March 3, 1959 — S. HOLM — 2,875,986

HEAT EXCHANGER

Filed April 12, 1957 — 3 Sheets-Sheet 1

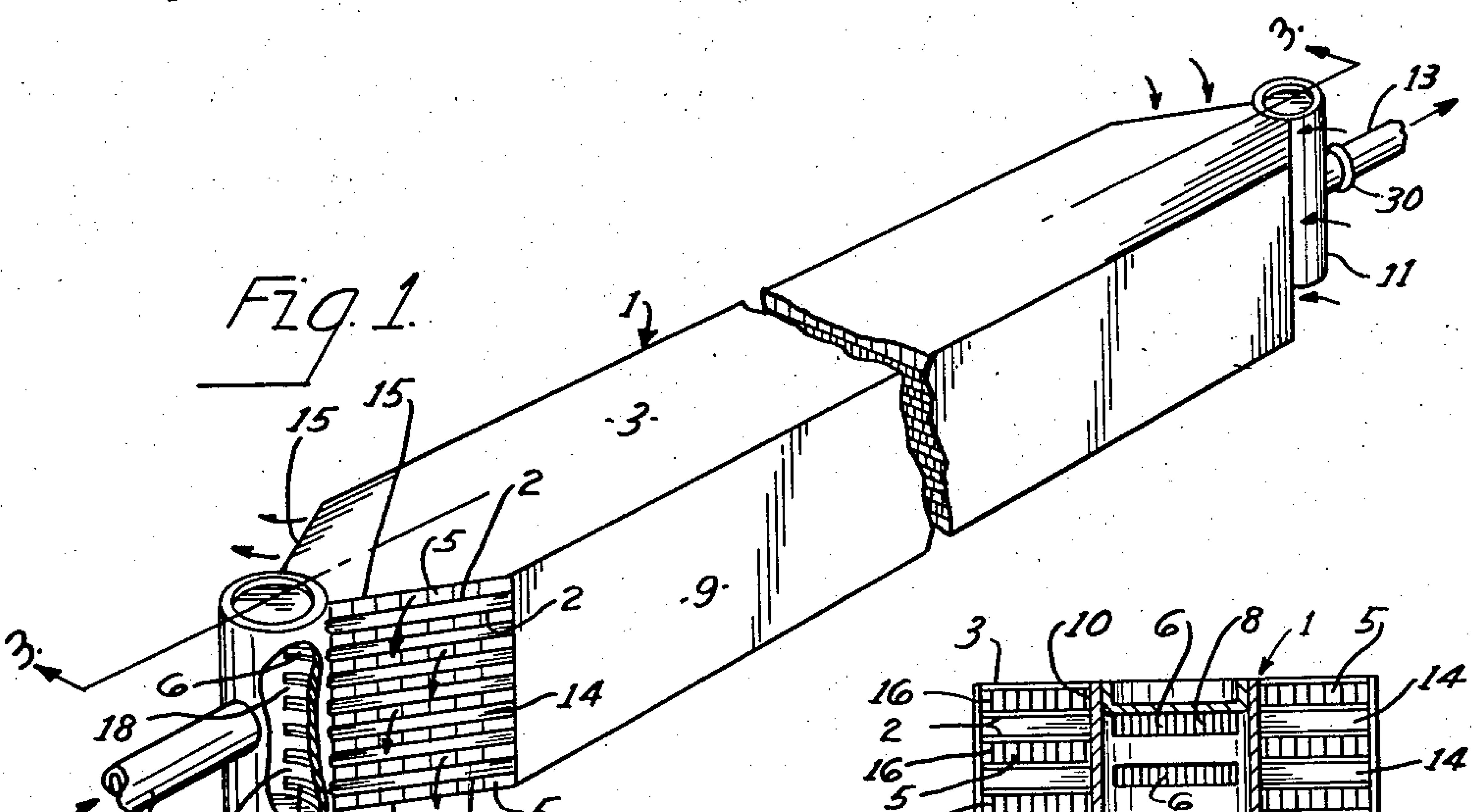


Fig. 1.

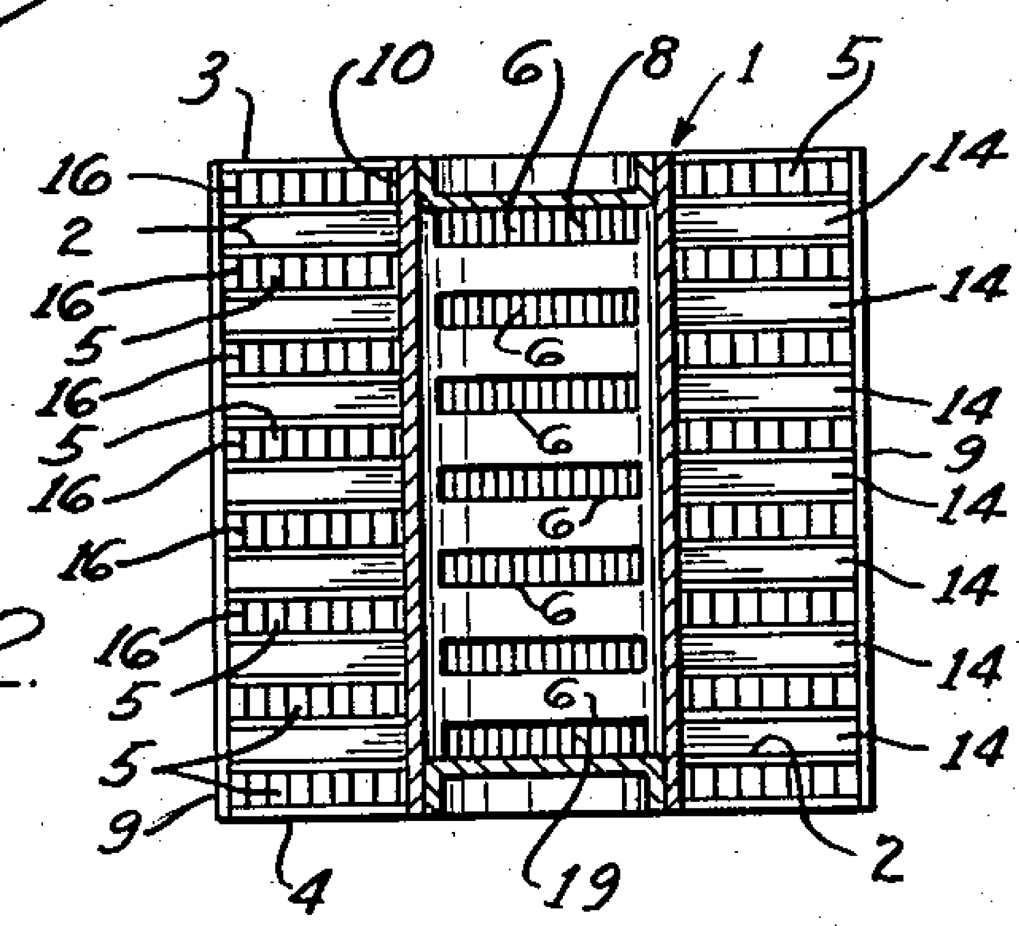


Fig. 2.

