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(54) **Method for fuel combustion and combustion apparatus**

(57) Method for fuel combustion wherein the main fuel stream (1) is divided into three smaller streams (or groups of streams) (2), which subsequently one after each other fall in various sections into an air flow (3) in the casing, wherein the time of the distribution along the distributing tube from the fall of the first stream (or the first group of streams) to the fall of the last stream (or the last group of streams) is the period T_{feed}, then the fuel and air are mixed in a flow during the period T_{mix}, wherein "poor" homogeneous air/fuel mixture is created, and this mixture then falls in the hot combustion products in a half-limited (with one opened end) combustion tube (4) where the mixture burns during the period T_{comb} and combustion gases are created and the heat is released, wherein the streams (or groups of streams) of the fuel are brought to the air stream according a certain relation. The presented invention allows to improve the stability of the combustion process

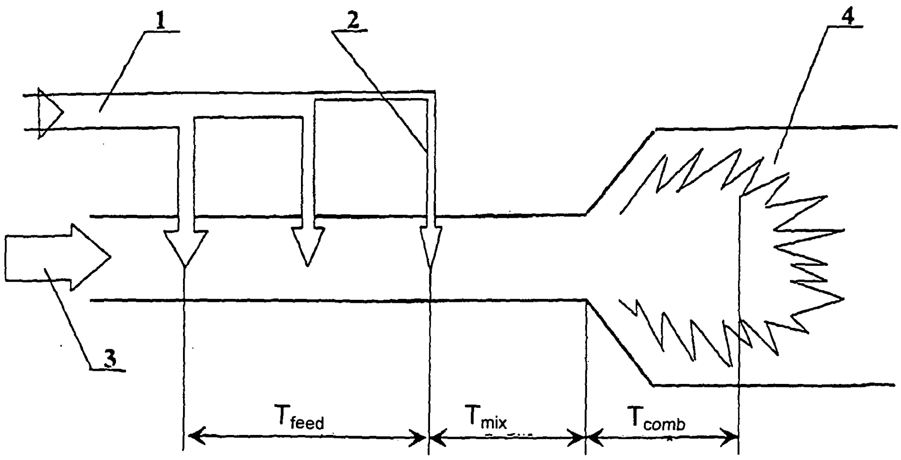

Fig.2

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Description

Technical field of the invention

[0001] The invention concerns power, transport and chemical industry and can also be used in the gas turbine systems.

State of the art

[0002] There is a known method for fuel combustion for the above system. This method is used in burners and consists of dividing the fuel stream into more smaller streams or groups of streams, which subsequently one after another fall into an air flow and are mixed in that flow during the period T_{mix}, resulting in the so-called "poor" homogeneous mixture, and this mixture is conveyed to a partly closed combustion tube (with only one opened end) where hot combustion products release the heat. This known burner in which the method is realized consists of an cylindrical casing with the diameter D, an air vane vortex generator arranged coaxially with the casing and the the vanes are located in the casing where a cylindrical forehearth is created. In this place there is a beginning of the distributing tube for fuel, which is installed inside and along the axis in the external casing. The fuel distributing tube is provided with openings as a fuel distributing equipment to feed the fuel into the forehearth. The exitence of the time delay (retarder) between the moment of fuel feeding into the air flow and the moment of releasing of the thermal energy within the time range of T_{mix} and T_{comb} results in a certain phase-shift between the oscillation of the released pressure and releasing of heat, at the end of which pressure pulsing may occur in the flow. The disadvantage of this known method and system seems to be a relatively low stability of the combustion process, reflected in the pressure pulsing which often reaches dangerous levels, which results in a reduced service lifetime and mechanical damages of the whole fuel combustion system.

[0003] The known method of combustion consist on the fact that the fuel flow is divided into three smaller streams (or groups of streams) conveyed in various sectors to the air flow and on the route from the sector where the first fuel stream falls (or a group of streams) to the section where the last stream falls (or a group of streams) during the period T_{feed} a "poor" homogeneous mixture of air and fuel is created and this mixture is fed to the half-limited combustion tube (with one opened end) filled with the hot combustion gases where during the period T_{comb} combustion products are created and heat is released.

