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(72) Inventeurs/Inventors:
SAVIHARJU, KARI, FI;
SIMONEN, JORMA, US;
SIMONEN, LIISA, US;
VAKKILAINEN, ESA, FI;
MATTELMAKI, ESKO, FI

(73) Propriétaire/Owner:
ANDRITZ OY, FI

(74) Agent: GOWLING LAFLEUR HENDERSON LLP

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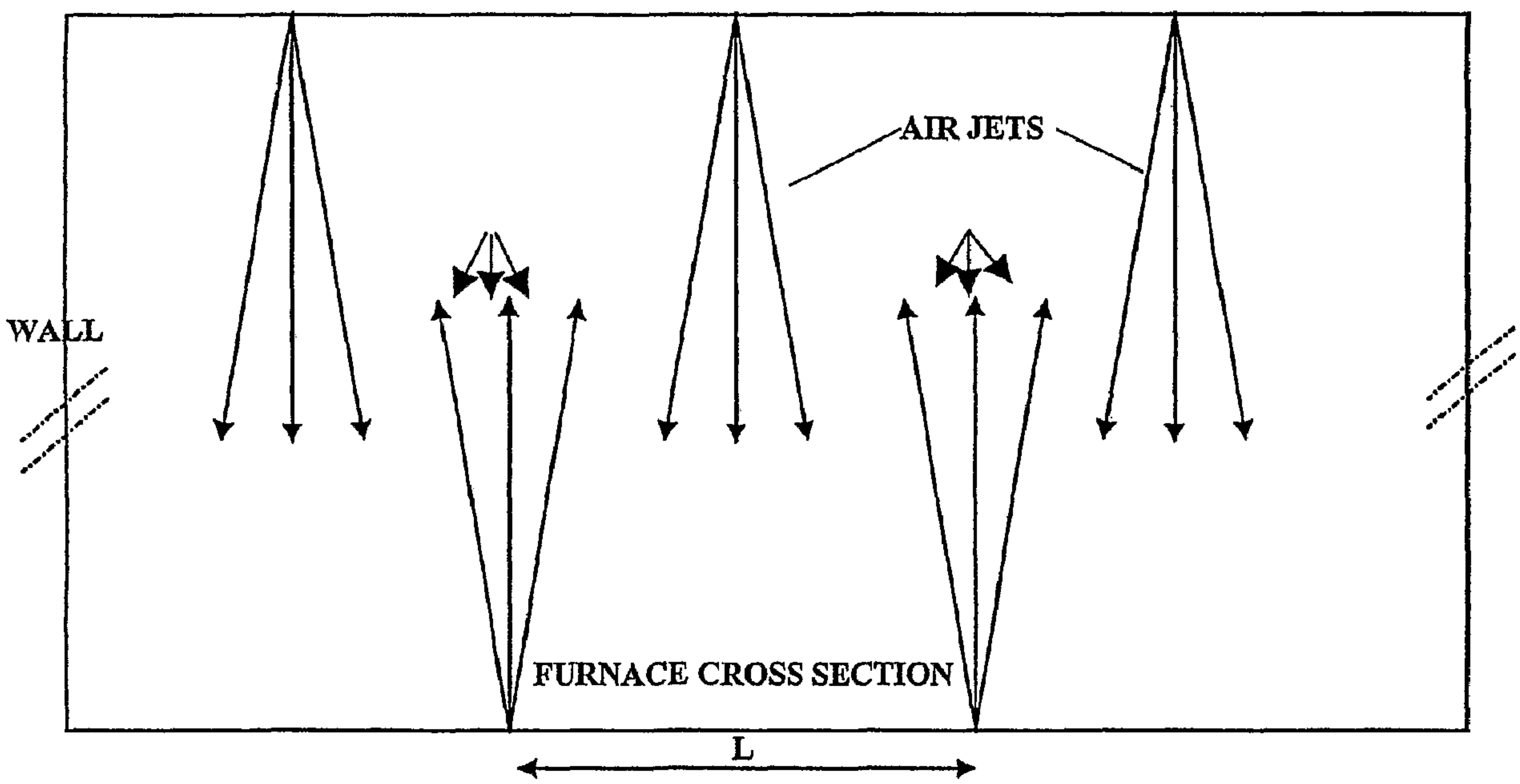
(54) Title: COMBUSTION AIR SYSTEM FOR RECOVERY BOILERS, BURNING SPENT LIQUORS FROM PULPING PROCESSES



(57) Abrégé/Abstract:
An arrangement is disclosed for supplying an air jet form to the furnace of a recovery boiler, where the furnace has a front wall, a rear wall and side walls. Black liquor spraying devices are disposed on the furnace walls at one or several levels of the furnace. I addition a plurality of air ports are located on several horizontal levels for introducing air into the furnace from an air supply. In the arrangement for the secondary air flows two horizontal air levels at different elevations are arranged above the lowest air level or levels and below the black liquor spraying level or levels. Air is supplied from two opposite walls on said two levels and the air ports are located so that the air jets are introduced in an interlaced pattern having an even number of jets on one opposite wall and an uneven number of jets on the other opposite wall. The air jets of said at least two air levels are located substantially one above each other in substantially vertical rows.

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(71) Applicant *(for all designated States except US)*: **ANDRITZ OY** [FI/FI]; Tammasaarenkatu 1, FIN-00180 Helsinki (FI).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: **SAVIHARJU, Kari** [FI/FI]; Rakentajanrinne 3, FIN-02340 Espoo (FI). **SIMONEN, Jorma** [FI/US]; c/o Andritz Inc., 10745 Westside Parkway, Alpharetta, GA 30004 (US). **SIMONEN, Liisa** [FI/US]; c/o Andritz Inc., 10745 Westside Parkway, Alpharetta, GA 30004 (US). **VAKKILAINEN, Esa** [FI/FI]; Laurinniityntie 3, FIN-00440 Helsinki (FI). **MATTELMÄKI, Esko** [FI/FI]; Sillanmäki 6B, FIN-01600 Porvoo (FI).

(74) Agent: **ANDRITZ OY**; Patent Department, P.O.Box 500, FIN-48601 Kotka (FI).

