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Ostersetzer et al.

(54) **HEAT EXCHANGER**

(75) Inventors: **Shlomo Ostersetzer**, Ramat Gan (IL); **Avraham Gorodetzky**, Kiryat Ono (IL)

Correspondence Address:
Lilling & Lilling PLLC
PO Box 435
Jerusalem 91003 (IL)

(73) Assignee: **TAT TECHNOLOGIES LTD.**, Gedera (IL)

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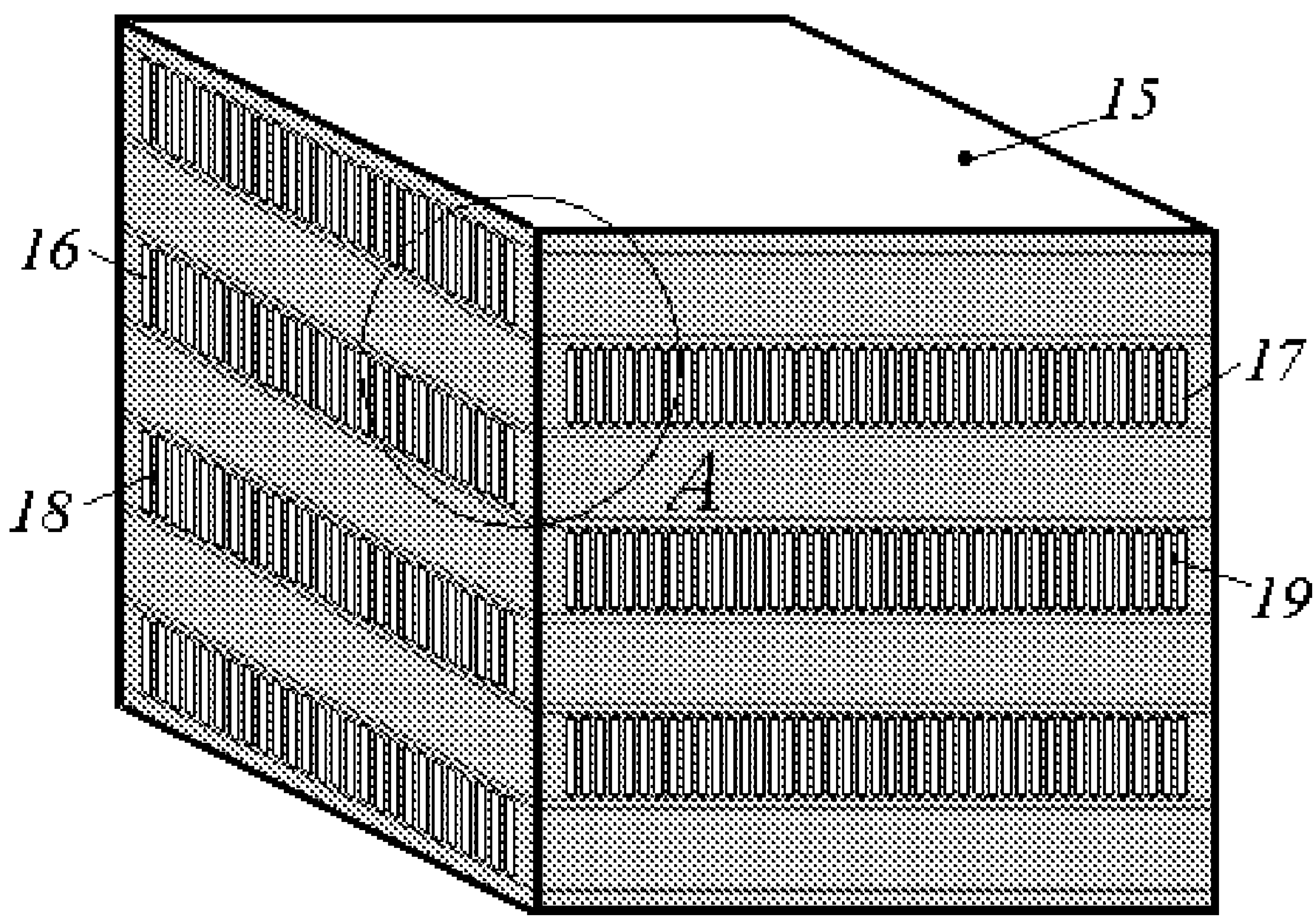
(52) **U.S. Cl.** **165/164**

(57) **ABSTRACT**

The invention presents a MONOBLOC fin and plate heat exchanger design preventing internal leakages and intermixing of high-temperature and low-temperature flows, e.g. oil and fuel. This is achieved through a particular configuration of the heat exchanger, whereby its core assembly is completely or partially produced from a one-piece monolithic metallic block. Owing to that, all brazed seams, which in conventional fin and plate heat exchangers contact with both hot medium and cold medium flows, are fully abolished thereby excluding a source for imperfections usually developing in brazed joints and base metal in the process of pressure-temperature cyclic loading. Employing custom-made individual fins allows about two-fold increase in the strength of brazed joints in comparison with ordinary corrugated fins (due to doubling of the brazed surface). As a result, the suggested configuration allows the design of a high reliability compact heat transfer device for much higher operating pressures than what may be achieved in the conventional fin and plate heat exchanger. This invention may be used in different fields of modern technology, especially for aeronautical engine applications, where the challenge of ensuring reliability levels of one failure in millions of (fleet-cumulative) flight hours, and operating pressure levels of thousands of pounds per square inch, must be met.