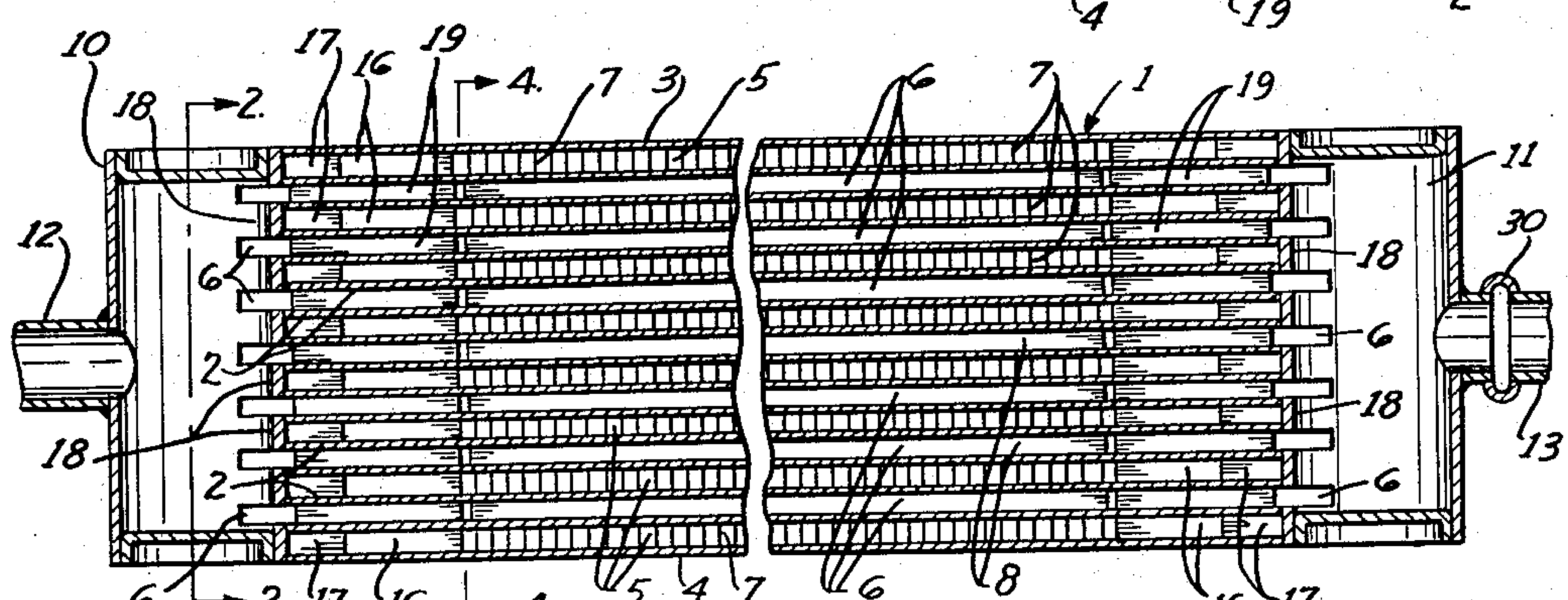


Fig. 3.

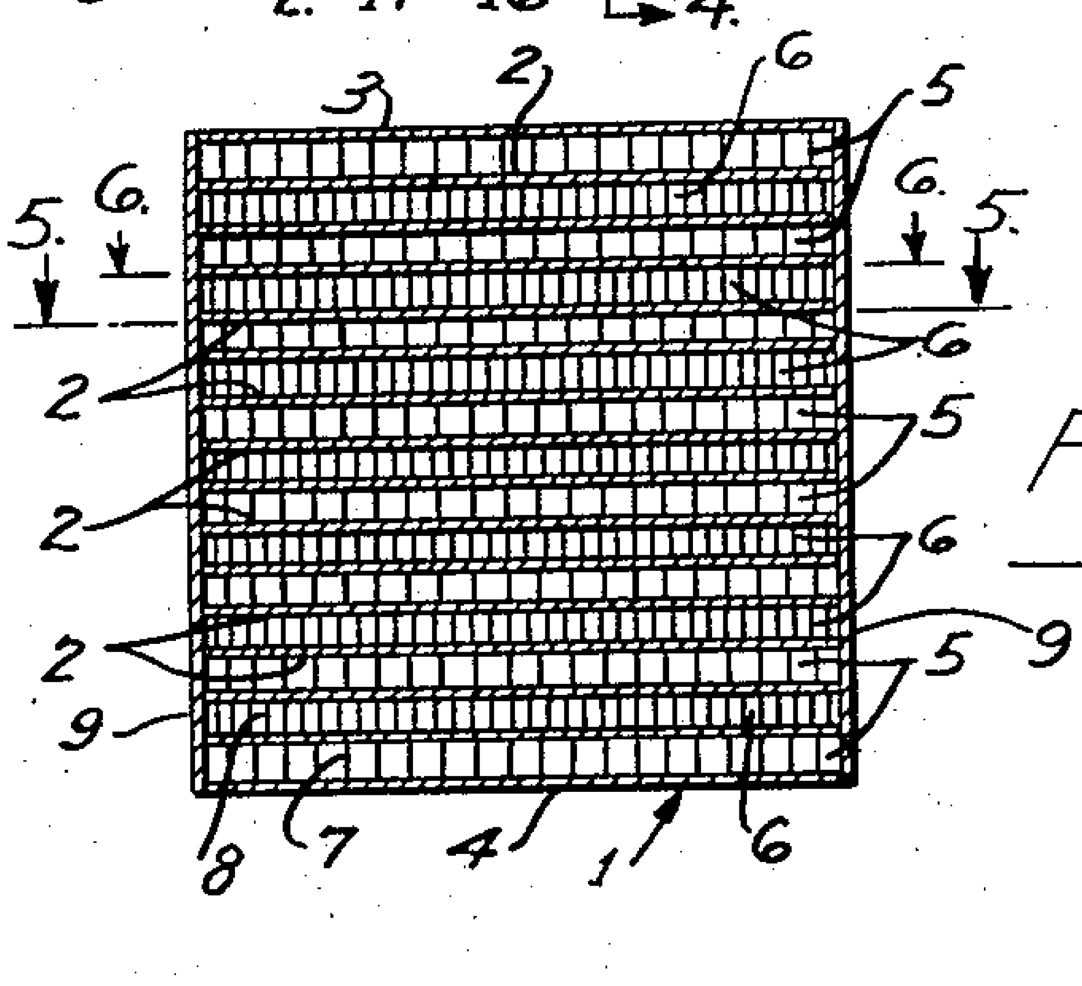


Fig. 4.

INVENTOR.
SVEN HOLM

BY John H. Leonard,
ATTORNEY.