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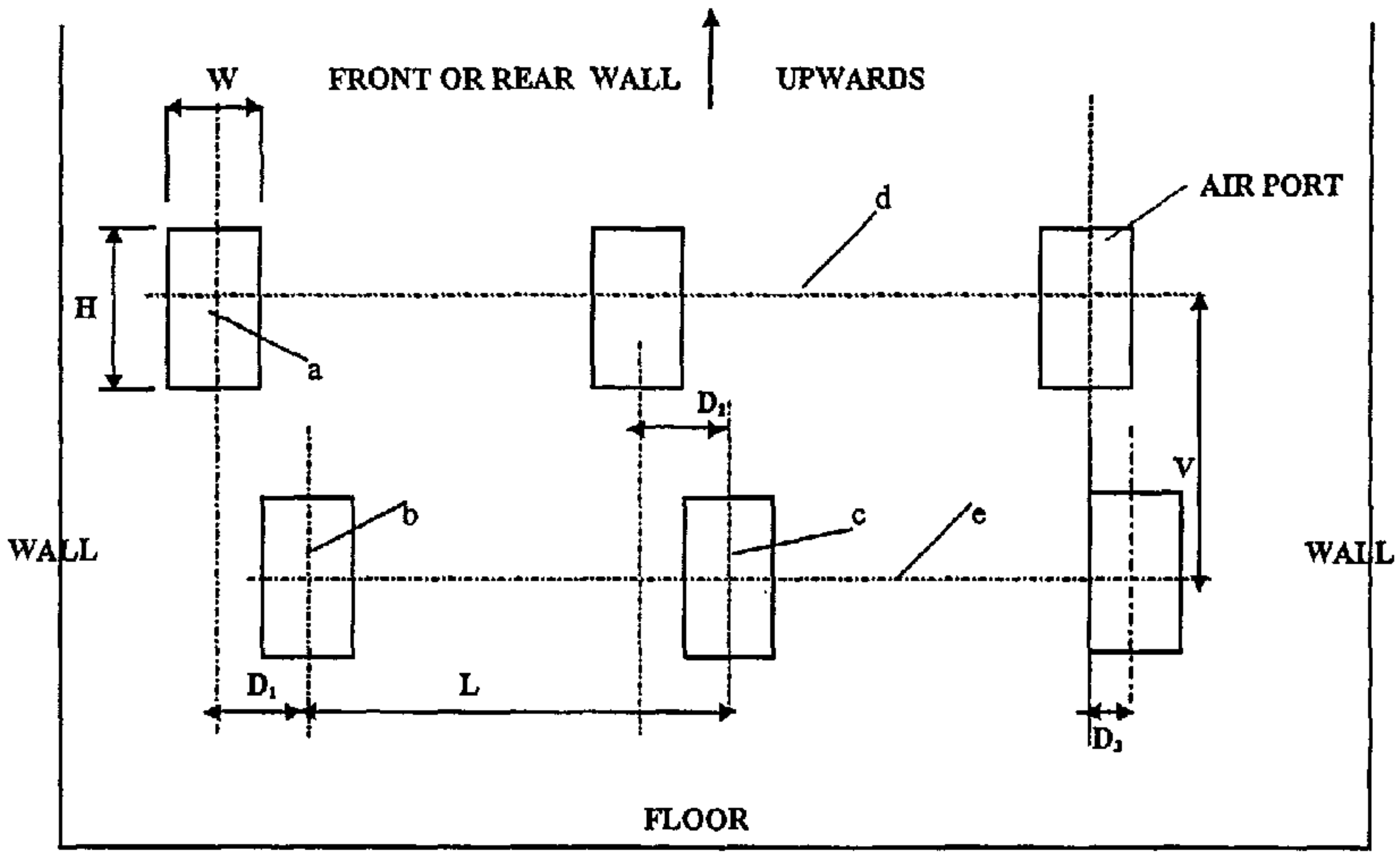
(54) **Title:** COMBUSTION AIR SYSTEM FOR RECOVERY BOILERS, BURNING SPENT LIQUORS FROM PULPING PROCESSES



(57) **Abstract:** An arrangement is disclosed for supplying an air jet form to the furnace of a recovery boiler, where the furnace has a front wall, a rear wall and side walls. Black liquor spraying devices are disposed on the furnace walls at one or several levels of the furnace. I addition a plurality of air ports are located on several horizontal levels for introducing air into the furnace from an air supply. In the arrangement for the secondary air flows two horizontal air levels at different elevations are arranged above the lowest air level or levels and below the black liquor spraying level or levels. Air is supplied from two opposite walls on said two levels and the air ports are located so that the air jets are introduced in an interlaced pattern having an even number of jets on one opposite wall and an uneven number of jets on the other opposite wall. The air jets of said at least two air levels are located substantially one above each other in substantially vertical rows.

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COMBUSTION AIR SYSTEM FOR RECOVERY BOILERS, BURNING SPENT LIQUORS FROM PULPING PROCESSES

The present invention relates to an arrangement for supplying air in an air jet form to the furnace of a recovery boiler. The furnace has a front wall, a rear wall and side walls. Black liquor spraying devices are disposed on these walls at one or several levels. A plurality of air ports are located on several horizontal levels on said walls for introducing air into the furnace from an air supply. Specifically, the invention relates to an arrangement for organizing the secondary air flows below the black liquor spraying devices.

An optimal supply of combustion air in the lower part of the furnace of a black liquor recovery boiler plays a considerable role in the control of a combustion process in the boiler.

Since the chemical reactions in the kraft recovery boiler are very rapid, the speed of the process becomes substantially dependent on the mixing of combustion air and black liquor. This mixing step determines the burning rate and also has an effect on the process efficiency. Air and black liquor are typically introduced into the boiler through individual ports, and it is particularly important that a rapid mixing in the boiler is effected by the air supply without generating large differences in the upward flow profile. The high velocity “lift” in the center of the furnace is especially harmful as it results in carry-over of the sprayed liquor droplets. The burning symmetry must be controlled throughout the whole cross-sectional area of the boiler and the air supply must be adjusted when required.

Black liquor is generally introduced in the form of considerably large droplets into a kraft recovery boiler so as to facilitate the downward flow of the droplets, and to prevent them from flowing, unreacted (as fine fume), upwards together with the upward flowing gases to the upper part of the boiler. The large droplet size, which results in the droplets being spaced further from each other than in a fine black liquor spray, means that proper mixing is even more important in a recovery boiler. Pyrolysis of black liquor solids produces char as well as combustible gases. The char falls down to the bottom of the furnace and forms a char bed which must be burned.