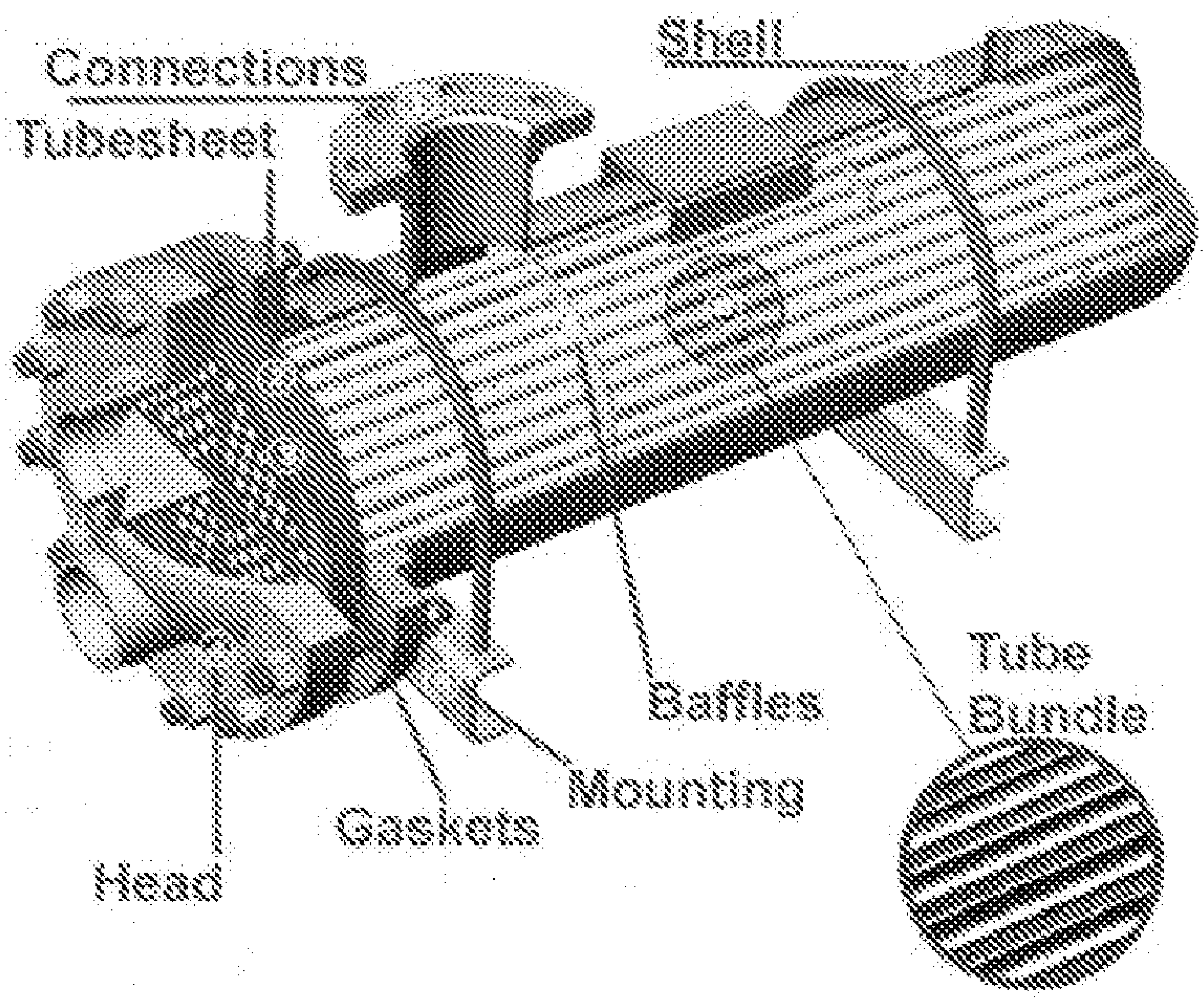

Connections
Tubesheet
Shell
Tube
Bundle
Baffles
Mounting
Gaskets
Head

FIG. 1

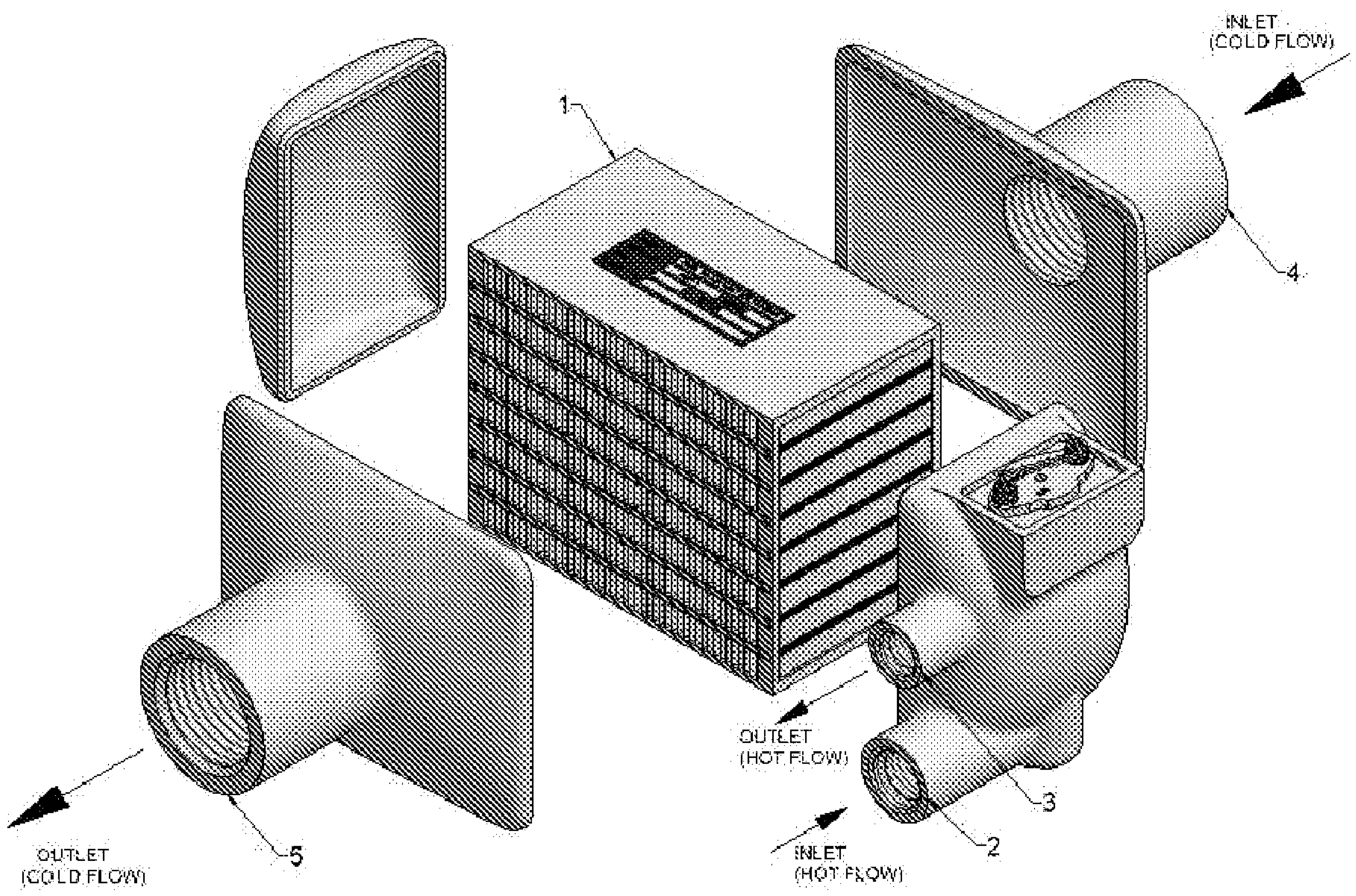

INLET
(COLD FLOW)
1
4
OUTLET
(HOT FLOW)
3
2
INLET
(HOT FLOW)
5
OUTLET
(COLD FLOW)

