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(54) **METHOD OF PRODUCING STEAM IN A GAS TUBE STEAM BOILER AND GAS TUBE STEAM BOILER**

VERFAHREN FÜR DIE ERZEUGUNG VON DAMPF IN EINEM GASROHR-DAMPFKESSEL UND GASROHR-DAMPFKESSEL

MÉTHODE POUR LA PRODUCTION DE VAPEUR DANS UNE CHAUDIÈRE À TUBES DE GAZ ET CHAUDIÈRE À TUBES DE GAZ

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Description

[0001] The present invention relates to a method of producing steam in a gas tube steam boiler and a gas tube steam boiler.

[0002] In connection with such a method and apparatus it is of importance to optimise the energy transfer from the gas tubes to the water and steam in order to reduce the overall size of the boiler for a given energy output. Typically, the primary design parameters are involving the input gas temperature, the exhaust gas temperature and the desired maximum energy output, i.e. feed water temperature, steam pressure, temperature and mass flow. Preferably, the steam should be dry or even more preferred superheated.

[0003] From US 1,546,665 it is known to provide a gas tube steam boiler with a baffle plate providing an annular opening along the boiler wall, whereby the steam flow from the water surface is restricted to flow from the water surface to the annular opening and from there to the centrally positioned steam outlet. In this construction a major part of the generated steam will only pass the gas tubes over a distance corresponding to approximately 1/2 of the diameter of the gas tube boiler leading to insufficient heat exchange between the gas tubes and the generated steam.

[0004] GB114222 also shows a gas tube stream boiler.

[0005] In particular, but not exclusively, for marine boilers, the size of the boiler is of great importance due to limited space available, and accordingly it is an object of the present invention to provide a method and an apparatus of the type in reference that allows reduction of the space requirements of a boiler.

[0006] According to the invention this object is achieved by the method according to independent claim 1.

[0007] Hereby, the heat transfer from the gas tubes to the steam in the steam head space is significantly improved, whereby the efficiency of the boiler is increased and at the same time the produced steam has a higher quality by being dried and possibly superheated.

[0008] In a currently preferred embodiment of the method according to the invention said horizontal projection of said flow path is at least two times said distance. In this way the contact between the gas tubes and the flow of steam from the water surface to the steam outlet is increased, thus increasing the heat transfer in the steam head space.

[0009] In a currently preferred embodiment of the method according to the invention the steam outlet is located at a distance from the axis of the wall, preferably proximate to the wall of the head space, thus restricting the steam flow to flow sideways along all of the gas tubes before leaving through the steam outlet..

[0010] In a currently preferred embodiment of the method according to the invention the horizontal projection of the flow path extends from proximate or at a first point on said wall past said axis to proximate or at a second point on said wall opposite said first point and preferably extends back from the second point and at least partways back to said first point. In this way the steam flow is caused to move past all of the gas tubes, preferably at least two times before leaving through the steam outlet steam outlet.

[0011] In a currently preferred embodiment of the method according to the invention the steam flow velocity is lower when flowing from the second point towards the first point than when flowing from proximate said first point towards said second point, providing a relative high velocity, preferably approximately 15-30 m/s, more preferably 15-25 m/s over a part of the distance between the water surface and the steam outlet and to pass the gas tubes at a reduced velocity, preferably approximately 10-15 m/s over a subsequent part of the path from the water surface to the steam outlet, whereby the high velocity provides a turbulent flow around the gas tubes securing a high heat transfer and securing that possible droplets of water in the steam will hit the tubes and evaporate.

[0012] In a currently preferred embodiment of the method according to the invention the hot gasses for the gas tubes are provided from a combustion chamber, combusting a fuel such as oil, carbon dust, natural gas, etc., however, also hot exhaust gasses from a gas turbine or an internal combustion motor and the like may be used. When using hot gasses from a combustion chamber, said combustion chamber may be provided in contact with the water in the heat exchange compartment, in order to deliver further heating to the water directly from the combustion chamber.

[0013] In a second aspect the present invention relates to a gas tube steam boiler according to independent claim 10.

[0014] In the following the invention will be explained in more detail with reference to the embodiments shown solely by way of example in the drawings, where

Fig. 1 schematically shows a vertical cross sectional view along A-A in a boiler in accordance with a preferred embodiment of the present invention,

Fig 1a schematically shows the boiler in Fig. 1 seen from the top and indicating the lines along which the cross sectional views in Figs. 1 and 2 are taken,

Fig. 2 schematically shows a vertical cross sectional view along B-B perpendicular to the one in Fig. 1,

Fig. 3 schematically shows a perspective view of the baffle plate configuration,

Fig. 4-7 show four different possible configurations of the boiler steam head space.

[0015] The gas tube steam boiler shown in Fig. 1 comprises a heat exchange compartment 2 filled with water, said water forming a water surface 2a, and a steam head space 8 above said water surface and delimited by a cylindrical wall 1 with a substantially vertical axis 10, a top plate 4 and a diameter D. A steam outlet 6 is connected to the steam head space 8 and several gas tubes 3 extend through the heat exchange compartment 2 and the steam head space 8. Heated gas flows through the gas tubes 3 in order to generate a flow of steam from the water surface by heat exchange between the gas tubes 3 and the water in the heat exchange compartment 2.

[0016] In the embodiment shown in Figs. 1-3 and Fig. 5 the steam flow from the water surface is caused to flow along a conduit delimited by the baffle plates 7', 7", whereby said steam is made to flow in a direction transverse to the gas tubes 3 and all of the steam in the flow is constrained to flow between the two baffle plates 7', 7" in a horizontal direction and back between the upper baffle plate 7" and the top plate 4 in an opposite horizontal direction and out through the steam outlet 6.

[0017] As shown in Figs. 2 and 3 the two baffle plates 7', 7" each covers a smaller area than the cross sectional area of the steam head space 5 and the edges of the two baffle plates 7', 7" are connected to vertical plates 9 extending from the top plate 4 down to the lower baffle plate 7' in the vertical direction and in the horizontal direction all the way across between individual positions on the cylindrical wall of the steam head space 5.

[0018] The gas tubes 3 extend from the bottom of the boiler, possibly from a combustion chamber 14 as shown in Fig. 2 up through the water filled heat exchange compartment 2 and the steam head space 5, where the gas tubes 3 extend through the plates 7', 7" and through holes in the top plate 4, from where the gas leaves through a gas exhaust 11.