A stoichiometric amount of air, relative to the amount of black liquor, is introduced into the recovery boiler and additionally, a surplus amount of air is supplied to ensure complete combustion. Too much excessive air, however, causes a loss in efficiency of the boiler and an increase in costs. Air is usually introduced into the boiler on three different levels: primary air at the lower part of the furnace, secondary air above the primary air level but below the liquor nozzles, and tertiary air above the liquor nozzles to ensure complete combustion. Air is usually introduced through several air ports located on all four furnace walls, or only on two opposing walls of the furnace.

Primary air is typically 20-35 % of the total air supplied into the furnace, depending on liquor and dry solids content of the liquor. The task of the primary air is to keep the char bed from rising into air ports of the furnace. Secondary air is typically 35-60 % of total air, and tertiary air, which may be distributed into several levels in vertical direction, is typically 10-40 % of the total air. More than three air levels for introducing air into the furnace may be arranged in the boiler.

Mixing of black liquor and air is difficult because of the upflow of gas which is formed in the center part of the boiler, through which it is difficult for the weak secondary air flow to penetrate. More specifically, the primary air flows, supplied from the sides in the bottom part of the boiler, collide with each other in the center part of the boiler and form, with secondary air flow pattern, in the center part of the boiler, a gas flow flowing very rapidly upwards, catching flue gases and other incompletely burnt gaseous or dusty material from the lower part of the furnace. This gas flow, also called a "droplet lift", also catches black liquor particles flowing counter-currently downwards and carries them to the upper part of the boiler, where they stick to the heat surfaces of the boiler, thus causing fouling and clogging. In the center part of the boiler, the speed of the upwards flowing gas may become as much as four times as great as the average speed of the gases as a result of incomplete or weak mixing. Thus, a zone of rapid flow is formed in the center part of the boiler, and this renders mixing of flue gases from the side of the flow very difficult to achieve.

The “droplet lift” mentioned above, results in such a situation where the tertiary air(s) has (have) to burn not only the unburned gases from combustion (CO, H_2S,

NH_3, etc.), but the unburned char from the droplets as well. As the combustion rate for char is much slower than for the unburned gases, increased excess oxygen has to be used to ensure complete combustion. Then the flue gas leaving the furnace contains higher amounts of residual CO and H_2S, and the utilization of the furnace is less effective than would be possible.

Current secondary air arrangements are also characterized by at least one secondary air level where secondary air ports are placed close to another in horizontal direction. This leads to mixing patterns where furnace gases are circulated in vertical direction, with the above mentioned "lift", i.e. they flow towards the walls and then turn up (or down) and follow the main flue gas direction.

Another variation of the secondary air design is to use partial interlaced jets (e.g. US Patents 5,121,700, 5,305,698), whereby a large jet opposes a small jet. The large and small jets are alternated between the two opposite walls used.

US Patent 5,724,895 discloses an arrangement for feeding combustion air. In this system, a more favorable flow pattern in furnaces can be achieved by replacing vertical mixing by horizontal mixing, whereby a strong central flow channel, upward "lift", can be prevented. This horizontal mixing is applied for the whole furnace. The horizontal mixing is improved by disposing additional air inlet ports e.g. at more than six different elevations in a pattern of vertical spaced-apart rows above the lowest air levels.

In the method of US Patent 5,454,908 a portion of combustion air is introduced into a recovery boiler at a distance above the black liquor inlet so as to provide a reducing atmosphere with a residence time of at least three seconds between the black liquor inlet and the introduction of said portion of combustion air. A drawback of the described arrangement is a high vertical combustion area, reaching in extreme cases the bullnose of the furnace. As this combustion area has a reducing atmosphere, at least locally, more expensive materials have to be used in the furnace to a higher position than would be needed if combustion took place lower in the furnace. Other disadvantages of the air systems, where combustion takes place high up in the furnace include high furnace outlet temperature resulting in large convective heat transfer surfaces later in the boiler, lower temperature in the lower furnace, and more expensive layout. The lower temperature in the lower furnace does not allow as high sulfidity without SO_2 emissions as a combustion system having a higher lower furnace temperature does.

The present invention provides an improved air supply system of combustion air to a recovery boiler. Particularly, a secondary combustion air supply is provided in which either local and/or central upward gas flows having a high velocity compared to an average upward gas velocity are efficiently avoided. Another feature of the invention is to enable a constant penetration of combustion air into the boiler at different loading levels. A further feature of the invention is to produce a better mixing of black liquor and combustion air in the furnace. The improved air supply arrangement of this invention is also designed to reduce the amount of harmful emissions from the boiler furnace.

The present invention may be embodied in a recovery boiler having a furnace that comprises:

- two horizontal air levels at different elevations are arranged above the lowest air level or levels and below the black liquor spraying level or levels,

- air is supplied from two opposite walls on said two levels and the air ports on each level are located so that the air jets are introduced in an interlaced pattern having an even number of jets on one opposite wall and an uneven number of jets on the other opposite wall, and

- the air jets of said two air levels are located in substantially vertical rows.

According to the invention secondary air on two air levels is introduced only from the two opposite walls, preferably from the front and rear walls. Substantially no air is supplied from the two remaining walls, i.e. the side walls. In the interlaced pattern, an air flow coming from an air port located on a wall having an even number of air jets is directed in between two adjacent air ports of the opposite wall having an uneven number of air jets. Correspondingly, the air jets coming from the wall having an uneven number of air jets are directed substantially directly in a horizontal plane towards the opposite wall. The air jets coming from the opposite walls by-pass each other without actually colliding with each other.

Thus on the two secondary levels, the lateral arrangement of the jets on one level sideways is symmetrical. On the wall having an uneven number of air jets, e.g. three, the middle air jet is located substantially on the center line of the wall, and the other jets are located within an equal distance on both sides of the middle jet. On the opposite wall having an even number of jets, two in this example, the jets are located laterally midway between the jets on the opposite wall. Thus, the jet arrangement is symmetrical in relation to the vertical plane parallel to the remaining walls (i.e. the walls having no secondary air jets) and passing through the center lines of the walls having the secondary air jets.

