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(54) Title: METHOD AND APPARATUS FOR THE HOMOGENEOUS OXIDATION OF A FUEL

(57) Abstract: Method for the homogeneous oxidation from a main burner of a fuel, wherein combustion air and hot flue gases, that in an initial stage originate from an auxiliary burner, are mixed with the fuel in a combustion chamber, whereby a mixture is formed with a temperature above the auto-ignition temperature of the fuel, and wherein the hot flue gases at least in the initial stage originate at least partly from the auxiliary burner and in that the hot flue gases originating from the auxiliary burner and the combustion air are fed into the combustion chamber through separate inlets, and apparatus for carrying out this method.

METHOD AND APPARATUS FOR THE HOMOGENEOUS OXIDATION OF A FUEL

The invention relates to a method for the homogeneous oxidation from a main burner of a fuel, wherein combustion air and hot flue gases, that in an initial stage originate from an auxiliary burner, are mixed with the fuel in a combustion chamber, whereby a mixture is formed with a temperature above the auto-ignition temperature of the fuel. This homogeneous oxidation is almost invisible to the naked eye and is therefore also referred to as flameless combustion.

Such an apparatus is known from for example DE 198 60 636 A1. In this document a burner apparatus is described for the homogeneous oxidation of fuel, wherein the hot flue gases from the auxiliary burner are premixed with the combustion air and this premixture is mixed with the fuel after the latter's entrance into the combustion chamber. The auxiliary burner uses a it's combustion air part of the air supplied to the main burner and it's hot flue gases are mixed with the remainder of the air supplied to the main burner.

A disadvantage of the known method is that early ignition of the fuel may occur when it is contacted with the hot mixture of combustion air and flue gas, which may cause uneven burning of the fuel causing higher NO_x levels.

The invention aims to completely or largely overcome this disadvantage.

This object is achieved by the invention in that the hot flue gases at least in the initial stage originate at least partly from the auxiliary burner and in that the hot flue gases originating from the auxiliary burner and the combustion air are fed into the combustion chamber through separate inlets.

By this method it is possible to control the fuel-combustion air ratio and the total amounts of burnable mixtures independently for the main burner and the auxiliary burner. This gives a high flexibility in the initial stage to reach the conditions for homogeneous oxidation in the combustion chamber. It also allows to keep said oxidation during a steady-state situation in a stable condition by independently supplying an extra amount of heat to the combustion chamber if necessary.

By utilising the hot flue gases from an auxiliary burner instead of only those from the combustion of the fuel itself as in e.g. US 6,206,686 one is no longer bound to keep the whole combustion chamber at a sufficiently high temperature for

spontaneous ignition because adequate heat can be supplied to the three-component mixture by regulating the auxiliary burner. Also the NO_x content of the final combustion gases is still found to be very low, even when conventional combustion and no homogeneous oxidation takes place in the auxiliary burner.

An additional advantage is that flame monitoring on the conventional auxiliary burner may be achieved in a simple manner so that an adequate feed of sufficiently hot flue gases can be better monitored directly.

In the method according to the invention a mixture of the fuel to be oxidised, combustion air and hot flue gases is formed, in stead of a mixture of the fule and a pre-mixture of combustion air and flue gases of the auxiliary burner.

As a fuel the known gaseous fuels are suitable, in particular natural gas, but also liquid fuels, of which paraffin oil and domestic fuel oil are suitable examples.

As combustion air gas mixtures are suitable in which at least 10 vol.% of oxygen is present. The best-known example hereof is ambient air. The combustion air can be preheated, for example with the off-gases discharged from the combustion chamber. The temperature of the combustion air thus is between the ambient temperature and around 1100º

Under steady-state operating conditions the hot flue gases may but preferably do originate at least partially from an auxiliary burner. In the latter case the monitoring of the virtually invisible homogeneous oxidation may be omitted.