[0004] In the known combustion apparatus for the application of the above method, the fuel combustion burner contains an external cylindrical casing with the diameter D, coaxial to the casing there is an air vane vortex generator and this generator together with the external casing creates a cylindrical foreharth at the inlet of which there is a fuel distributing tube with three smaller openings (or three groups of openings) to feed the fuel into the forehearth The openings (groups of openings) are located in a relative distance from each other in the burner axis and the axis distances from the closest to the more distant opening (group of openings) to the outlet from the forehearth correspond to the distances L1 and L2. When splitting the fuel stream to the individual streams (groups of streams) and their subsequent feeding in various sections to the air flow, each stream (group of streams) is provided with its own time delay between the fuel feeding moment and the power releasing moment, at the end of which a number of pulsing processes with various frequencies may be generated. Nevertheless, the pulsing pressure amplitudes of the individual frequencies will be substantially lower in an embodiment according to the invention than by fuel combustion taking place in the known system and the heat energy released by pulsing limited by the temperature of fuel combustion will be divided amongst all the pulsing processes in the series. The disadvantage of known burners seems to be an insufficient stability of the combustion process. This is shown by the fact that the likelihood of the occurrence of the pressure pulses with individual frequencies showing dangerous amplitudes remains substantially high due to the fact that in some relations (ratios) of T_{feed}, T_{mix} and T_{comb} in the aforementioned series of pulsing processes the frequencies of some pulsing may coincide with harmonious components (multiple frequencies) of other pulsing, resulting in a response.

[0005] Besides, given relatively low T_{comb} values, this fuel combustion method approaches the known methods and its combustion stability is low, too. The known fuel combustion burner shows a certain disadvantages - it does not ensure a high combustion process stability. The geometrical characteristics of the burner D, L_1 and L_2 determine (given a constant flow) the characteristic time intervals T_{feed}, T_{mix} and T_{comb} of the fuel combustion method. And thus, by analogy, given some relations in the presented geometrical characteristics, the combustion process system will not be sufficient.

[0006] The aim is for a new fuel combustion method is to increase the stability of the combustion process while excluding the possibility of pressure pulsing with high amplitudes. The purpose of the presented system is to realize the proposed fuel combustion process, to be specific, the design of such a burner, that would exclude pressure pulsing with high magnitudes.

Summary of the invention

[0007] The above shortcomings are eliminated to a great extent by the method of fuel combustion with the use of the combustion apparatus according to the invention, where the task is handled in the following way:

[0008] Method for fuel combustion wherein the fuel flow is divided into three smaller flows (or groups of flows), which subsequently one after each other fall in various places into an air stream in the casing, wherein the time of the distribution along the inlet tube from the fall of the first stream (or the first group of streams) to the fall of the last stream (or the last group of streams) is the time period T_{feed}, then the fuel and air are mixed in a flow during the period T_{mix}, wherein "poor" homogeneous air/fuel mixture is created, and this mixture then falls to the hot combustion gases in a half-limited (with one open end) combustion tube where the mixture burns during period T_{comb} and combustion gases are created and the heat is released. The method is characterized by the fact that streams (or groups of streams) of the fuel is brought to the air stream in such a manner that the following relation:

$$1.2 < (T_{feed} + T_{sm} + T_{comb}) / (T_{sm} + T_{comb}) < 2$$

can be assured,
where

T_{feed} - is the time period of the distribution along the distributing tube from the fall of the first stream (or the first group of streams) to the fall of the last stream (or the last group of streams)

T_{mix} - is the time period from the fall of the last stream (or the last group of streams) into the air flow when the fuel and air are mixed to the entrance to the half-limited combustion tube (with one open end) filled up with hot combustion gases,

T_{comb} - is the period of the combustion of the mixture.