The present invention is based on the following principles in order to avoid strong vertical gas flows, but still to obtain effective mixing in the furnace between combustion air and unburned/burning liquor droplets:

- strong secondary air jets (strong air jets below black liquor spraying devices).

- arrange these jets so that they do not collide against each other, which easily generates strong upflow jets and unwanted upflow profile for the gases in the furnaces. Instead, strong shearing flows should be generated to obtain good mixing.

- minimize suction of gases in vertical direction into these jets above the liquor spraying devices as this increases gas flow up.

- minimize suction of liquor droplets from liquor sprays into tertiary air jets

- cover the tertiary air stage(s) with several jets, which cover the furnace cross section evenly and well in order to prevent the formation of vertical jets that may punch the final combustion area where the final combustion of the unburned gases cannot take place. Also, here the jets should not collide against each other but generate strong shearing flows and good mixing.

According to a preferred embodiment of the invention, there is a distance, V, in vertical direction between the horizontal air levels, when measured from the lateral center lines of the air ports of the air levels. This distance, V, fulfils the following formula: $V/L \leq 0.5$, where L is the distance between two adjacent air ports on the same air level, when measured from the longitudinal center lines of the adjacent air ports. Preferably V/L is 0.25-0.5. Typically the vertical distance, V, is 1-2 meter.

Preferably the air ports located one above the other are positioned in a vertical row so that they are located on the same straight vertical line. The invention covers also an embodiment in which the air ports laterally deviate so that there a transverse distance, D, between the air ports above each other. The transverse distance is a distance between the longitudinal center lines of the ports one above the other. D is less than 1.5 x H or less than 1.5 x W depending on which number is greater. H is the height of the highest air port and W is the width of the widest air port.

According to an embodiment of the invention there is only one air level below the two secondary air levels. According to another embodiment, the number of the lowest air levels below the two secondary air levels is two. The air jets of the air level which is located higher in vertical direction below the two secondary air levels are arranged in an interlaced pattern on two opposite walls, preferably on the front and rear walls, so that the number of air jets is greater by one than the number of air jets of the two secondary air levels on the same wall. For example, if the secondary air level has one air jet on the front wall and two jets on the rear wall, the above-mentioned lower air level has two air jets on the front wall and three jets on the rear wall. However, the air velocity is lower on this lower air level. On this air level which thus is located above the lowest air level and below the two secondary air levels and which can be called a low-secondary air level, the air jets are arranged also on the remaining opposite walls, i.e. preferably on the side walls. The air jets on the side walls are smaller than the air jets on the front and rear walls.

The invention is directed also to an arrangement for supplying secondary air in an air jet form to the furnace of a recovery boiler, said furnace having a front wall, a rear wall and side walls, black liquor spraying devices disposed on said walls on a level and a plurality of air ports located on several horizontal levels on said walls for introducing air into the furnace from an air supply, said arrangement comprising: one horizontal air level is arranged above the lowest air level or levels and below the black liquor spraying level or levels, and air is supplied from two opposite walls on said level and the air ports are located so that the air jets are introduced in an interlaced pattern having an even number of jets on one opposite wall and an uneven number of jets on the other opposite wall. The air port has an area, A, and a width, W, and the ratio of the area to the width to the power of 2 (A/W^2) is more than 4, preferably more than 10.

The invention will be described in more detail with reference to the attached drawings, in which

FIG. 1 illustrates a schematic cross-sectional view of a recovery boiler,

FIG. 2 illustrates a side view of the lower furnace of a recovery boiler with an air port arrangement according to an embodiment of the invention, and

FIG. 3 illustrates a plan view of the lower furnace of a recovery boiler with an arrangement of air jets according to an embodiment of the invention, and

FIG. 1 illustrates a conventional recovery boiler. The boiler 1 comprises a furnace 2 provided with a bottom, boiler walls 4, and a super heater 5. In the combustion process, a bed of dried and partly burnt black liquor is formed at the bottom of the furnace. Melt chemicals flow through the porous bed to the bottom of the furnace, from where they are transferred as an overflow via melt chutes to a dissolving tank 7. Black liquor is introduced to the furnace through openings in zone 8. Air is introduced from three different levels: primary air ports 9, secondary air ports 10 and tertiary air ports 11.

As known, the recovery boiler furnace has a front wall, a rear wall and side walls. Black liquor spraying devices are disposed on these walls at one or several levels. A plurality of air ports are located on several horizontal levels on said walls for introducing air into the furnace from an air supply.

According to this invention the air ports of the furnace for supplying secondary air are arranged in a specific way. In connection with this invention, the secondary air is used to refer to the air that is introduced between the lowest air level, i.e., the primary air level, and the black liquor spraying level or levels. In the arrangement of the invention the secondary air is supplied as interlaced jets from two opposite walls on at least two levels, preferably on two levels.

Each air level has an even number of jets on one opposite wall and an uneven number of jets on the other opposite wall, as shown in Fig. 3. A first set of air jets is shown in FIG. 3. In this interlaced pattern, an air flow coming from an air port located on a wall having an even number of air ports is directed in between two adjacent air ports of the opposite wall having an uneven number of air ports. The air flows coming from the opposite walls by-pass each other without actually colliding with each other. The air ports of the different air levels are located on the same walls, e.g. on the front and rear walls.

According to an embodiment of the invention, as shown in Fig. 2, the air ports one above the other of two air levels are located in vertical rows so that there is a transverse distance, D, in horizontal direction. Distance D is measured so that it is a distance between the longitudinal center lines of two air ports above each other. In Fig. 1, D_1 is a distance between longitudinal center lines a and b. D is less than 1.5 x H or less than 1.5 x W depending on which number is greater. H is the height of the highest air port and W is the width of the widest air port of the two air levels. Because of the water circulation in the tubes forming the walls of the furnace it may be advantageous to have this transverse distance between the air ports above each other.

Preferably the transverse distance (D) is less than 1.0 x H or less than 1.0 x W. Typically this transverse distance between two air ports above each other is 0.075 – 0.16 m.

