Nov. 17, 1953 M. FRENKEL 2,659,392

HEAT EXCHANGER

Filed Sept. 15, 1947 4 Sheets-Sheet 1

FIG. 3.

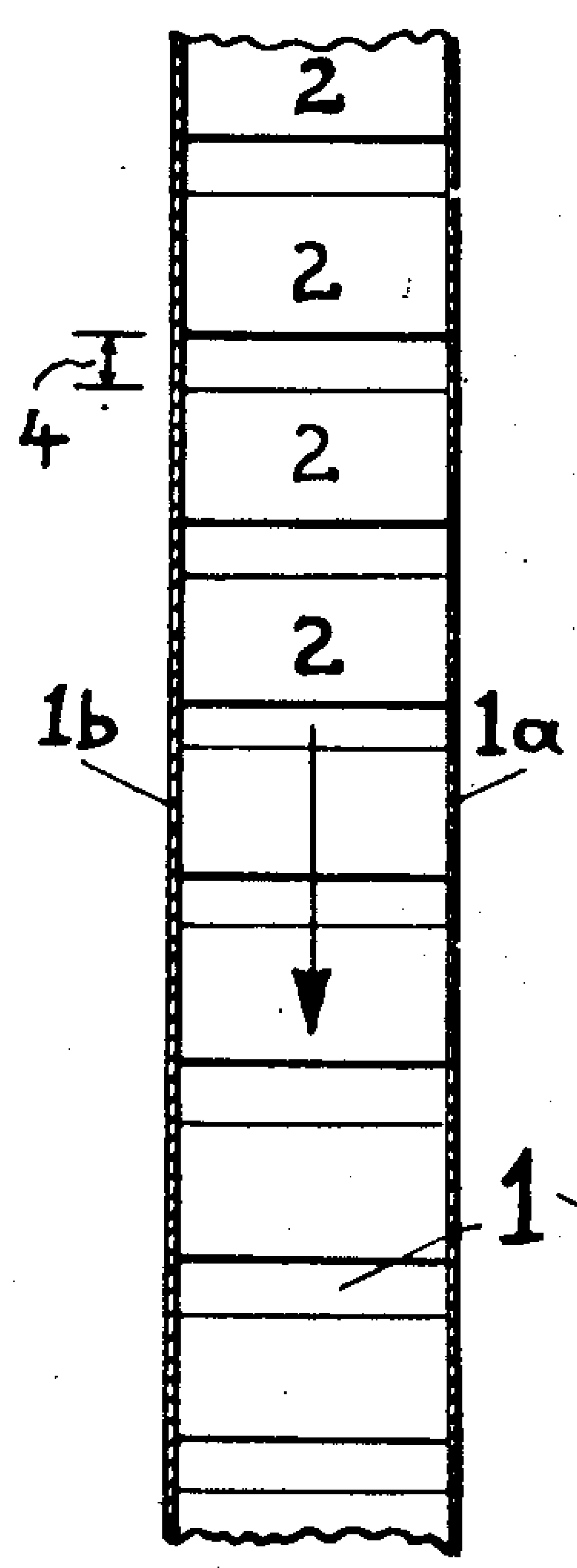
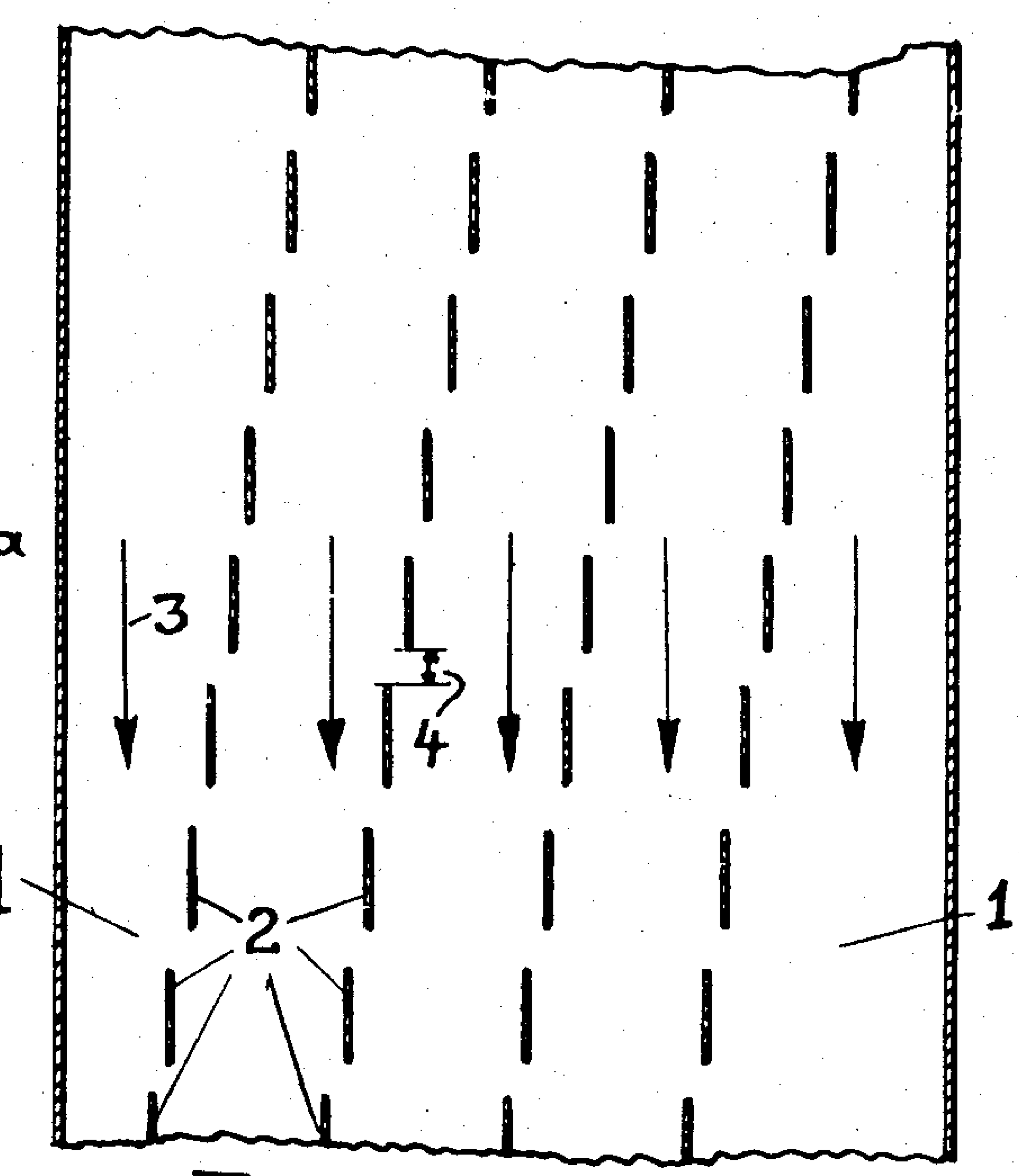