[0009] In an advantageous embodiment the fuel stream is divided into streams (groups of streams) with various flow volumes wherein these streams (groups of streams) are conveyed into the air stream with decreasing flow volumes.

[0010] The fuel combustion apparatus consisting of an external cylindrical casing with diameter D, an air vane vortex generator arranged coaxially with the casing and the place where the vanes are located in the casing creates a cylindrical forehearth, wherein in this place there is a beginning of the main distributing tube for fuel, which is installed inside and along the axis in the external casing, the main distributing tube has as a fuel distributing equipment openings to feed the fuel to the forehearth, the fuel feeder has three smaller openings (or three groups of openings) to feed the fuel to the pre-chamber, the openings are located in a relative distance from each other in the burner axis and the distance from the outlet of the forehearth to the closest stream (or groups of streams is L1 and the distance from the outlet of the forehearth to the most distant stream (or groups of streams) is L2. According to the invention the openings (or groups of openings) for fuel feeding into the forehearth are located according to the following relation:

$$1.2 < (L2 + k * D) / (L1 + K * D) < 2$$

where

L2 - axis distance from the most distant opening (or most distant group of openings) from the outlet from the forehearth,

K - empiric coefficient

D - diameter of the external cylindrical casing,

L 1 - axis distance from the closest opening (or closest group of openings) to the outlet from the forehearth.

[0011] In an advantageous embodiment the diameter of the fuel feeding openings gets smaller as their location is more situated to the outlet of the forehearth.

[0012] The technical conclusion to the proposed method and system consists in increasing the combustion process stability while excluding the possibility of pressure pulsing with high amplitudes.

[0013] This is achieved by the fuel stream (group of streams) to the air flow effected as mentioned in the above relation. This is explained below. It is known that deceleration of time T between the fuel feed moment to the air stream and the moment of its burning with thermal energy releasing may result in an instability of the combustion processes expressed by the pressure pulsing with a frequency determined by the following relation:

$$F = 1/(2T)$$

where

F - is frequency
T - time between the fuel feed moment to the air stream and the moment of its burning.

[0014] The physics mechanism of the aforementioned relation is based on the fact that when defects occur in the fuel and air mixture stream with a frequency f, phase shift between oscillation of the flow, pressure and heat releasing related to the decelerated time T, it may happen that in the air and fuel mixture combustion zone in the oscillation phase of heat releasing and mixture concentrations coincide. This results in a response (resonance). In the context of the described mechanism of the occurrence and maintaining of the pulsing process during time T_{comb} it is necessary to understand the time interval from the moment of fuel and air mixture feeding to the half-limited space to the moment when the heat released during combustion reaches its maximum. In practice, T_{comb} can be determined mathematically, using the known methods of mathematical modelling of reacting flows or by experiments. When dividing the fuel stream into streams (groups of streams) and subsequent feeding through various sections into the air stream, just like in this invention, each of them may generate pressure pulsing of a defined (determined) frequency. The amplitudes of the pulsing may be smaller than in the case of one-time feeding of all fuel to the air stream as the power of the oscillating process which seems to be a function of the performance of heat releasing during air and fuel mixture combustion is divided into a number of these pulsing processes. The first stream (group of streams) falling to the air flow generates pulsing with the lowest frequency:

$$f_{min} = 1 / (T_{feed} + T_{mix} + T_{comb})$$

where

f_{min} - lowest pulsing frequency
Last - with the highest frequency

$$f_{max} = 1 / (T_{mix} + T_{comb})$$

where

f_{max} -highest pulsing frequency

[0015] In general in a number of frequencies generated by corresponding fuel flows in a range from f_{min} to f_{max} there can be frequencies, harmonies (multiple frequencies), which coincide with other frequencies of the series. Such coincidences may result in dangerous increases in the amplitudes by pressure pulsing at the relevant frequency and therefore it must be excluded as son as possible.

