05-2008
		FR 2890155 A1	02-03-2007
		JP 5097958 B2	12-12-2012
		JP 2009506290 A	12-02-2009
		US 2010291493 A1	18-11-2010
		WO 2007023238 A1	01-03-2007
EP 3098512 A1	30-11-2016	BR 102016011626 A2	29-11-2016
		CA 2930950 A1	26-11-2016
		CN 106197009 A	07-12-2016
		EP 3098512 A1	30-11-2016
		KR 20160138915 A	06-12-2016
		TW 201641907 A	01-12-2016
		US 2016348970 A1	01-12-2016
WO 2016168099 A1	20-10-2016	US 2016305656 A1	20-10-2016
		WO 2016168099 A1	20-10-2016

EPO FORM P0459

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

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- WO 2016070977 A1 [0007]
- US 20160348904 A1 [0008]