[0019] Heat exchange between the gas tubes and the water will produce steam entering the steam head space 5 at the water surface and the plate 7' forces the steam to move to the left as seen in Fig. 1 around a gap forming edge 12 and in between the two plates 7', 7" moving to the right as seen in Fig. 1 and around a gap forming edge 13 and moving between the plate 7' and the top plate 4 to the steam outlet 6. In this way the steam is forced to move in a direction transverse to the gas tubes 3 over a distance corresponding to approximately two times the diameter of the boiler 1. Minor leakage of steam between the openings in the plates 7', 7" and the gas tubes 3 will be no problem as the steam in these small gaps will come very close to the tube walls and be heated up here. In order to provide a sufficient heat exchange between the gas tubes and the flow of steam, more than half of all the steam in the flow in the head space is constrained to flow in a direction transverse, preferably generally orthogonal, to said gas tubes along a flow path, which when projected on a horizontal surface has a length at least equal to the diameter of the circular cylindrical wall. By this feature the present invention is distinguished over the above-mentioned US 1, 546,665, in which less than half of the steam flows over a distance corresponding to less than 3/4 of the diameter of the circular cylindrical wall.

[0020] When the steam leaves the water surface it will typically contain small water droplets, which, by the forced flow across the gas tubes 3 with a relatively high flow velocity, will hit the gas tubes 3 and evaporate, and furthermore the relatively high velocity of the steam will provide a heat exchange between the steam and the gas tubes in the steam head space 5, said heat exchange is increased compared to the traditional boiler construction in which the steam simply moves from the water surface to the steam outlet in a slow flow mainly parallel to the gas tubes 3 in an open steam head space without plate 7', 7". Furthermore, the distance between the water level and the top plate can be reduced, said distance normally being relatively high in order to avoid a high concentration of water droplets in the steam leaving the steam outlet 6.

[0021] When the water in the boiler 1 is not boiling, the water level inside the boiler corresponds to the level measured with different traditional equipment, such as pressure difference between two known levels, water level glasses, etc. However, the actual water level seen inside the boiler will rise because of the presence of a large amount of steam bubbles inside the water area, and the water level will be fluctuating more or less, dependent on the heat load and the steam pressure. The highest water level will be around the gas tubes 3 and accordingly the gas tubes are wetted by water up to this water level, which typically is about 250 mm above the measured water level, in the following named water surface in cold condition.

[0022] The total height h of the steam head space 5 is subdivided into the distance h1 between the top plate 4 and the first plate 7", the distance h2 between the first plate 7" and the second plate 7', and finally the distance h3 between the second plate 7' and the water surface in cold condition.

[0023] In a preferred embodiment the distances h1 and h2 are dimensioned in such a way that the steam velocity between the top plate 4 and the first plate 7" is approximately 10-15 m/s and the steam velocity between the two plates 7' and 7" is approximately 20-30 m/s., i.e. the distance h1 is approximately two times the distance h2. Under all circumstances the distance h3 should be sufficient to secure that during boiling at full load, the actual water level should be approximately 200 mm below the second plate 7'.

[0024] In the steam head space, as described above, the flow of the steam perpendicular to the gas tubes 3 is relatively high between the two plates 7', 7", a bit lower between the top plate 4 and the plate 7" and even between the water surface and the plate 7' a certain cross flow relative to the gas tubes 3 will be present. The steam velocity provides a higher heat transfer coefficient from the gas tubes 3 to the steam compared to a traditional situation in which the steam head space 5 transmits steam at a low velocity, substantially parallel to the tubes. Actually, the heat transfer is close to the same heat transfer that exists in the water filled heat exchange compartment 2 in which water is in direct contact with the gas tubes 3.

[0025] The produced steam is not only free of water droplets when it leaves the boiler through the steam outlet 6, but it is actually superheated. This superheating ensures that no salts leave the boiler, resulting in that there will be no deposits in the steam pipe from the boiler to the user. Furthermore, a possible steam outlet valve after the steam outlets can be dimensioned to a higher steam velocity, which means that the size of the valve can be reduced, thus saving both space, weight and costs for said steam outlet valve. Furthermore, the total heating surface can be reduced due to increased heat transfer, which means reduced tube length, number of tubes, boiler height and thus both weight and cost price for the boiler.

[0026] In the following table process data for at gas tube steam boiler in accordance with the present invention are indicated.

Boiler steam capacity	kg/h	3700
Working pressure of steam	barg	6.5
Saturation point	°C	167
Fuel flow (HFO)	kg/h	250
Flue gas flow	kg/h	3900
Smoke tube dimension	mm	Ø18 x 2
Number of smoke tubes	pcs	300
Total tube length, furnace top plate to boiler top plate	mm	1440
Boiler shell, inside diameter	mm	Ø1276
h1, distance between boiler top plate and upper baffle plate	mm	125
h2, distance between the two baffle plates	mm	75
h3, distance below lower baffle plate and measured water level (Normal Water Level)	mm	450
Boiling up (wet heating surface above measured water level)	mm	250
Wet tube length	mm	1040
Max. steam velocity, 2. pass (between the two baffle plates)	m/s	16
Max. steam velocity, 3. pass (between upper baffle plate and boiler top plate)	m/s	10
Steam space volume load (to measured NWL)	h^{-1}	1100
Inlet gas temperature (leaving furnace)	°C	1360
Gas velocity, tube inlet	m/s	107
Gas temperature inside smoke tubes at actual water level (upper part of wet heating surface)	°C	550
Outlet gas temperature	°C	400
Outlet steam temperature	°C	220

[0027] The following table compares a traditionally dimensioned gas tube steam boiler indicated as standard, and a gas tube steam boiler in accordance with the present invention indicated as new. The two boilers have been designed for having the same steam capacity, thermal efficiency (i.e. same flue gas outlet temperature) and same pressure drop.

Description	Unit	Standard	New
Tube dimension	mm	18x2	18x2
Number of tubes	Pcs	375	300
Wet tube length	mm	1370	1040

(continued)

Description	Unit	Standard	New
Length to normal water level (measured)	mm	1120	790
Steam space to measured water level	mm	840	650
Total tube length	mm	1960	1440
Total tube length in boiler	m	735	432

[0028] It can be seen that the direct result of using the present invention is that approximately 40% of the tubes (approximately 240 kg) in the standard boiler design can be saved. Furthermore, the tube length and accordingly the boiler height is shortened by 520 mm, which with a boiler diameter of 1300 and a plate thickness of 12 mm provides a difference in plate weight of approximately 200 kg.

[0029] Above the invention has been described in connection with a preferred embodiment, however, many modifications may be envisaged without departing from the following claims. Among such modifications are the omission of the second plate 7' leading to a more simplified construction, but, however, still providing a flow of the steam through the steam head space 5 from the water surface to the steam outlet 6 in such a manner that the majority of the steam in the flow in said head space 5 is constrained to flow in a direction transverse to the gas tubes along a flow path having a length corresponding to the diameter of the boiler 1. This possibility is shown in Fig. 4, and the above described preferred embodiment is schematically shown in Fig. 5. Other possibilities not forming part of the invention as shown in Fig. 6 and Fig. 7 provide a steam flow from the water surface to the steam outlet restricted by a first plate having a central hole for passing the steam and a second plate above said first plate, said second plate providing an annular opening along the boiler wall, whereby the steam flow is restricted to flow across the gas tubes, first in a radially outward direction and following in a radially inward direction towards the centrally positioned steam outlet 6.