March 3, 1959 S. HOLM 2,875,986

HEAT EXCHANGER

Filed April 12, 1957 3 Sheets-Sheet 2

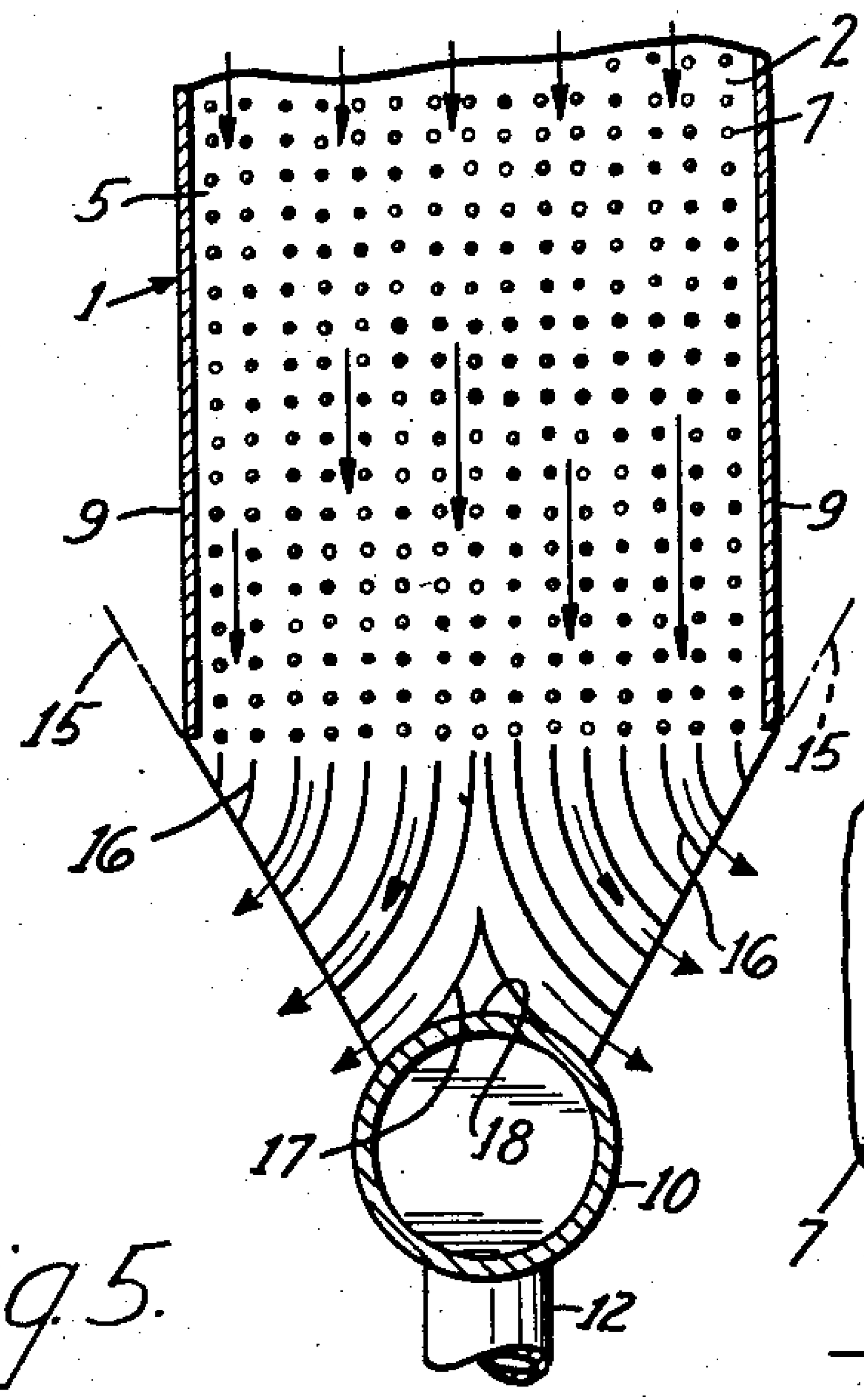


Fig. 5.

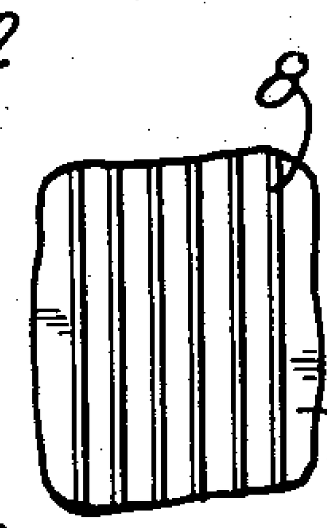


Fig. 6A.

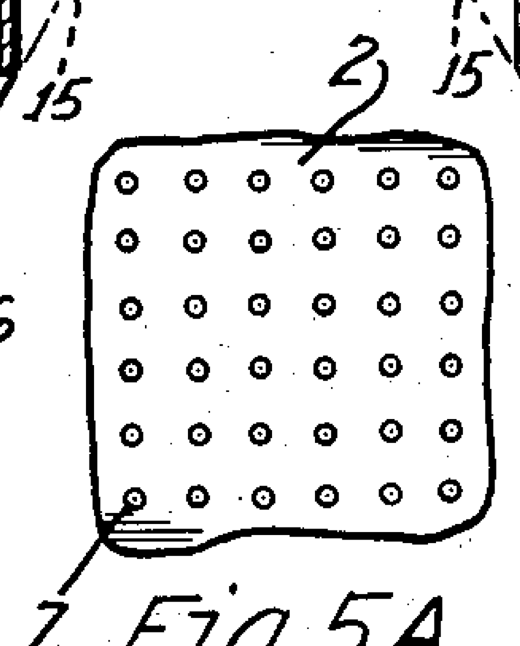


Fig. 5A.