FIG. 2

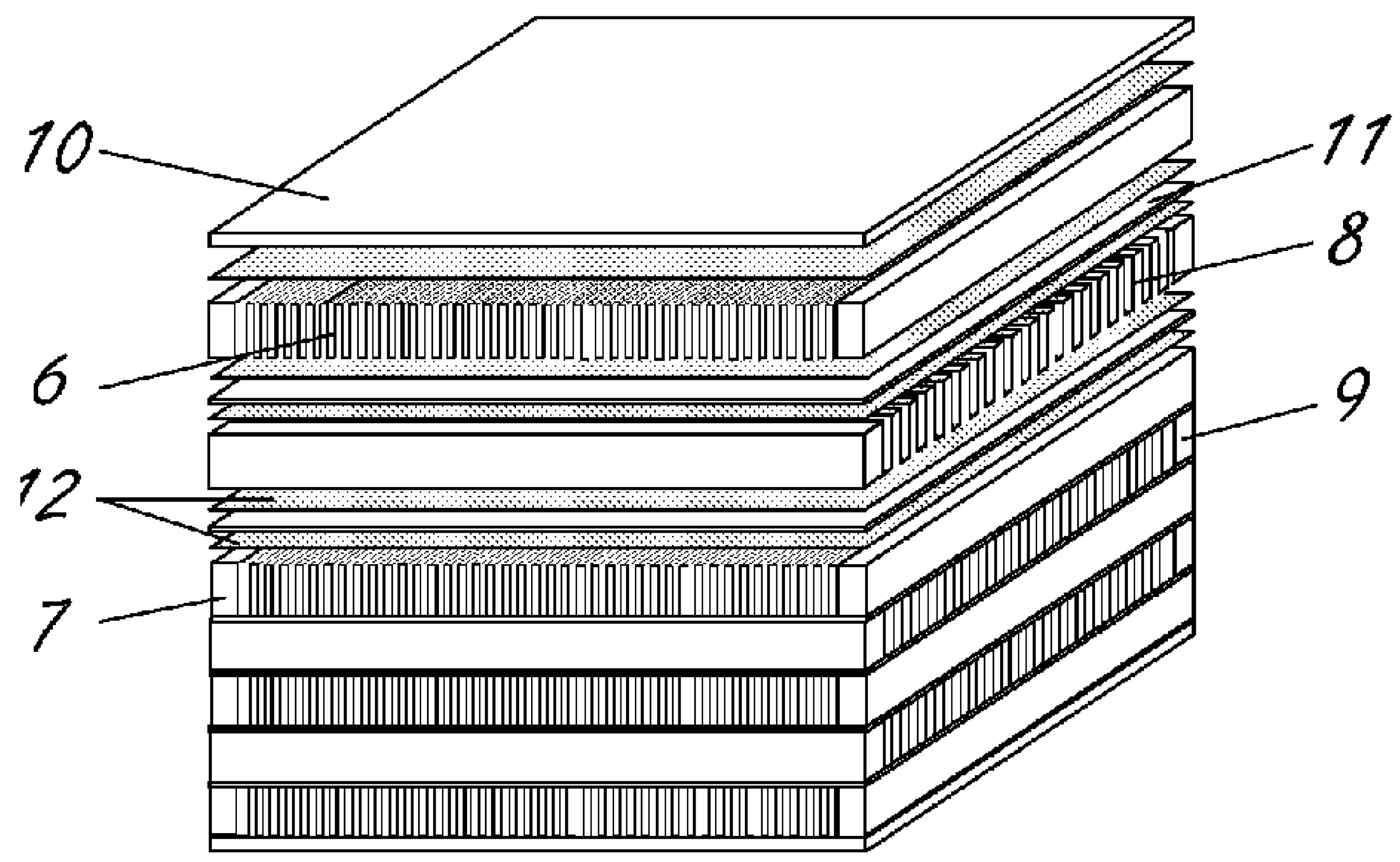


FIG. 3

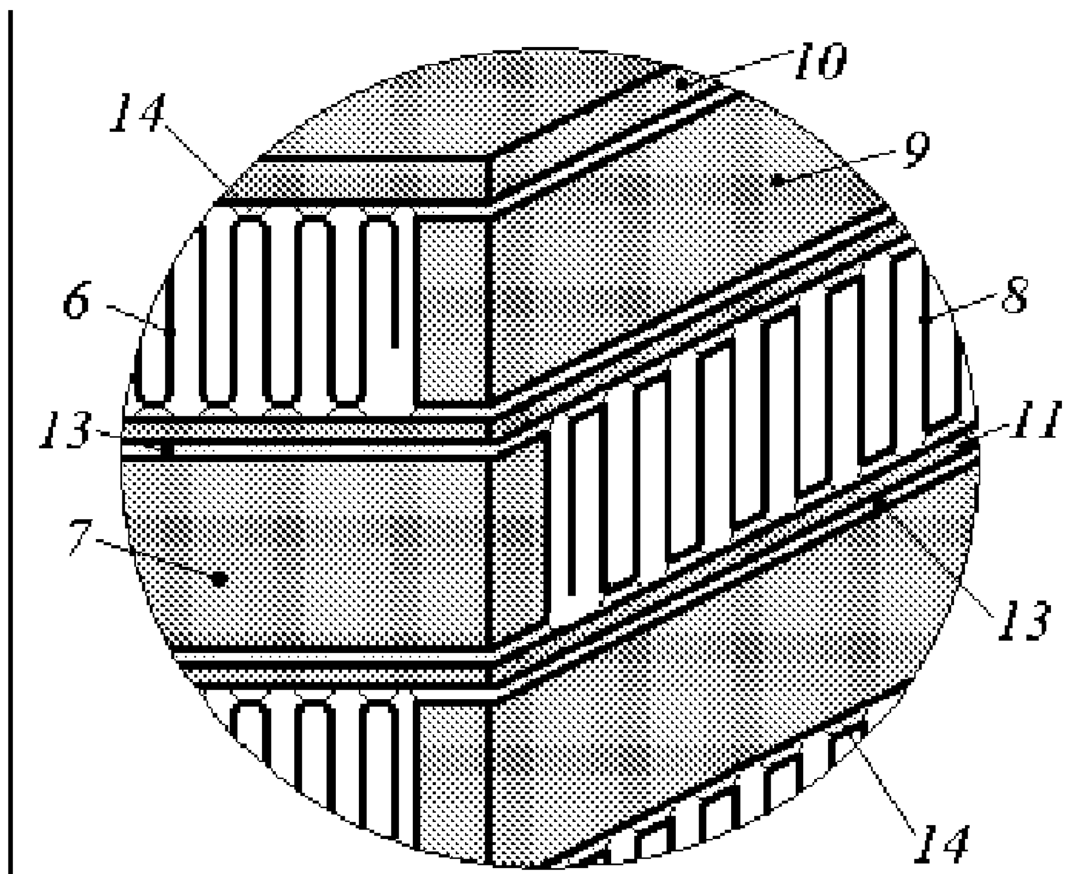


FIG. 4

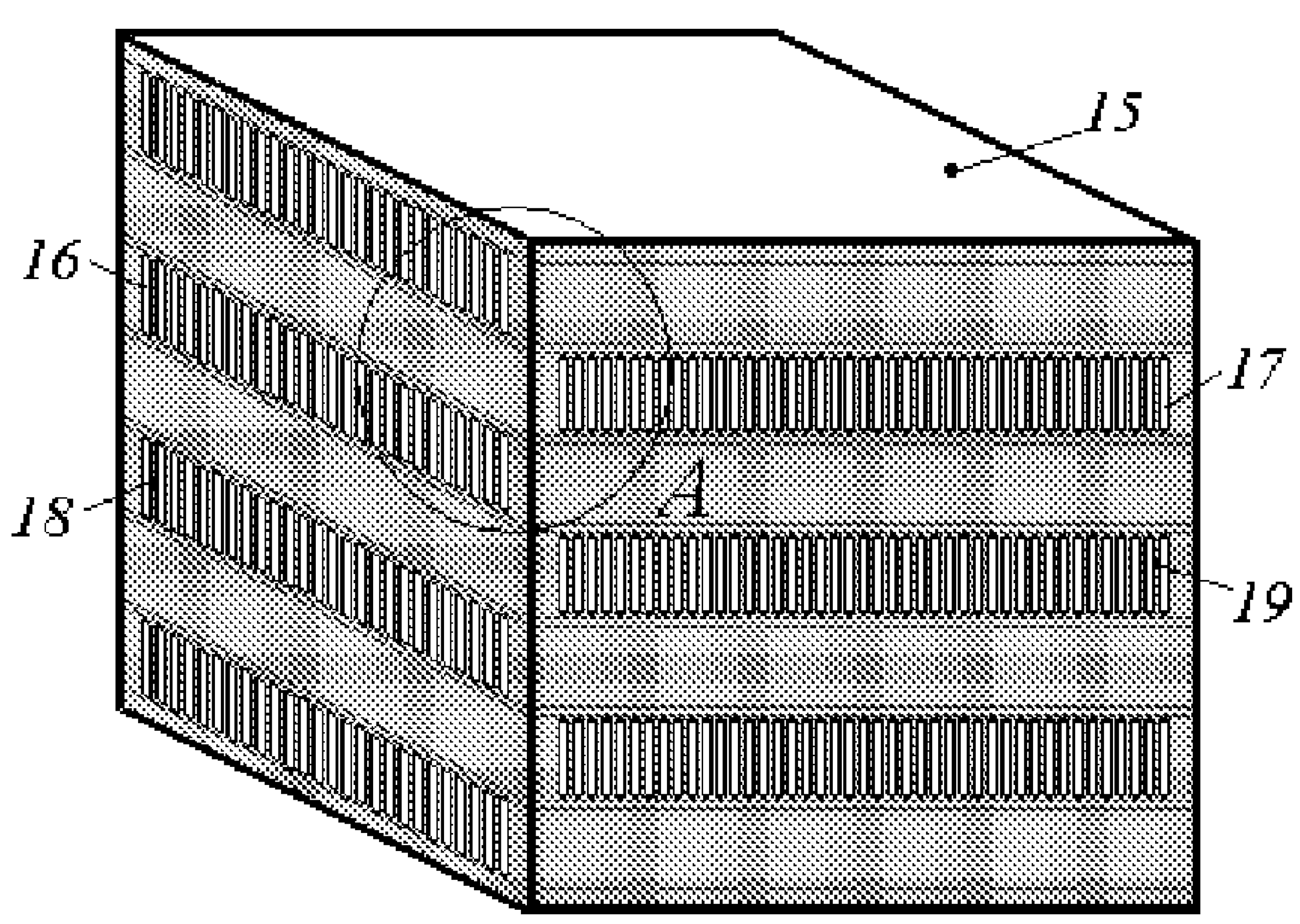


FIG. 5

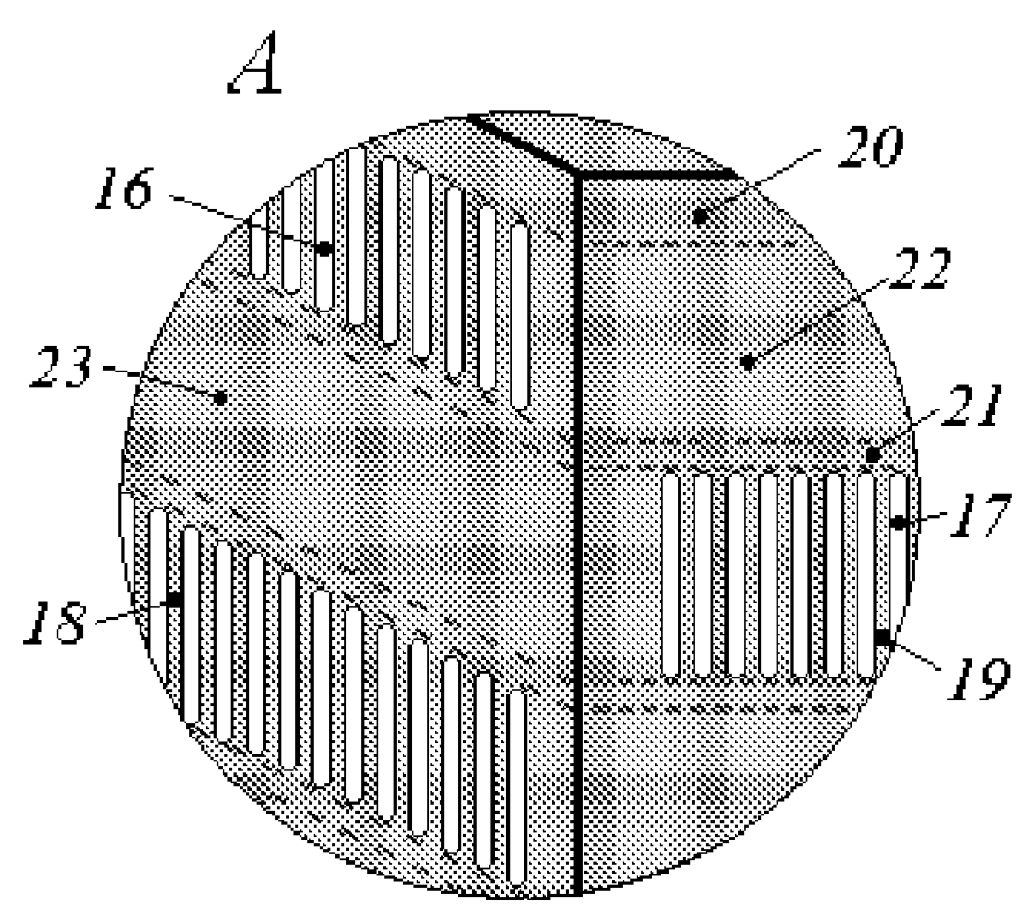


FIG. 6

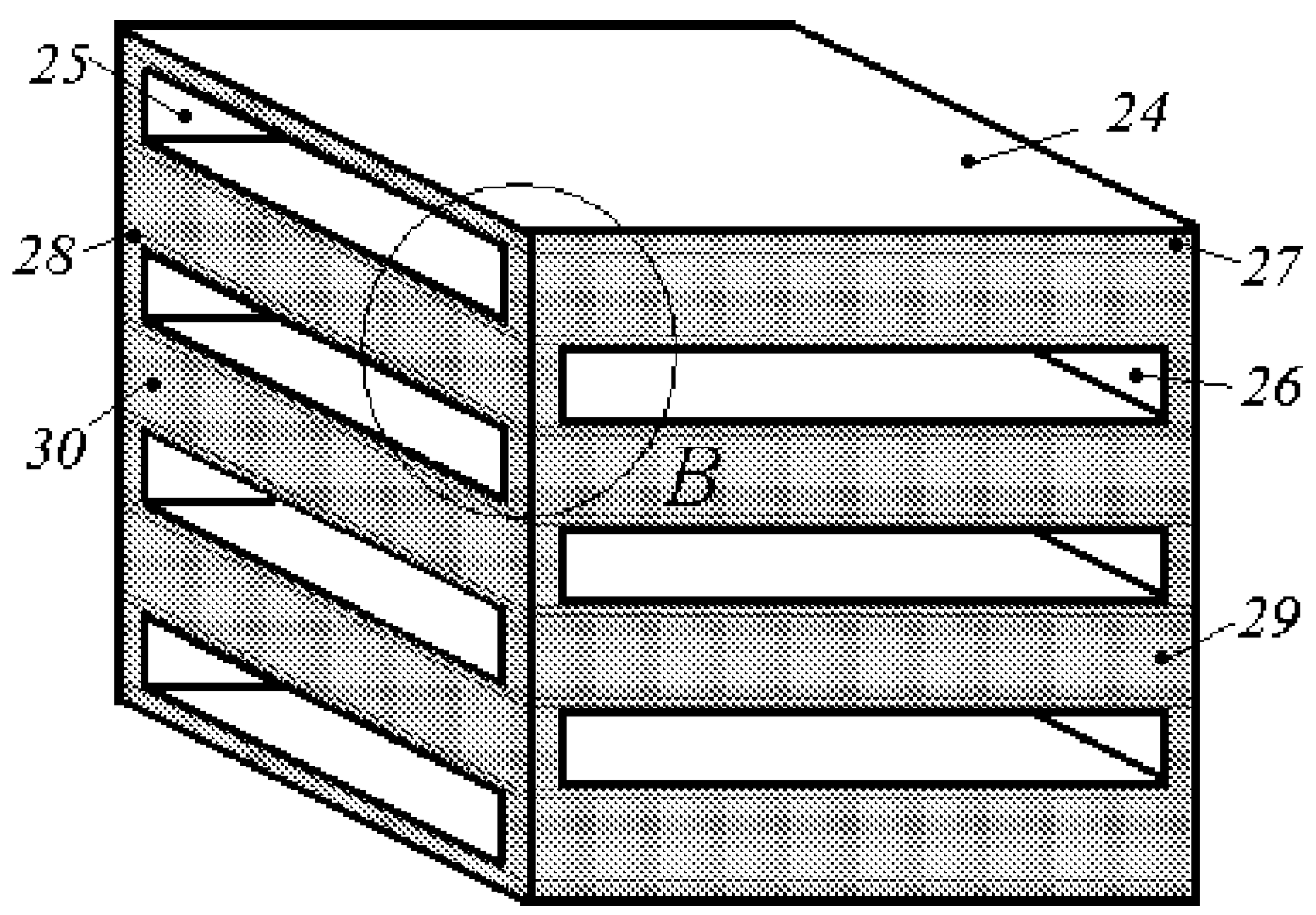


FIG. 7

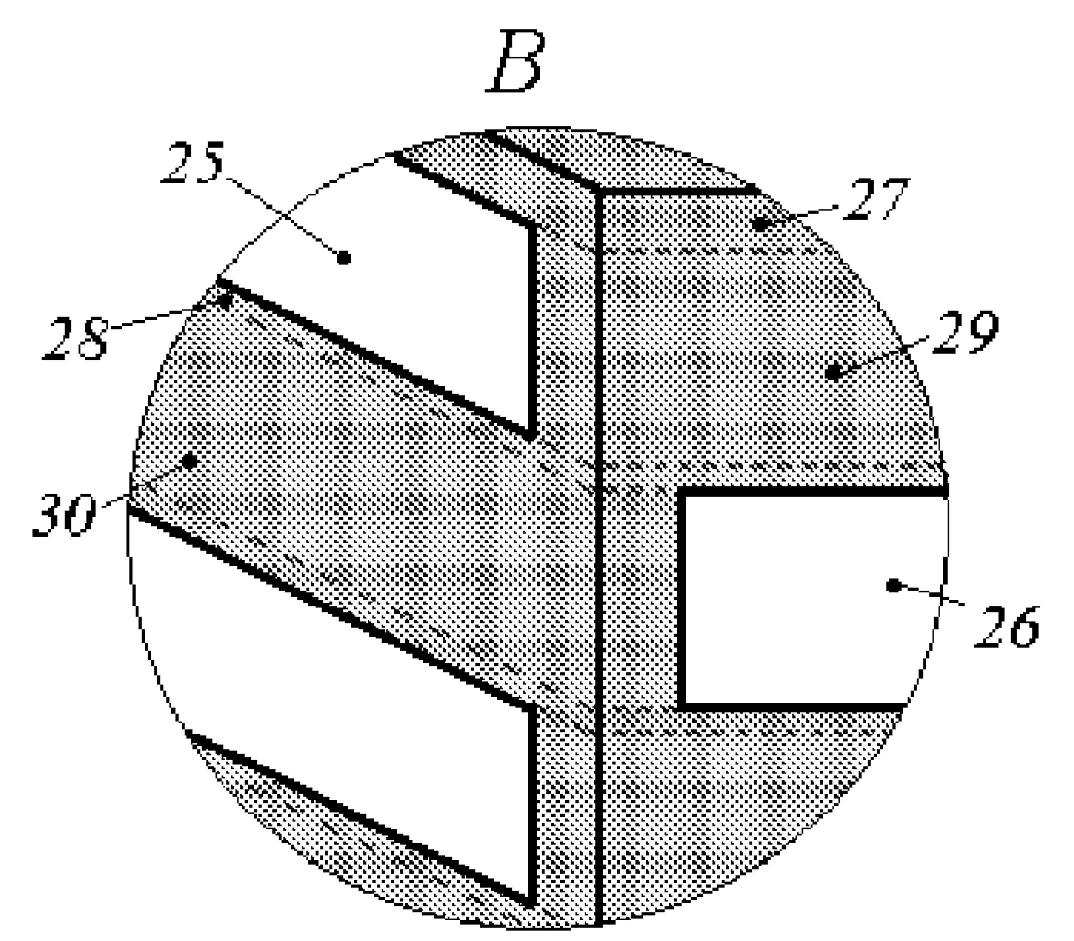


FIG. 8

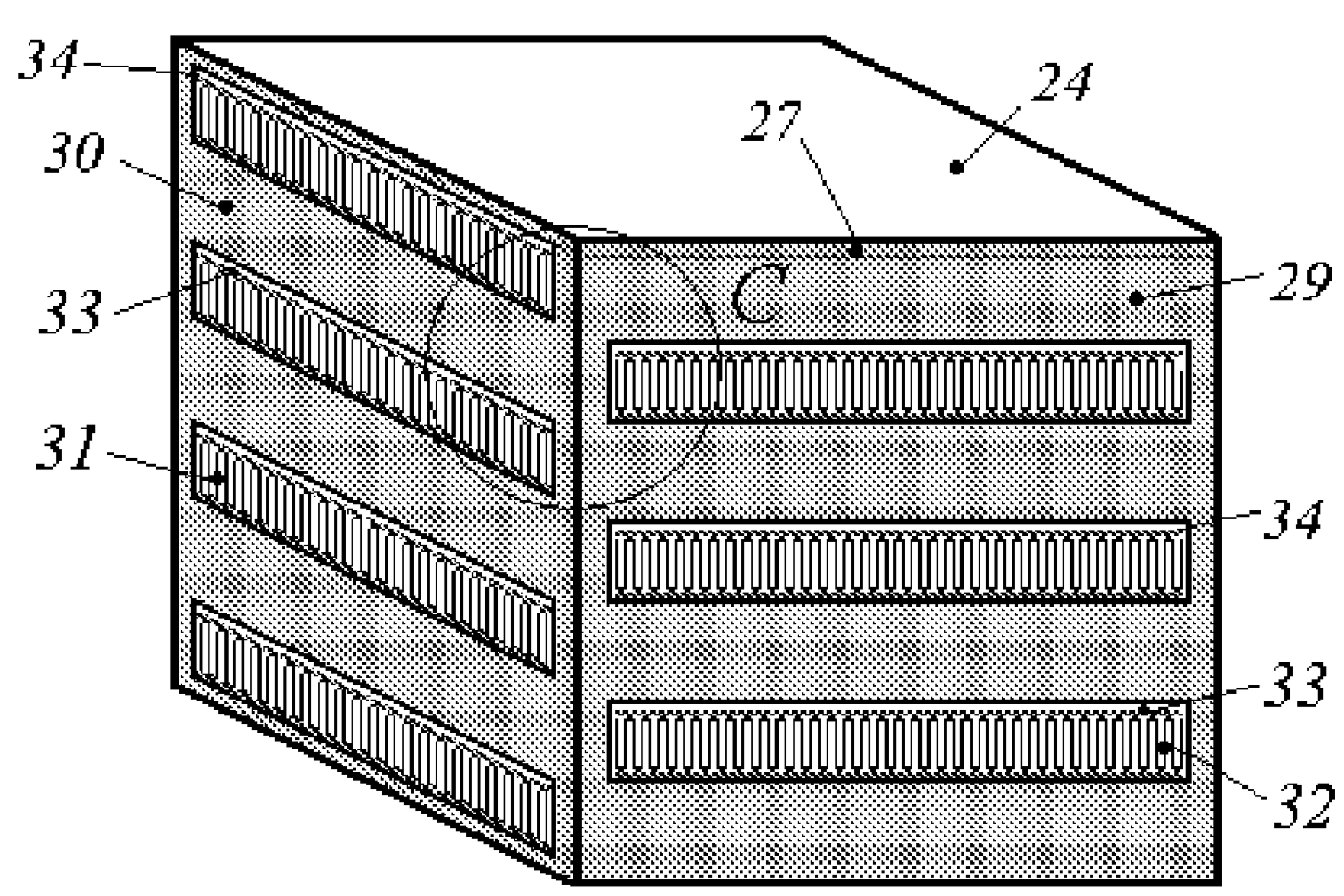


FIG. 9

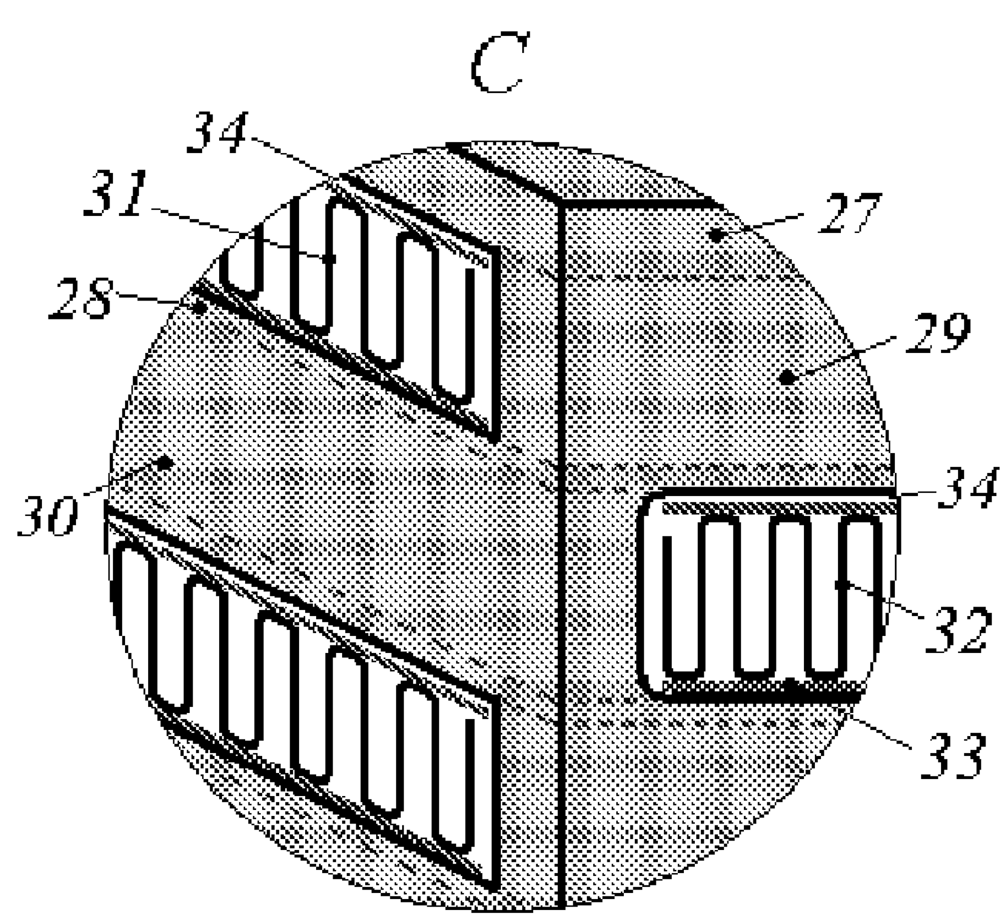


FIG. 10

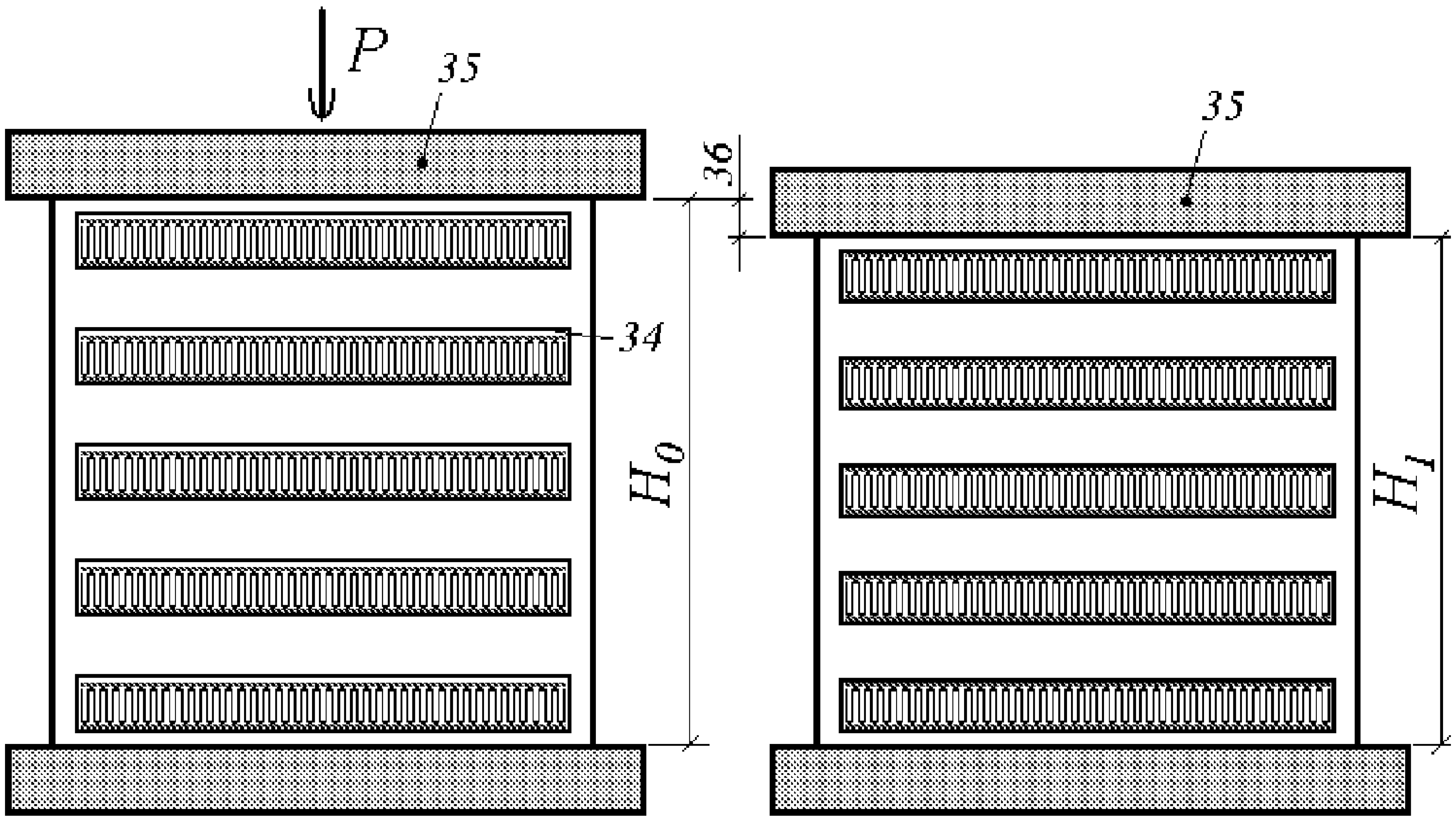


FIG. 11, a

FIG. 11, b

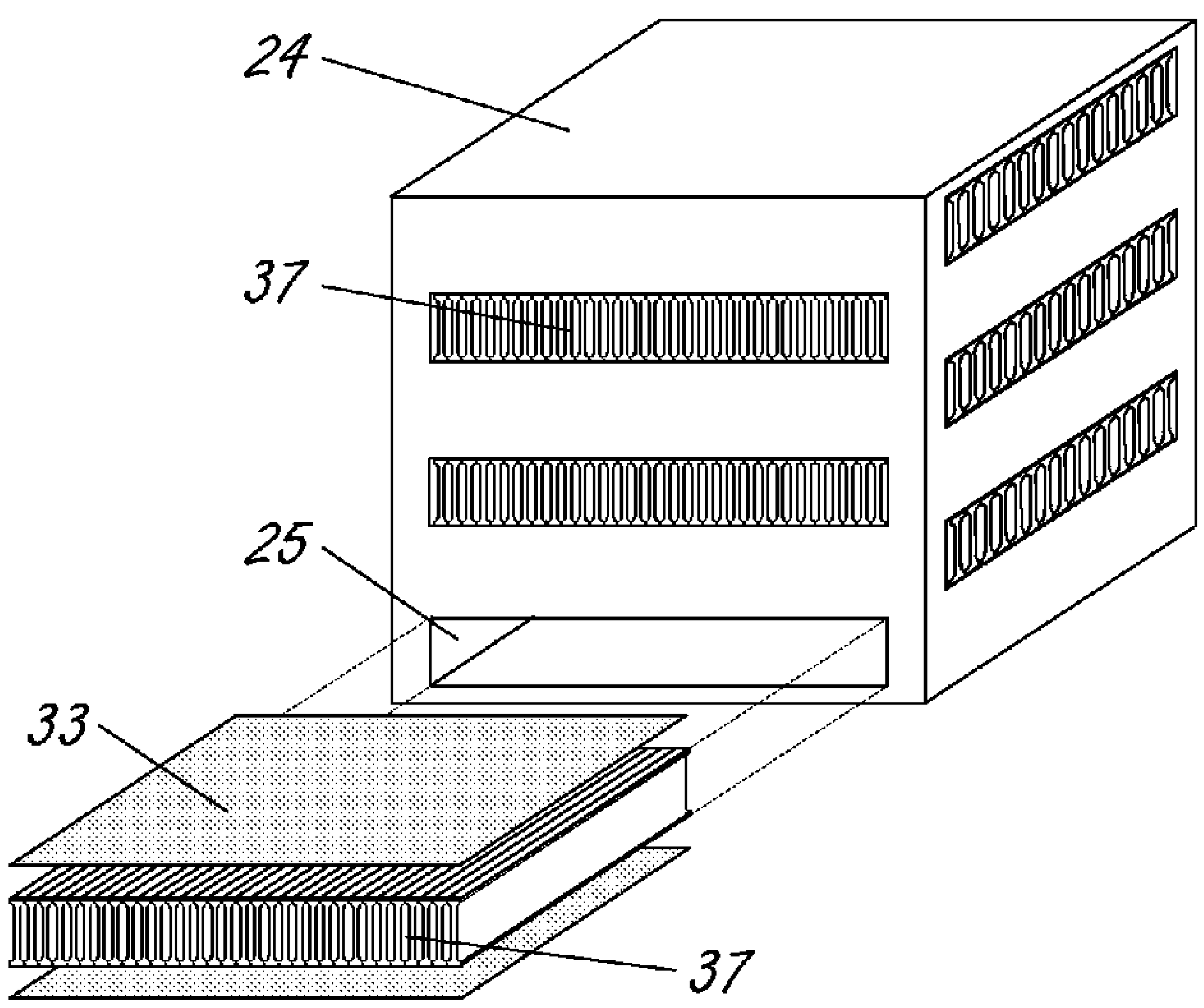


FIG. 12

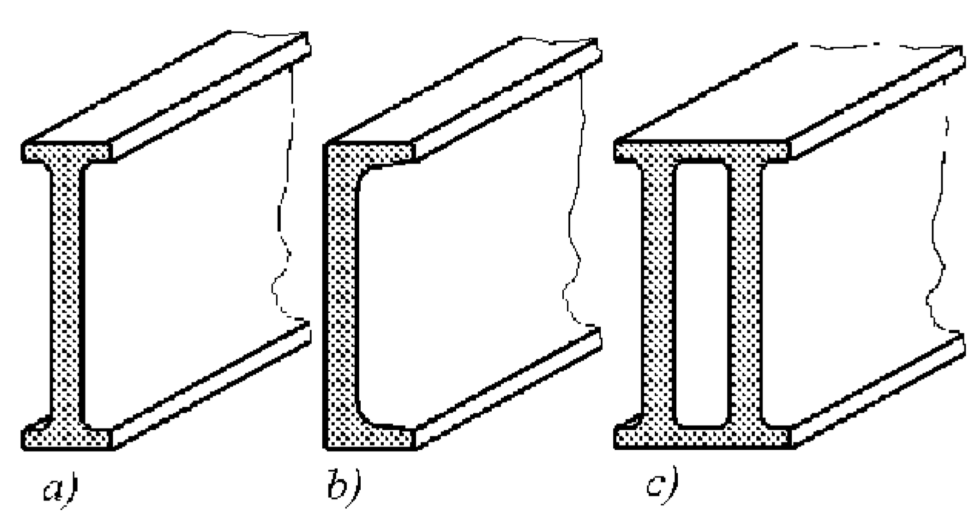


FIG. 13

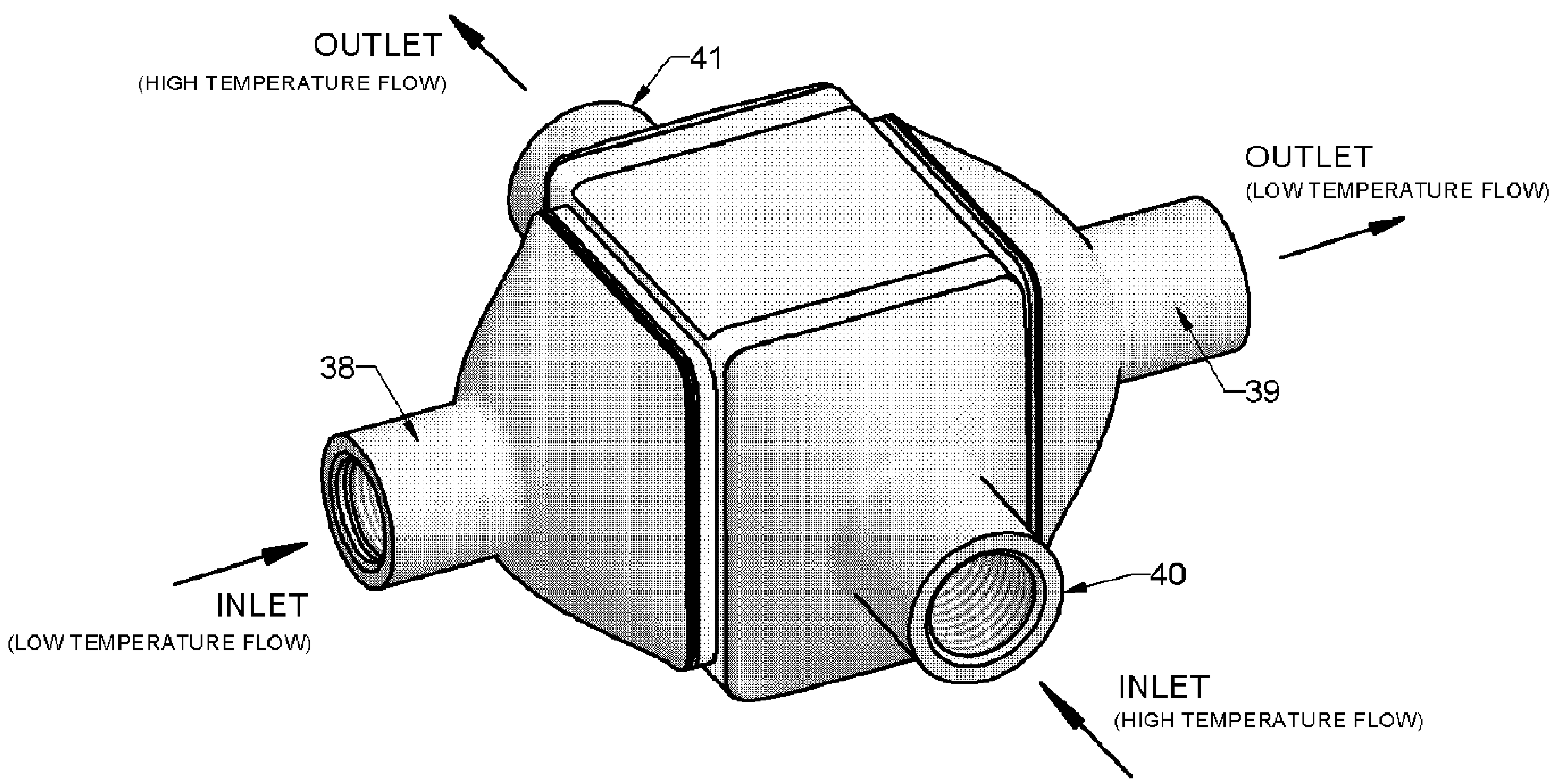

OUTLET
(HIGH TEMPERATURE FLOW)
41
OUTLET
(LOW TEMPERATURE FLOW)
38
39
40
INLET
(LOW TEMPERATURE FLOW)
INLET
(HIGH TEMPERATURE FLOW)

FIG. 14

HEAT EXCHANGER

BACKGROUND OF THE INVENTION

[0001] The present invention relates to heat exchange technology and equipment, and more particularly concerns design and methods of manufacture of heat exchangers for aeronautical applications. It may prove to be most advantageous for the production of highly reliable compact heat transfer devices, particularly adapted for high pressure operating conditions.

[0002] At present in aeronautical engineering both the shell-tube and fin-plate heat exchangers are widely used for high pressure applications. With rising pressure magnitudes, however, the fin and plate heat exchanger will be limited in the future.