[0016] In this case, this may be achieved by the aforementioned fuel flow feeding to the air stream while keeping the following relation:

$$f_{max}/f_{min} = (T_{feed} + T_{mix} + T_{comb}) / (T_{mix} + T_{comb}) < 2 \qquad (1)$$

[0017] If the range of frequencies is from f_{min} to f_{max}, where the oscillation power is divided into a number of pulsing processes, the result is quite narrow:

$$f_{max}/f_{min} = (T_{feed} + T_{mix} + T_{comb}) / (T_{mix} + T_{comb}) < 1.2 \qquad (2)$$

[0018] The analyzed mechanism of increasing the pressure pulsing is little efficient as the described fuel combustion method approaches known method and takes over its disadvantages, see above.

[0019] The presented system of the burner, ensures that technical result. The inlets in the relation (2), the axis distances L1 and L2 from the closest to the most distant opening (group of openings) to the outlets from the forehearth ensuring fuel combusting can be determined, if we know the basic geometrical dimensions of the burner and the air flow amount. If the data is used to calculate the medium, axial air speed in the forehearth $W_{ax.speed}$, we can determine L1 and L2.

$$L1 = W_{ax.speed} * T_{mix}$$

$$L2 = Wax.speed * (T_{feed} + T_{mix})$$

$W_{ax.speed}$ - medium axial speed of air flow in the pre-chamber, m/s

The empiric coefficient K ensuring the fuel combustion, may be determined as follows:

$$K = W_{ax.speed} + T_{comb}/D$$

[0020] By using the results of L1, L2 and the relation (2) we can to relation (1) i.e. the presented method of fuel combustion.

[0021] The technical solution to the purposed method and system consists in an increase in the degree of homogeneity of the fuel and air mixture which is very important for the generation of low toxic combustion equipment.

[0022] This can be achieved as follows. It is known that the more time is provided for the fuel and air mixing, the higher the quality of the mixture, the more even and homogeneous the mixture. If we consider the aforementioned, to achieve the degree of homogeneity of the fuel and air mixture in this option, the fuel stream is divided into three streams (groups of streams) with uneven flow amounts and the flows flowing later to the air flow have a lower flow amount. To achieve this result in the presented burner option, the fuel feeding openings in the pre-chamber located closer to the outlet are manufactured with smaller diameters.

Brief description of the drawings

[0023] The invention will be presented by means of drawings where Fig.1 is a scheme of the fuel feeding system according to the state of the art, Fig. 2 is a scheme of the fuel feeding system according to the invention, Fig.3 is a burner and fuel distributing assembly according to the state of the art with fuel distribution tube with radial pillars with openings, Fig.4 is the burner and fuel distributing assembly according to the invention with a spiral fuel distribution tube.

The reference signs on the figures are:

> Fuel main stream 1, fuel streams 2, air flow 3, combustion products (gases), half-limited (with one opened end) combustion tube 4, external cylindrical casing 5, vanes 6, vane vortex generator 7, fuel distribution tube 8, 9 - cylindrical forehearth, 10 - fuel distributing spiral, 11 - openings for fuel feeding to the forehearth.

Examples of the embodiments

[0024] The presented method and system according to the state of the art and according to the invention is compared of Figs.1 and 2. The main fuel stream 1 is divided into three smaller streams (or groups of streams) 2 and the streams are then conveyed in various sections of the forehearth to the air flow 3 and the fuel is added on the route from the sector where the first fuel stream falls (or a group of streams) to the section where the last stream falls (or a group of streams) during the period T_{feed} and the fuel and air are mixed in the stream during the period T_{mix}. The so-called "poor" homogeneous fuel and air mixture is created and this mixture is conveyed in the hot combustion product streams in the half-limited (with one open air) combustion tube, where it burns during the period T_{comb} and combustion products are generated and heat is released. In the embodiment according to the invention (Fig.2) the fuel flow is divided into streams (groups of streams) with various flow volumes wherein these streams (groups of streams) are conveyed into the air stream with decreasing flow volumes.