[0030] In the Fig. 7 embodiment also not forming part of the invention the steam flow is restricted to a helically flow path by means of a helically shaped plate positioned between a central tube and the outer wall of the boiler 1, said steam flow path again having a length corresponding to at least the distance between two opposite point of the wall of the boiler 1.

Claims

1. A method of generating steam comprising the steps of:

- providing a gas tube steam boiler comprising:

    - a heat exchange compartment (2) filled with water forming a water surface (2a),
    - a steam head space (5) above said water surface (2a) and delimited by a cylindrical wall (1) with a substantially vertical axis and a top plate (4),
    - a steam outlet (6) communicating with said steam head space (5),
    - one or more gas tubes (3) extending through said heat exchange compartment (2) and said steam head space (5),
    - a steam flow conduit comprising a first plate (7") arranged at a vertical distance h1 below said top plate (4) and having a first gap forming edge (13) arranged at a distance from said wall (1) to provide a first steam flow gap between said first plate (7") and said wall (1) arranged in said steam head space (5) for conducting said flow of steam from said water surface (2a) to said steam outlet (6), at least one of said gas tubes (3) extending transversely through said conduit such that said flow of steam flows in a direction transverse, preferably generally orthogonal, to said gas tubes (3), the configuration of said conduit being such that more than half, preferably substantially all, of the steam in said flow is constrained to flow along a flow path which when projected on a horizontal surface has a length at least equal to the shortest distance between a first point of said wall (1) and a second point of said wall (1) horizontally opposite said first point, said distance, in the case said wall (1) is circular cylindrical, being the diameter of said circular cylindrical wall (1);
    - wherein said first plate (7") has a smaller area than the cross sectional area of said steam head space (5) and the edges of said first plate (7") extending from said first gap forming edge (13), respectively, are interconnected by means of vertical plates (9) to form a tube, where said vertical plates (9) extend in the horizontal direction all the way across between individual positions on the cylindrical wall (1) of the steam head space (5);

- supplying heated gas to said gas tubes for generating a flow of steam from said water surface by heat exchange between said gas tubes and said water in said heat exchange compartment,
- causing said flow of steam to flow through said steam flow conduit in said steam head space from said water surface to said steam outlet in such a manner that more than half, preferably substantially all, of the steam in said flow in said head space is constrained to flow in a direction transverse, preferably generally orthogonal, to said gas tubes along a flow path which when projected on a horizontal surface has a length at least equal to the shortest distance between a first point of said wall and a second point of said wall horizontally opposite said first point, said distance, in the case said wall is circular cylindrical, being the diameter of said circular cylindrical wall,

such that residual heat in said gas tubes is transferred to said flow of steam.

2. A method according to claim 1, wherein said residual heat in said gas tubes is transferred to said flow of steam to an extent that all the steam exiting said steam space through said steam outlet is super-heated.

3. A method according to claim 1 or 2, wherein the length of said horizontal projection of said flow path is at least two times said distance.

4. A method according to any of the preceding claims, wherein said steam outlet is located at a distance from said axis of said wall, preferably proximate to or in said wall.

5. A method according to any of the preceding claims, wherein said horizontal projection of said flow path extends from proximate or at a first point on said wall past said axis to proximate or at a second point on said wall opposite said first point.

6. A method according to claim 5, wherein said horizontal projection of said flow path extends back from said second point and at least part ways back to said first point.

7. A method according to claim 6, wherein the flow velocity of said flow is lower when flowing from said second point towards said first point than when flowing from proximate said first point towards said second point.

8. A method according to claim 7, wherein the flow velocity of said flow is approximately 10-15 m/s when flowing from said second point towards said first point and preferably approximately 15-30 m/s, more preferably 15-25 m/s when flowing from proximate said first point towards said second point

9. A method according to any of the preceding claims, wherein said heated gas is supplied from any of the following sources:

a) a combustion chamber,
b) a gas turbine,
c) an internal combustion motor, and
d) a gas or oilfired engine used e.g. for ships propulsion or electricity production, heating processes, industrial and power plants.

10. A gas tube steam boiler comprising:

- a heat exchange compartment (2) filled with water forming a water surface (2a),
- a steam head space (5) above said water surface (2a) and delimited by a circular cylindrical wall (1) with a substantially vertical axis and a top plate (4),
- a steam outlet (6) communicating with said steam head space (5),
- one or more gas tubes (3) extending through said heat exchange compartment (2) and said steam head space (5),
- means for supplying heated gas to said gas tubes (3) for generating a flow of steam from said water surface (2a) by heat exchange between said gas tubes (3) and said water in said heat exchange compartment (2),
- a steam flow conduit arranged in said steam head space (5) for conducting said flow of steam from said water surface (2a) to said steam outlet (6) and comprising:
- a first generally horizontal plate (7") arranged at a vertical distance h 1 below said top plate (4) and having a first gap forming edge (13) arranged at a distance from said wall (1) to provide a first steam flow gap between

said first plate (7") and said wall (1);
- **characterized in that** said first plate (7") has a smaller area than the cross sectional area of said steam head space (5) and the edges of said first plate (7") extending from said first gap forming edge (13), respectively, are interconnected with the top plate (4) by means of vertical plates (9) to form a tube and where said vertical plates (9) extend in the horizontal direction all the way across between individual positions on the cylindrical wall (1) of the steam head space (5).

11. A gas tube boiler according to claim 10, wherein said steam flow conduit comprises a second generally horizontal plate (7') arranged at a vertical distance h2 below said first plate (7") and having a second gap forming edge (12) arranged at a distance from said wall (1) to provide a second steam flow gap between said second plate (7') and said wall (1).

12. A gas tube boiler according to claim 11, wherein said first gap and said second gap are located opposite one another relative to said axis.

13. A gas tube boiler according to any of the claims 10-12, wherein said steam outlet (6) is located proximate or in said wall opposite said first gap relative to said axis.

14. A gas tube boiler according to any of the claims 10-13, wherein the distance h1 is larger than the distance h2 such that the flow velocity of said steam flow is lower in the portion of said conduit located between said top plate and said first plate than said flow velocity in the portion of said conduit located between said first and second plates.

15. A gas tube boiler according to any of the claims 10-14, wherein all said gas tubes (3) extend through said first (7") and second (7') plates.

16. A gas tube boiler according to any of the claims 10-15, wherein said water surface in cold condition of said water is located at a vertical distance h below said top plate (4) and said distance h1 is approximately 15-25%, preferably 18-22% of said distance h and said distance h2 is approximately 7-13%, preferably 8-12% of said distance h.