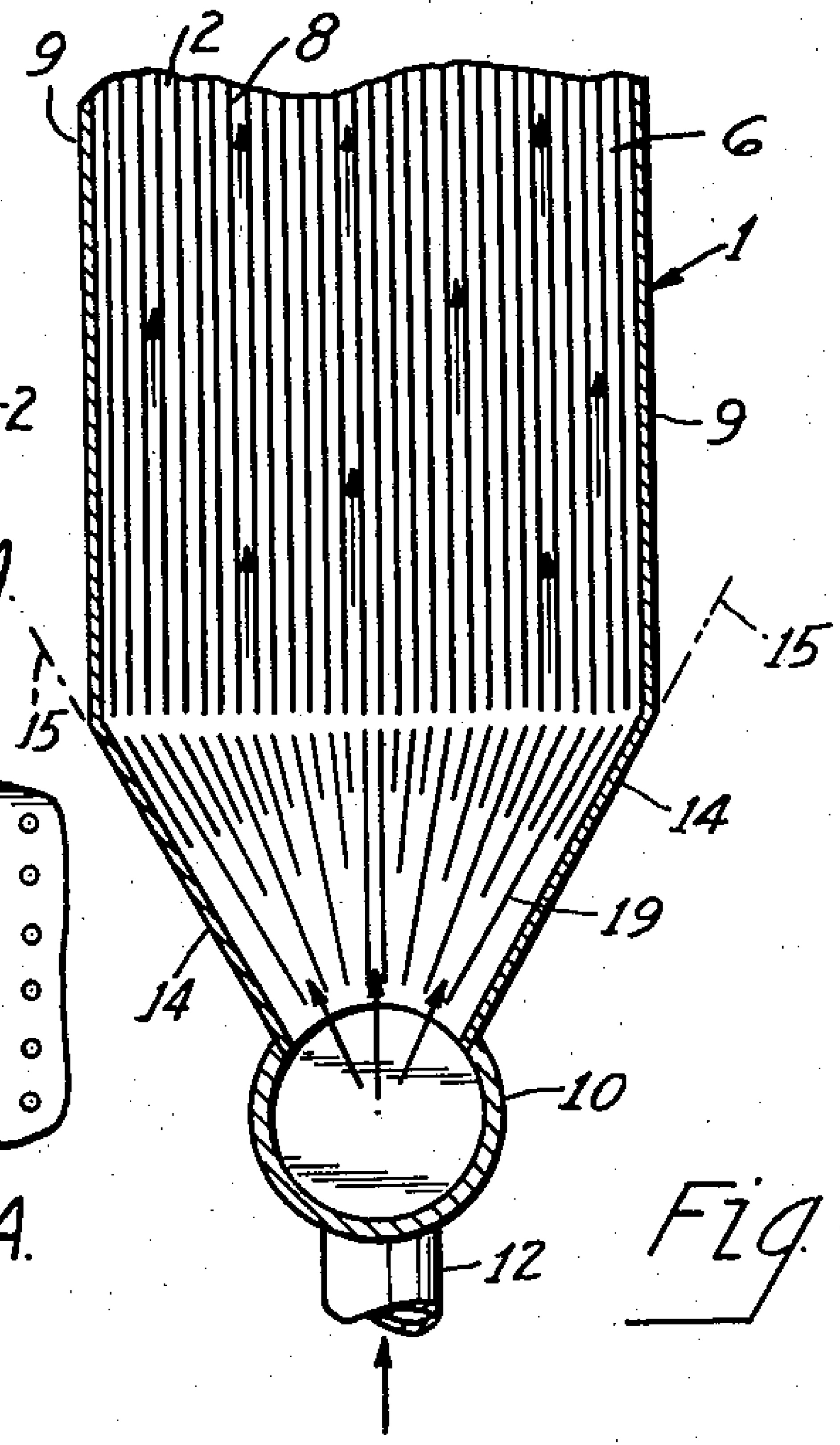


Fig. 6.

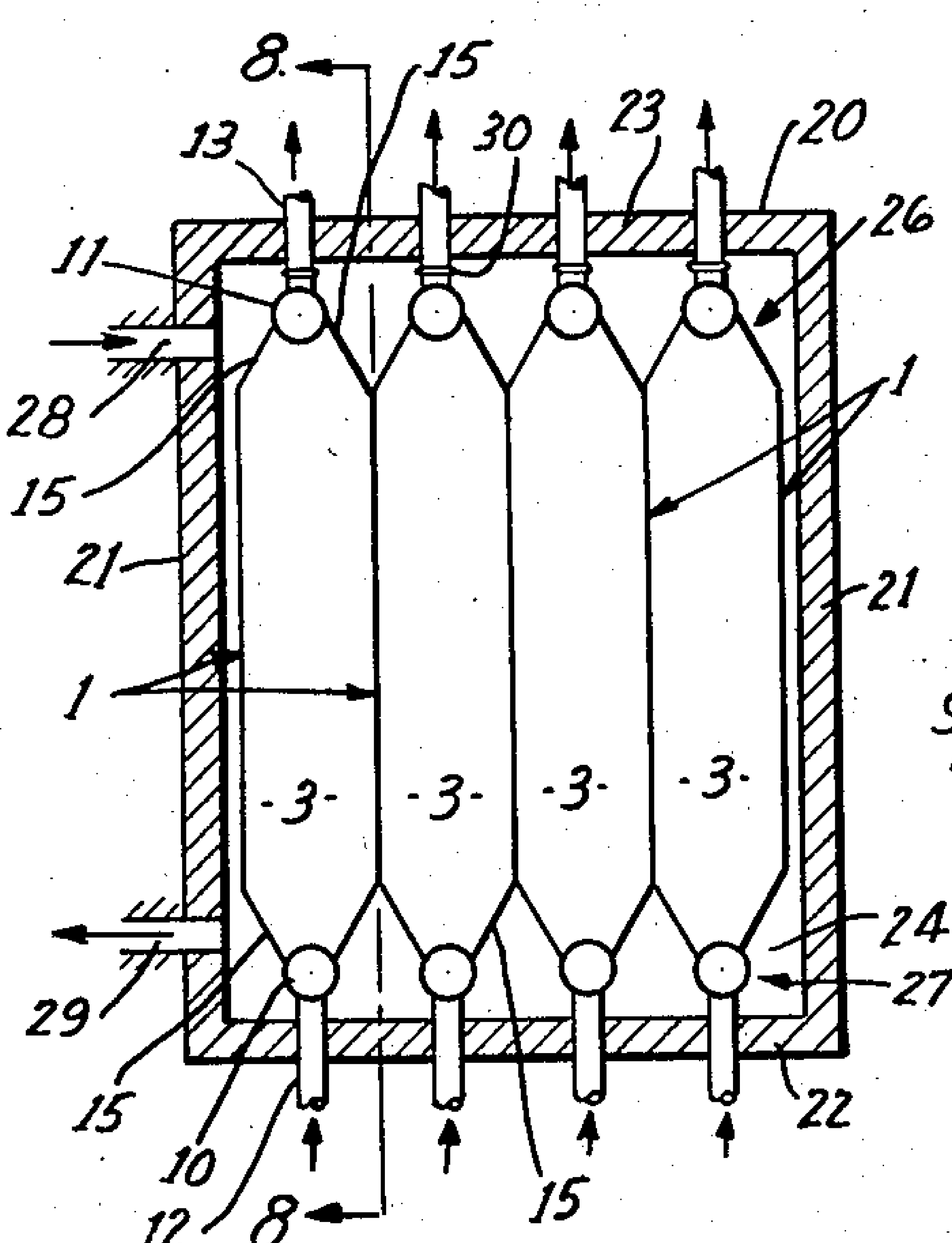
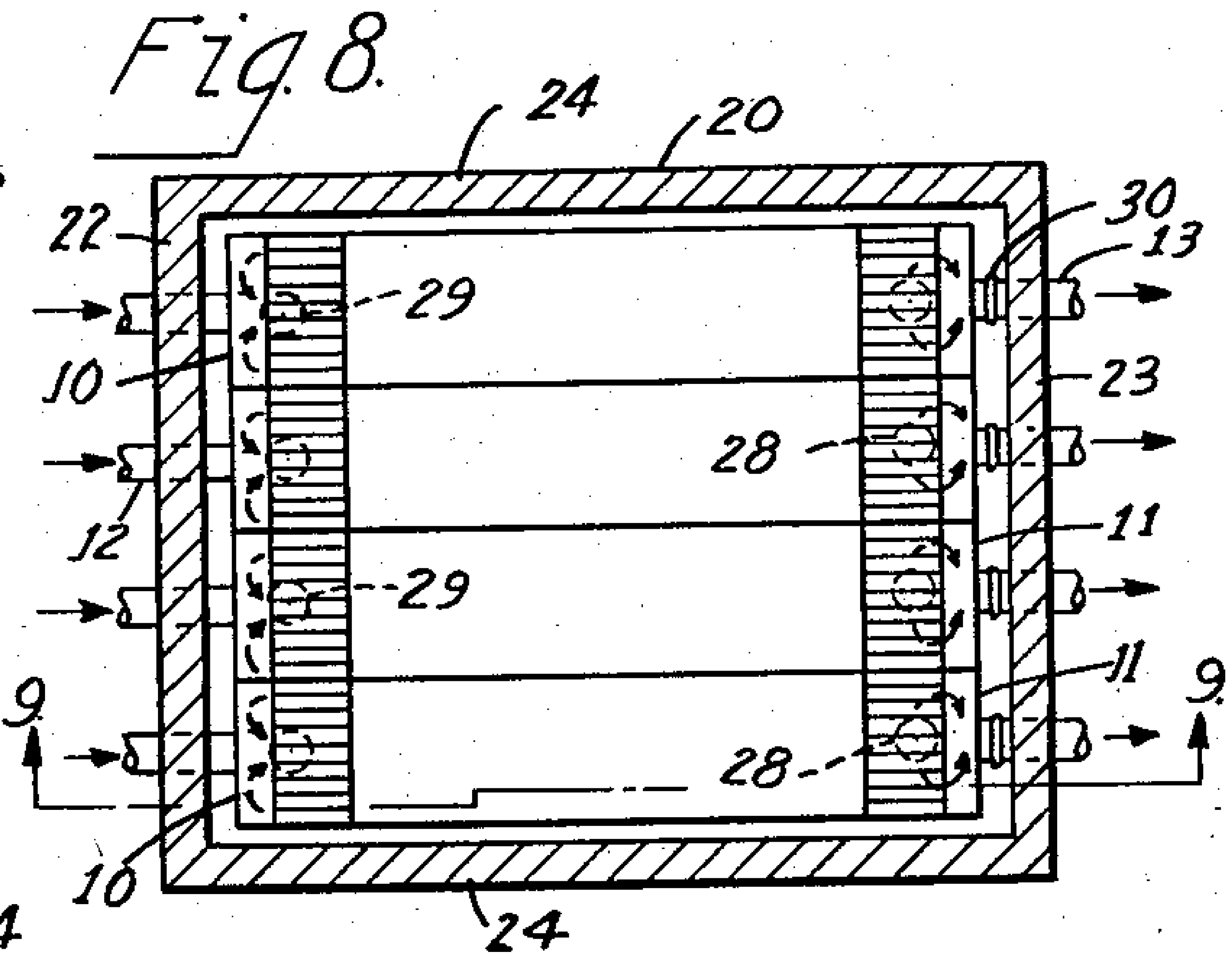