DESCRIPTION OF THE PRIOR ART

[0003] The classical shell and tube heat exchanger is diagrammatically shown in FIG. **1**.

[0004] This type of heat exchanger is suited for high pressures in view of its tubular construction which provides uniform stresses. At the same time it suffers from some serious disadvantages.

[0005] The shell and tube heat exchanger transfers heat through a primary surface, i.e. the walls of the tubes, and the corresponding area of this surface is relatively small. This leads to a poorer unitary thermal performance resulting in a larger volume and increased weight.

[0006] Another imperfection of the shell and tube heat exchanger consists in that the connection between the tubes and the tube-sheet, which is achieved by swaging, welding or brazing, is a sensitive area in respect of leakage. An additional point of concern is the possible breakage of tubes as a result of vibration-induced fatigue failures.

[0007] Owing to these considerations the shell and tube heat exchanger cannot meet the reliability required e.g. for modern jet engines.

[0008] The conventional fin and plate heat exchanger is schematically depicted in FIG. **2**.

[0009] This type of heat exchanger possesses greatly extended surfaces of heat transfer. Its relative efficiency is significantly larger in comparison with the shell and tube heat exchanger, and this produces savings in both volume and weight. For this reason the fin and plate heat exchanger is increasingly used for high pressure applications (e.g. on jet engines to cool oil lubricants by means of high pressure fuel).

[0010] The classical fin and plate heat exchanger (FIG. **2**) is constructed from core assembly **1** and, welded (or attached to it) headers **2**, **3** for high-temperature flow and **4**, **5** for low-temperature flow. Core assembly **1** (FIG. **3**) consists of several types of functional elements, such as low-temperature fins **6** and low-temperature closure bars **7**, high-temperature fins **8** and high-temperature closure bars **9**, end plates **10** and parting plates **11**.

[0011] When assembled (FIG. **3**) these components form two types of elementary heat transfer layers. One of these is intended for cold flow and the other for hot flow. Each of these layers includes fin layers **6** or **8** and two closure bars **7** or **9**; adjacent layers are separated by parting plates **11**. The cold and hot layers are disposed alternatively in mutually perpendicular flow directions.

[0012] The above described parts of the core assembly constitute its functional elements since each of these has one or more operational functions. For example, parting plates serve for separation of hot and cold flows and also for heat transfer from high-temperature to low-temperature fins, while closure bars and end plates act as flow enclosures.

