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(54) METHOD OF FUEL COMBUSTION AND BURNER FOR ITS IMPLEMENTATION

(57) Method of combustion of fuel in which the air flow in form at least one jet annular is swirled and is supplied into the semi bounded (with one open end) space filled in with the hot combustion products, tthe annular air stream is swirled gradually during the time Twhirl, during which the stream crosses the distance between the section where the swirling of the annular stream starts and the section where the swirling ends, and then the air in the swirled annular stream mix up with fuel during the time Twhmix till the moment of delivery of air-fuel mixture into the semi bounded (with one open end) space, wherein the swirling of the annular air stream is realized with observation of the relation 1,2<Twhirl+Twhmix+Tcomb)/(Twhmix+Tcomb) <M

where M is usually accepted equal to 2, in some cases M > 2;
Twhirl- time during which the stream crosses the distance between the section of the beginning of the swirling of the air annular stream and the section where the swirling is ended;
Twhmix - time during which the stream crosses the distance between the section of the ending of the swirling of the air annular stream and the inlet to the semi bounded (with one open end) space filled in with the hot combustion products;
Tcomb- time of combustion of the air-combustible mixture.

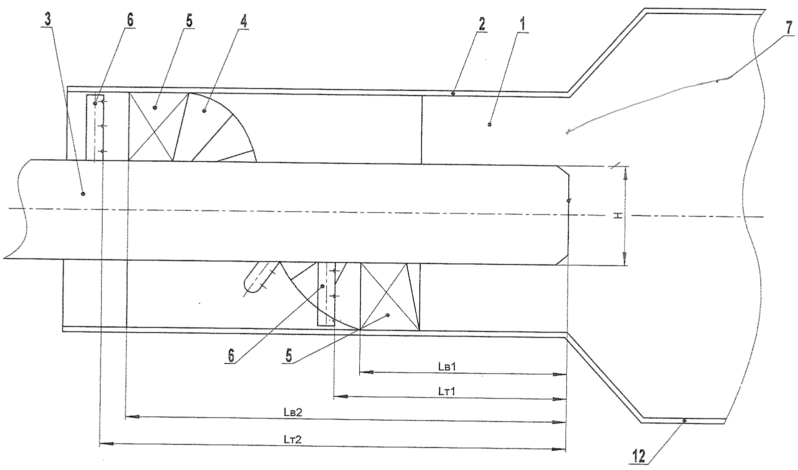

fig.2

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Description

[0001] The invention concerns the power, transport and chemical engineering and it can be used in the gas turbine units.

State of the art

[0002] It is known the method of fuel combustion which is implemented in the devise published in EP 1852656 B1.According to the known method the air flow in form at least one jet annular is whirled and is supplied into the semi bounded (with one open end) space filled in with the hot combustion products where before it is preliminary mixed up with the flow of combustible, wherein the fuel stream is divided into streams (or group of streams) which are fed successively in different sections of the annular air stream such a way, that the distance from the section in which the first stream of combustible is injected (first group of streams) till the section where the last stream of combustible (last group of streams) is injected, the annular air stream crosses during the time T_{podv}, after this the fuel and the air are mixed up in the stream during the time T_{sm} till the moment when the delivery of the air-combustible mixture to the semi bounded (with one open end) space filled in with the hot combustion products in form of the swirled annular stream, where this air-combustible mixture burns during the time T_{gor} with appearance of the products of burning and liberation of heat, and during this time the injection of combustible stream (group of streams) is done such a way that the value of relation

$$(T_{feed} + T_{mix} + T_{comb}) / (T_{mix} + T_{comb}),$$

where T_{feed} - time during which the stream passes the distance between the section in which the first stream of combustible is injected (first group of streams) and the section where the last stream of combustible (last group of streams),

T_{mix} - time during which the stream passes the distance between the section where the last stream (group of streams) of combustible is supplied and the entrance to the semi bounded (with one open end) space filled in with the hot combustion products,

T_{comb} - time of combustion of the air-combustible mixture,

should be inside the established limits.

[0003] There burner according to the state of the art shown in Fig 1 contains at least one cylindrical annular for-chamber formed by the elements of the burner, inside of which there is the coaxial bladed air swirl and the combustible supplying device with the holes for the combustible, and in the outlet of the for-chamber there is one or more coaxial combustion stabilizer/s, whereas the holes (or group of holes) for the supply of the combustible to the for-chamber are set with displacement in relation of each other along the burner axis such a way that the value of the relation

$$(L2 + k^*D)/(L1 + k^*D)$$

where the L1 - axial distance between the closest hole (group of holes) and inlet to the for-chamber,

L2 - axial distance between the distant hole (group of holes) and outlet from the for-chamber,

D - specific size if the combustion stabilizer,

k - empiric coefficient

[0004] In the mentioned method during the swirling of the annular stream of the air, the absolute air speed of the stream is growing and the pressure is decreasing, it means that in the section of the flow where the swirling of the stream is taking place there exist some pressure drop. The value of this drop is largely determined by the air flow. In the event of fluctuation of the pressure during the combustion of the air-combustible mixture, the drop of the air flow in the swirling section is changing respectively and thus changing the air consumption. Accordingly, the composition of the air-combustion mixture and heat release will be changed.

[0005] The existence of the time delay between the moment of the air swirling and the moment of combustion of the air-combustible mixture with the release of the combustion products and heat leads to certain phase drop between the drops in the consumption, pressure and heat release, as a result of which the drops of pressure in the stream can appear and maintain. Usually, the amplitudes of the pressure drops that appear as a result of the air consumption fluctuation are lower than those as a result of the combustible consumption fluctuation. Nevertheless, they can reach the dangerous level under certain conditions.

[0006] The burner possesses the deficiency of the method: insufficient stability of the combustion process. The geometrical characteristics of the burner D, L1 and L2 determine (at a constant flow rate) the characteristic time intervals T_{feed}, T_{mix}, and T_{comb} in the method of combustion. Therefore, similarly to the method, at certain relation of geometric characteristics the stability of the combustion process will be insufficient.

[0007] It can be explained the following way. It is known that the delay of the time T between the moment of injection of the combustible into the air stream and the moment of its combustion with the release of heat can lead to the instability of the combustion process expressed in the pressure fluctuation with the frequency

$$f = 1/(2T) .$$

[0008] This phenomena is a result of the fluctuation of the fuel consumption and corresponding heat release fluctuation during combustion as a result of the pressure fluctuation.

[0009] The physical mechanism of this phenomena consists in the fact that in case of the appearance the weak perturbation with frequency f in the air-combustible mixture, the phase shift between the fluctuations of consumption, pressure and heat release caused by the time delay T leads to the situation when phases of the heat release and the mixture concentration o the combustion zone coincide and resonance occurs.

[0010] In the context of the described mechanism of occurrence and maintenance of the fluctuation process, it is necessary to understand the time T_{comb} as an interval of time from the moment of intake air-fuel mixture into the filled-in semi bounded space till the moment when the heat release during the combustion riches its maximum value. In real conditions, T_{comb} can be determined by the calculation using the known methods of digital modeling of acting streams or by experiment.