FIG. 2



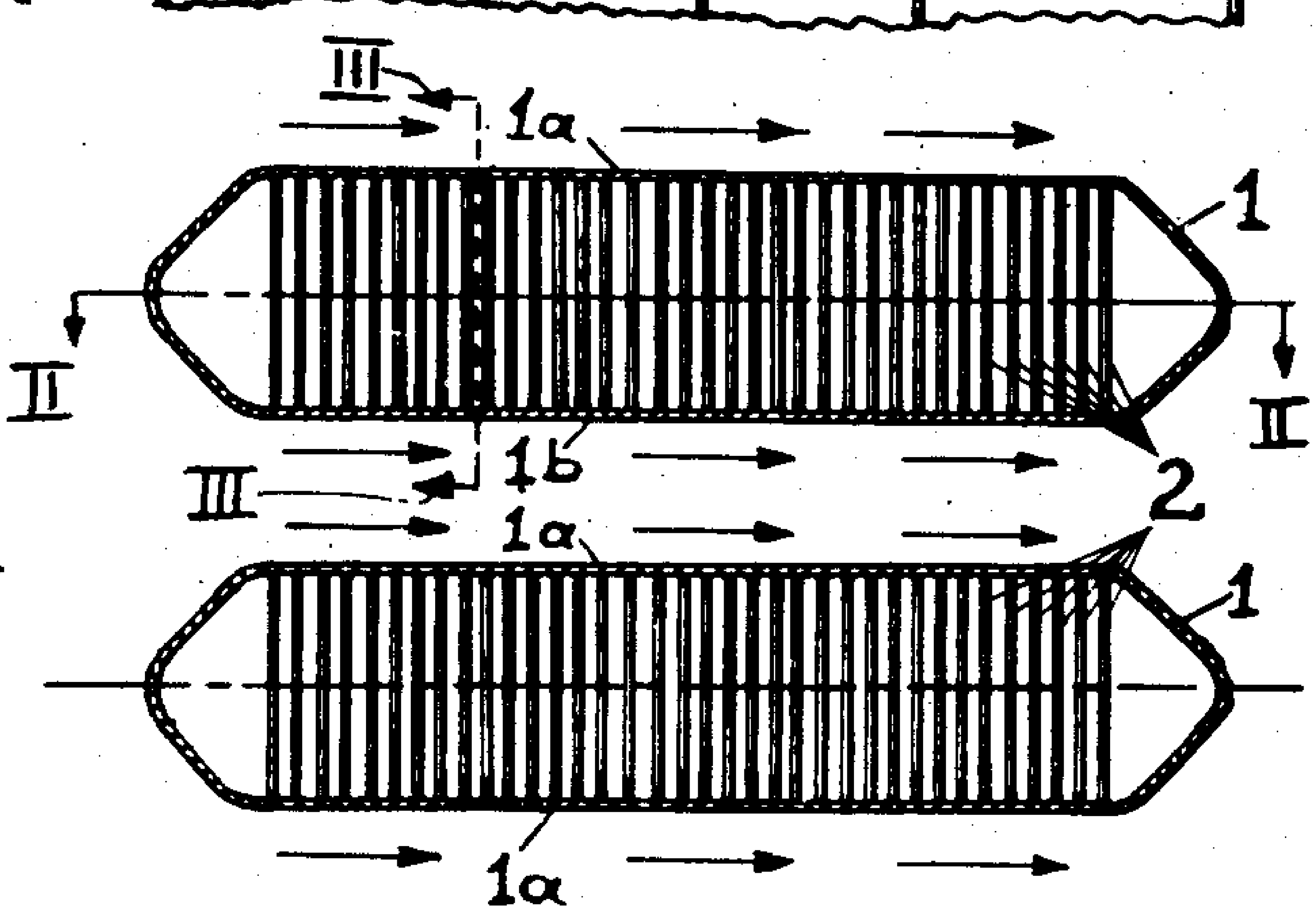


FIG. 1

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Filed Sept. 15, 1947

4 Sheets-Sheet 2