Fig. 7.

Fig. 8.



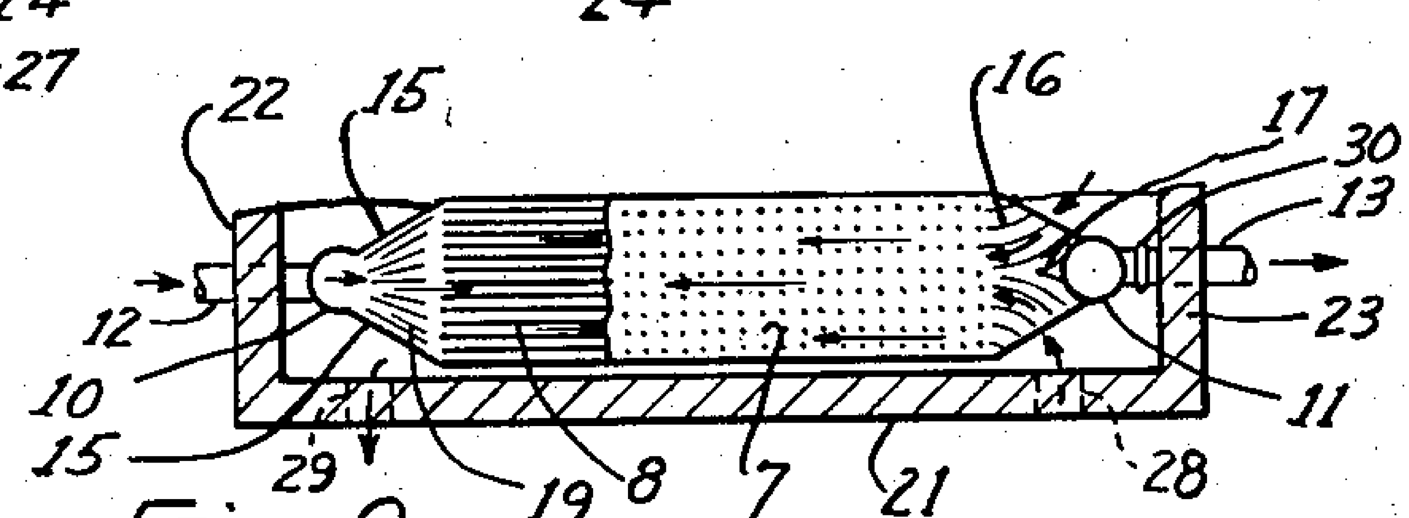


Fig. 9.

INVENTOR.
SVEN HOLM

BY John H. Howard, his ATTORNEY.

March 3, 1959 S. HOLM 2,875,986

HEAT EXCHANGER

Filed April 12, 1957 3 Sheets-Sheet 3

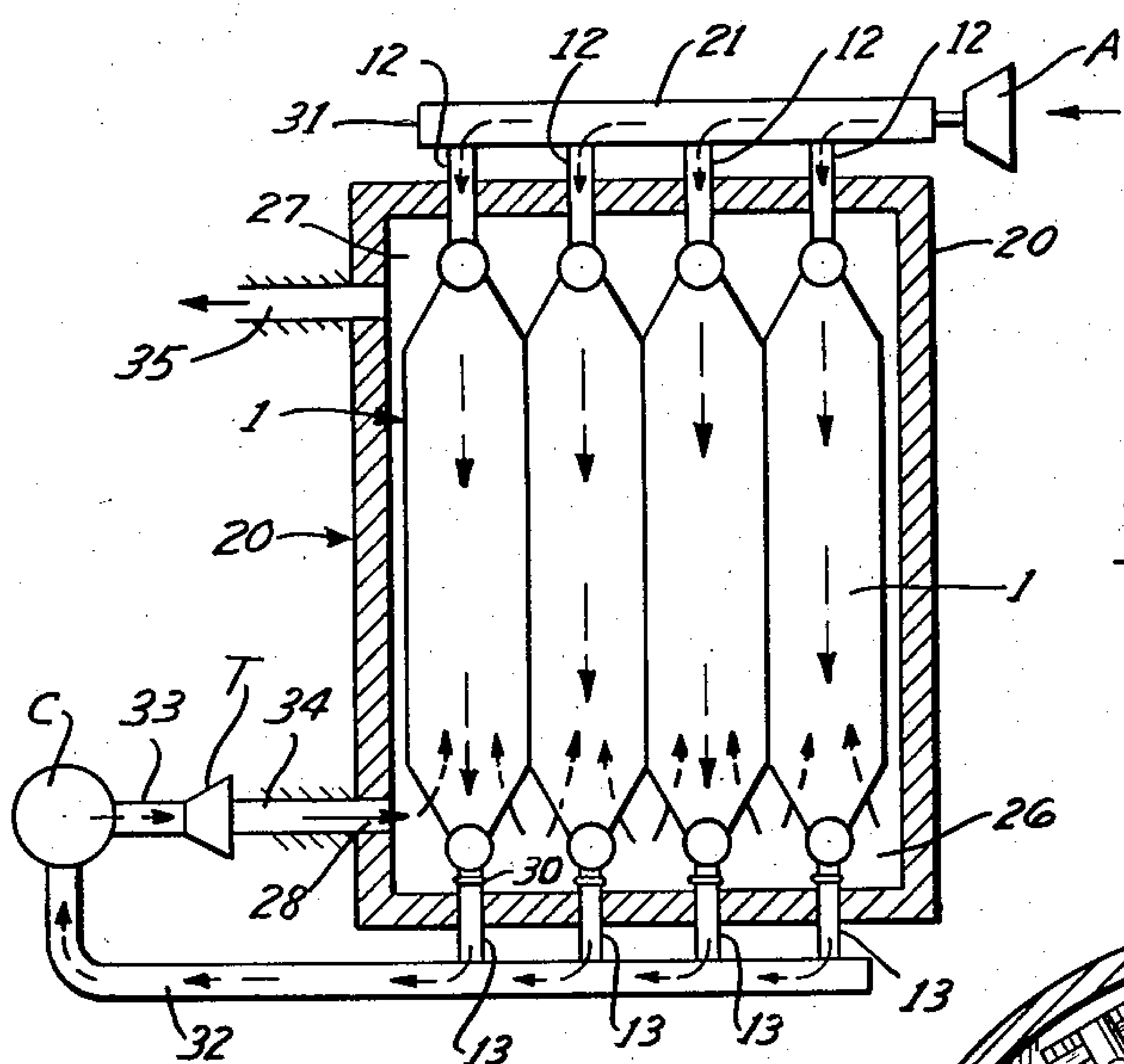


Fig. 10.