17. A gas tube boiler according to any of the claims 10 - 16, wherein said first and second plates (7", 7') have smaller areas than the cross sectional area of said steam head space (5) and the edges of said first and second plates extending from said first and second gap forming edges (13, 12), respectively, are interconnected by means of vertical plates (9) to form a tube.

Patentansprüche

1. Verfahren für die Erzeugung von Dampf, das folgende Schritte umfasst:

- Bereitstellen eines Gasrohr-Dampfkessels, der Folgendes umfasst:

  - einen Wärmeaustauschraum (2), der mit Wasser gefüllt ist, das eine Wasseroberfläche (2a) bildet,
  - einen Dampfraum (5) über der Wasseroberfläche (2a) und begrenzt durch eine zylindrische Wand (1) mit einer im Wesentlichen senkrechten Achse und einer oberen Platte (4),
  - einen Dampfaustritt (6), der mit dem Dampfraum (5) in Verbindung steht,
  - ein oder mehrere Gasrohre (3), die durch den Wärmeaustauschraum (2) und den Dampfraum (5) verlaufen,
  - einen Dampfstromkanal, der eine erste Platte (7") umfasst, die in einem senkrechten Abstand h1 unter der oberen Platte (4) angeordnet ist und einen ersten spaltbildenden Rand (13) aufweist, der in einem Abstand zu der Wand (1) angeordnet ist, um einen ersten Dampfstromspalt zwischen der ersten Platte (7") und der Wand (1) vorzusehen, der in dem Dampfraum (5) zum Leiten des Dampfstroms von der Wasseroberfläche (2a) zu dem Dampfaustritt (6) angeordnet ist, wobei mindestens eins der Gasrohre (3) quer durch den Kanal verläuft, sodass der Dampfstrom in einer Richtung quer, vorzugsweise im Allgemeinen rechtwinklig, zu den Gasrohren (3) strömt, wobei die Gestaltung des Kanals derart ist, dass mehr als die Hälfte des Dampfs, vorzugsweise im Wesentlichen der gesamte Dampf in dem Strom, gezwungen wird, entlang eines Strömungswegs zu strömen, der bei Projektion auf eine waagerechte Fläche eine Länge aufweist, die mindestens dem kürzesten Abstand zwischen einem ersten Punkt der Wand (1) und einem zweiten Punkt der Wand (1) waagerecht gegenüber dem ersten Punkt entspricht, wobei der Abstand in dem Fall, dass die Wand (1) kreiszylindrisch ist, der Durchmesser der kreiszylindrischen Wand (1) ist;

- wobei die erste Platte (7") eine kleinere Fläche als die Querschnittsfläche des Dampfraums (5) aufweist und die Ränder der ersten Platte (7"), die jeweils von dem ersten spaltbildenden Rand (13) aus verlaufen, mittels senkrechten Platten (9) miteinander verbunden sind, um ein Rohr zu bilden, wo die senkrechten Platten (9) in der waagerechten Richtung entlang der ganzen Strecke zwischen einzelnen Positionen an der zylindrischen Wand (1) des Dampfraums (5) verlaufen;

- Zuführen von erwärmtem Gas zu den Gasrohren zum Erzeugen eines Dampfstroms von der Wasseroberfläche durch Wärmeaustausch zwischen den Gasrohren und dem Wasser in dem Wärmeaustauschraum,
- Bewirken, dass der Dampfstrom durch den Dampfstromkanal in dem Dampfraum von der Wasseroberfläche zu dem Dampfaustritt strömt, sodass mehr als die Hälfte des Dampfs, vorzugsweise im Wesentlichen der gesamte Dampf in dem Strom in dem Dampfraum gezwungen wird, in eine Richtung quer, vorzugsweise im Allgemeinen rechtwinklig, zu den Gasrohren entlang eines Strömungswegs zu strömen, der bei Projektion auf eine waagerechte Fläche eine Länge aufweist, die mindestens dem kürzesten Abstand zwischen einem ersten Punkt der Wand und einem zweiten Punkt der Wand waagerecht gegenüber dem ersten Punkt entspricht, wobei der Abstand in dem Fall, dass die Wand kreiszylindrisch ist, der Durchmesser der kreiszylindrischen Wand ist,

sodass Restwärme in den Gasrohren auf den Dampfstrom übertragen wird.

2. Verfahren nach Anspruch 1, wobei die Restwärme in den Gasrohren in dem Maße auf den Dampfstrom übertragen wird, dass der gesamte Dampf, der den Dampfraum durch den Dampfaustritt verlässt, überhitzt wird.

3. Verfahren nach Anspruch 1 oder 2, wobei die Länge der waagerechten Projektion des Strömungswegs mindestens zweimal der Abstand ist.

4. Verfahren nach einem der vorhergehenden Ansprüche, wobei sich der Dampfaustritt in einem Abstand zu der Achse der Wand, vorzugsweise in der Nähe der oder in der Wand, befindet.

5. Verfahren nach einem der vorhergehenden Ansprüche, wobei die waagerechte Projektion des Strömungswegs von nahe oder an einem ersten Punkt an der Wand an der Achse vorbei bis nahe oder an einem zweiten Punkt an der Wand gegenüber dem ersten Punkt verläuft.

6. Verfahren nach Anspruch 5, wobei die waagerechte Projektion des Strömungswegs von dem zweiten Punkt aus zurück und zumindest teilweise zurück bis zu dem ersten Punkt verläuft.

7. Verfahren nach Anspruch 6, wobei die Strömungsgeschwindigkeit des Stroms geringer ist, wenn er von dem zweiten Punkt in Richtung des ersten Punkts strömt, als wenn er von nahe dem ersten Punkt in Richtung des zweiten Punkts strömt.

8. Verfahren nach Anspruch 7, wobei die Strömungsgeschwindigkeit des Stroms ungefähr 10 bis 15 m/s beträgt, wenn er von dem zweiten Punkt in Richtung des ersten Punkts strömt und vorzugsweise ungefähr 15 bis 30 m/s, bevorzugter 15 bis 25 m/s, wenn er von nahe dem ersten Punkt in Richtung des zweiten Punkts strömt.

9. Verfahren nach einem der vorhergehenden Ansprüche, wobei das erwärmte Gas von einer der folgenden Quellen zugeführt wird:

a) ein Verbrennungsraum,
b) eine Gasturbine,
c) ein Verbrennungsmotor, und
d) ein Gas- oder Ölmotor, der z.B. für den Antrieb von Schiffen oder die Stromerzeugung, Heizprozesse, Industrieanlagen und Kraftwerke verwendet wird.