For the rest or in total the heat required to heat the mixture of fuel to be oxidised and the combustion air to above the auto-ignition temperature may originate from the combustion of the said fuel itself, such as in the known burner. In the auxiliary burner preferably the same fuel is burned as the fuel to be oxidised because this is simplest in technical terms. If desired, the two said fuels can also be chosen to be different. The auxiliary burner is preferably of a type that generates flue gases with a low NOx content. The temperature of these flue gases at entry into the combustion chamber preferably amounts to at least 900 °C and preferably is between 800 ºC and 1400 °C. The velocity at which these flue gases exit can be significantly lower than that described hereafter for the fuel to be oxidised and the combustion air and is preferably between 5 and 15 m/s.

The said velocity ensures a stable "flow skin" which can screen the main burner from the low-oxygen combustion chamber atmosphere, so retarding any further dilution of the oxygen in the combustion air.

The auxiliary burner is so designed that the formed flue gases enter the combustion chamber through a separate inlet and in the vicinity of the point where the fuel and the combustion air are supplied to that space. One skilled in the art is in a position to consider sundry suitable embodiments whose common feature should be that the hot flue gases are adequately entrained by the supplied fuel to be oxidised and combustion air. In a suitable embodiment the combustion air and the fuel to be oxidised are supplied through two coaxial feed channels that open into the combustion chamber. The flue gases of the auxiliary burner are then supplied preferably coaxially around the aforementioned coaxial feed channel. The flue gases can be supplied through a number of separate openings but the supply thereof through an annular opening, coaxial with the said feed channel, is very suitable. In that case the three supplied components are mixed highly uniformly. This annular opening may be separated from the combustion chamber by a gauze in order to achieve an even inflow of the flue gases from the auxiliary burner in the combustion chamber. By not premixing fuel and combustion air but feeding them separately the situation is avoided where combustion takes place before the combustion air has been diluted adequately with the hot flue gases and avoidable NO_x formation is avoided. As a rule, the outlets of the channels for fuel and combustion air in the combustion chamber and of the opening through which the flue gases of the auxiliary burner are supplied to that space lie virtually in one plane, with the said openings preferably extending over some distance past the opening for the flue gases. More preferably the fuel channel outlet extends somewhat past the combustion air channel outlet. Said distances depend on the overall size of the burner and are between 20 and 200% of its largest cross-section perpendicular to the channels. This embodiment has been found to provide more homogeneous mixing of the three components.

The fuel and the combustion air are preferably supplied so that a turbulent flow is formed. This can for example be achieved by choosing the inflow velocity high enough. The inflow velocity preferably is at least 25 m/s and preferably is between 50 and 100 m/s. The inflow velocities of the fuel and the combustion air are preferably approximately equal to each other to accomplish controlled, slow mixing of both. As a result, the conditions for homogeneous oxidation are created at some distance from the lances. In that region the oxidising mixture is already strongly diluted with (hot) flue gases from the auxiliary burner and, possibly additionally, from the furnace atmosphere, which strongly limits NO_x-formation.

Due to this turbulent inflow the hot flue gases coming from the auxiliary burner are entrained and there is formed a mixture of the three components.

In a cold combustion chamber the flow rate of the combustion gases coming from the auxiliary burner should amount to at least 20% of that of the joint fuel and combustion air flow of the main burner. Due to the dilution of the combustion air with the hot flue gases, this mixture has a low oxygen content, preferably at most 10 vol.%, which leads to low NO_x production in the homogeneous oxidation of the fuel.

Due to mixing with the hot flue gases the temperature of the mixture rises to above the fuel's auto-ignition temperature so that the latter oxidises in a homogeneous flameless way at a certain distance and separate from the inflow openings.

The auxiliary burner may remain and preferably remains in operation as long as fuel and combustion air are supplied via the main burner. At the start of the combustion process, when the whole apparatus in which the combustion takes place is still at a temperature far below the operating temperature, the auxiliary burner is operated at a higher power level than when the operating temperature has been reached. During the heating process the power of the auxiliary burner can be gradually reduced and can be controlled independently from the main burner. At the start-up, the proportion of the total power of auxiliary burner and main burner, which is supplied by the auxiliary burner, is between 20 and 50% and is reduced under steady-state operating conditions to a share of between 0 and 15%, preferably between 5 and 15%.