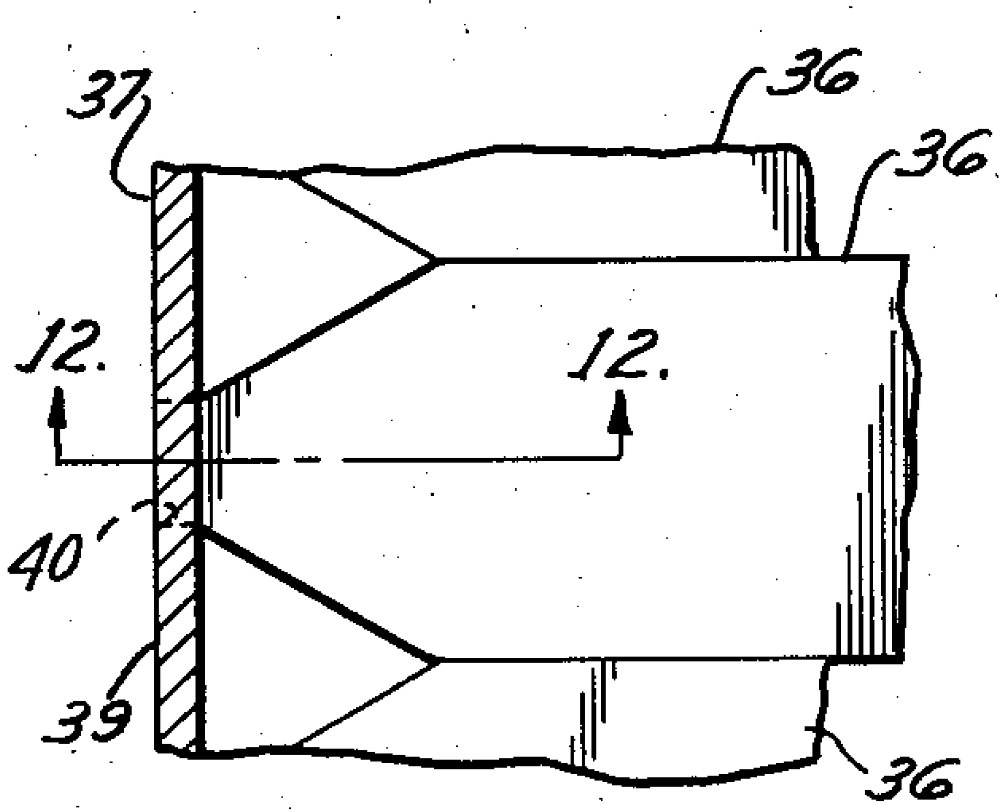


Fig. 11.

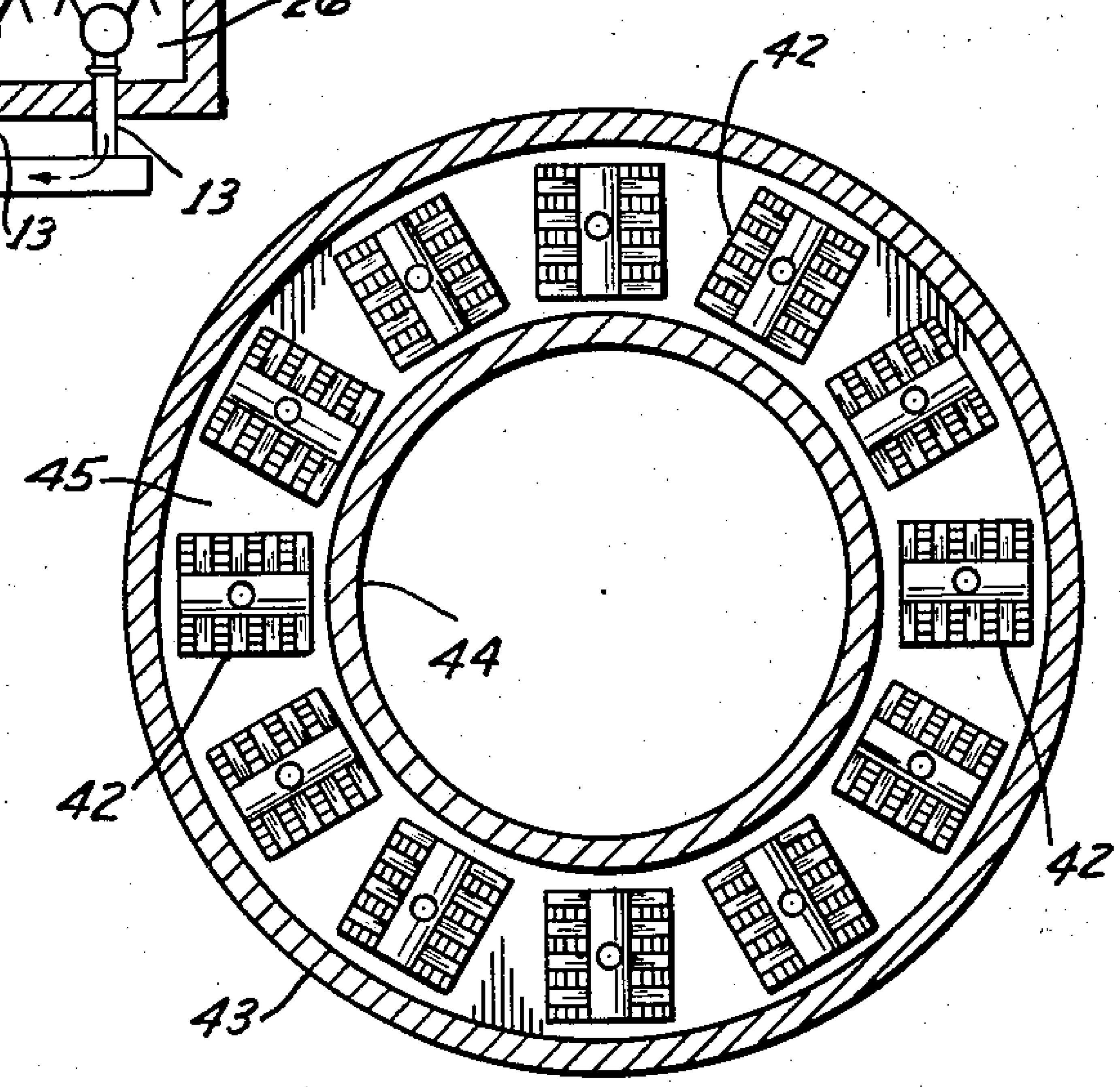


Fig. 13.