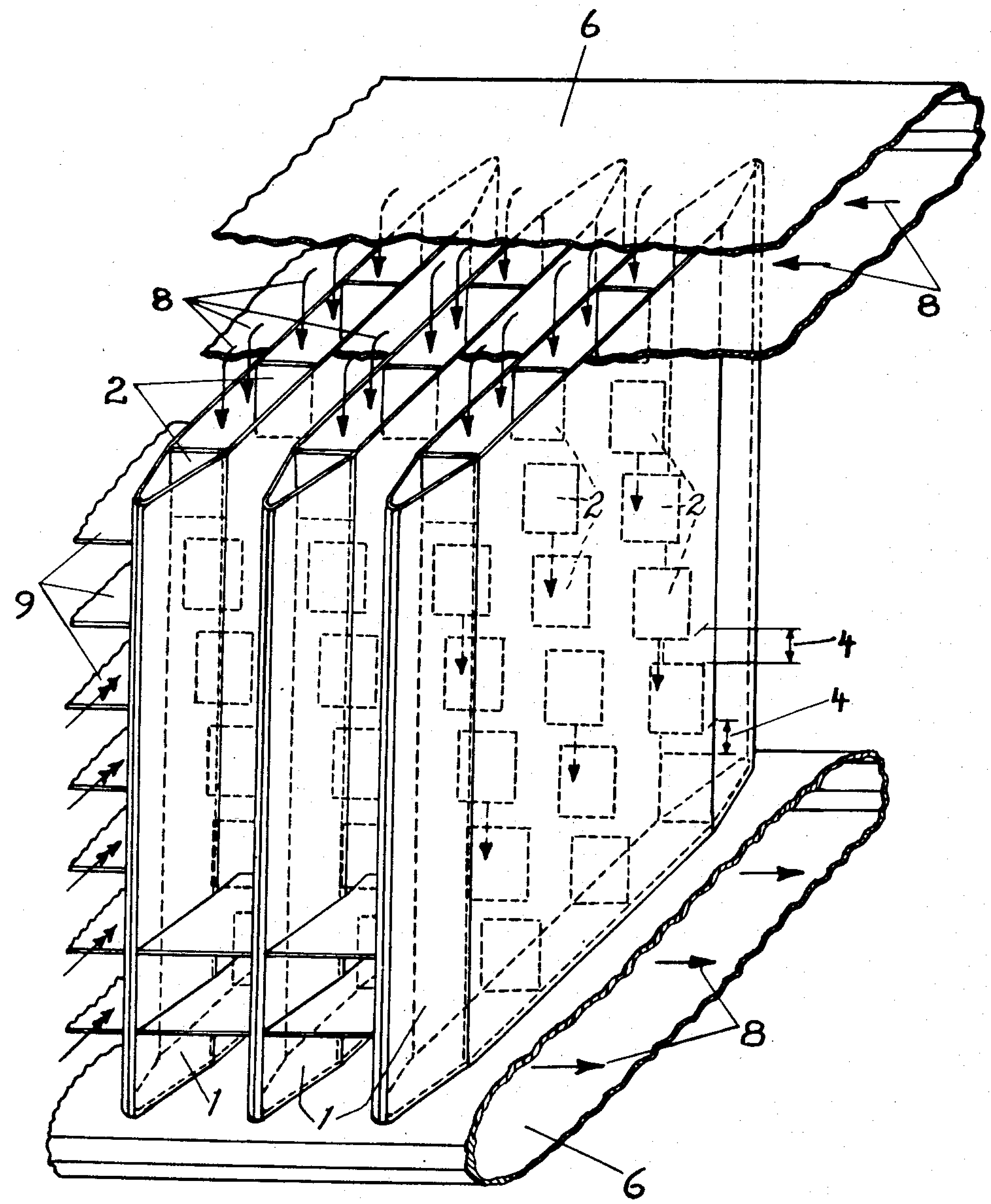

FIG. 4

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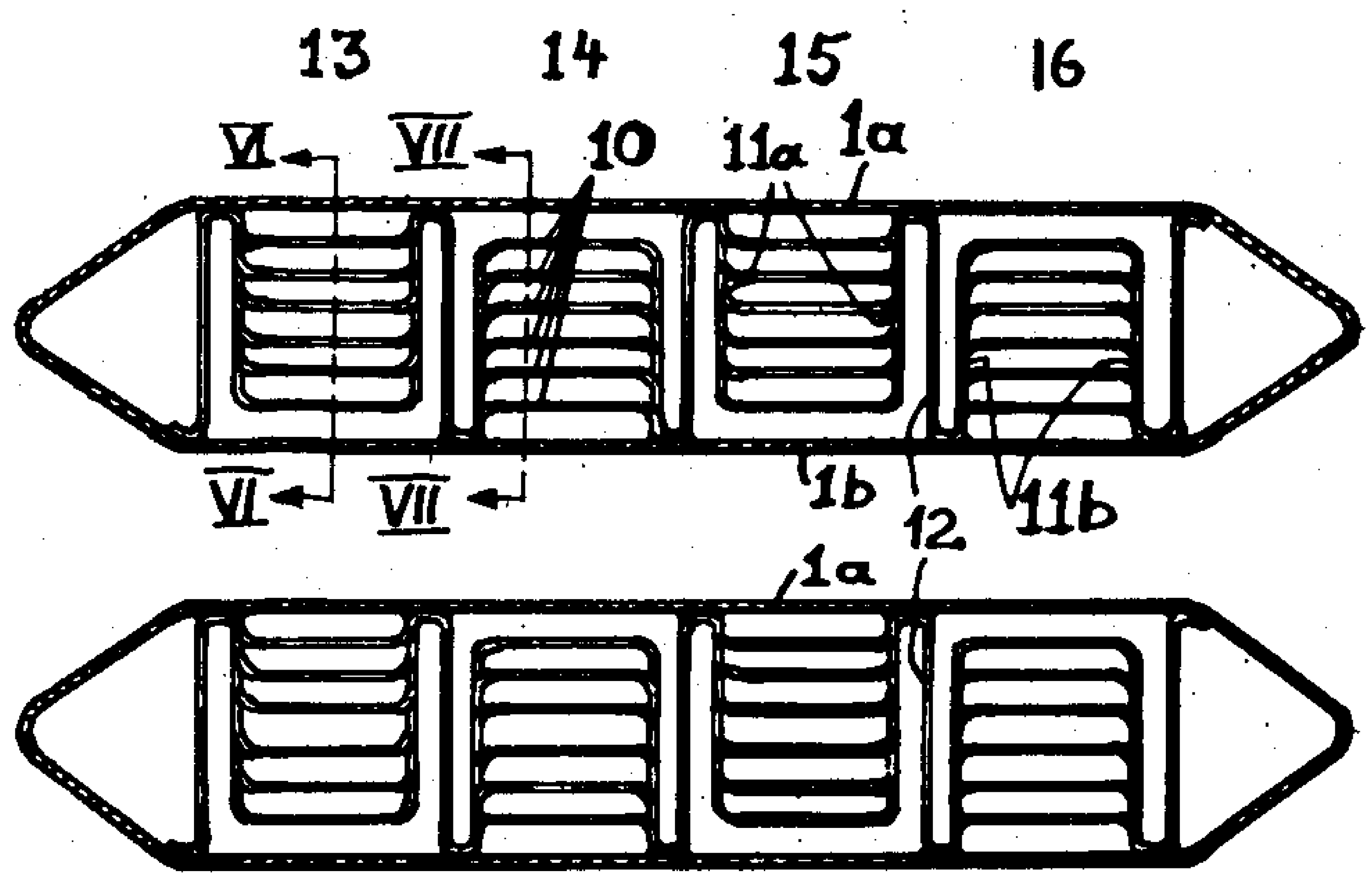