[0025] The burner projected for the use of such a method for fuel combustion is presented also according to the state of the art and according to the invention is Figs.3 and 4. The burner contains an external cylindrical casing 5 with the diameter D, coaxial to the casing 5 there is an air vane vortex generator 6 with vanes 7 and this generator 6 together with the external casing 5 creates a cylindrical foreharth 9 at the inlet of which there is a fuel distributing spiral 10 with three small openings 11 (or three groups of openings) to feed the fuel to the forehearth 9,

[0026] The fuel distributing equipment may have various shapes. As regards the burner according state of the art shown in Fig. 3, on the inlet of the fuel distribution tube a vane air generator is provided and the distributing equipment of the distributing tube is in the form of radial pillars located in various distances from the outlet of the forehearth and is provided with three fuel distributing openings each. As regards the burner shown in Fig.4, the fuel distributing equipment is shaped as a spatial spiral distribution tube installed in front of the vane air generator and is provided with openings distributing the fuel, each of which is located in its place from the outlet from the foreheart and the diameter of the fuel feeding openings gets smaller as their location is more situated to the outlet from the forehearth. the openings are located in a relative distance from each other in the burner axis and the distance from the outlet of the forehearth to the closest stream (or groups of streams is L1 and the distance from the outlet of the forehearth to the most distant stream (or groups of streams) is L2

The burner works as follows:

The fuel stream in the main distributing tube 8 is conveyed to the fuel distributing equipment in the form of spiral distributing tube 10 and using openings 11 the main stream is divided into streams (or groups of streams) and then falls in various sections of the forehearth 9 into the air flow. The fuel and air are then mixed by means of the vane ir generator 6 and a "poor" homogenous mixture of fuel and air is created and the mixture is conveyed from the forehearth 9 to a zone filled up with hot combustion products which is a half-limited combustion tube (with one open end) 4, where it burns and combustion products are generated and heat is released. The walls defining this filled up space (not shown in the pictures only schematicaly on the Fig.1 and 2) are usually made of a steel tube.

[0027] The invention is not limited only on the presented embodiment and that widely available elements and pieces of equipment, such as pipes, cylindrical and conical casings at the air inlet, vane air generator, fuel distribution tubes, fuel pillars, steel tubes are used does not limit the scope of the invention..

Claims

1. Method for fuel combustion wherein the fuel stream is divided into three smaller streams (or groups of streams), which subsequently one after each other fall in various sections into an air flow in the casing, wherein the time of the distribution along the distributing tube from the fall of the first stream (or the first group of streams) to the fall of the last stream (or the last group of streams) is the time period T_{feed}, then the fuel and air are mixed in a flow during the period T_{mix}, wherein "poor" homogeneous air/fuel mixture is created, and this mixture then falls in the hot combustion products in a half-limited (with one opened end) combustion tube where the mixture burns during period T_{comb} and combustion gases are created and the heat is released, **characterized in that** the streams (or groups of streams) of the fuel is brought to the air stream in such a manner that the following relation:

$$1.2 < (T_{feed} + T_{sm} + T_{comb}) / (T_{sm} + T_{comb}) < 2$$

can be assured,
where

T_{feed} - is the time period of the distribution along the distributing tube from the fall of the first stream (or the first group of streams) to the fall of the last stream (or the last group of streams)
T_{mix} - is the time period from the fall of the last stream (or the last group of streams) into the air flow when the fuel and air are mixed to the entrance to the half-limited combustion tube (with one open end) filled up with hot combustion gases,
T_{comb} - is the period of combustion of the mixture.

2. Method according to the claim 1, **characterized in that** the fuel stream is divided into streams (groups of streams) with various flow volumes wherein these streams (groups of streams) are conveyed into the air flow with decreasing flow volumes.