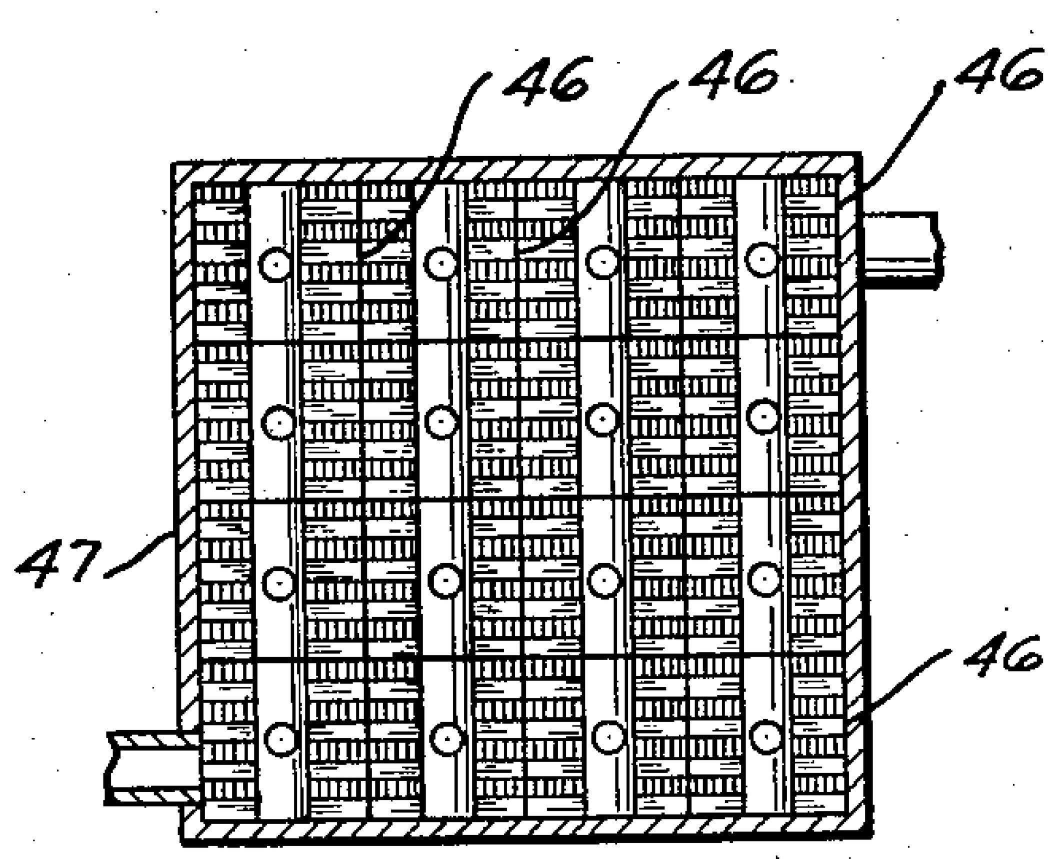


Fig. 14.

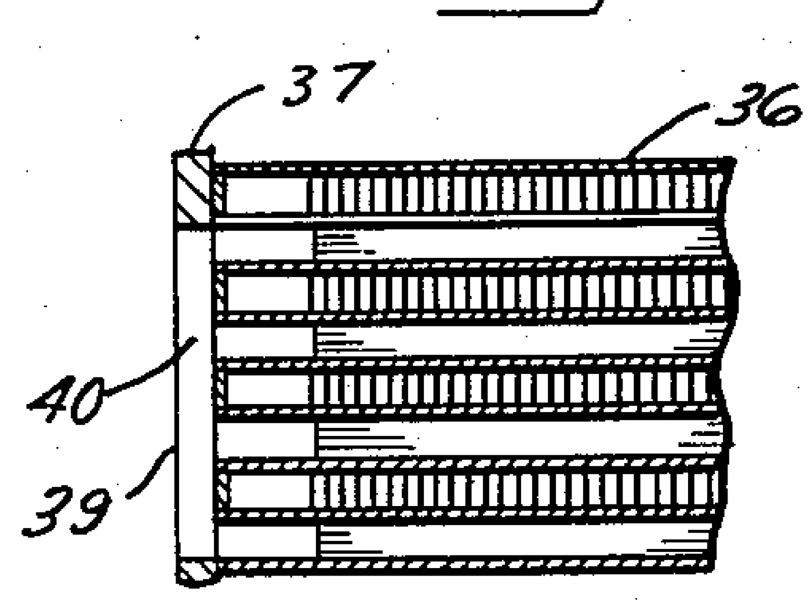


Fig. 12.

INVENTOR.

SVEN HOLM

BY

John H. Leonard,

his ATTORNEY.

United States Patent Office

2,875,986

Patented Mar. 3, 1959

1

2,875,986

HEAT EXCHANGER

Sven Holm, Hudson, Ohio, assignor to Ferrotherm Company, Cleveland, Ohio, a corporation of Ohio

Application April 12, 1957, Serial No. 652,526

10 Claims. (Cl. 257—245)

This invention relates to heat exchangers, and particularly to heat exchangers in the form of a single core section or a combined group of core sections.

Heat exchangers of the extended heating surface type are usually in the form of a single large core with heat conducting walls spaced apart flatwise from each other and defining fluid passages therebetween, the passages for one fluid alternating with those of the other fluid. For high flow rates, a number of cores are connected in parallel by welding headers for both fluids to each core, and manifolding the heads into a common inlet duct and a common outlet duct for each fluid. For compact, high performance heat exchangers, the core is built up of very light components which reach thermal equilibrium more quickly than the heavy header and manifold construction.

The present invention is directed to an improved heat exchanger having welded header connections for one fluid only, preferably the high density fluid, thereby simplifying the manifolding problem. The exchanger is built up of a group of small core sections so constructed that the material in the headers is light and thus avoids thermal stresses, and the common enclosure or shell for the group of core sections constitutes a common simple manifold for the second fluid, thus eliminating much of the header and manifold structure heretofore required.

The heat exchangers of the present invention are of general applicability, but are particularly useful in connection with counterflow, high effectiveness, heat exchange operations wherein the ratio of the density of the fluids exchanging heat is larger, such as in an exchange of heat between a high pressure gas or liquid metal as the high density fluid and low pressure air or gas as the low density fluid.

In heat exchangers for this general purpose, it is necessary to make provision for adequate heat exchange surface for an adequate flow of both high density fluid and low density fluid, and also for a proper volume and disposition of metal of the required conductivity for efficient conduction and exchange of heat from one fluid to the other.

While a certain amount of turbulence is desirable for the purpose of breaking up the laminar flow of the fluid through the exchanger, nevertheless, it is necessary to avoid any formation which tends to obstruct the flow unduly, or to change abruptly the direction of flow of the main streams of fluid, or to increase the turbulence without obtaining some offsetting beneficial effect.

Quite often the zones of very low pressure, or substantially no pressure, result from excessive turbulence and the areas at such zones are sometimes useless for heat exchange since the areas are, in effect, out of heat exchange contact with the fluid. Sometimes they are not swept uniformly by the fluid and, consequently, cause inefficiency of heat exchange, thermal shocks, and detrimental stresses, to the structure.

Again, in heat exchangers, it is desirable that flexibility in design be permitted without an undue change in the

2

fundamental heat exchange balance in the structure, and without requiring complete redesign to meet requirements of each different installation.

A heat exchanger composed of core sections, each of which is itself a unitary heat exchanger, is desirable for this purpose inasmuch as it can employ a single core section or large or small groups of like core sections. As a result, the exchanger can be of an infinite number of selected over-all shapes, sizes, and capacities, without fundamental redesign.