[0013] At the same time, upon assembly and brazing by filler metal **12** (FIG. **3**), the same functional elements may be considered as structural ones since the resulting structure of core assembly comprises only said elements and brazed seams **13** and **14** (FIG. **4**). The joints are formed between parts **6-11** during the process of heating of the core assembly to brazing temperature and subsequent crystallization of the liquid filler metal.

[0014] Brazing filler metal **12** may be used as separate foil elements as shown in FIG. **3**. Alternatively, brazing compound may be introduced into the joining zone by spraying filler metal powder unto the relevant surfaces or by using structural sheets that are pre-clad with said compound, whereby both the inner surfaces of the end plates and both surfaces of each parting sheet are coated with brazing compound.

[0015] The resulting structure of assembled and brazed core assembly is shown in FIG. **4**. From this picture it is clear that any of the brazing seams **13** (between closure bars and parting sheets or end plates) are in contact with both hot and cold flows.

[0016] It is well known that braze joints have polycrystalline cast structure of lower density and some characteristic micro-defects such as micro-pores, blisters, voids, oxide inclusions which result in bonding imperfections. Such small discontinuity flaws are usually not detectable on a finished new product which successfully passes a routine standard leak test. However, after a certain period of operational use, such micro-defects may develop into more serious imperfections under the influence of differential heat stresses and resulting in internal leakages.

[0017] In certain applications such a failure mode may prove particularly critical e.g. in a fuel/oil heat exchanger when the oil becomes contaminated with fuel and its lubricity is impaired hence causing mechanical damage and this could be catastrophic.

[0018] The modern requirements for reliability of one failure in 10^7 or 10^8 (fleet cumulative) flight hours and operating pressure of working media of thousands of pounds per square inch appear to be non-achievable when using the conventional architecture of the fin and plate heat exchanger. (Note that in the case of a shell and tube heat exchanger, and for reasons mentioned above, such reliability achievement is highly questionable, to say the least.)

[0019] It is obvious from FIG. **4** that due to the specific shape of corrugated fins brazed joints **14** cover about 50% of the parting sheet area. This decreases the capability of a heat exchanger to withstand high pressures.