[0011] In the method accepted as a prototype, the exclusion of the possibility of occurrence of pressure fluctuations with high amplitudes is achieved by the respective distribution in time of the combustible into the air stream. Nevertheless, in case of the swirling of air stream before the injection of the semi bounded (with one open end) space filled in with the hot combustion products, the perturbation in form of local increase of the absolute velocity and pressure drop is introduced in the moment of swirling.

[0012] Similarly to the described mechanism, the time delay T between the moment of swirling of the air stream and the moment of the combustion of air-fuel mixture with the release of heat energy can lead to the instability of the combustion process that appears in fluctuation of pressure with frequency

$$f = 1/(2T) .$$

[0013] This phenomena is given by the fact that under the influence of pressure fluctuation arise the air flow fluctuation and corresponding fluctuation of concentration of air-fuel mixture that influence the combustion process.

[0014] With the gradual swirling of air stream during time T_{feed} during which the stream crosses the way from the section where they start the swirling of the annular stream till the section where they stop the swirling of the annular stream, there will be its own time delay T in the intermediate sections and there will be its own fluctuation frequency f corresponding to this time.

[0015] The amplitudes of fluctuation at every of these frequencies will be lower than in case of lamp swirling of entire air stream, because the energy of fluctuation process during the air-fuel mixture combustion divides among various fluctuation processes.

[0016] In the section where they start the swirling of the annular stream, there are generated the fluctuations with the lowest frequency

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

[0017] In the section where they end the swirling of the annular stream, there are generated the fluctuations with the highest frequency

$$f_{max} = 1/(2(T_{mix} + T_{comb}))\ .$$

[0018] Generally, among the frequencies from f_{min} till f_{max}, there can exist multiple frequencies, a so-called low frequency harmonics of the series. In the same time, the generation of fluctuations of pressure with basic frequency and with its harmonics can lead to the dangerous increasing of the amplitude of pressure fluctuation at this frequency and it is advisable to exclude this phenomena. It can be achieved in the claimed method if the swirling of the annular air stream is carried out maintaining the relation

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

[0019] If the frequency range (f_{min}, f_{max}) where the distribution of fluctuation energy is dividing into series of fluctuation processes is too narrow

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

the considered mechanism of pressure fluctuation suppression is of low efficiency, because in this case the given fuel combustion method is approaching the method and therefore acquires its shortcomings described above.

[0020] So, in case of maintaining of the relation

$$1,2 < (T_{feed} + T_{mix} + T_{comb})/(T_{mix} + T_{comb}) < 2\ ,$$

it decreases the probability of occurrence of pressure pulsations with high amplitudes, it improves the stability of the combustion process, thereby increasing the reliability of the fuel combustion device, i.e., it achieves the desired technical result.

[0021] In some cases the task is solved by the swirling the air annular stream maintaining the relation

$$(T_{feed} + T_{mix} + T_{comb})/(T_{mix} + T_{comb}) > 2\ .$$

[0022] It can have sense for example in the following case. Every semi bounded (with one open end) space filled in with the hot combustion products has its own frequency f_{sobstv} that depends on the size and form of this space and parameters of the combustion products.

[0023] As it was said above, the time delay $T_{feed} + T_{mix} + T_{comb}$ can lead to the appearance of fluctuations in the stream with the frequency

$$f = 1/(2(T_{feed} + T_{mix} + T_{comb}))$$

[0024] If the pressure fluctuation frequency coincides with the proper frequency of the filled-in semi bounded space, the resonance can arise where the fluctuation amplitude will reach the dangerous values. The condition of amplitude appearance has a form

$$f = 1/(2(T_{feed} + T_{mix} + T_{comb})) = f_{sobstv}$$

[0025] This condition can be expressed as follows

$$(T_{feed} + T_{mix} + T_{comb})/(T_{mix} + T_{comb}) = 1/(2(T_{mix} + T_{comb})^* f_{sobstv}).$$

[0026] As a result, if the value $1/(2(T_{mix} + T_{comb})^* f_{sobstv})$ lays inside 1,2 - 2 during the swirling of the air annular stream in accordance with the relation

$$1,2 < (T_{feed} + T_{mix} + T_{comb})/(T_{mix} + T_{comb}) < 2 \ ,$$

there exist the a possibility of appearance o resonance where the fluctuation amplitude can reach dangerous values.

[0027] To decrease the possibility of appearance of this undesirable phenomena, it is advisable to change the relation of the characteristic time the following way

$$(T_{feed} + T_{mix} + T_{comb})/(T_{mix} + T_{comb}) \ > \ 2,$$

[0028] Therefore, in some cases while maintaining the above said relation the possibility of pressure fluctuation with the high amplitudes decreases, the stability of the combustion process improves, thanks to what the reliability of the fuel combusting devices increases, i.e. the desirable technical result is reached.

[0029] Thus in some cases the said task for similar reasons is solved such a way that the supply of the stream (group of streams) of the fuel to the air stream is made maintaining the relation

$$(T_{feed} + T_{mix} + T_{comb})/(T_{mix} + T_{comb}) \ > \ 2 \ .$$

[0030] By analogy with the previous, if for example the own frequency of the semi bounded space enters into the limits of frequencies generated during the supply of the fuel streams into the air annular stream is done such a way that the value of relation

$$(T_{feed} + T_{mix} + T_{comb})/(T_{mix} + T_{comb}) \ ,$$

where T_{feed} - time during which the stream passes the distance between the section in which the first stream of combustible is injected (first group of streams) and the section where the last stream of combustible (last group of streams),

T_{mix} - time during which the stream passes the distance between the section where the last stream (group of streams) of combustible is supplied and the entrance to the semi bounded (with one open end) space filled in with the hot combustion products,

T_{comb} - time of combustion of the air-combustible mixture,

would appear inside the respective limits (for example 1,2 - 2), it is advisable to appropriately expand the range of frequency of pressure fluctuation generated during the supply of the fuel streams into the annular air stream and thus to reduce the probability of the dangerous resonance phenomena. In this case the supply of the streams (or groups of streams) of fuel into the air stream is made in accordance with the relation (2). Thus the probability of the appearance of the pressure fluctuation with high amplitudes reduces, the stability of the combustion process increases, thanks to what the reliability of the fuel combusting devices increases, i.e. the desirable technical result is reached.

[0031] In the known device, the burner, for realization if the known method of combustion that contains at least one cylindrical annular for-chamber formed by the elements of the burner, inside of which there is the coaxial bladed air swirl and the combustible supplying device with the holes for the combustible, and in the outlet of the for-chamber there is one or more coaxial combustion stabilizer/s, whereas the holes (or group of holes) for the supply of the combustible to the for-chamber are set with displacement in relation of each other along the burner axis such a way that the value of the relation

$$(L_{T}2 + k^{*}H)/(L_{T}1 + k^{*}H),$$

where the L_{T1} - axial distance between the closest hole (group of holes) and inlet to the for-chamber,

L_{T2} - axial distance between the closest hole (closest group of holes) and outlet from the for-chamber, H - specific size if the combustion stabilizer,

k - empiric coefficient

would be inside the respective limits, the blades (or group of blades) of the bladed air swirl are set with displacement in relation of each other along the burner axis such a way that the value of the relation

$$1,2 < (L_{B}2 + k^*H)/(L_{B}1 + k^*H) < N \quad , \quad (3)$$

where N usually is equal to 2, in some cases N > 2;

the L_{B1} - axial distance between the closest bade (closest group of blades) of the swirl vane and outlet of the for-chamber,

L_{B2} - axial distance between the distant bade (distant group of blades) of the swirl vane and outlet of the for-chamber,

H - specific size if the combustion stabilizer,

k - empiric coefficient

[0032] The task to be solved by the claimed method of combustion is the increasing of the stability of the process of combustion by reducing of possibility of appearance of the fluctuation of pressure with high amplitudes.