10. Gasrohr-Dampfkessel, der Folgendes umfasst:

- einen Wärmeaustauschraum (2), der mit Wasser gefüllt ist, das eine Wasseroberfläche (2a) bildet,
- einen Dampfraum (5) über der Wasseroberfläche (2a) und begrenzt durch eine kreiszylindrische Wand (1) mit einer im Wesentlichen senkrechten Achse und einer oberen Platte (4),
- einen Dampfaustritt (6), der mit dem Dampfraum (5) in Verbindung steht,
- ein oder mehrere Gasrohre (3), die durch den Wärmeaustauschraum (2) und den Dampfraum (5) verlaufen,

- Mittel zum Zuführen von erwärmtem Gas zu den Gasrohren (3) zum Erzeugen eines Dampfstroms von der Wasseroberfläche (2a) durch Wärmeaustausch zwischen den Gasrohren (3) und dem Wasser in dem Wärmeaustauschraum (2),
- einen Dampfstromkanal, der in dem Dampfraum (5) zum Leiten des Dampfstroms von der Wasseroberfläche (2a) zu dem Dampfaustritt (6) angeordnet ist und Folgendes umfasst:
- eine erste im allgemeinen waagerechte Platte (7"), die in einem senkrechten Abstand h1 unter der oberen Platte (4) angeordnet ist und einen ersten spaltbildenden Rand (13) aufweist, der in einem Abstand zu der Wand (1) angeordnet ist, um einen ersten Dampfstromspalt zwischen der ersten Platte (7") und der Wand (1) vorzusehen;
- **dadurch gekennzeichnet, dass** die erste Platte (7") eine kleinere Fläche als die Querschnittsfläche des Dampfraums (5) aufweist und die Ränder der ersten Platte (7"), die jeweils von dem ersten spaltbildenden Rand (13) aus verlaufen, mittels senkrechten Platten (9) mit der oberen Platte (4) verbunden sind, um ein Rohr zu bilden, und wo die senkrechten Platten (9) in der waagerechten Richtung entlang der ganzen Strecke zwischen einzelnen Positionen an der zylindrischen Wand (1) des Dampfraums (5) verlaufen.

11. Gasrohrkessel nach Anspruch 10, wobei der Dampfstromkanal eine zweite im allgemeinen waagerechte Platte (7') umfasst, die in einem senkrechten Abstand h2 unter der ersten Platte (7") angeordnet ist und einen zweiten spaltbildenden Rand (12) aufweist, der in einem Abstand zu der Wand (1) angeordnet ist, um einen zweiten Dampfstromspalt zwischen der zweiten Platte (7') und der Wand (1) vorzusehen.

12. Gasrohrkessel nach Anspruch 11, wobei der erste Spalt und der zweite Spalt bezogen auf die Achse einander gegenüber angeordnet sind.

13. Gasrohrkessel nach einem der Ansprüche 10 bis 12, wobei sich der Dampfaustritt (6) in der Nähe der oder in der Wand gegenüber dem ersten Spalt bezogen auf die Achse befindet.

14. Gasrohrkessel nach einem der Ansprüche 10 bis 13, wobei der Abstand h1 größer ist als der Abstand h2, sodass die Strömungsgeschwindigkeit des Dampfstroms in dem Bereich des Kanals, der zwischen der oberen Platte und der ersten Platte liegt, geringer ist als die Strömungsgeschwindigkeit in dem Bereich des Kanals, der zwischen der ersten und zweiten Platte liegt.

15. Gasrohrkessel nach einem der Ansprüche 10 bis 14, wobei alle Gasrohre (3) durch die erste (7") und zweite (7') Platte verlaufen.

16. Gasrohrkessel nach einem der Ansprüche 10 bis 15, wobei sich die Wasseroberfläche im kalten Zustand des Wassers in einem senkrechten Abstand h unter der oberen Platte (4) befindet und der Abstand h1 ungefähr 15 bis 25%, vorzugsweise 18 bis 22% des Abstands h beträgt und der Abstand h2 ungefähr 7 bis 13%, vorzugsweise 8 bis 12% des Abstands h beträgt.

17. Gasrohrkessel nach einem der Ansprüche 10 bis 16, wobei die erste und zweite Platte (7", 7') eine kleinere Fläche als die Querschnittsfläche des Dampfraums (5) aufweisen und die Ränder der ersten und zweiten Platte, die von dem ersten beziehungsweise zweiten spaltbildenden Rand (13, 12) aus verlaufen, mittels senkrechten Platten (9) miteinander verbunden sind, um ein Rohr zu bilden.

Revendications

1. Méthode pour la génération de vapeur comprenant les étapes consistant à :

- prévoir une chaudière à tubes de gaz comprenant :

  - un compartiment d'échange de chaleur (2) rempli avec de l'eau formant une surface d'eau (2a),
  - un espace à vapeur (5) au-dessus de ladite surface d'eau (2a) et délimité par une paroi cylindrique (1) avec un axe essentiellement vertical et une plaque supérieure (4),
  - un orifice de sortie de la vapeur (6) communicant avec ledit espace à vapeur (5),
  - un ou plusieurs tubes de gaz (3) s'étendant à travers ledit compartiment d'échange de chaleur (2) et ledit espace à vapeur (5),
  - une conduite d'écoulement de vapeur comprenant une première plaque (7) disposée à une distance

verticale h1 sous ladite plaque supérieure (4) et présentant un premier bord (13) formant un jeu disposé à une distance de ladite paroi (1) pour mettre à disposition un premier jeu d'écoulement de vapeur entre ladite première plaque (7) et ladite paroi (1) disposé dans ledit espace à vapeur (5) pour guider ledit écoulement de vapeur de ladite surface d'eau (2a) audit orifice de sortie de la vapeur (6), au moins l'un desdits tubes de gaz (3) s'étendant de manière transversale à travers ladite conduite de sorte que ledit écoulement de vapeur s'écoule dans une direction transversale, de préférence en générale orthogonale, auxdits tubes de gaz (3), la configuration de ladite conduite étant telle que plus de la moitié, de préférence essentiellement la totalité, de la vapeur dans ledit écoulement est forcée de s'écouler le long d'une voie d'écoulement qui, quand elle est projetée sur une surface horizontale, présente une longueur au moins égale à la distance la plus courte entre un premier point de ladite paroi (1) et un second point de ladite paroi (1) opposé horizontalement audit premier point, ladite distance, dans le cas où ladite paroi (1) est cylindrique circulaire, étant le diamètre de ladite paroi cylindrique circulaire (1) ;

- dans laquelle ladite première plaque (7) présente une aire inférieure à l'aire de la section droite dudit espace à vapeur (5) et les bords de ladite première plaque (7) s'étendant respectivement dudit premier bord (13) formant un jeu, sont interconnectés au moyen de plaques verticales (9) pour former un tube, dans laquelle lesdites plaques verticale (9) s'étendent dans la direction horizontale sur toute la distance entre des positions individuelles sur la paroi cylindrique (1) de l'espace à vapeur (5) ;