3. The fuel combustion apparatus consisting of an external cylindrical casing with diameter D, an air vane vortex generator arranged coaxially with the casing and the place where the vanes are located in the casing creates a cylindrical forehearth, wherein in this place there is a beginning of the distributing tube for fuel, which is installed inside and along the axis in the external casing, the distribution tube is provided with openings as a fuel distributing equipment to feed the fuel into the forehearth, the distributing tube has three smaller openings (or three groups of openings) to feed the fuel to the forehearth, the openings are located in a relative distance from each other in the burner axis and the distance from the outlet of the forehearth to the closest stream (or groups of streams is L1 and the distance from the outlet of the forehearth to the most distant stream (or groups of streams) is L2, **characterized in that** the openings (or groups of openings) for fuel feeding into the forehearth are located according to the following relation:

$$1.2 < (L2 + k * D) / (L1 + K * D) < 2$$

where

L2 - is axis distance from the most distant opening (or most distant group of openings) from the outlet of the forehearth,
K - empiric coefficient
D - diameter of the external cylindrical casing,
L 1 - axis distance from the closest opening (or closest group of openings) to the outlet of the forehearth.

4. Burner according to the claim 3, **characterized in that** the diameter of the fuel feeding openings gets smaller as their location is more situated to the outlet from the forehearth.