FIG 5

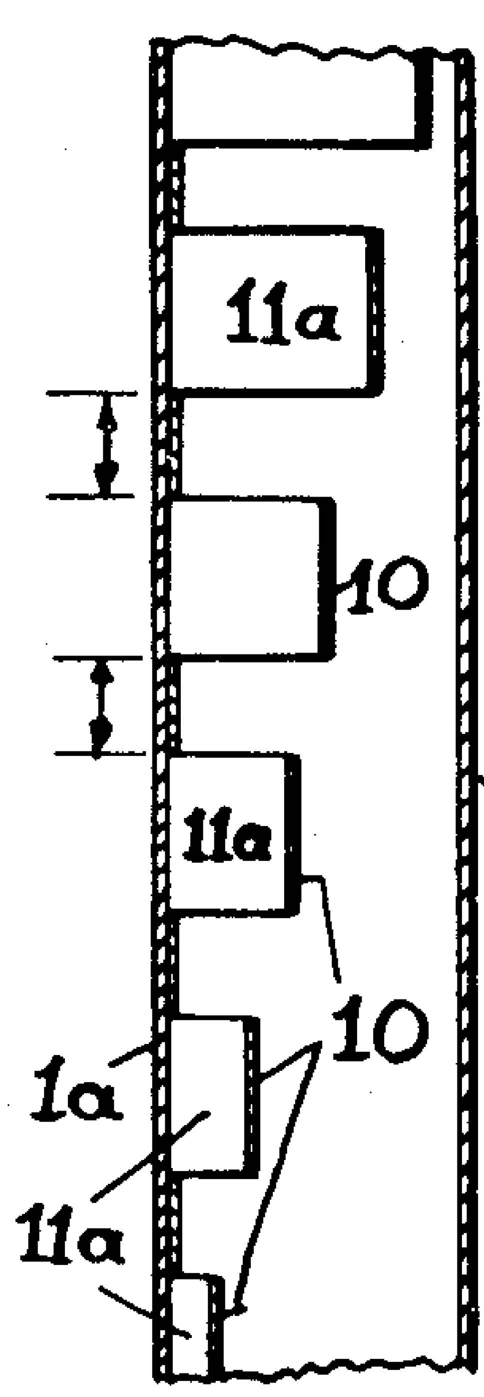

FIG. 6

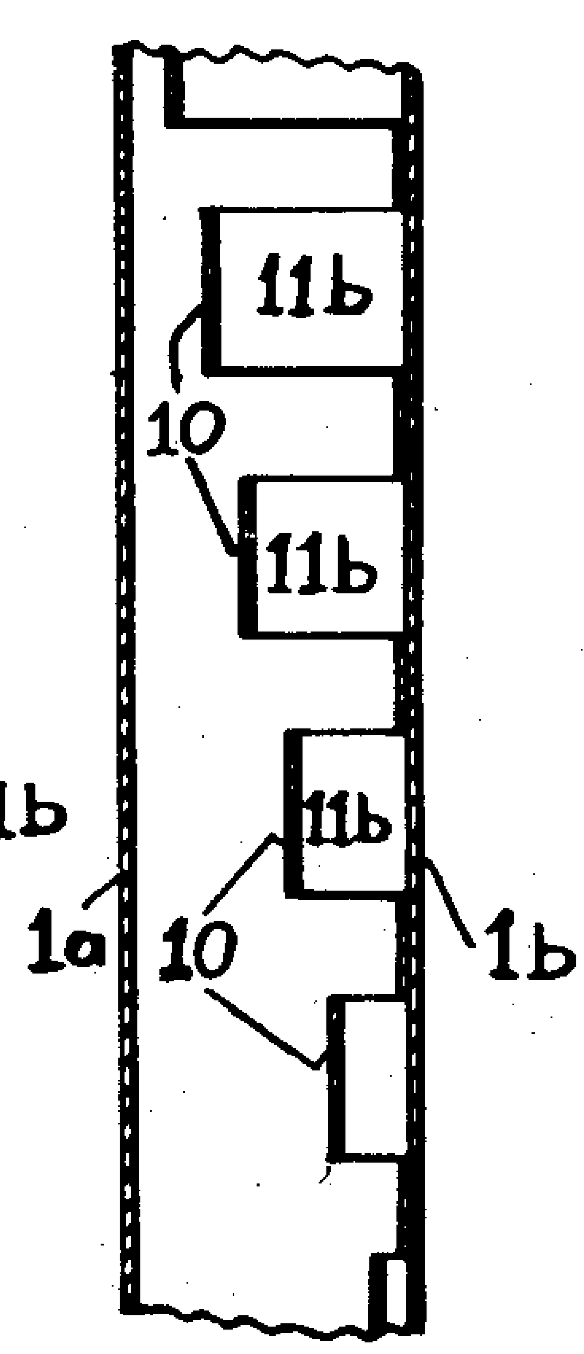

FIG. 7

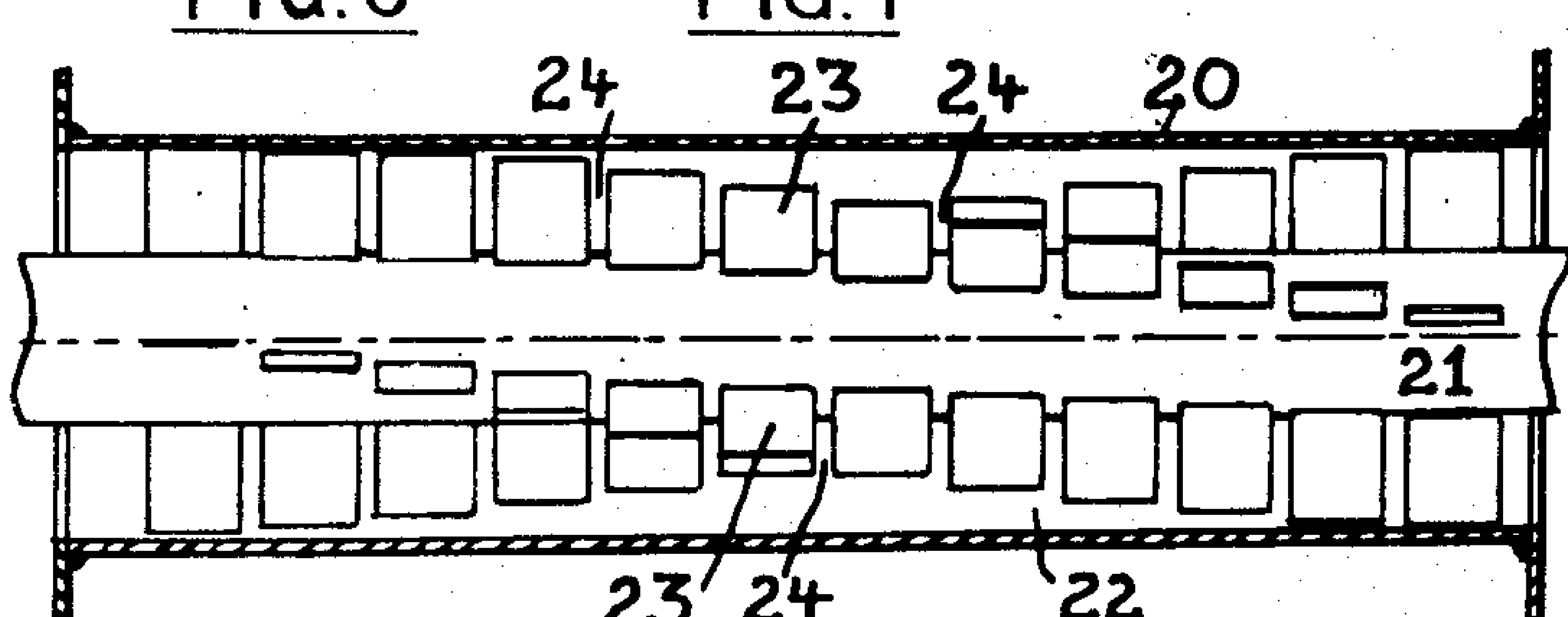

FIG. 8

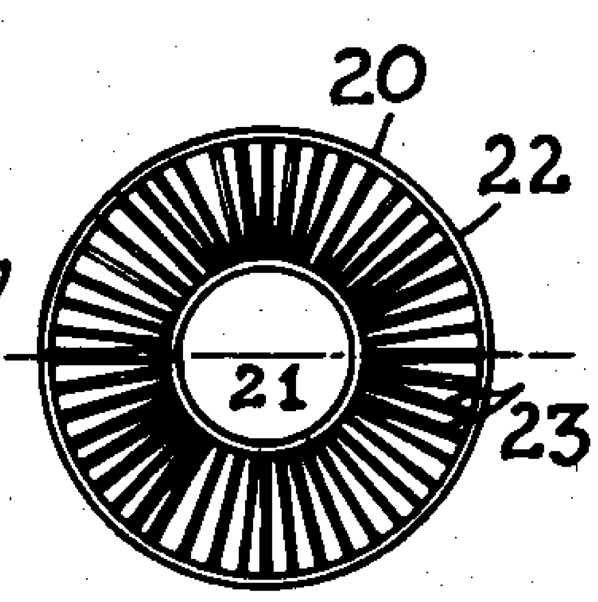

FIG. 9

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HEAT EXCHANGER

2,659,392

Filed Sept. 15, 1947

4 Sheets-Sheet 4

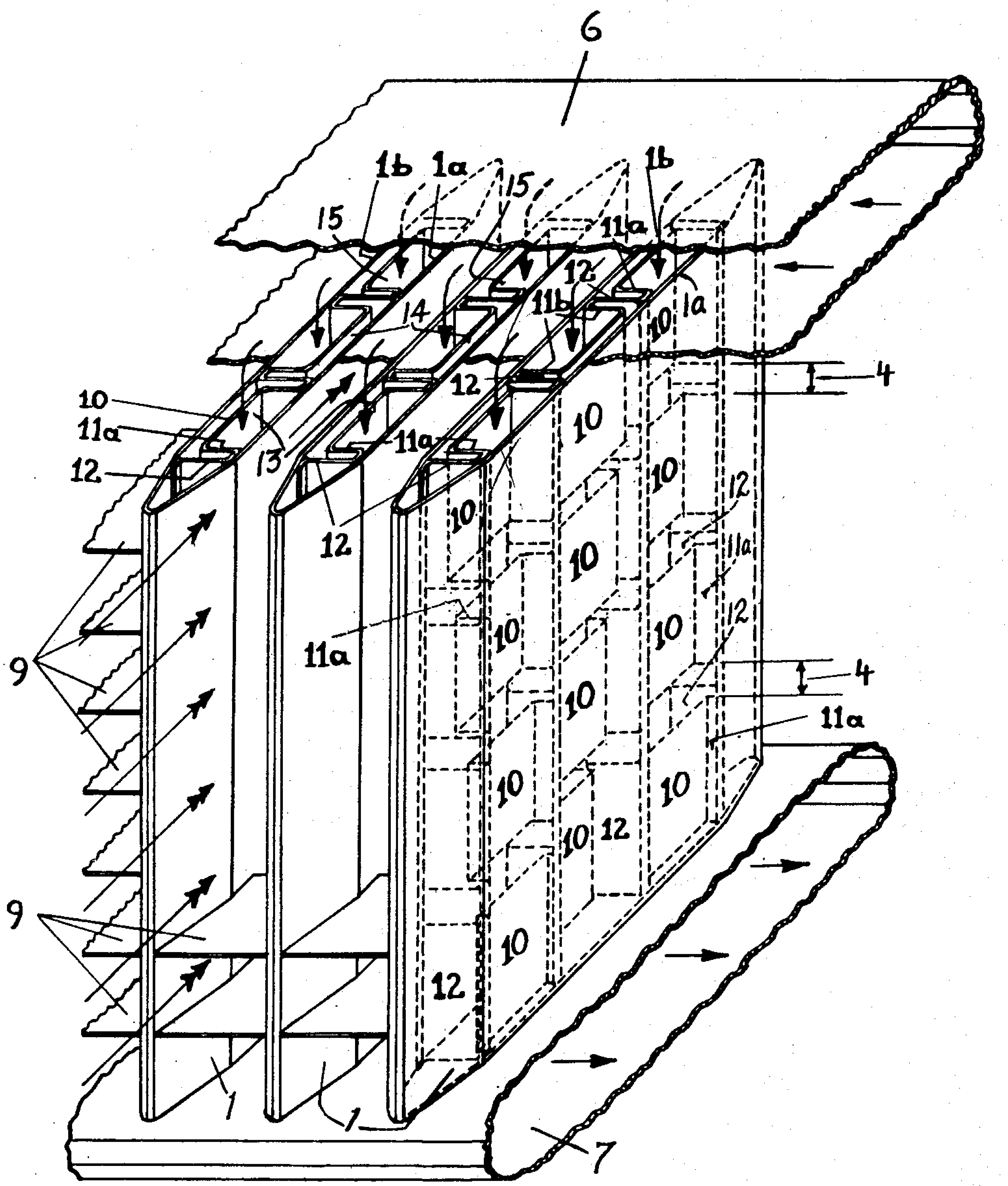

FIG. 10.

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HEAT EXCHANGER

Meyer Frenkel, London, England

Application September 15, 1947, Serial No. 774,151

7 Claims. (Cl. 138—38)

1

This invention relates to apparatus for effecting heat exchange between two fluids, or between a fluid and a heating or cooling element and especially to apparatus such as radiators for internal combustion engines, oil coolers for internal combustion engines and other purposes, chemical heat exchangers, condensers and evaporaters for use in refrigerating plant and for other purposes.

More particularly, the invention relates to heat exchangers in which secondary walls, i. e. walls connected with the primary heat transferring walls separating the media partaking in the heat exchange, and immersed in one of the fluids taking part in the heat exchange, are provided for the purpose of transferring heat by conduction between the primary heat transferring walls and layers of the fluid coming into heat exchange contact therewith.

Now before coming to the invention itself, consider the heat exchange for a fluid flowing between two plates, whether primary heat transferring walls or secondary heat transferring walls, when these are not very close together.

Even with large velocities of flow producing strongly turbulent flow, the vortices in a fluid develop mainly in a thin layer adjacent the wall, and rapidly fall off towards the centre of the flow-cross-section. Hence the mixing and thus heat exchange of particles mainly takes place adjacent the heat transferring walls, there being hardly any mixing in the middle layers, so that, particularly for a bad conductor, the faster flowing middle layers of the flow hardly take any part in the heat-exchange.