Summary of the invention

[0033] The method is characterized by features in claim 1 and the burner in claim 3.

Overview of the figures in drawings

[0034] The invention will be explained by use of drawings, where Fig.1 is a functional diagram of the burner according to the invention, Fig. 2 is a construction diagram of the burner with one prechamber according to the invention and Fig.3 is top view on unrolled fuel tube of the burner of Fig.2 with the illustration of distribution of the fuel protrusions and whirl blades on the circumference of the fuel tube, the blades are displaced to each other and thus creating two parallel rows in this unrolled state, Fig. 4 is a construction diagram of the burner with two prechambers according to the invention, where in the first prechamber the whirler is spirally placed along the length of the fuel tube and in second prechamber the whirler is arranged only in one location along the length in a circle around the whole perimeter, Fig. 5 is a top view of the unrolled fuel tube of the burner of Fig. 4 with the illustration of the distribution of fuel protrusions and whirl blades on the circumference of the fuel tube, the blades are displaced to each other and thus creating always two parallel rows in this unrolled state, Fig. 6 is a construction diagram of the burner with one prechamber according to the invention with a long whirler having blades arranged along the length of the fuel tube in one location only, where the protrusions are spaced on a helix, while the length of the whirl occupies the entire height of the helix created by protrusions and thus the protrusions are in each case arranged between two adjacent blades, Fig. 7 is a top view of the unrolled fuel tube of the burner of Fig. 6 with the illustration of the distribution of fuel protrusions and whirl blades.

Description of the preferred embodiment

[0035] The air stream (see fig. 2) in form at least one annular stream is swirled and supplied into the semi bounded (with one open end) space filled in with the hot combustion products, before this it is preliminary mixed up with the fuel, wherein the fuel flow is divided in the stream (or group of streams) that are supplied successively in different sections of the annular air stream such a way that distance from the section I - I in which the first stream (group of streams) of fuel is provided till the section II - II in which the last stream (group of streams) of fuel is provided, the annular air stream passes during the time T_{feed} , after what the fuel and the air are mixed up during time T_{mix} up to the moment of the supply of the received air-fuel mixture into the semi bounded (with one open end) space in form of the annular swirled stream where the fuel-air mixture burns during the time T_{comb} with the products of combustion and the heat release, wherein the supply of the streams (groups of streams) of fuel into the air flow is done such a way that the value of the relation

$$(T_{feed} + T_{mix} + T_{comb})/(T_{mix} + T_{comb}) ,$$

[0036] The annular air stream is swirled gradually during time T_{feed} during which the flow crosses the distance from the section IV - IV in which the swirling of the stream is started till the section V - V in which the swirling of the stream is ended, and after it the air in the swirled stream is mixed up with the fuel during time T_{mix} till the moment of delivery in the section III - III of the air-fuel mixture into the semi bounded (with one open end) space filled in with the hot combustion products, wherein the swirling of the annular air stream is done the way that observes the relation

$$1,2 < (T_{feed} + T_{mix} + T_{comb})/(T_{mix} + T_{comb}) < 2$$

would be inside the respective limits, but in comparison with the prototype the annular air stream is swirled gradually during time T_{feed} during which the flow crosses the distance from the section IV - IV in which the swirling of the stream is started till the section V - V in which the swirling of the stream is ended, and after it the air in the swirled stream is mixed up with the fuel during time T_{mix} till the moment of delivery in the section III - III of the air-fuel mixture into the semi bounded (with one open end) space filled in with the hot combustion products, wherein the swirling of the annular air stream is done the way that observes the relation

$$1,2 < (T_{feed} + T_{mix} + T_{comb})/(T_{mix} + T_{comb}) < 2$$

[0037] Concerning the length distances, which can be seen in Fig.3, those are similar to that in Fig.1. The difference is in arrangement of the swirler 4 resp. its blades 5. It will be discussed later. Beacause of other arrangement of blades 5 of the swirler 4 the air stream is twisted gradually during the time T_{whirl}, during which the stream passes the way from the section where the swirling of the annular stream starts till the section where the swirling of the annular stream ends, consequently the air in the twisted annular stream is mixed up with the combustible during the time T_{whmix} till te moment of the supply of the air-combustible mixture to the semi bounded (with one open end) space filled in with the hot combustion products, and the twisting of the air annular stream is made the way that maintains the relation

$$1,2<(T_{whirl} + T_{whmix} + T_{comb}) / (T_{whmix} + T_{comb}),<M$$

where M is usually accepted equal to 2, in some cases M > 2;

T_{feed} - time during which the stream crosses the distance between the section of the beginning of the swirling of the air annular stream and the section where the swirling is ended;

T_{whmix} - time during which the stream crosses the distance between the section of the ending of the swirling of the air annular stream and the inlet to the semi bounded (with one open end) space filled in with the hot combustion products;

T_{comb} - time of combustion of the air-combustible mixture.

[0038] Thus in some cases the injection of the stream (group of streams) of the combustible in the air flow is made the way that maintains the relation

$$(T_{feed}+ T_{mix} + T_{comb})/(T_{mix} + T_{comb}) > 2 \ . (2)$$

[0039] The burner for realization of fuel combustion method (see fig. 2, fig.3) containing one cylindrical annular pre-chamber 1, the pre-chamber 1 is made by the external cylindrical shell 2 and between this shell 2 and coaxial fuel feed tube 3, a coaxial bladed air swirl 4 with blades 5 is located and from the tube 3 fuel distribution devices made in form of pylons 6 are protruding. They are disposed in a helical arrangement around the tube 3 and along this tube in a specific mutual distance. Thy pylons 6 have groups of holes for supply of fuel from the feed tube 3 into the pre-chamber 1. And there is an outlet 7 from the pre-chamber 1 and the pylons 6 with the groups of holes for fuel supply to the pre-chamber with displacement between each other done such a way that the relation

$$(L_T2 + k*H)/(L_T1 + k*H),$$

where the L_{T1} - axial distance between the closest hole (group of holes) and inlet to the pre-chamber,

L_{T2} - axial distance between the closest hole (closest group of holes) and outlet from the pre-chamber,

H - specific size if the fuel fee tube 3,

k - empiric coefficient

and the blades 5 of the air swirl 4 are placed with displacement in relation of each other along the burner axis the way that observed the relation

$$1,2 < (L_B2 + k*H)/(L_B1 + k*H) < 2 \quad ,$$

Where the L_{B1} - axial distance between the closest bade of the swirl vane and outlet of the for-chamber,