The two air levels are located so that there is a vertical distance, V, between the air levels. V is measured so that it is a distance in vertical direction between the lateral center lines of air ports above each other, in Fig. 1 lines d and e. This distance, V, fulfils the following formula: $V/L \leq 0.5$, where L is the distance between two adjacent air ports on the same air level, when measured from the longitudinal center lines of the adjacent air ports. In Fig. 2 distance L is a distance between lines b and c. The value of the distance L depends on e.g. the number of air ports of a wall. When there is an even number of ports on one wall and an uneven number of ports on the opposite wall, the value of L used in the above formula is the minimum of these L values.

Typically V/L is 0.05-0.5, preferably 0.25-0.5. Typically the vertical distance, V, is 1-2 meter.

Preferably the shape of the secondary air ports is close to a hexahedral form to minimize the area of uncooled fin areas. The air ports have an area, A, and a width, W. Preferably the ratio between the area and the width to the power of 2, A/W^2, is more than 4, but it can also be smaller. For instance, the ratio can vary from 5 to 10. An essential feature of the invention is that each air port is closer to the air port located above it than the adjacent air port on the same level. In the extreme case the vertical distance V is close to 0, whereby two air ports located above each other are to be replaced with one air port that is very high and narrow.

Typically, the lowest primary level is located about 0.7 – 1.0 m from the floor of the furnace (from the smelt level). The distance between the primary level and the lowest secondary level having air jets only on two walls is about 0.8-1.5 m, in which case the lowest secondary level is about 1.5-2.5 m from the floor of the furnace (from the smelt level). The low-secondary level having air jets on four walls is located about 1-1.4 m from the smelt level.

The air ports of the same secondary air level do not have to be located exactly at the same elevation on the opposite walls. This means that the air jets on the opposite walls on the same air level are not located in the same horizontal plane. However, the difference between the elevations of the air ports of the same level on the opposite walls is less than 10 % of the depth of the furnace.

According to a preferred embodiment the air jets of the secondary air levels are located on the front and rear walls of the furnace, but the arrangement of the invention can be applied to the side walls of the furnace as well.

The number of jets on the secondary air levels is characterized by the following numbers, depending on the spent liquor dry solids combustion capacity of a recovery boiler:

capacity: less than 500 metric tons D.S./d : 1+2 jets per level (6 jets together in the case of two air levels)

500 - 1500: 1+2 or 2+3 jets per level

1500 – 2500: 2+3 or 3+4 jets per level

2500 – 4000: 2+3,3+4 or 4+5 jets per level

>4000: 3+4, 4+5, 5+6 or 6+7 jets per level.

Where "1+2 jets per level" means that one jet is located on one of the opposite walls and two jets on the other of the opposite walls. Figs. 2 and 3 show 2 + 3 arrangement on two levels.

According to the invention the velocity of the secondary air supplied through the air ports into the furnace is preferably at least 40 m/s.

In order to prevent the formation of vertical jets that may punch the final combustion area where the final combustion of the unburned gases should take place, the number of air jets on each tertiary air level in the claimed arrangement is higher than the number of the air jets on the secondary air levels. Preferably the vertical distance between the lowest tertiary air level and the black liquor spraying level is more than two times greater than the vertical distance between each secondary air level.

In the arrangement in accordance with the invention the combustion air supply can be connected to means for conveying flue gas from the recovery boiler in order to recirculate a portion of the flue gas into the furnace. The air supply can also be connected to a line for odorous gases for introducing the gases into the furnace.

While the invention has been described in connection with what is presently considered to be the most practical and preferred embodiment, it is to be understood that the invention is not to be limited to the disclosed embodiment, but on the contrary, is intended to cover various modifications and equivalent arrangements included within the spirit and scope of the appended claims.

The invention covers also an embodiment according to which the air jets described above form a first set of air jets. In addition to the first air jets, a second set of air jets is arranged on the opposite walls at the horizontal air levels so that first and second air jets form opposed pairs and the air stream through each second jet is less than 25 % of the air stream of the opposed first jet. The major part, i.e. more than 75 %, of the air is introduced through the first jets. The air ports for the second air jets are arranged one above the other in the same manner as the first air ports described above. According to another embodiment of the invention a second set of air ports is arranged close to or at the corners of the furnace, whereby the air stream of the second jets is less than 25 % of the air stream of the first jets. Preferably one second air port is located at each corner. Gas streams in the corner areas of the furnace can be controlled by means of these weaker air jets. However, preferably the entire air stream is introduced into the furnace through the first set of jets, in which case the furnace has no second air jets.

CLAIMS

1. A furnace for a recovery boiler with an arrangement for supplying secondary air in an air jet form to said furnace, said furnace having a front wall, a rear wall and side walls, black liquor spraying devices disposed on said walls on a black liquor spraying level and a plurality of air ports located on several horizontal levels on said walls for introducing air jets into the furnace from an air supply, said arrangement comprising:

- two horizontal secondary air levels having air ports at different elevations are arranged above a lowest air level or lowest air levels and below the black liquor spraying level or levels,

- air jets are supplied from two opposite walls through the air ports on said two levels which air ports are located so that the air jets are introduced in an interlaced pattern having an even number of jets on one opposite wall and an uneven number of jets on the other opposite wall, and

- the air jets of said two air levels are located substantially one above each other in substantially vertical rows, each of which rows is formed by two air jets.

2. A furnace in accordance with claim 1, wherein the air ports of said two air levels are located on the front and rear walls of the furnace.

3. A furnace in accordance with claim 1, wherein the distance, V, in vertical direction between the air levels, when measured from the lateral center lines of the air ports of the air levels, is in accordance with the formula: $V/L \leq 0.5$, where L is a distance between two adjacent air ports on the same air level, when measured from the longitudinal center lines of the adjacent air ports.

4. A furnace in accordance with claim 3, wherein V/L is 0.25-0.5.

5. A furnace in accordance with claim 3, wherein the vertical distance, V, is 1-2 meter.

6. A furnace in accordance with claim 1, wherein substantially no air is introduced from two remaining walls.

7. A furnace in accordance with claim 1, wherein the number of the air jets on each level of said two air levels is three, of which one jet is supplied from one of the opposite walls and two jets are supplied from the other of the opposite walls, the capacity of the recovery boiler being less than 500 metric tons D.S./d.

8. A furnace in accordance with claim 1, wherein the number of the air jets on each level of said two air levels is three, of which one jet is supplied from one of the opposite walls and two jets are supplied from the other of the opposite walls, the capacity of the recovery boiler being between 500 and 1500 metric tons D.S./d.