It will be seen that even in the turbulent layers near the wall there is:

1. Mixing of particles which have taken part in the heat exchange among themselves,

2. Mixing of particles which have not yet taken part in the heat exchange among themselves, all of which is useless for the heat exchange, and

3. Only to a smaller extent mixing of particles which have taken part in the heat exchange with particles which have not yet taken part in the heat exchange, which is the only kind of mixing useful for the heat exchange.

Hence for a required mean temperature of the fluid emerging from the passage, the outer layers have experienced a much greater temperature change than is required, so that the temperature difference between the outer layers and the walls will have fallen very quickly in the flow direction and with it the rate of heat transfer

2

per unit area of heat transferring wall per unit volume of fluid flowing therealong, so that the mean rate of heat transfer per unit area of heat-transferring wall taken over the length of the passage is low. Moreover, although the fluid will leave the passage with a required mean temperature, different layers will leave the passage with widely differing temperatures.

Thus, in order to achieve in such passages, a transfer of a certain quantity of heat, very large surface areas of heat transferring wall are required.

If now secondary walls extending the whole length of the passage and spaced relatively far apart are provided, then with turbulent flow the same phenomena will occur. Moreover, stagnant boundary layers form on the secondary walls as well as on the main heat transferring walls and provide layers of low heat conductivity between the flowing fluid and the metal, the thickness of the stagnant boundary layers being a function of the temperature and, in the case of narrow, elongated cross-sections, being inversely proportional to the distance between the heat-transferring walls. These stagnant boundary layers considerably reduce the rate of heat transfer per unit area of heat transferring wall, and further restrict the effective cross-sectional area of flow of the passage.

One object of the present invention is to provide heat exchangers in which the surface area and weight of the secondary walls and the primary heat transferring walls is considerably reduced as compared with conventional heat exchangers, for the same performance.

A further object of the invention is to ensure that each layer of the fluid stream, irrespective of its thickness for effective heat exchange, emerges from the heat exchanger passage with substantially the same temperature.

Still a further object of the invention is to reduce pressure losses for the fluids flowing through and taking part in the heat exchange.

Still a further object of the invention is to hinder the formation of stagnant boundary layers on the secondary walls.

Still a further object of the invention is to raise to a substantial extent the rate of heat transfer per unit area of heat transferring wall as compared with conventional constructions.

Further objects and advantages will become apparent from the following description.

With the foregoing objects in view, the present invention provides:

A heat exchanger comprising at least one primary heat transferring wall forming, at least in part, a channel for a heat exchange fluid flowing therealong, and a series of secondary heat transferring walls, of which each extends along said channel and has a fraction of the length of said primary heat transferring wall along said channel, the said secondary walls of said series being in a staggered arrangement relative to one another with, for at least two consecutive secondary walls of said series, a gap along said channel between the trailing edge of the one and the leading edge of the consecutive secondary wall, and with at least said two secondary walls of said series out of alignment along the flow-lines of said fluid with any secondary wall in said channel, and at least one of said two secondary walls having two opposite edges connected to a primary heat transferring wall, the said edges extending along said channel.

In such a staggered arrangement of secondary walls, those out of alignment along the flow lines of said fluid may be displaced parallel relative to one another, or displaced rotationally relative to one another, or displaced through a combination of parallel and rotary displacement.

Accordingly, the orthogonal projections of trailing and leading edges of adjacent secondary walls onto a flow-cross-section of said fluid in the gap between said secondary walls may or may not be parallel, and may or may not intersect, and they may, of course, be of similar of or different shapes.

It will further be understood that the secondary walls may be plane or may be curved, e. g. corrugated, or there may be plane and curved walls in one series.

In preferred embodiment of the invention, the secondary walls of a plurality of series are arranged in step-wise staggered progression relative to one another, with a gap along said passage between the trailing edge of each secondary wall and the leading edge of the consecutive secondary wall, and with each secondary wall of each series out of alignment with all other secondary walls in the passage, and each secondary wall of a series having two opposite edges connected with said primary wall, the said edges extending along said passage, and the said contacts with said primary wall being arranged in an evenly distributive pattern thereon.

The invention will now be described by way of example and in some detail with reference to the accompanying drawing, in which:

Fig. 1 is a plan section of part of an oil-cooler for an air-craft;

Fig. 2 is a section in elevation through one passage of this part, along the line II—II of Fig. 1;

Fig. 3 is another section in elevation along a passage of this part, along the line III—III of Fig. 1;

Fig. 4 is a part isometric view of an assembled oil cooler to which the detail of Figs. 1–3 relates;

Fig. 5 is a plan section of different embodiment of secondary walls;

Fig. 6 is a section in elevation along the line VI—VI of Fig. 5;

Fig. 7 is a seetion along the line VII—VII of Fig. 5;

Fig. 8 is a longitudinal section through an annular tube heat exchanger passage;

Fig. 9 is a cross-section at the end of the tube shown in Fig. 8.

Fig. 10 is a part isometric view of an assembled oil cooler to which the detail of Figs. 5–7 relates.

In the embodiment shown in Figs. 1 to 4 inclusive, 1 denotes heat exchanger passages of elongated cross-sectional shape, with surfaces of primary heat transferring wall parallel to one another over the width of the passage. These passages, as seen on Fig. 4, are arranged between the entry header tank 6 (shown broken open) and the exit header tank 7 below, the oil as indicated by black arrows 8, flowing through the passages 1 from the top to the bottom header. Between these oil-passages, passages for air in cross-flow are formed, the air flow being indicated by double-headed arrows.

As seen with reference to Figs. 1 to 3, and also with reference to Fig. 4, secondary walls 2 are mounted in series, which series respectively extend from the entry to the exit cross-section of the passage. Each secondary wall 2 extends along the passage, has only a fraction of the length of the primary heat transferring wall along the passage, and the secondary walls of each series are arranged in step-wise staggered progression, with a gap 4 in the direction of the passage between the trailing edge of one and the leading edge of the following secondary wall, the said gaps extending through all series of secondary walls, and with each secondary wall of each series being parallel to, but out of alignment along the flow-direction of the oil (indicated by arrows 3 on Figs. 1 to 3) with every other secondary wall in the passage. Each of the secondary walls is arranged normally to the parallel facing surfaces of primary heat transferring wall in each passage, and connects to these surfaces at two opposite edges which extend along the passage, the positions of contact forming an evenly distributive pattern over the surfaces of primary heat transferring wall.

As seen with reference to Fig. 4, similar secondary walls 9 in the arrangement according to the invention as described above for the oil-passages, are provided in the air-passages.