L_{B2} - axial distance between the distant bade of the swirl vane and outlet of the for-chamber,

H - specific size if the furl feed tube 3,

k - empiric coefficient

[0040] The burner according Fig.3 has the axial distances L_{B1}, L_{B2} forming part of the above relations, from the closest and the distant blades 5 (group of blades) of swirler 4 respectively till the outlet from the pre-chamber 1, and the axial distances L_{T1}, L_{T2} from the closest and the distant hole (group of holes) respectively up to the outlet of the pre-chamber, that ensure the method of fuel combustion, can determine while knowing the burner dimensions and the air consumption in it. After calculation the average axial speed of air stream in the for-chamber W_{os} on the basis of that data we define L_{B1}, L_{B2}, L_{T1}, L_{T2}:

$$L_B1 = W_{os}*T_{mix},$$

$$L_B2= W_{os}*(T_{feed}+ T_{mix}),$$

$$L_T1 = W_{os}*T_{mix},$$

$$L_T2 = W_{os}*(T_{feed}+ T_{mix}).$$

[0041] The empiric coefficient k that provides the realization of the suggested method of fuel combustion can be defined be the formula

$$k = W_{os}*T_{comb}/H \ .$$

[0042] Thus in some cases the holes (or group of holes) for combustible injection to the for-chamber are located with displacement along the burner's axis between each other the way that maintains the relation

$$(L_{B}2 + K^{*}H)/(L_{B}1 + k^{*}H) > 2 \ .$$

[0043] The technical consequence of the application (use) of the suggested method results in increasing of the reliability of operation of fuel combustion devices by ensuring the stability of combustion process by reducing the probability of occurrence of pressure fluctuations with high amplitudes

[0044] The indicated result is reached in case, when the air annular stream is effected maintaining the relation (1).

[0045] The variant of burner for realization of combustion method (see fig. 4, fig. 5) contains two coaxial cylindrical annular pre-chambers 1. The pre-chamber 1 is made between the external wall of the of the annular fuel feed tube 9 and internal wall of a cylindrical shell 10 and in this space the blades 5 of the air swirls 4 are located and fuel distribution devices made as pylons 6 with the hole groups for fuel supply from fuel feed tube 9 to the pre-chamber 1, and there is the outlet 11 from pre-chamber in the end of fuel freed tube 9. The pylons 6 and blades 5 are both in pre-chamber located with the axial displacement in relation of each other in the way that fulfills the respective relations indicated above.

[0046] The variant of burner for realization of combustion method (see fig. 6, fig. 7) contains one cylindrical annular pre-chamber 1. Pre-chamber 1 is made by the cylindrical shell 2 and coaxial fuel feed tube 3 inside of which there are the coaxial air swirl 4 with blades 5 and fuel distributing devices made in form of pylons 6 with groups of holes for fuel supply from tube 3 to pre-chamber 1, and there is the outlet 7 from the pre-chamber. The pylons 6 in the pre-chamber 1 are located with the axial displacement in relation of each other such a way that observes the respective relation. The long bladed air swirl 4 is made with the axially installed blades 5 that provide gradual (during established time T_{feed}) swirling of the annular air stream. The longitude of the blades 5 is selected in view of the preserving of respective relation. The arrangement of blades 5 and pylons 6 can be well seen in fig.7.

[0047] The method of combustion is realized during the burner operation that takes place the following way. The air stream in form of annular stream formed in the annular pre-chamber 1 (see Fig.2, Fig.3, Fig.6 and Fig.7) is swirled gradually during the established time by the coaxial bladed air swirl device 4 with blades 5 and is delivered into the semi bounded space 12 filled in with the hot combustion products ad made by the flue at the outlet 7 from pre-chamber 1 at the end of tube 3 Before this is preliminary mixed up with the fuel stream wherein the fuel stream is divided into groups that are supplied gradually in the different sections of the annular air stream through the holes in the pylons 6. After the supply of the coaxial swirled fuel-air mixture into the semi bounded space 12 the mixture burns out after coming out at the outlet 7 at the end of the tube 3 with the release of combustion products and heat.

[0048] Similarly, the combustion process is carried out in case of operation of a burner with two or more pre-chambers.

Claims

1. Method of combustion of fuel in which the air flow in form at least one jet annular is swirled and is supplied into the semi bounded (with one open end) space filled in with the hot combustion products where before it is preliminary mixed up with the flow of combustible, wherein the fuel stream is divided into streams (or group of streams) which are fed successively in different sections of the annular air stream such a way, that the distance from the section in which the first stream of combustible is injected (first group of streams) till the section where the last stream of combustible (last group of streams) is injected, the annular air stream crosses during the time T_{feed}, after this the fuel and the air are mixed up in the stream during the time T_{mix} till the moment when the delivery of the air-combustible mixture to the semi bounded (with one open end) space filled in with the hot combustion products in form of the swirled annular stream, where this air-combustible mixture burns during the time T_{comb} with appearance of the products of burning and liberation of heat, and during this time the injection of combustible stream (group of streams) is done such a way that the value of relation

$$(T_{feed} + T_{mix} + T_{comb})/(T_{mix} + T_{comb})$$

where T_{feed} - time during which the stream passes the distance between the section in which the first stream of combustible is injected (first group of streams) and the section where the last stream of combustible (last group of streams),

T_{mix} - time during which the stream passes the distance between the section where the last stream (group of streams) of combustible is supplied and the entrance to the semi bounded (with one open end) space filled in with the hot combustion products,

T_{comb} - time of combustion of the air-combustible mixture, should be inside the established limits, **characterized in that** the annular air stream is swirled gradually during the time T_{whirl}, during which the stream crosses the distance between the section where the swirling of the annular stream starts and the section where the swirling ends, and then the air in the swirled annular stream mix up with fuel during the time T_{whmix} till the moment of delivery of air-fuel mixture into the semi bounded (with one open end) space, wherein the swirling of the annular air stream is realized with observation of the relation

$$1{,}2<(T_{whirl} + T_{whmix} + T_{comb}) / (T_{whmix} + T_{comb}),<M$$

where M is usually accepted equal to 2, in some cases M > 2;
T_{whirl} - time during which the stream crosses the distance between the section of the beginning of the swirling of the air annular stream and the section where the swirling is ended;
T_{whmix} - time during which the stream crosses the distance between the section of the ending of the swirling of the air annular stream and the inlet to the semi bounded (with one open end) space filled in with the hot combustion products;
T_{comb} - time of combustion of the air-combustible mixture.