- alimenter du gaz chauffé vers lesdits tubes de gaz pour générer un écoulement de vapeur depuis ladite surface d'eau par échange de chaleur entre lesdits tubes de gaz et ladite eau dans ledit compartiment d'échange de chaleur,
- amener ledit écoulement de vapeur à s'écouler à travers ladite conduite d'écoulement de vapeur dans ledit espace à vapeur de ladite surface d'eau audit orifice de sortie de la vapeur de telle manière que plus de la moitié, de préférence essentiellement la totalité, de la vapeur dans ledit écoulement dans ledit espace à vapeur est forcée de s'écouler dans une direction transversale, de préférence en général orthogonale, auxdits tubes de gaz le long d'une voie d'écoulement qui, quand elle est projetée sur une surface horizontale, présente une longueur au moins égale à la distance la plus courte entre un premier point de ladite paroi et un second point de ladite paroi opposé horizontalement audit premier point, ladite distance, dans le cas où ladite paroi est cylindrique circulaire, étant le diamètre de ladite paroi cylindrique circulaire,

de sorte que de la chaleur résiduelle dans lesdits tubes de gaz est transférée audit écoulement de vapeur.

2. Méthode selon la revendication 1, dans laquelle ladite chaleur résiduelle dans lesdits tubes de gaz est transférée audit écoulement de vapeur à un tel point que toute la vapeur sortant dudit espace à vapeur à travers ledit orifice de sortie de la vapeur est surchauffée.

3. Méthode selon la revendication 1 ou 2, dans laquelle la longueur de ladite projection horizontale de ladite voie d'écoulement est au moins deux fois ladite distance.

4. Méthode selon l'une quelconque des revendications précédentes, dans laquelle ledit orifice de sortie de la vapeur est situé à une distance dudit axe de ladite paroi, de préférence à proximité de ou dans ladite paroi.

5. Méthode selon l'une quelconque des revendications précédentes, dans laquelle ladite projection horizontale de ladite voie d'écoulement s'étend de la proximité d'un ou d'un premier point sur ladite paroi au-delà dudit axe à la proximité d'un ou à un second point sur ladite paroi opposé audit premier point.

6. Méthode selon la revendication 5, dans laquelle ladite projection horizontale de ladite voie d'écoulement revient dudit second point et au moins en partie jusqu'au dit premier point.

7. Méthode selon la revendication 6, dans laquelle la vitesse d'écoulement dudit écoulement est plus faible quand l'écoulement va dudit second point vers ledit premier point que quand l'écoulement va de la proximité dudit premier point vers ledit second point.

8. Méthode selon la revendication 7, dans laquelle la vitesse d'écoulement dudit écoulement est d'environ 10 à 15 m/s quand l'écoulement va dudit second point vers ledit premier point et de préférence d'environ 15 à 30 m/s, de manière plus préférentielle de 15 à 25 m/s, quand l'écoulement va de la proximité dudit premier point vers ledit second point.

9. Méthode selon l'une quelconque des revendications précédentes, dans laquelle ledit gaz chauffé est alimenté depuis l'une quelconque des sources suivantes :

a) une chambre de combustion,
b) une turbine à gaz,
c) un moteur à combustion interne, et
d) un moteur au gaz ou au mazout utilisé p. ex. dans la propulsion navale ou la production électrique, les processus de chauffage, les installations industrielles et les centrales.

10. Chaudière à tubes de gaz comprenant :

- un compartiment d'échange de chaleur (2) rempli avec de l'eau formant une surface d'eau (2a),
- un espace à vapeur (5) au-dessus de ladite surface d'eau (2a) et délimité par une paroi cylindrique circulaire (1) avec un axe essentiellement vertical et une plaque supérieure (4),
- un orifice de sortie de la vapeur (6) communicant avec ledit espace à vapeur (5),
- un ou plusieurs tubes de gaz (3) s'étendant à travers ledit compartiment d'échange de chaleur (2) et ledit espace à vapeur (5),
- des moyens pour alimenter du gaz chauffé vers lesdits tubes de gaz (3) pour générer un écoulement de vapeur depuis ladite surface d'eau (2a) par échange de chaleur entre lesdits tubes de gaz (3) et ladite eau dans ledit compartiment d'échange de chaleur (2),
- une conduite d'écoulement de vapeur disposée dans ledit espace à vapeur (5) pour guider ledit écoulement de vapeur de ladite surface d'eau (2a) audit orifice de sortie de la vapeur (6) et comprenant :
- une première plaque généralement horizontale (7) disposée à une distance verticale h1 sous ladite plaque supérieure (4) et présentant un premier bord (13) formant un jeu disposé à une distance de ladite paroi (1) pour mettre à disposition un premier jeu d'écoulement de vapeur entre ladite première plaque (7) et ladite paroi (1) ;
- **caractérisée en ce que** ladite première plaque (7) présente une aire inférieure à l'aire de la section droite dudit espace à vapeur (5) et les bords de ladite première plaque (7) s'étendant respectivement dudit premier bord (13) formant un jeu, sont interconnectés avec la plaque supérieure (4) au moyen de plaques verticales (9) pour former un tube et dans laquelle lesdites plaques verticale (9) s'étendent dans la direction horizontale sur toute la distance entre des positions individuelles sur la paroi cylindrique (1) de l'espace à vapeur (5).

11. Chaudière à tubes de gaz selon la revendication 10, dans laquelle ladite conduite d'écoulement de vapeur comprend une seconde plaque généralement horizontale (7') disposée à une distance verticale h2 sous ladite première plaque (7) et présentant un second bord (12) formant un jeu disposé à une distance de ladite paroi (1) pour mettre à disposition un second jeu d'écoulement de vapeur entre ladite seconde plaque (7') et ladite paroi (1).

12. Chaudière à tubes de gaz selon la revendication 11, dans laquelle ledit premier jeu et ledit second jeu sont situés à l'opposé l'un de l'autre par rapport audit axe.

13. Chaudière à tubes de gaz selon l'une quelconque des revendications 10 à 12, dans laquelle ledit orifice de sortie de la vapeur (6) est situé à proximité de ou dans ladite paroi à l'opposé dudit premier jeu par rapport audit axe.

14. Chaudière à tubes de gaz selon l'une quelconque des revendications 10 à 13, dans laquelle la distance h1 est supérieure à la distance h2 de sorte que la vitesse d'écoulement dudit écoulement de vapeur est plus faible dans la partie de ladite conduite située entre ladite plaque supérieure et ladite première plaque que ladite vitesse d'écoulement dans la partie de ladite conduite située entre lesdites première et seconde plaques.

15. Chaudière à tubes de gaz selon l'une quelconque des revendications 10 à 14, dans laquelle tous lesdits tubes de gaz (3) s'étendent à travers lesdites première (7) et seconde (7') plaques.