The details shown with reference to Figs. 5 to 7, apply to an oil-cooler arrangement of tanks 6 and 7 with passags 1 as shown in Fig. 10, and illustrate a different embodiment of secondary walls according to the invention inside the oil-passages 1 of elongated cross-sectional shape. In contradistinction to the embodiment of Figs. 1–4, secondary walls 10, each extending along the passage and of short length compared therewith, and arranged in series 13, 14, 15 (indicated on Fig. 10) and 16 (indicated on Fig. 5) which series extend from the entry to exit of the passages, are each arranged parallel to the parallel side-parts 1*a* and 1*b* of primary heat transferring wall in a passage. In other words, secondary walls 10 extend longitudinally of the cross-section of the passage 1 instead of transversely, as in the first embodiment. The secondary walls of alternate series 14 and 16 are respectively connected to the side-part of primary heat transferring wall by carrying parts 11*b* which extend normally of the side-part 1*b*, while the secondary walls 10 of the series 13 and 15 are connected to the side-part 1*a* of the primary wall by the carrying parts 11a, as shown on Figs. 5, 6, 7 and 10. Two opposite edges of each secondary wall 10 are thus connected to primary heat transferring wall, the contacts with the primary wall forming an evenly distributive pattern thereon. Connections 12 (see Figs. 5 and 10) connect each series of carrying parts 11*a* and 11*b* so that the series of secondary walls with their carrying parts for each passage form one unit, to be inserted into the passage on assembly. The secondary walls 10 of each series are staggered in step-wise progression, with gaps 4 along the passage between the trailing edge of one and the leading edge of the following secondary wall, and with every secondary wall of each series parallel to, but out of alignment along said passage with every other secondary wall in the passage. The said gaps 4 extend at the same level through all series of secondary walls, since the connection walls 12 are interrupted by these gaps.

Figs. 8 and 9 illustrate secondary walls according to this invention in a passage 22 of annular shape formed between two concentric tubes 20 and 21 as primary heat transferring walls. Such passages might be visualized as components of a heat exchanger in place of passages 1 on Fig. 4, on which a number of passages 22, suitably arranged, would replace one passage 1, the outer tubes fitting into the nearer surfaces of the tanks 6 and 7, and the inner tubes 21 into the outer surfaces of these tanks, so that oil would flow through the annular spaces and air past the outside of tubes 20, while air or another cooling fluid might flow through the inside tubes 21.

The secondary heat transferring walls 23, which each extend along the passage and have only a fraction of the length of this passage, are arranged in four series. Each series of secondary walls extends the whole length of the passage, and the secondary walls 23 in it are staggered angularly in step-wise progression to cover respectively one quadrant of the annular space. As in the embodiments described before, there are gaps 24 between the trailing edge of each secondary wall and the leading edge of the following secondary wall, and each secondary wall is out of alignment with every other secondary wall, and furthermore connects at two opposite edges, which extend along the passage, to the primary heat transferring walls formed by tubes 20 and 21, these edges forming an evenly distributive pattern over the surfaces of the primary heat transferring walls.

It is seen with reference to all three of the embodiments described, that one sheet of metal, instead of forming one or a number of secondary walls which extend from the beginning to the end of the passage, and having contact only with two layers of the fluid flowing in the passage (oil in this instance) forms according to this invention a series of secondary walls which are each of short length, are staggered in step-wise progression and have gaps along the passage between them, which come into contact with different layers of the flow of the fluid, and provide a considerable saving of metal if only due to the gaps and the fact that each series covers a considerable portion of the cross-section of the passage, as seen with reference to the various views.

In operation then, each layer of fluid in the cross-sectional area of flow, irrespective of its thickness for effective heat exchange, comes into contact with a secondary wall, and remains in contact therewith only for such time (depending on speed of flow and length of secondary wall) as is required for it to take its required part in the heat transfer. Thereupon an adjacent pair of flow-layers reaches a following secondary wall of the series, so that all secondary walls of the series disposed along the length of the passage transfer heat to the primary heat transferring walls from layers of fluid which have not yet taken direct part in the heat transfer and thus still are near to their entering temperature. Therefore the temperature of the primary heat transferring wall, and thereby the temperature difference to the other fluid taking part in the heat exchange (air in this instance) is maintained along its length. This factor raises the rate of heat transfer per unit area of wall considerably compared with conventional constructions.

Furthermore, on secondary walls of any considerable length, stagnant boundary layers of the fluid, particularly if a liquid, are formed which have severe heat insulating effects.

In contradistinction to this, the effects of the gaps between the trailing edge of one and leading edges of the following secondary wall are as follows:

(1) Due to the gaps, impact occurs on the fluid meeting the leading edge of a secondary wall, producing a pressure, and suction occurs on the fluid leaving the trailing edge, producing a depression, both these pressure changes being due to sudden changes in velocity at these edges. Since the secondary walls are purposely of short length, this impact and suction will suffice to remove the stagnant layers from the secondary walls, or at least to considerably reduce the thickness of such layers, thus greatly enhancing heat transfer between the fluid and the secondary walls.

(2) Due to the gaps extending right across the flow cross-section of a passage, the vortices due to such impact and suction can spread right across the flow cross-section, and produce intermixing of the fluid particles of a kind which assists heat transfer between fluid and secondary and primary heat transferring walls.

(3) A most important effect of the gaps consists in separating from one another the connections of the secondary walls with the primary heat transferring wall. This is important because the heat flowing from a source on a secondary wall, say, to a second fluid outside the primary heat transferring wall flows into this second fluid not merely through the small contact-area between primary and secondary wall, but through a wider "area of effectiveness" surrounding this contact-area, since metal conducts heat so much better. If connections of secondary walls to primary walls would not be separated, such "areas of effectiveness" of the various secondary walls would overlap on the primary walls, which would be wasteful since such overlapping portions of "areas of effectiveness" have no more heat transfer than non-overlapping "areas of effectiveness", and accordingly any part of the secondary wall causing such overlap is superfluous. The gaps, which together with the step-wise staggering of short secondary walls provide for separation of such "areas of effectiveness" and for even distribution of these over a surface of primary heat transferring wall, thus contribute in this way to improved heat transfer over the whole area of primary heat transferring wall.

Due to the effects of the provisions of this invention, the width of passages for the fluid could be increased as compared to conventional constructions, thus considerably reducing the pressure loss of the fluid. This is still further reduced by the fact that in any flow-cross-section there are only few secondary walls, and none at all in the gaps, which factors in combination reduce the ratio of wetted circumference to flow-cross-section which strongly influences pressure loss. With wider passages, fewer passages could handle the same performance, which further to the saving of metal on the actual secondary surfaces and the saving due to improved rate of heat transfer, adds up to a considerable saving of metal.