2. The method of combustion according to the claim 1, **characterized in that** the delivery of the streams (groups of streams) of fuel into the air stream is realized with observation of the relation

$$(T_{feed} + T_{mix} + T_{comb})/(T_{mix} + T_{comb}) > 2$$

3. The burner for realization of the method of combustion according to the claim 1 and 2 containing at least one cylindrical annular for-chamber (1) formed by the elements of the burner, inside of which there is the coaxial air swirl (4) with blades (5) and the fuel supplying devices (6) with the holes for the fuel, whereas the holes (or group of holes) for the supply of the fuel to the pre-chamber (1) are set with displacement in relation of each other along the burner axis such a way that the value of the relation

$$(L_{T}2 + k^*H)/(L_{T}1 + k^*H),$$

where the L_{T1} - axial distance between the closest hole (group of holes) and inlet to the for-chamber,
L_{T2} - axial distance between the closest hole (closest group of holes) and outlet from the pre-chamber,
H - specific size if the fuel feed tube (3),
k - empiric coefficient

would be inside the respective limits, **characterized in that** the blades (5), or groups of blades, of the air swirl (4) are located with displacement in relation of each other, but maintaining the relation

$$1{,}2 < (L_{B}2 + k^*H)/(L_{B}1 + k^*H) < N$$

where N is equal to 2, in some cases N > 2;
the L_{B1} - axial distance between the closest bade (5), or closest group of blades, of the swirl 4 and outlet 7 from the pre-chamber (1),
L_{B2} - axial distance between the distant blade (5), or distant group of blades, of the swirl (4) and outlet (7) from the pre-chamber (1),
H - specific size if the fuel feed tube (3),
k - empiric coefficient

4. The burner according to the claim 3, **characterized by** that the holes (or group of holes) for fuel injection into the pre-chamber (1) are located with displacement between each other along the burner's axis the way that maintains the relation

$$(L_B2 + K*H)/(L_B1 + k*H) > 2 \quad .$$

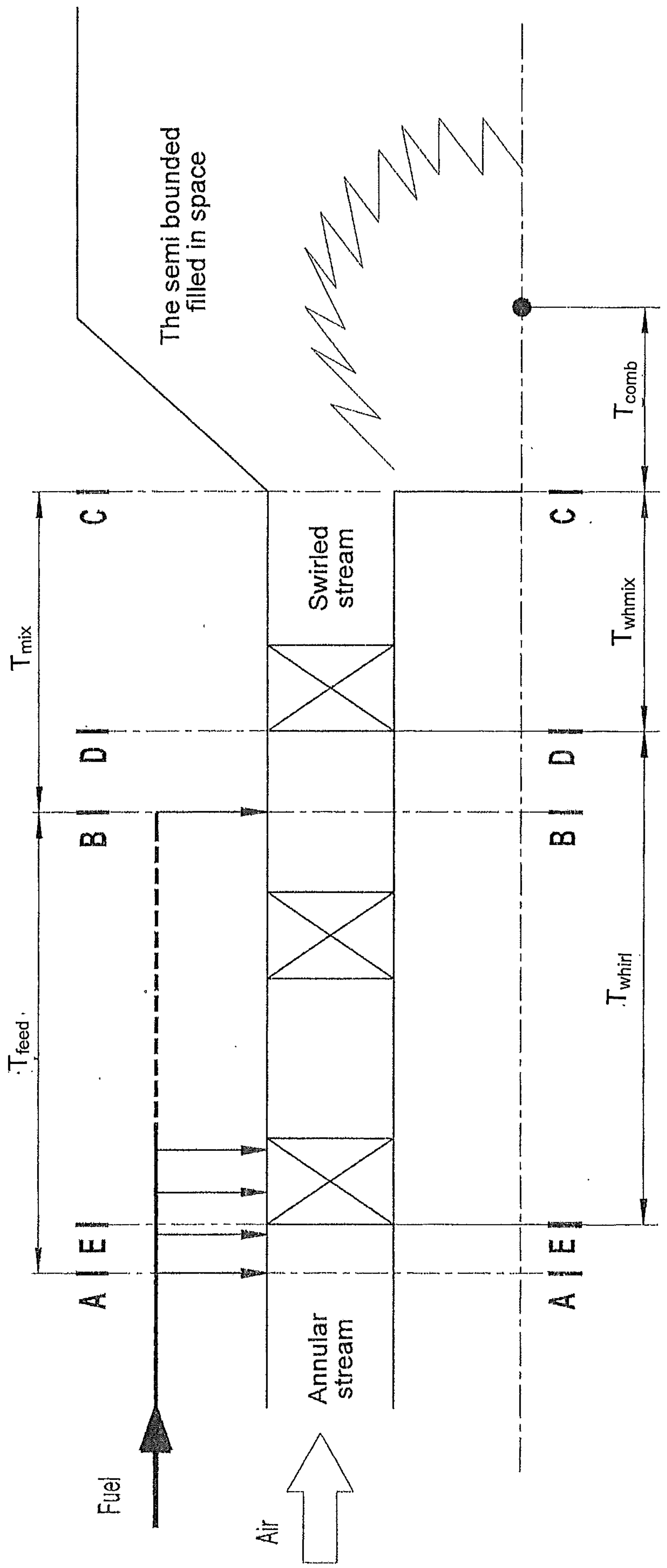
The semi bounded
filled in space
Swirled
stream
Annular
stream
Fuel
Air
A
B
C
D
E
T_mix
T_feed
T_whirl
T_whmix
T_comb