[0020] Summarizing the above, it can be stated that a conventional fin and plate heat exchanger suffers from certain drawbacks of which the most salient are possible development of internal leaks and limited strength of joints between fins and parting sheets or end plates. Hence, a conventional fin and plate heat exchanger is limited in terms of reliability and operational pressure.

BRIEF SUMMARY OF THE INVENTION

[0021] The purpose of the present invention is the development of a highly effective, lightweight, compact and reliable heat exchanger for high pressure applications capable of preventing internal leakages and mutual mixing of hot and cold flows.

BRIEF DESCRIPTION OF THE DRAWINGS

[0022] The present invention will be better understood from a consideration of a detailed description of an exemplary embodiment thereof, taken in conjunction with the accompanying drawings, wherein:

[0023] FIG. **1** is a fragmentary cutaway view of the conventional shell and tube heat exchanger;

[0024] FIG. **2** schematically depicts the conventional fin and plate heat exchanger, an axonometric overall view;

[0025] FIG. **3** is a layout of the core assembly of the conventional fin and plate heat exchanger of FIG. **2**, in the course of assembly;

[0026] FIG. **4** is a scheme of the resulting structure of the core assembly of the conventional fin and plate heat exchanger of FIG. **2**, after assembly and brazing, a fragmentary axonometric view;

[0027] FIG. **5** diagrammatically shows the core assembly of a heat exchanger, according to the first embodiment of the invention;

[0028] FIG. **6** is a view of fragment A of FIG. **5**;

[0029] FIG. **7** is a view similar to FIG. **5**, according to the second embodiment of the invention;

[0030] FIG. **8** is a view of fragment B of FIG. **7**;

[0031] FIG. **9** illustrates the core assembly of FIG. **7** with high temperature and low temperature corrugated fins and foils of filler metal, according to the invention, in the course of assembly;

[0032] FIG. **10** is a view of fragment C of FIG. **9**;

[0033] FIGS. **11***a, b* is a layout of compression of the core assembly of FIGS. **9** and **10**, according to the invention:

[0034] a—before compression;

[0035] b—after compression;

[0036] FIG. **12** illustrates the core assembly of FIG. **7** with high temperature and low temperature custom-made individual fins and foils of filler metal, according to the invention, in the course of assembly;

[0037] FIGS. **13***a, b, c*-demonstrates possible alternative embodiments of the custom-made individual fins, applied to the core assembly FIG. **7**, according to the invention, axonometric views;

[0038] FIG. **14** diagrammatically shows the MONOBLOC fin and plate heat exchanger, according to the invention, a general view.

DETAILED DESCRIPTION OF THE INVENTION

[0039] The objective is achieved by using a core assembly manufactured in part or in full as a one-piece monolithic metallic block, similar in configuration to a conventional fin-and-plate heat exchanger. In such a structure, the brazing seams, which usually are a source for imperfections and internal leakages, have been eliminated. All the voids in the suggested construction allowing the passage of both the hot and cold flows are obtained by removal of material from a single piece of metal.

[0040] FIGS. **5**, **6** show one embodiment of the invention where a core assembly is manufactured as a one-piece monolithic metallic block **15** having two sets of parallel and mutually perpendicular flow channels **16** and **17**. Each of these channels are provided for one of the hot and cold flow passages.

[0041] The aggregate volume of channels **16** (FIGS. **5**, **6**) and their respective headers **38** and **39** (FIG. **14**) form a confined space for the cold flow passage, while the aggregate volume of Channels **17** (FIGS. **5**, **6**) and their respective headers **40** and **41** (FIG. **14**) form a confined space for the hot flow passage.

[0042] Channels **16** and **17** are sub-divided into thin flow channels by fin partitions **18** and **19** respectively. The height and density of the fin partitions in channels **16** and **17** are determined by thermal and hydraulic performance analysis of a heat exchanger, while their thickness is primarily defined by strength considerations.

[0043] As shown in FIGS. **5**, **6**, the structure remaining after forming channels **16** and **17** is an aggregate of separate thin-walled inter-layer partitions **21**, end enclosures **20** and side enclosures **22** and **23**, each fulfilling a specific function. Thus, inter-layer partitions **21** may be functionally considered as parting sheets, end enclosures as end plates and side enclosures as closure bars.

[0044] Considering that by the invention, the core assembly features the same functional elements as the classical fin and plate heat exchanger, it also shares the performance advantages of the latter, namely high efficiency and compactness. At the same time, it is devoid of the shortcomings of its predecessor since all abovementioned elements of the core assembly are structurally its integral parts.

[0045] The obvious advantages of this embodiment of the invention are the total absence of piece parts for assembly of the core and the absence of braze joints altogether.

[0046] FIGS. **7**, **8** show another embodiment of the invention where the fins are not integral to the monobloc core. Instead, adequate slots **25**, **26** are cut out from the block of metal to accommodate the fin layers. Other than that, all the integral elements of the core are identical to those described in the previous embodiment of the invention.

[0047] FIGS. **9**, **10** show the details of the introduction of fins **31**, **32** and braze sheets **33** into the said slots **25**, **26**. As can be seen, the slots are made to a certain height which leaves a small free space **34** for ease of introduction of the said fins and braze sheets. These Figures depict one alternative of this embodiment consisting in the use of corrugated fins.

[0048] Another alternative consisting in the use of individual fins **37** is depicted in FIG. **12** and various shapes of such individual fins are shown in FIG. **13** *a, b, c*. As explained above, the obvious advantage of individual fins resides in the significant increase of the brazing area which extends over the total surface of the parting sheet. Also, it is interesting to note that this in no way requires additional brazing material compared to the corrugated fins alternative and hence there is no weight penalty involved.

[0049] The choice between the two just described alternatives is a function of strength only and depends on the working pressure of the heat exchanger.

[0050] By applying individual fins, core burst pressures of exceptionally high magnitudes (and never heard of in conventional fin and plate heat exchanger technology) have been obtained.

[0051] The method of elimination of the above described gap of the fin slots in preparation for brazing is shown in FIGS. **11***a, b*. The necessary pressure conditions for brazing are obtained by introducing the assembled core into a hydraulic press **35** and hence by decreasing its height by a predetermined precise amount **36**. The core block is subjected to this process in an annealed condition.

We claim:

1. A compact plate and fin heat exchanger

comprising a core assembly and, welded or attached thereon, two sets of inlet and outlet headers for low temperature and high temperature gas or liquid fluid flows;

and said core assembly incorporates a plurality of functional elements identified as low temperature and high temperature fins, parting sheets, end plates and low temperature and high temperature closure bars;

and where the said low temperature and high temperature fins are separated from one another by said parting sheets;

and where the said low temperature and high temperature fins are enclosed respectively by said low temperature and high temperature closure bars;

and where the two outermost layers of either the said low temperature fins and/or high temperature fins are enclosed by the said end plates;

and where the said functional elements constitute a set of elementary heat transfer layers for the said low temperature and high temperature fluid flows;

and where the said elementary heat transfer layers are disposed alternately along parallel planes in mutually perpendicular directions for low temperature and high temperature fluid flows;

and where a plurality of the said elementary heat transfer layers for low temperature and high temperature fluid flows together with the said two sets of inlet and outlet headers constitute a confined enclosure for segregated low temperature and high temperature fluid flows;

wherein the said core is entirely produced from one monolithic metallic block and is entirely devoid of any brazed joints;

and wherein all the said functional elements of the core, including the low temperature and high temperature fins, form its integral parts;

and wherein the said low temperature and high temperature fins are formed by a plurality of parallel thin channels cut out from the said block of metal;

2. A compact plate and fin heat exchanger of claim **1**, wherein the said core is partially produced from one monolithic metallic block and wherein all the said functional elements of the said core with the exception of the low temperature and high temperature fins are its integral parts; and

wherein special slots are cut out in parallel planes and alternating in mutually perpendicular directions for alternate introduction of said low temperature and high temperature fin layers for the said low temperature and high temperature fluid flows; and where, in each of the said special slots, two braze filler metal foils are introduced to fully cover both of the fin layer faces; and

wherein the said fin layers together with the said braze filler foils are snugly fitting into the said special cut slots; and wherein the said low temperature and high temperature snugly fitted fin layer surfaces are brazed to the adjacent surfaces of the said special slots.

3. A compact heat exchanger of claim **2** wherein both sets of the said special slots for low temperature and high temperature fluid flows are fitted with corrugated fins.

4. A compact heat exchanger of claim **2** wherein the said special slots for low temperature and high temperature fluid flows are alternately fitted with corrugated and individual fins.

5. A compact heat exchanger of claim **2** wherein both sets of the said special slots for low temperature and high temperature fluid flows are fitted with individual fins.

* * * * *