16. Chaudière à tubes de gaz selon l'une quelconque des revendications 10 à 15, dans laquelle ladite surface d'eau à l'état froid de ladite eau est située à une distance verticale h sous ladite plaque supérieure (4) et ladite distance h1 est d'environ 15 à 25 %, de préférence 18 à 22 %, de ladite distance h et ladite distance h2 est d'environ 7 à 13 %, de préférence 8 à 12 %, de ladite distance h.

17. Chaudière à tubes de gaz selon l'une quelconque des revendications 10 à 16, dans laquelle lesdites première et seconde plaques (7 , 7') présentent des aires inférieures à l'aire de la section droite dudit espace à vapeur (5) et les bords desdites première et seconde plaques s'étendant respectivement desdits bords (13, 12) formant les premier et second jeux, sont interconnectés au moyen de plaques verticales (9) pour former un tube.

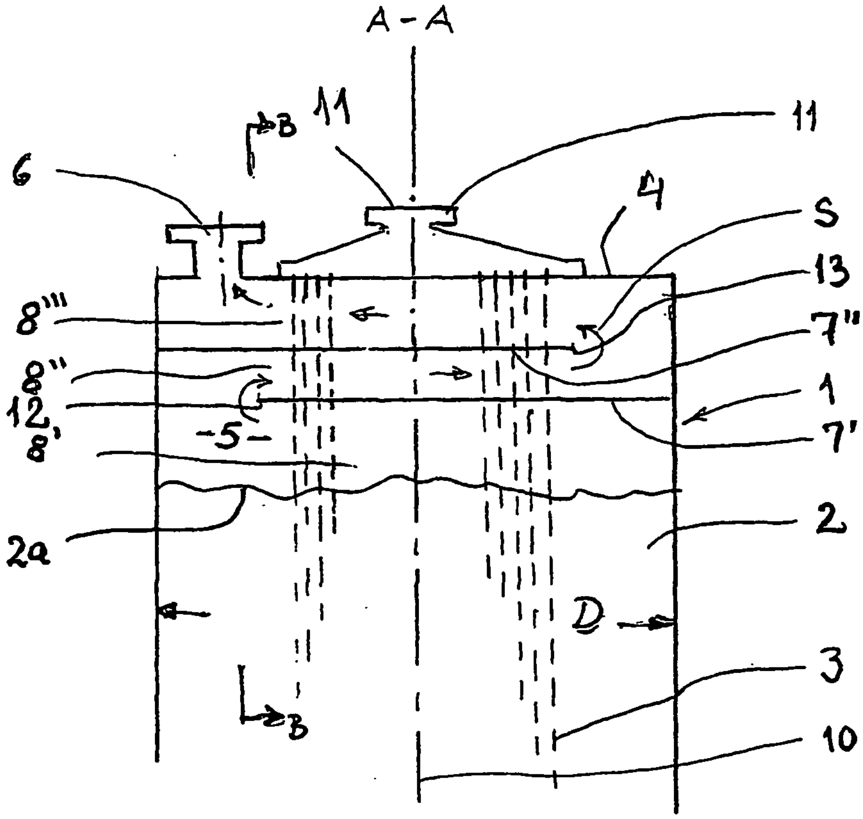

Fig.1

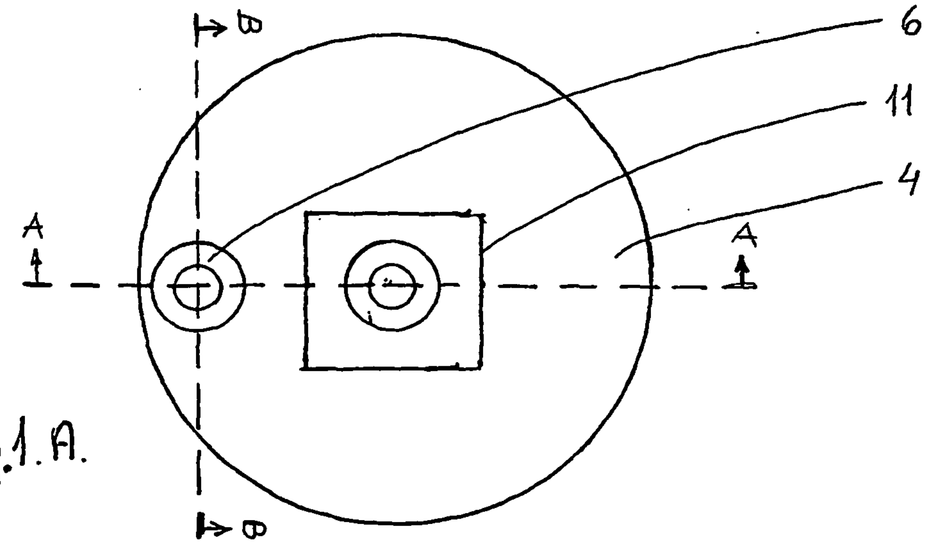

Fig.1.A.