The invention also relates to an apparatus for the homogeneous oxidation of a fuel that is provided with a main burner for feeding combustion air and the fuel to be oxidised into a combustion chamber and is provided with an auxiliary burner for generating hot flue gases, the auxiliary burner opening into the combustion chamber with a separate outlet and wherein the burner and the auxiliary burner are so designed and disposed in relation to each other that during operation a mixture is formed of the supplied combustion air, the fuel to be oxidised and, during start-up and optionally during steady-state operation, the hot flue gases with a temperature above the auto-ignition temperature of the fuel.

In the known apparatuses for the homogeneous oxidation of fuel as known for example from DE 198 60 636, the auxiliary burner opens into the space where the combustion air for the main burner is supplied so that the flue gases of the auxiliary burner and the combustion are pre-mixed before tmixing them with the fuel.The drawbacks hereof have been described above and are eliminated in large measure by the apparatus according to the invention. The additional advantages of the various preferred embodiments are also stated above.

Thus the main burner in the apparatus according to the invention is preferably a non-premix burner. Furthermore, the combustion air and the fuel to be oxidised are preferably supplied through coaxially positioned feed channels, which open into the combustion chamber. Likewise the auxiliary burner is preferably positioned annularly around the main burner. For the supply of the flue gases from the auxiliary burner to the combustion chamber the apparatus may be provided with a number of separate feed openings but preferably a continuous annular feed opening is present.

The apparatus according to the invention makes it possible at the start-up of the process for which the apparatus is designed to very quickly reach the regime wherein homogeneous oxidation of the fuel takes place because it is not necessary for the whole combustion chamber to be brought to the high temperature required for this; only the auxiliary burner needs to assume steady-state conditions wherein it supplies adequate heat to bring the fuel/combustion air mixture to above the auto-ignition temperature of the fuel. This generally takes place within a significantly shorter time than is necessary for bringing the whole combustion chamber to the required temperature.

The invention therefore also relates to a method of accomplishing the combustion of a fuel from a main burner by homogeneous oxidation wherein an apparatus according to the invention is applied and wherein the auxiliary burner is operated at almost full power until homogeneous oxidation occurs and is subsequently turned down to a level at which at least the combustion by homogeneous oxidation is sustained. This turned down level may even be zero but preferably, the proportion of the total power of auxiliary burner and main burner which is supplied by the auxiliary burner is between 5 and 15%.

With this method the condition under which homogeneous oxidation occurs is reached in a significantly shorter time than with the known applications of auxiliary burners wherein the whole combustion chamber must be brought to the required temperature. The homogeneous oxidation regime will be achieved faster as the auxiliary burner is operated at higher power levels, in particular when the auxiliary burner is operated at almost full power, for example at least 75 or even 90% of its full power. For a cold combustion chamber the flow rate of the combustion gases coming from the auxiliary burner should amount to at least 20% of that of the joint fuel and combustion air flow of the main burner.

Once homogeneous oxidation has started the temperature of the combustion chamber will rise and also the recirculating combustion gases of the main

burner will contribute to the heating up of the fuel/combustion air mixture for the main burner. The additional quantity of heat still to be supplied by the auxiliary burner will decrease proportionately therewith. As a consequence, the power of the auxiliary burner can also be reduced. This reduction must not exceed at least a level at which homogeneous oxidation is sustained, which under favourable conditions may be zero. Any further reduction of the power would otherwise lead to inadequate heat being supplied to keep the fuel/combustion air mixture above the auto-ignition temperature of the fuel and so would extinguish the homogeneous oxidation. This may lead to hazardous situations that admittedly can be prevented by installing monitoring equipment known per se but are undesirable for reasons of an undisturbed operation.

Depending on the capacity of the main burner, the size of the combustion chamber and other parameters that affect the heat consumption in and of the combustion chamber, at a certain moment the situation can occur where the additional heat of the auxiliary burner is no longer necessary to maintain homogeneous oxidation. In such a situation, usually steady-state conditions, the auxiliary burner can even be switched off completely. The advantage of rapid establishment of the homogeneous oxidation regime will then already have been achieved.

The invention will be elucidated on the basis of the following examples.

Fig. 1. is a front view of a burner with main and auxiliary burner suitable for application in the method and the apparatus according to the invention; and

Fig. 2. is a cross-section of the burner from Fig. 1 along the line AA'.