The arrangement of secondary wall perpendicularly to the primary heat transferring wall, as shown in Figs. 1–4 and 8 and 9 has the following advantage over the arrangement of secondary walls parallel to the primary heat transferring walls: Each secondary wall is directly connected to both primary heat transferring walls, and comes into contact both with fluid near the primary walls and centrally in the flow, which latter still have extreme temperatures. Hence between these and the primary walls the secondary walls conduct heat with the greatest temperature difference along the shortest paths, and simultaneously to two primary walls.

Secondary walls according to the present invention may be suitably corrugated, or provided with one corrugation each—the said corrugation running along the passage—to allow for thermal expansion or contraction. It will be understood further that secondary walls according to this invention may be plane or curved, or that there may be curved and plane secondary walls in the same series.

I claim:

1. A heat exchanger comprising at least one primary heat transferring wall forming, at least in part, a channel for a heat exchange fluid flowing therealong, and a series of secondary heat transferring walls, of which each extends along said channel and has a fraction of the length of said primary heat transferring wall along said channel, the said secondary walls of said series being in a staggered arrangement relative to one another with, for at least two consecutive secondary walls of said series, a gap along said channel between the trailing edge of the one and the leading edge of the consecutive secondary wall, and with at least said two secondary walls of said series out of alignment along said channel with any secondary wall in said channel, and at least one of said two secondary walls having two edges connected to a primary heat transferring wall, the said edges extending along said channel.

2. A heat exchanger comprising at least one primary heat transferring wall forming, at least in part, a channel for a heat exchange fluid flowing therealong, and a plurality of series of secondary heat transferring walls of which each secondary wall extends along said channel and has a fraction of the length of said primary heat transferring wall along said channel, the said secondary walls of each series being in a staggered arrangement relative to one another with, for at least two consecutive secondary walls of each series, a gap along said channel between the trailing edge of the one and the leading edge of the consecutive secondary wall, said gap extending across the width of said primary heat transferring wall through all said series of secondary walls, and with at least said two secondary walls of each series out of alignment along said channel with any secondary wall in said channel, and at least one of said two secondary walls of each series having two edges connected to said primary heat transferring wall, the said edges extending along said channel.

3. A heat exchanger comprising at least one primary heat transferring wall forming a substantially straight passage of elongated cross-sectional shape with at least two opposing surfaces of primary heat transferring wall substantially parallel to one another, for a heat exchange fluid flowing therealong, and a plurality of series of secondary heat transferring walls, of which each secondary wall extends along said passage and has a fraction of the length of said primary heat transferring wall along said passage, the said secondary walls of each series being in a staggered arrangement relative to one another with, for at least two consecutive secondary walls of each series, a gap along said passage between the trailing edge of the one and the leading edge of the consecutive secondary wall, said gap extending across the width of said primary heat transferring wall through all said series of secondary walls, and with at least said two secondary walls of each series out of alignment along said passage with any secondary wall in said passage, and at least one of said two secondary walls of each series having two edges connected to said primary heat transferring wall, the said edges extending along said passage.

4. A heat exchanger as claimed in claim 3 in which each secondary wall of each series has two opposite edges in contact with said two opposing parallel surfaces of primary heat transferring wall, the said edges contacting said primary wall being spaced from one another and being arranged in an evenly distributive pattern on said surfaces of primary heat transferring wall.

5. A heat exchanger comprising at least one primary heat transferring wall forming a substantially straight passage of elongated cross-sectional shape with at least two opposing surfaces of primary heat transferring wall substantially parallel to one another, for a heat exchange fluid flowing therethrough, and a plurality of series of secondary heat transferring walls, of which each secondary wall extends along said passage and normal to said opposing surfaces of primary heat transferring wall, and has a fraction of the length of said primary heat transferring wall along the length of said passage, the said secondary walls of each series being arranged in step-wise staggered progression relative to one another, with a gap along said passage between the trailing edge of each secondary wall and the leading edge of each consecutive secondary wall, said gaps extending across the width of said primary heat transferring wall through all said series of secondary walls, and with each secondary wall of each series parallel to and out of alignment along said passage with all other secondary walls, and each secondary wall of each series having two opposite edges connected with said opposite and parallel surfaces of primary heat transferring wall, the said edges extending along said passage, and having an evenly distributive arrangement on said primary wall surfaces.

6. A heat exchanger comprising two primary heat transferring walls each forming a passage of similar cross-sectional shape, one of said passages being arranged within and coextensive with the other one to form a passage of substantially annular cross-sectional shape between said two primary heat transferring walls, for a heat exchange fluid flowing therethrough, and a plurality of series of secondary heat transferring walls of which each secondary wall extends along said annular passage, has a fraction of the length of said primary heat transferring walls along said passage, and extends substantially normally to the surfaces of said primary heat transferring walls, the said secondary walls of each series being staggered in spirally step-wise progression

relative to one another, with a gap along said passage between the trailing edge of each secondary wall and the leading edge of the consecutive secondary wall, the said gaps extending respectively through all said series of secondary walls across the whole cross-section of said annular passage, and with each secondary wall of each series rotationally out of alignment with all other secondary walls, and each secondary wall of each series having two opposite edges respectively connected with said two primary heat transferring walls, the said edges extending along said passage, and being evenly distributed over said primary walls.

7. A heat exchanger comprising at least one primary heat transferring wall forming a substantially straight passage of elongated cross-sectional shape for a heat exchange fluid flowing therethrough, the said primary heat transferring wall comprising two elongated side-parts substantially parallel to one another and forming the elongated side-walls of said passage; the said heat exchanger further comprising a plurality of series of secondary heat transferring walls, each secondary wall of each series extending along said passage and substantially parallel to said elongated side-parts of said primary heat

transferring wall, and having a fraction of the length of said primary heat transferring wall along the length of said passage, the said secondary walls of each series being staggered in step-wise progression relative to one another, with a gap along said passage between the trailing edge of each secondary wall and the leading edge of each consecutive secondary wall, and with each secondary wall of each series substantially parallel to, but out of alignment along said passage, with every other secondary wall in said passage, and each secondary wall of each series having two edges connected to one of said side-parts of said primary heat transferring wall, the said edges extending along said passage.

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References Cited in the file of this patent

UNITED STATES PATENTS

Number	Name	Date
2,133,502	Emmons	Oct. 18, 1938
2,148,204	Kemp	Feb. 21, 1939
2,149,696	Holmes	Mar. 7, 1939
2,173,844	Houdry	Sept. 26, 1939
2,480,706	Brinen	Aug. 30, 1949