9. A furnace in accordance with claim 1, wherein the number of the air jets on each level of at least two air levels is five, of which two jets are supplied from one of the opposite walls and three jets from the other of the opposite walls, the capacity of the recovery boiler being between 500 and 4000 metric tons D.S./d.

10. A furnace in accordance with claim 1, wherein the number of the air jets on each level of said two air levels is seven, of which three jets are supplied from one of the opposite walls and four jets from the other of the opposite walls, the capacity of the recovery boiler being between 1500 and 4000 metric tons D.S./d.

11. A furnace in accordance with claim 1, wherein the number of the air jets on each level of said two air levels is nine, of which four jets are supplied from one of the opposite walls and five jets from the other of the opposite walls, the capacity of the recovery boiler being between 2500 and 4000 metric tons D.S./d.

12. A furnace in accordance with claim 1, wherein the number of the air jets on each level of said two air levels is seven, nine, eleven or thirteen, of which three, four, five or six jets are supplied from one of the opposite walls and four, five, six or seven jets from the other of the opposite walls, respectively, the capacity of the recovery boiler being more than 4000 metric tons D.S./d.

13. A furnace in accordance with claim 1, wherein the number of lowest air levels is one.

14. A furnace in accordance with claim 1, wherein the number of lowest air levels below said two air levels is two, and the air jets of the air level which is

located higher in vertical direction below said two air levels project an interlaced pattern from the air ports on two opposite walls so that the number of air jets is greater by one than the number of air jets of said two air levels on the same wall, and smaller air jets are arranged on the remaining opposite walls.

15. A furnace in accordance with claim 1, wherein the velocity of the air through the air ports on said at least two air levels is at least 40 m/s.

16. A furnace in accordance with claim 1, wherein the furnace has a tertiary air level or tertiary air levels above the black liquor spraying level or levels, and wherein the number of air jets on each tertiary air level is higher than the number of the air jets on the secondary air levels.

17. A furnace in accordance with claim 16, wherein the vertical distance between the lowest tertiary air level and the black liquor spraying level is more than 2 meter.

18. A furnace in accordance with claim 1, wherein the air ports form vertical lines so that the longitudinal center lines of the ports of a vertical row substantially pass through one single vertical line.

19. A furnace in accordance with claim 1, wherein the air ports forming a vertical row laterally deviate so that there is a transverse distance, D, between the air ports above each other, which transverse distance is a distance between the longitudinal center lines of the ports above each other and is less than 1.5 x H or less than 1.5 x W depending on which number is greater, in which H is the height of the highest air port and W is the width of the widest air port.

20. A furnace in accordance with claim 19, wherein the transverse distance is 0.075-0.16 m.

21. A furnace in accordance with claim 1, wherein the air supply is connected to means for conveying flue gas from the recovery boiler in order to recirculate a portion of the flue gas to the furnace.

22. A furnace in accordance with claim 1, wherein the air supply is connected to a line for odorous gases for introducing the gases to the furnace.