In Fig. 1, 2 is a burner with a rectangular casing 4, in which 6 is the annular opening for the combustion gases of an auxiliary burner. This opening is concentric with the similarly annular opening 8 for the combustion air for the main burner, which in turn is concentric with the circular opening 10 for the fuel, in particular the gas, for the main burner. These openings may also have other shapes or consist of separate apertures so long as the openings for the combustion gases are situated around outside the other apertures. The shape of the casing is not critical either and may be adapted to the combustion chamber and to the requirements imposed by the feed, the discharge, the further type and construction of the burner and the nature of the various gases.

Fig. 2 204 shows the casing of burner 202, where 206, 208 and 210 are the outflow openings of the combustion gases of the auxiliary burner, the combustion air for the main burner and the fuel for the auxiliary burner, respectively.

In the illustrated embodiment the auxiliary burner is a pre-mix burner. Through annular channel 212 a premixed gas-air mixture is supplied from a conventional mixing device not shown here and burns at the base of the burner cup 214. This base may be for example a metal fibre or ceramic burner.

Combustion air and gas are supplied through feed channels 216 and 218, respectively, for the main burner from conventional plenums not shown here. The main burner is thus of the non-premix type. Channels 216 and 218 both extend somewhat past the outlet 206, with the outlet of channel 218 protruding somewhat past the outlet of channel 216. Gas and combustion air from the main burner are mixed and flow out in an imaginary cone-shaped profile 220. The hot combustion gases from the auxiliary burner are entrained and mix with the said gases for the main burner, with the entire mixture comes exceeding the auto-ignition temperature of the gas and homogeneously oxidising in an imaginary area 222 at a certain distance from the outlets.

The assembly of main and auxiliary burner enclosed by casing 204 opens into a combustion chamber not shown here.

CLAIMS

1. Method for the homogeneous oxidation from a main burner of a fuel, wherein combustion air and hot flue gases, that in an initial stage originate from an auxiliary burner, are mixed with the fuel in a combustion chamber, whereby a mixture is formed with a temperature above the auto-ignition temperature of the fuel, characterised in that the hot flue gases at least in the initial stage originate at least partly from the auxiliary burner and in that the hot flue gases originating from the auxiliary burner and the combustion air are fed into the combustion chamber through separate inlets.
2. Method according to claim 1, wherein the main burner is a non-premix burner.
3. Method according to claim 2, wherein the combustion air and the fuel to be oxidised are supplied through two coaxial feed channels that open into the combustion chamber.
4. Method according to claim 2 or 3, wherein the flue gases from the auxiliary burner are supplied from openings that surround the supplied fuel and combustion air.
5. Apparatus for the homogeneous oxidation of a fuel, provided with a main burner for supplying combustion air and the fuel to be oxidised into a combustion chamber and provided with an auxiliary burner for the generation of hot flue gases, the auxiliary burner opening into the combustion chamber with a separate outlet and wherein the burner and the auxiliary burner are so designed and disposed in relation to each other that during operation a mixture is formed of the supplied combustion air, the fuel to be oxidised and, during start-up and optionally during steady-state operation, the hot flue gases with a temperature above the auto-ignition temperature of the fuel.
6. Apparatus according to claim 5 wherein the main burner is a non-premix burner.
7. Apparatus according to claim 6, wherein the combustion air and the fuel to be oxidised are supplied through coaxially placed feed channels that open into the combustion chamber.
8. Apparatus according to any one of claims 5-7 wherein the auxiliary burner is positioned annularly around the main burner.
9. Method for the accomplishment of combustion of a fuel from a main burner by homogeneous oxidation, wherein an apparatus according to any one of claims 5-8 is applied and wherein the auxiliary burner is operated at virtually full

power until homogeneous oxidation occurs and afterwards is reduced to a level at which at least the homogeneous oxidation is sustained.