fig.1

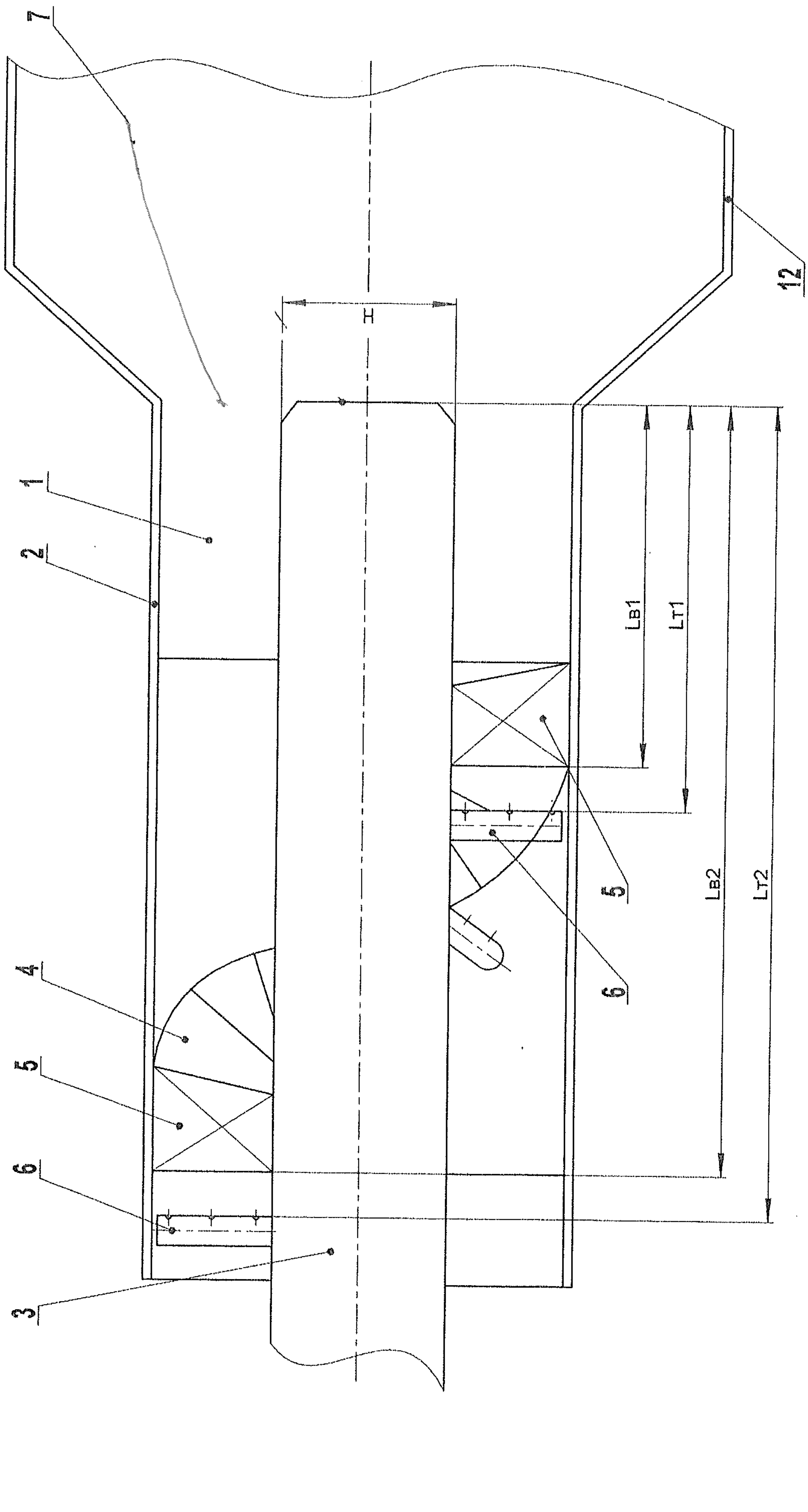

fig.2

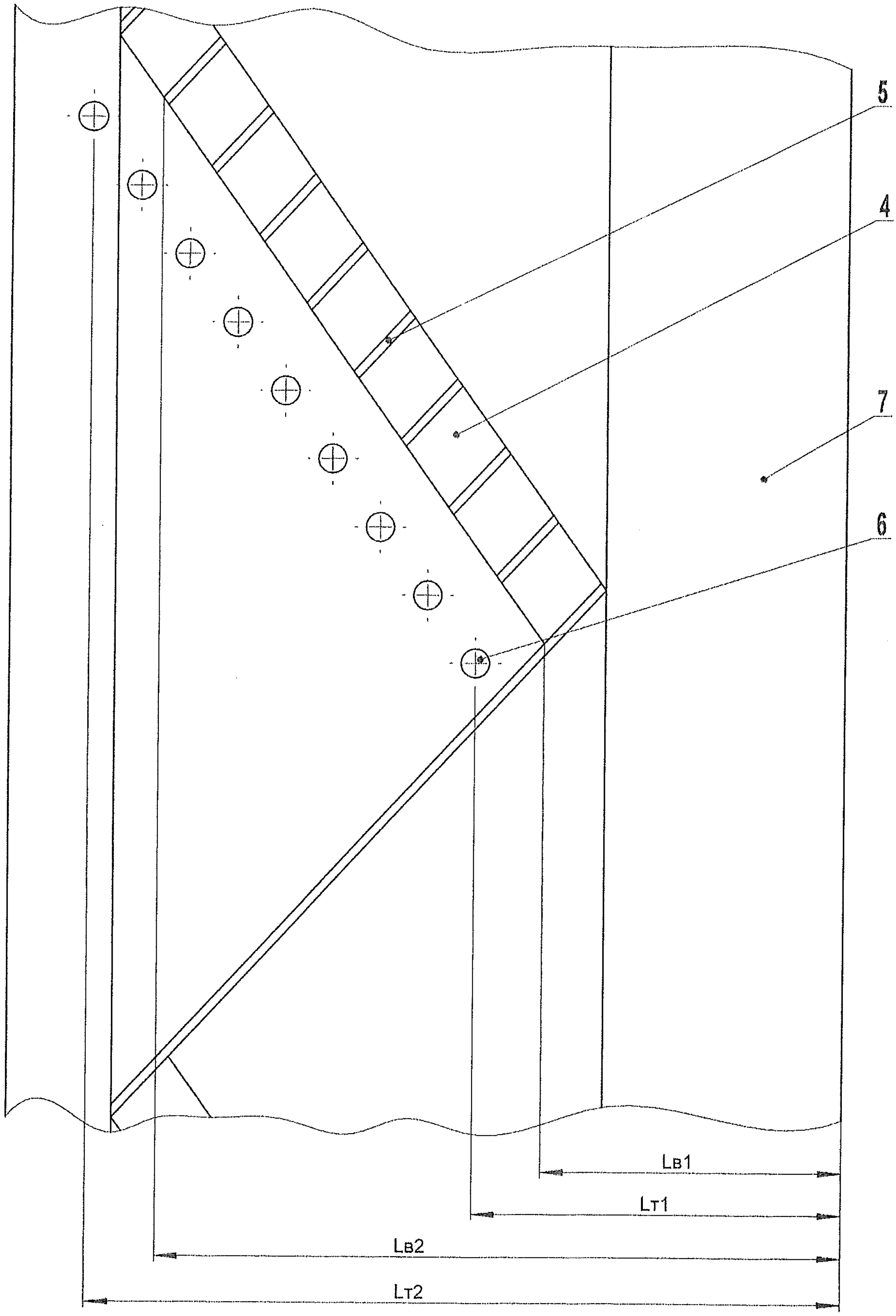

fig.3

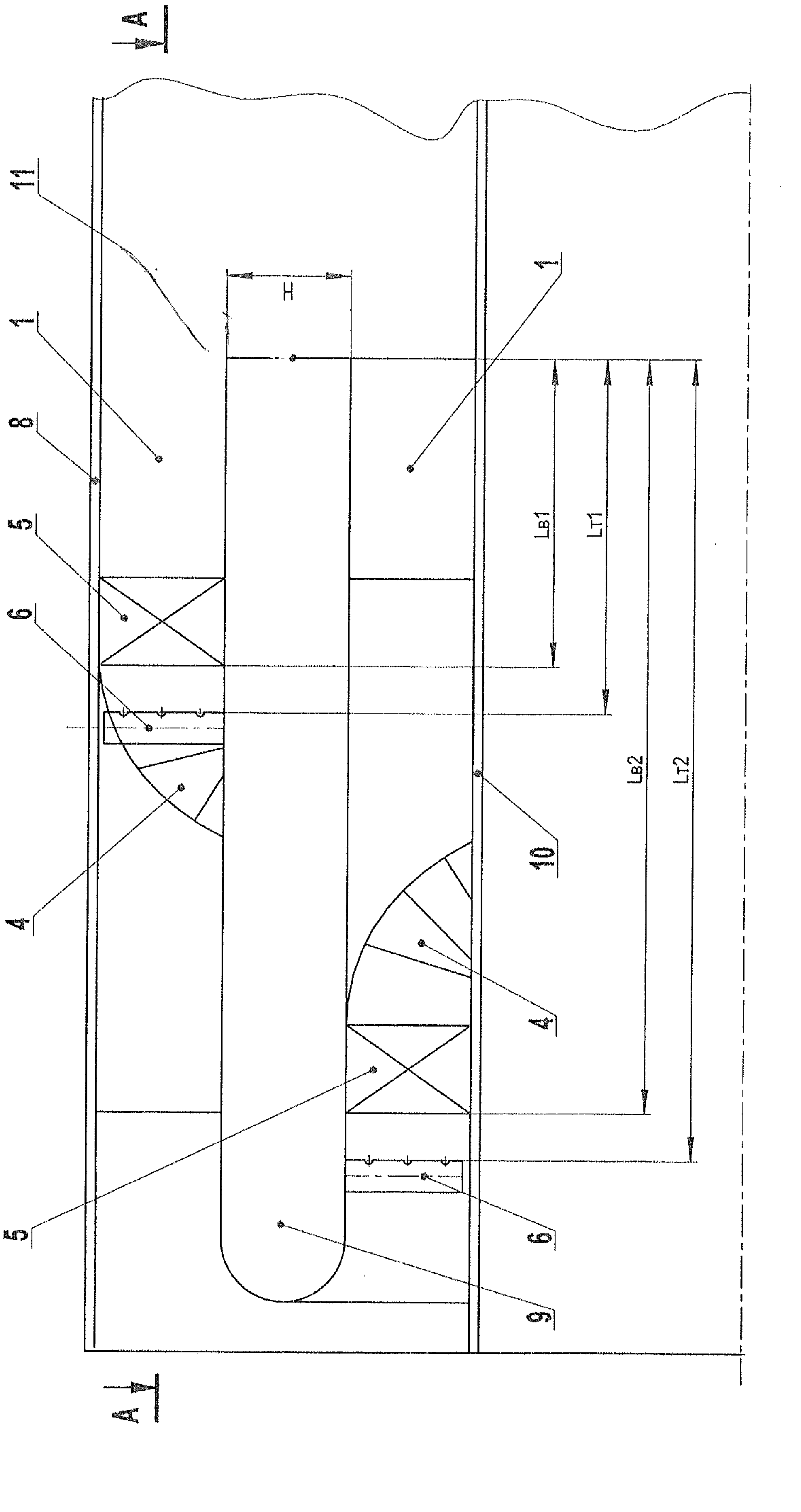

fig.4

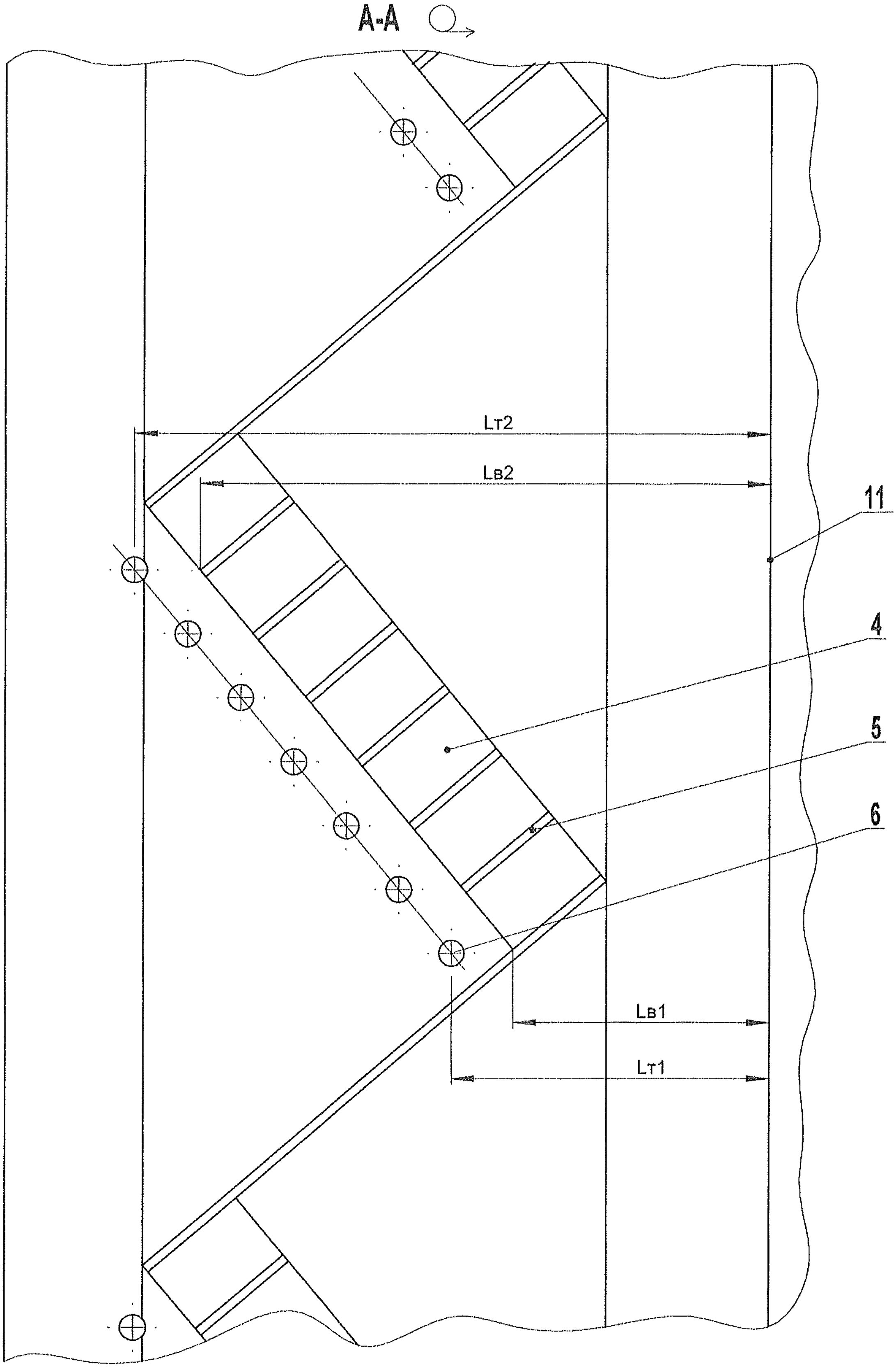

fig.5

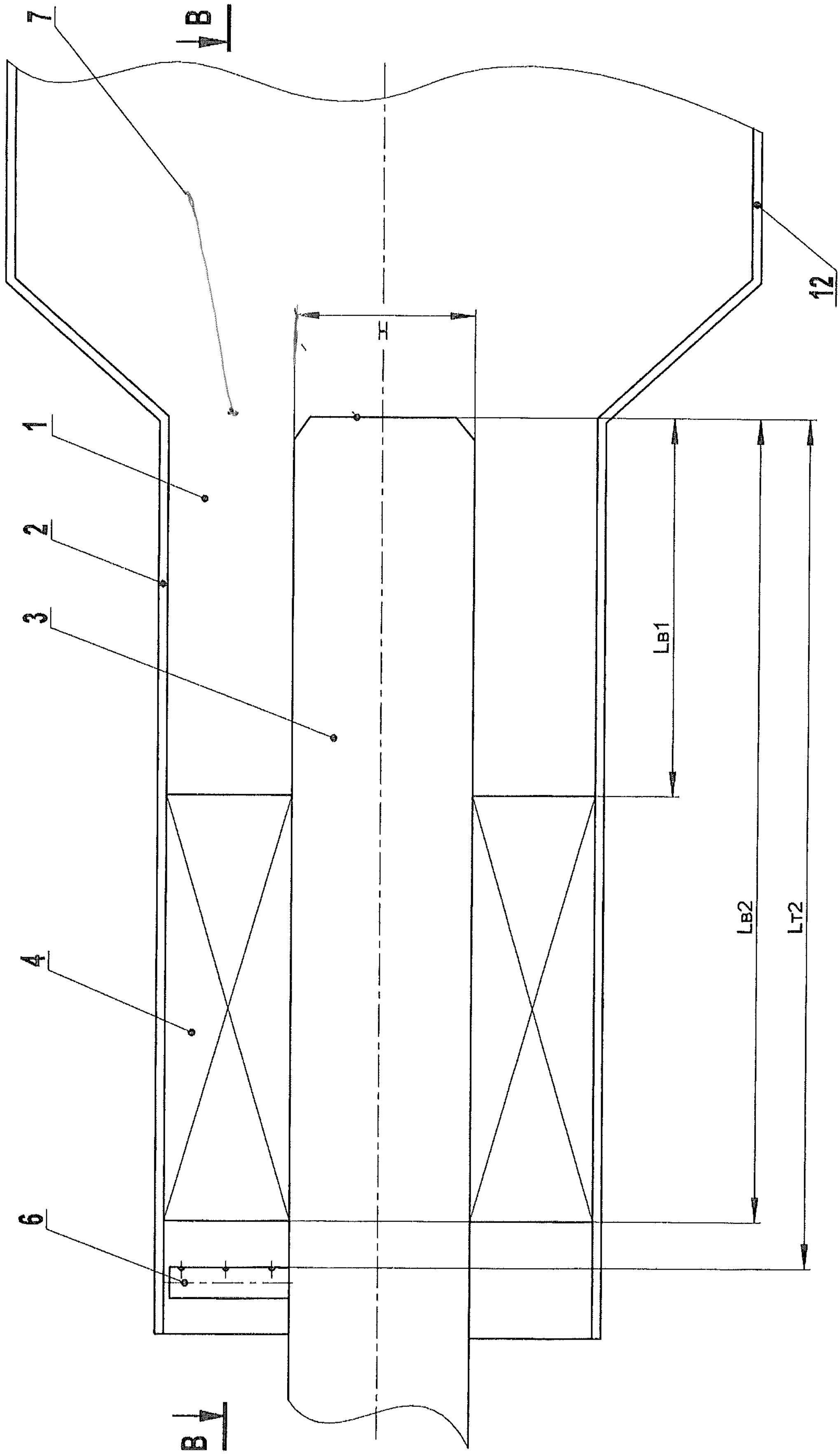