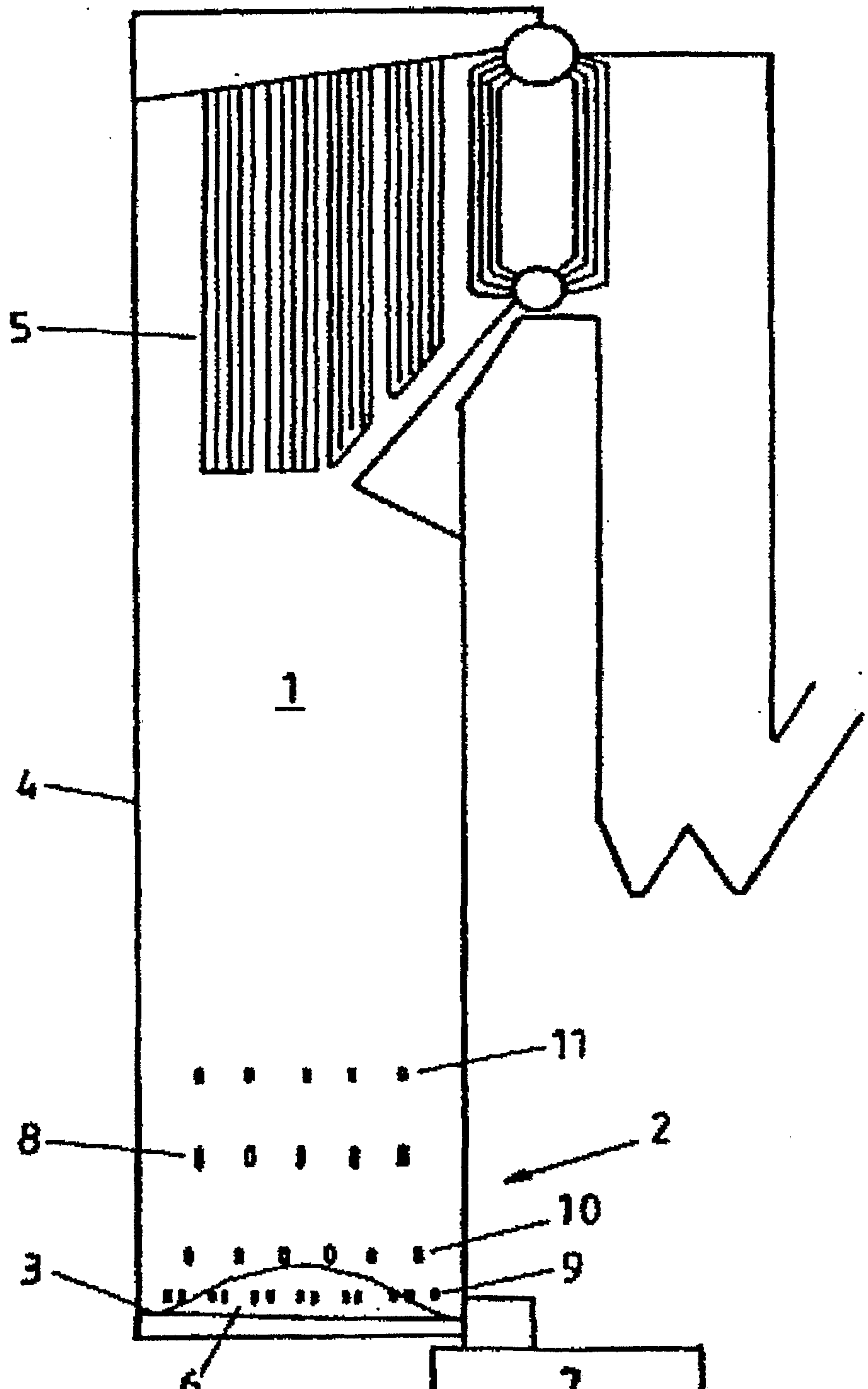


FIG 1

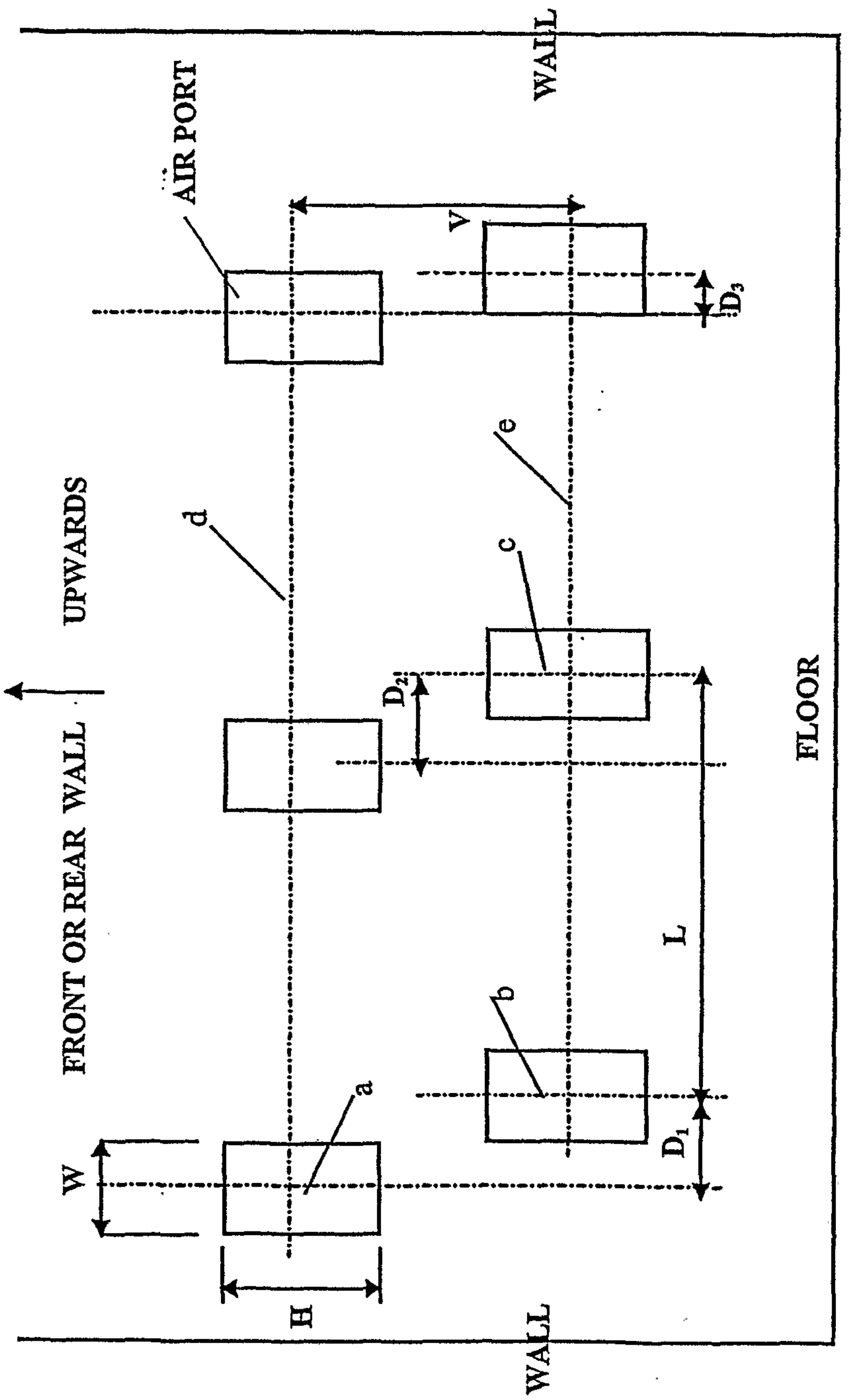

WALL
AIR PORT
V
D_3
e
d
c
UPWARDS
FRONT OR REAR WALL
D_2
FLOOR
L