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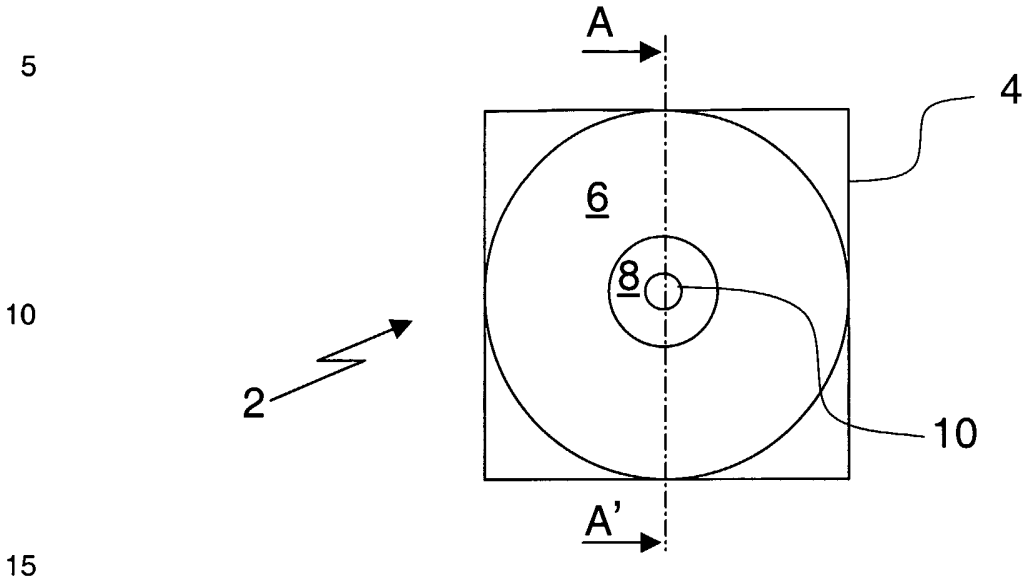


Fig.1

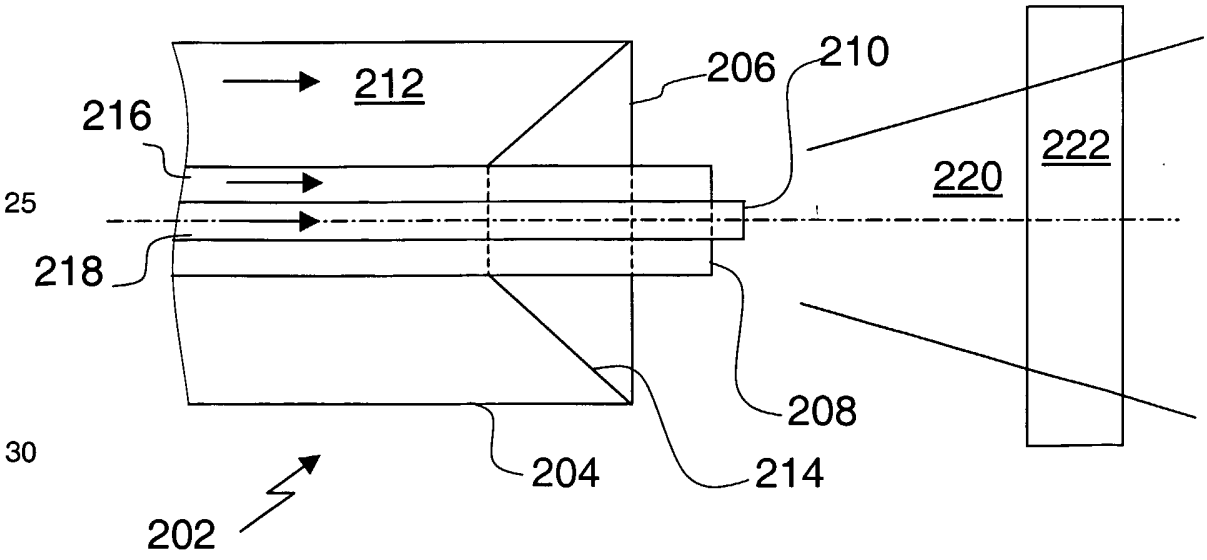


Fig.2

INTERNATIONAL SEARCH REPORT

Application No
/NL2004/000342

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 F23C11/00 F23C9/00 F23D23/00 F23L15/04

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)
IPC 7 F23C F23D F23L

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 practical, search terms used)
EPO-Internal

C. 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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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
15 September 2004	21/09/2004

Name and mailing address of the ISA	Authorized officer
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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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