fig.6

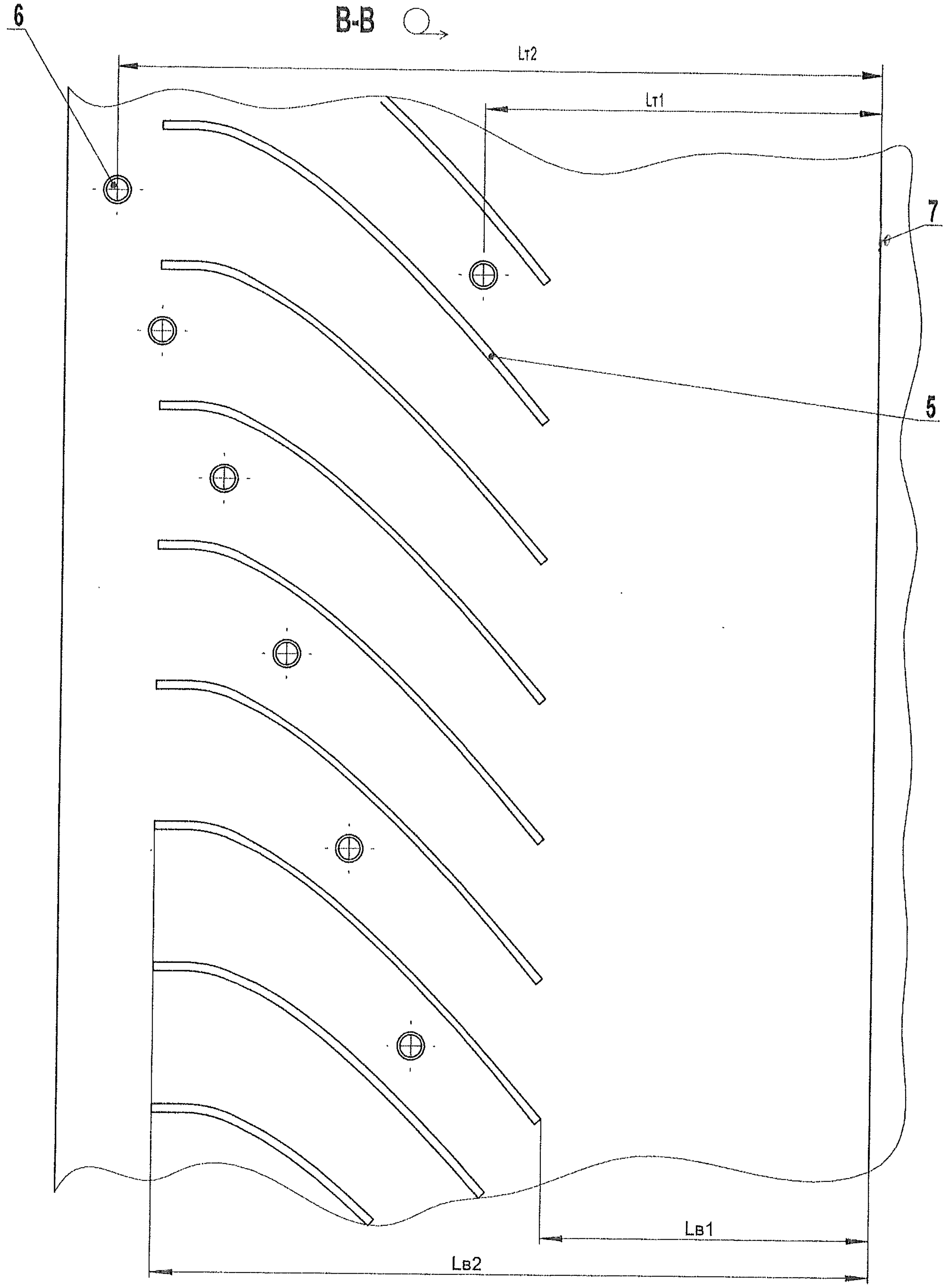

fig.7

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EUROPEAN SEARCH REPORT

Application Number
EP 16 18 9148

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The present search report has been drawn up for all claims

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Place of search	Date of completion of the search	Examiner
The Hague	7 March 2017	Harder, Sebastian

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