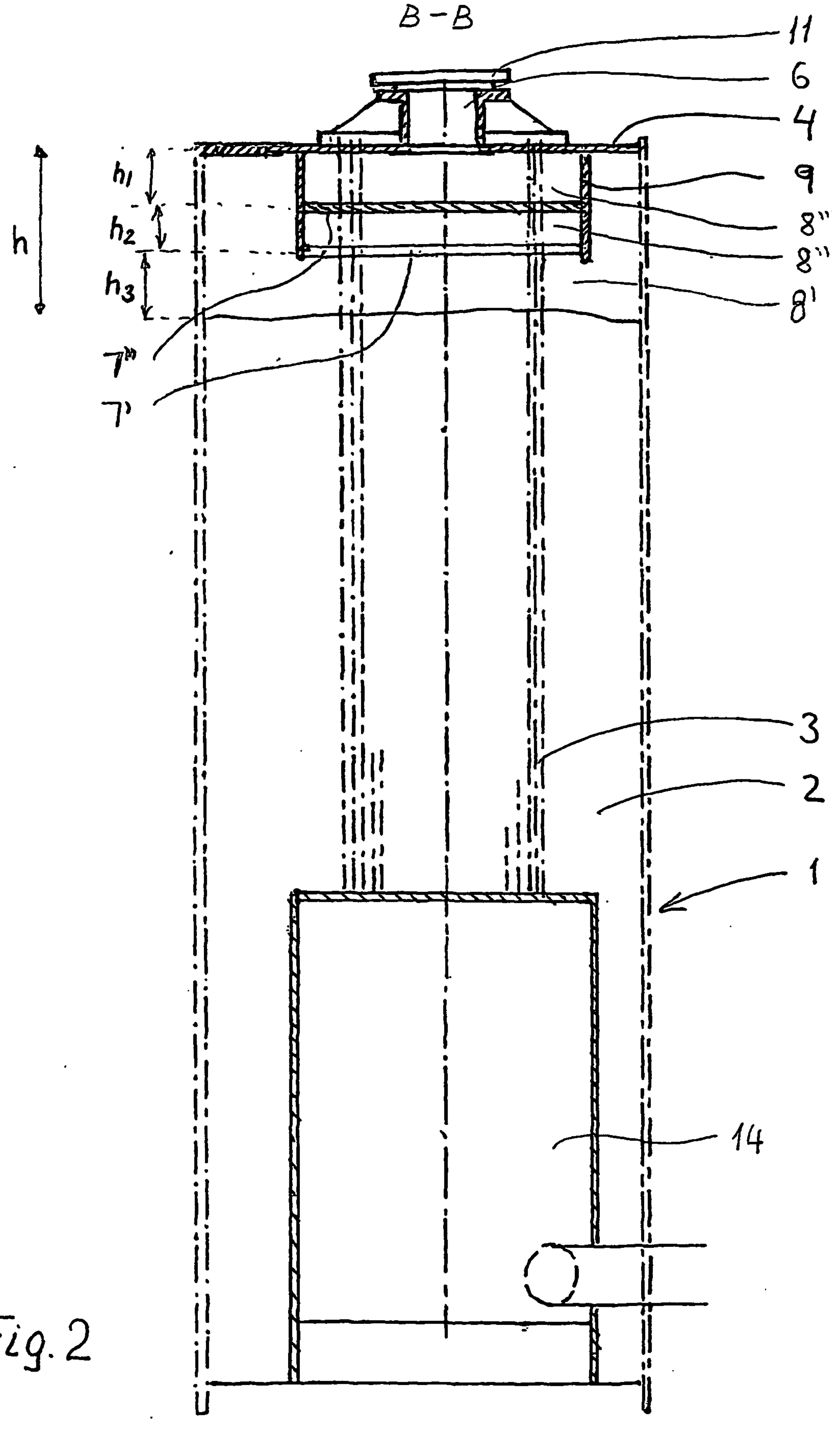

Fig. 2

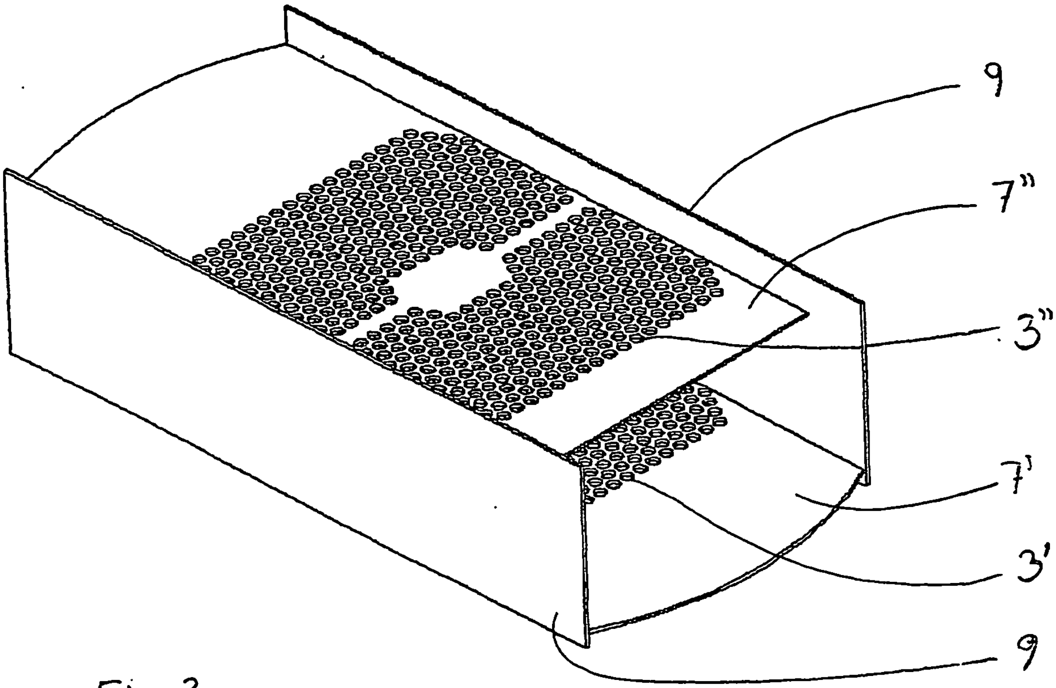

Fig. 3

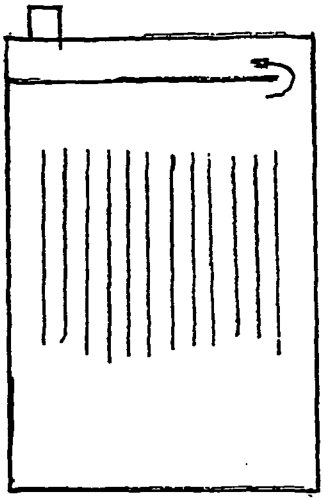
Fig.4.

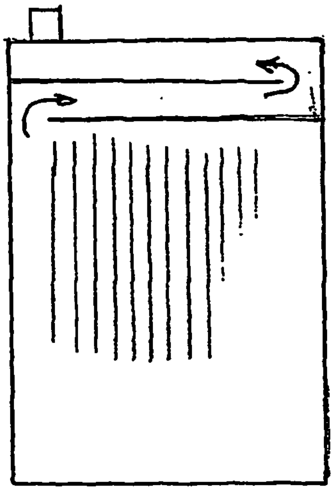
Fig. 5

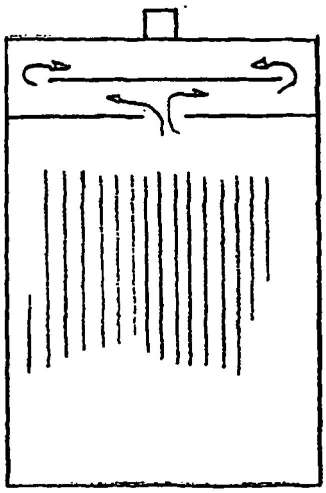
Fig. 6

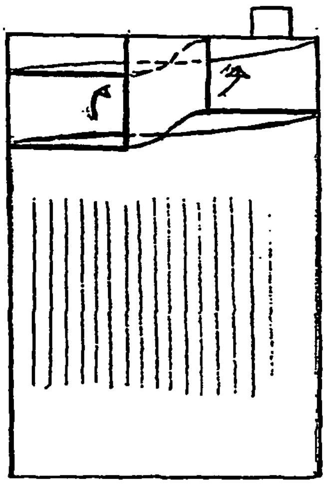
Fig.7.

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- US 1546665 A **[0003] [0019]**
- GB 114222 A **[0004]**