b
a
W
D_1
H
WALL

FIG. 2

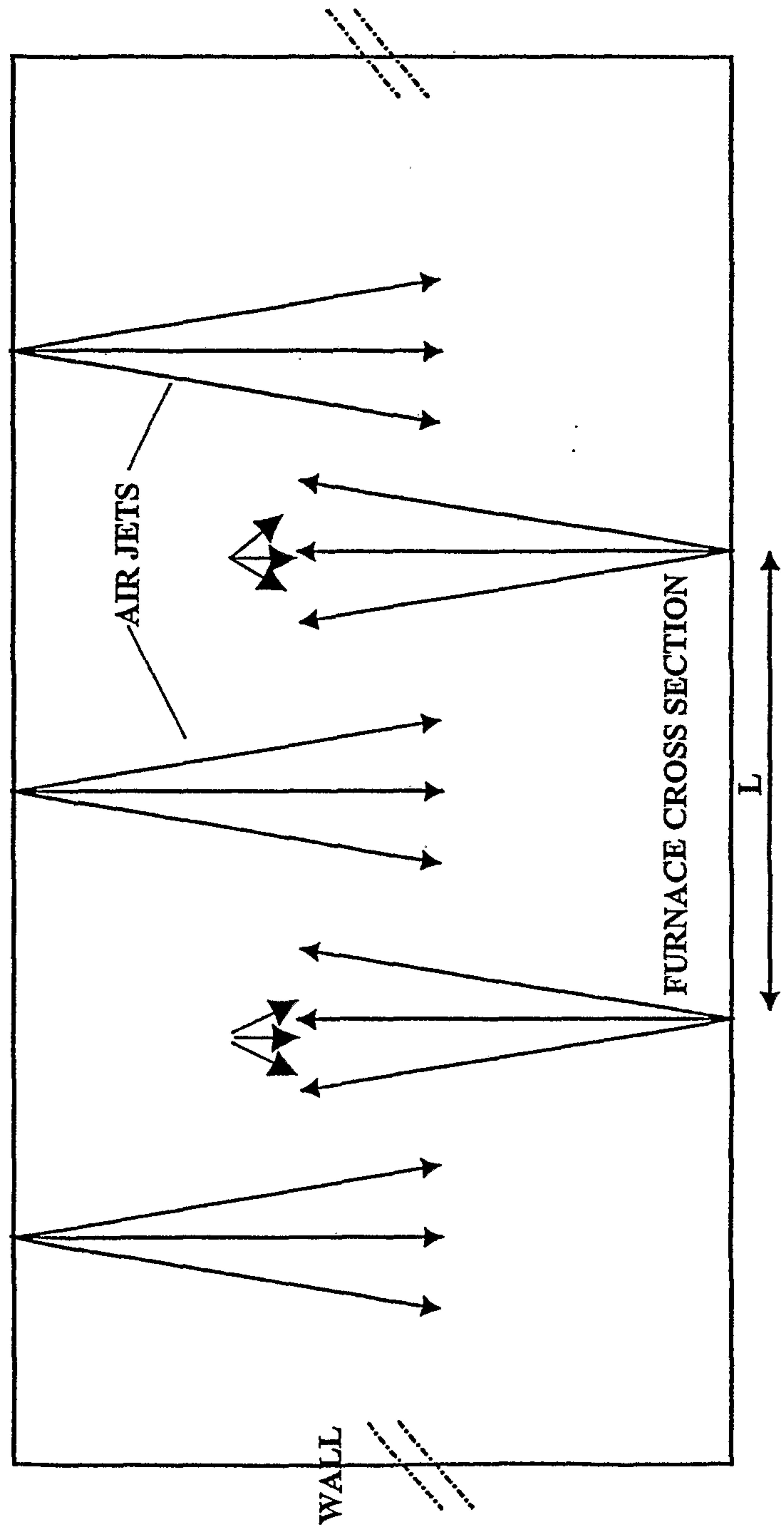
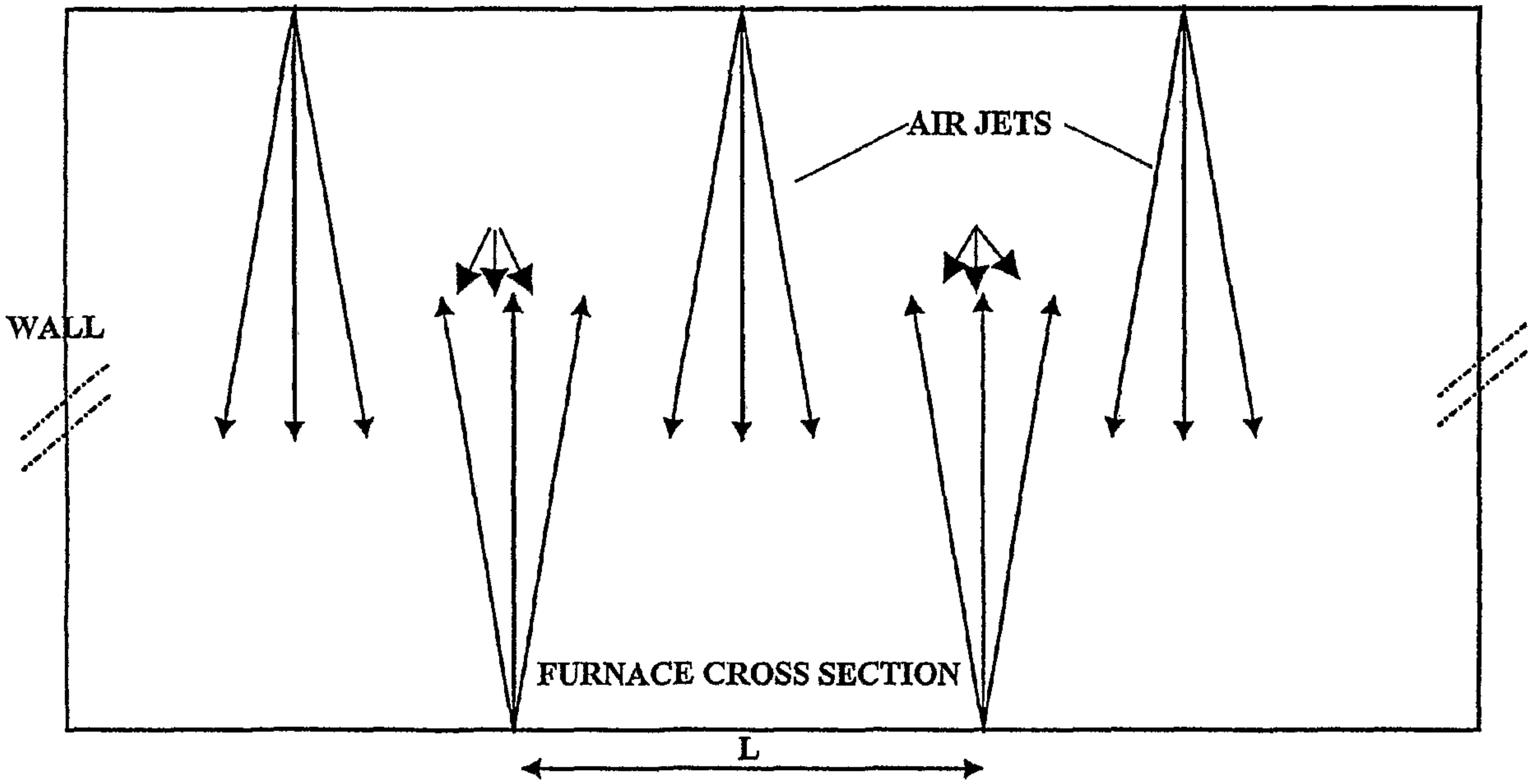


FIG. 3


AIR JETS
WALL
FURNACE CROSS SECTION
L