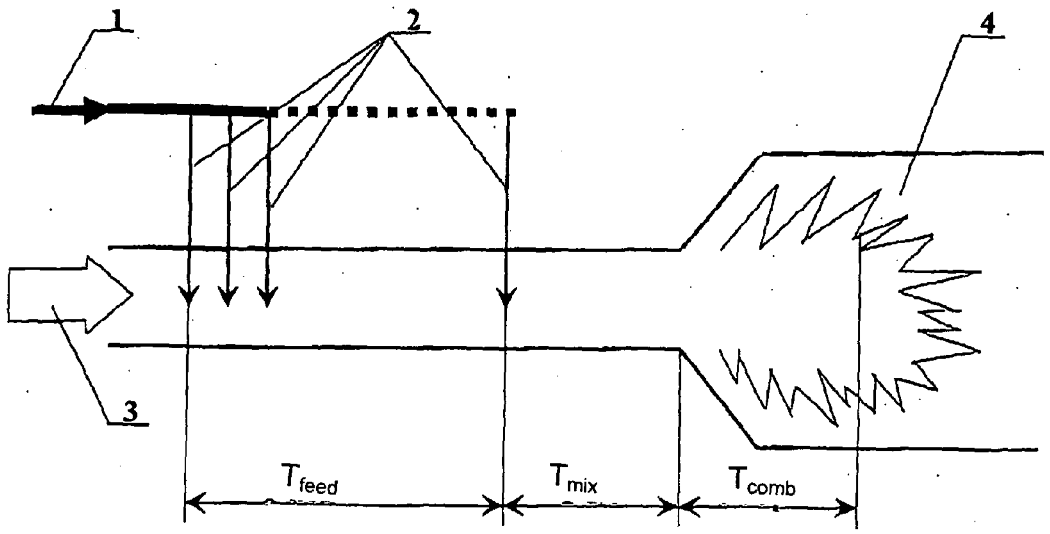


Fig.1

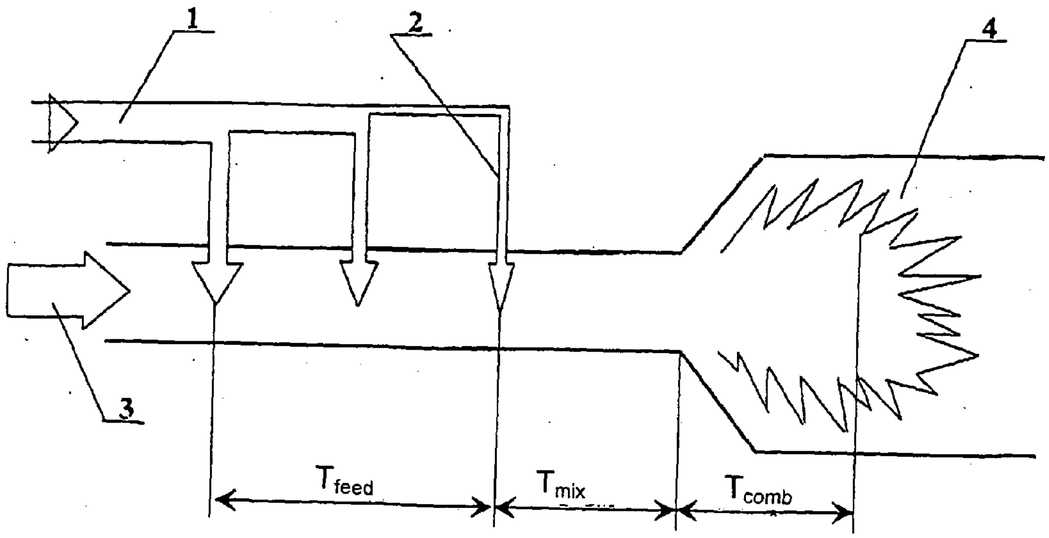


Fig.2

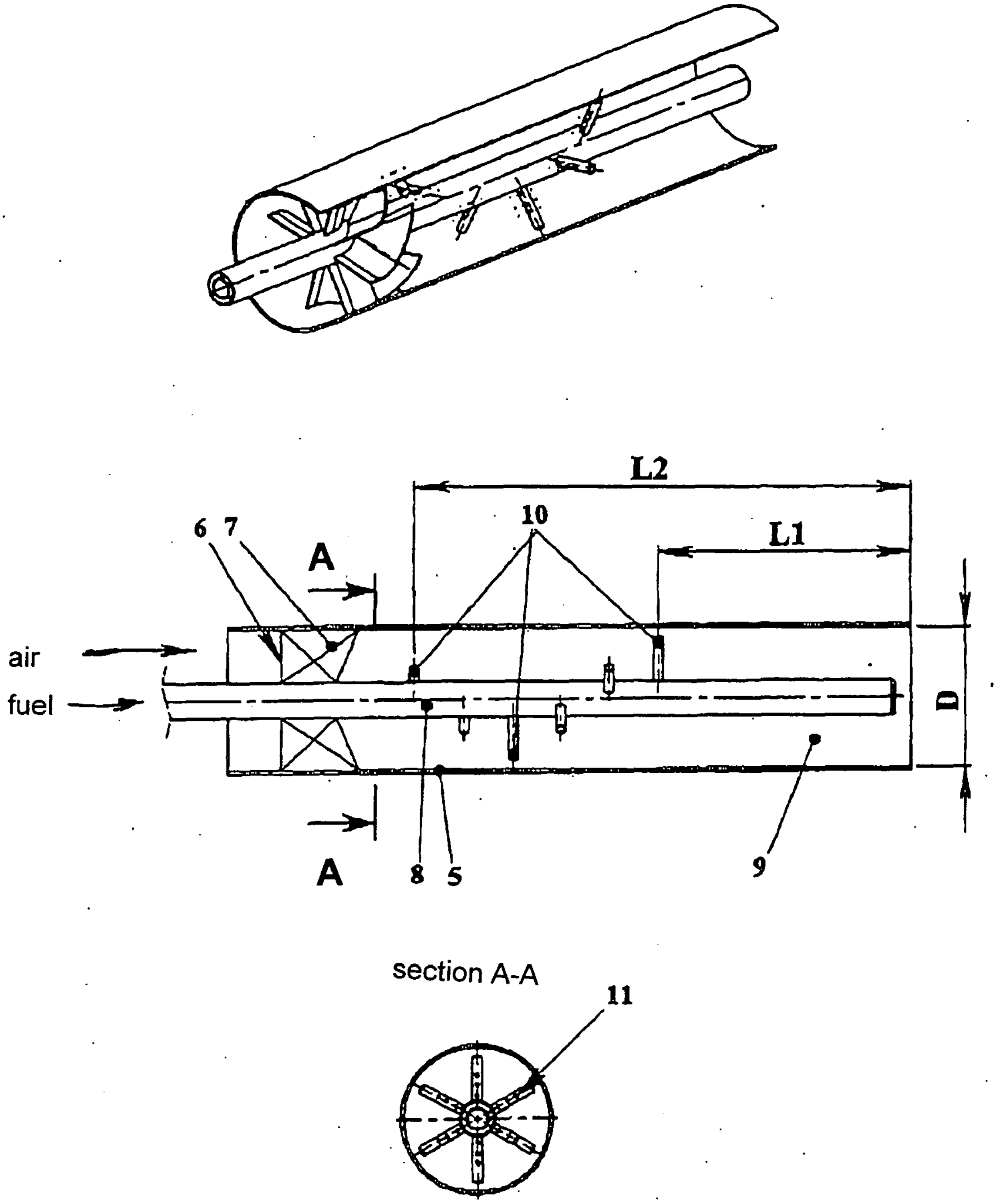
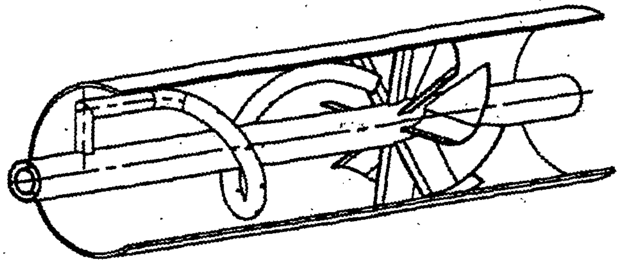
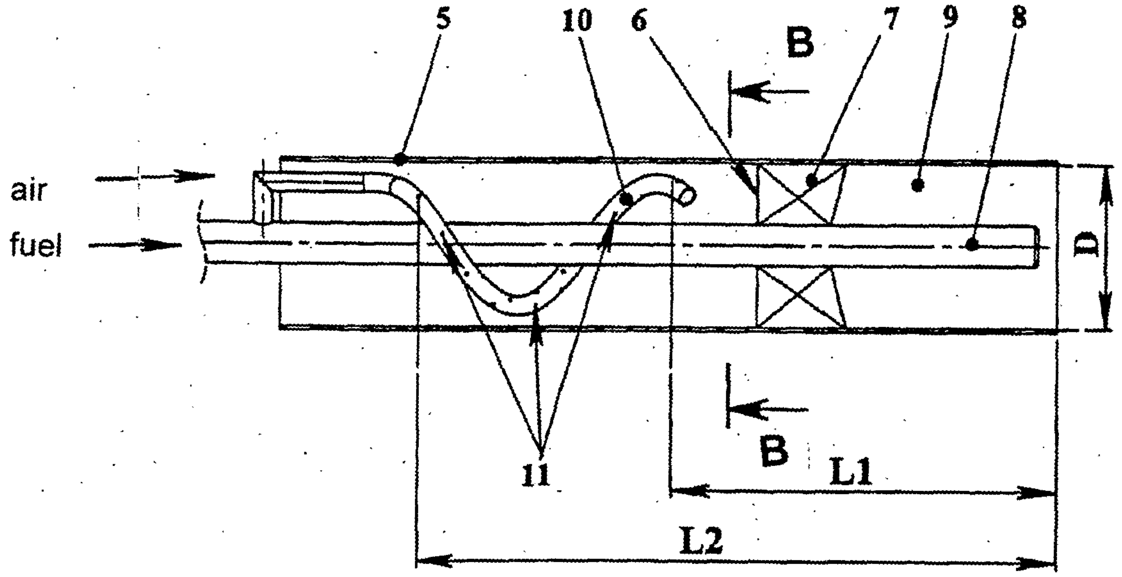


Fig.3





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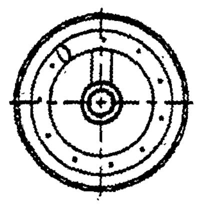

Fig. 4

European Patent Office

EUROPEAN SEARCH REPORT

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

Place of search	Date of completion of the search	Examiner
Munich	12 July 2007	Gavriliu, Costin

CATEGORY OF CITED DOCUMENTS

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