The heat exchangers of the present invention are characterized by effective and uniform contact between the fluid and the heat exchange surfaces for both the high pressure and the low pressure fluids, by effective proper ratio of length to cross section of the extended surface elements in the various parts of the structure, and by efficient and more nearly linear flow of the fluid media therethrough.

In the present structure, provision is made for the ready and efficient admission, flow, and discharge, of both fluids, abrupt changes in the direction of the generally linear path of flow thereof being very greatly reduced compared to prior exchangers, or being substantially eliminated.

The present heat exchanger is one which, whether comprised of one or more of the individual core sections, is very compact and simple, and in which the heat exchange surface ratio for the high pressure fluid and the low pressure fluid is well balanced.

The individual core sections are so designed that the envelope and extended surface elements of each can be bulk brazed into a unitary structure.

Various other objects and advantages of the present invention will become apparent from the following description wherein reference is made to the drawings in which:

Fig. 1 is a perspective view illustrating a core section embodying the principles of the present invention;

Fig. 2 is an enlarged, left end elevation of the core section illustrated in Fig. 1, with the inlet manifold for the high pressure fluid omitted for clearness in illustration;

Fig. 3 is an enlarged vertical, longitudinal sectional view taken on line 3—3 of Fig. 1;

Fig. 4 is a vertical cross sectional view taken on line 4—4 of Fig. 3;

Figs. 5 and 6 are enlarged horizontal longitudinal sectional views through a low pressure passage and a high pressure passage, respectively, taken on lines 5—5 and 6—6, respectively, of Fig. 4;

Figs. 5*a* and 6*a* are enlarged fragmentary views of portions of Figs. 5 and 6, respectively, enlarged to show the pins and vanes in larger scale;

Fig. 7 is a diagrammatic top plan view, partly in section, illustrating a plurality of identical core section heat exchangers combined into a larger heat exchanger;

Fig. 8 is a fragmentary, longitudinal, vertical, sectional view taken on line 8—8 of Fig. 7;

Fig. 9 is a fragmentary, horizontal, longitudinal, sectional view taken on the line 9—9 of Fig. 8;

Fig. 10 is a diagrammatic top plan view of a heat exchanger similar to that shown in Fig. 7, showing the manner in which it is connected to a gas turbine, part of the exchanger being shown in section for clearness in illustration;

Fig. 11 is an enlarged, fragmentary, top plan view illustrating a modified manner of disposing the core sections in a shell to form a larger heat exchanger;

Fig. 12 is an enlarged, vertical, sectional view taken on the line 12—12 in Fig. 11;

Fig. 13 is a diagrammatic front end elevation, partly in section, showing a number of the core sections combined into a larger heat exchanger of cylindrical shape; and

Fig. 14 is a diagrammatic front end elevation, partly in section, illustrating a modified combination of a number of the core sections.

The heat exchanger is described hereinafter, for purposes of illustration, as applied to a gas turbine in which the exhaust and air from a compressor, under superatmospheric pressure, provides the high pressure heat exchange fluid.

The use of a core section exchanger, either as an individual heat exchanger or in an assembly forming a larger exchanger, will become apparent from the illustrative examples.

Referring first to Figs. 1 through 6, a core section comprises a hollow body or envelope 1 in which are arranged a plurality of sheet metal partition wall members 2 which are spaced apart from each other flatwise so as to provide therebetween a plurality of elongated fluid conducting spaces.

The envelope 1 has a top wall 3 and a bottom wall 4, both of which are also sheet metal heat exchange walls. The resultant spaces between the adjacent walls 2, and between the top and bottom walls and the wall 2 adjacent to them, provide passages for the low pressure fluid and the high pressure fluid. For the purpose of illustration, alternate ones of the passages, beginning with the topmost passage, are considered low pressure fluid passages 5, and the passages therebetween are considered high pressure fluid passages 6, it being understood that the passage 5 may be high pressure and the passages 6 low pressure, if desired.

The spaces for the fluids are provided with extended surfaces. Generally a larger extended surface is required in the low pressure passages 5 than in the high pressure passages 6. The extended surface elements for the low pressure passages 5 preferably are in the form of pins 7, whereas those for the high pressure passages 6 may be in the form of vanes or fins 8. Thus, in the form illustrated, the extended surface elements of the low pressure passages 5 may be a plurality of rows of pins 7 of the character described in the United States Letters Patent No. 2,678,808 of John R. Gier, Jr., issued May 18, 1954. The extended surface elements of the high pressure passages 6 are preferably in the form of elongated vanes or fins 8 which extend endwise of the envelope 1 and are disposed vertically edgewise and are spaced apart from each other flatwise laterally of the envelope 1. Combinations of the two types of extended surface elements and modifications of the specific forms shown may be used. For example, if desired, the fins 8 may have roughened areas or perforations designed to break up laminar flow of heat exchange fluid passing therealong.

The envelope or body 1 of each core section is closed on its sides by suitable metal walls 9, each of which, if desired, may be a common closure for one side of all the spaces between the walls 2.

In order to supply high pressure fluid through the passages 6, the passages 6 are left open at their ends and manifolds 10 and 11 are provided at the inlet and outlet ends, respectively, of the envelope 1. An inlet pipe 12 and an outlet pipe 13 are connected to the manifolds 10 and 11, respectively, for delivering high pressure fluid into the manifold 10 and exhausting the high pressure fluid from the manifold 11. The manifolds 10 and 11 are aligned with each other endwise of the body 1 and preferably are coextensive in height therewith. Each of the manifolds, however, is of less width than the width of the envelope 1 and is centrally located transversely thereof. Each manifold is in communication with the open ends of the passages 6 between its lateral limits.

It is desirable to provide spaces between adjacent sections for the ingress and egress of the low pressure fluid when a number of sections placed side by side, as will be explained hereinafter. Accordingly, the walls 9 terminate short of the ends of the envelope 1 so that they do not obstruct the passages 5 or 6 between the lateral limits of the manifolds 10 and 11, respectively, and the adjacent side walls 9. However, each of the passages 6 is blocked and sealed between the ends of the side walls 9 and the adjacent lateral limits of the associated manifold 10 or 11 by means of auxiliary walls 14.

It is desirable that the main streams of the low pressure fluid be as free as possible from abrupt changes in their normal linear direction of flow endwise of the envelope 1. Also, it is desirable that the individual heat exchangers or core sections be such that, when a number of them are arranged close together in side by side relation to provide a rectangular sided composite structure, or around a common center to provide a cylindrical composite structure, there is free ingress and egress of low pressure fluid thereinto and therefrom.

Accordingly, beginning a short distance from the ends of the envelope 1, the sides of the envelope are made convergent toward the ends of the envelope so as to provide bias faces which, at each end of the envelope, are spaced from each other laterally of the envelope at their points of nearest approach, which points, in the illustrative example, are where they join the manifolds 10 and 11.

A convenient shape is illustrated in the drawings wherein the corners of the envelope 1 are omitted so that the ends of each of the passages 5 and 6, at the sides of each manifold, are angularly disposed to the side walls 9. Thus the ends of the passages, between each given side wall 9 and an adjacent limit of each manifold, lie in a vertical plane arranged on a bias to the longitudinal axis of the envelope and with the two planes for the biased faces at the same end of the envelope being convergent toward that end. In the illustrative example, such planes are indicated at 15.

The low pressure passages are closed at the ends of the envelope and are open at these bias areas or planes 15 so that the major portion of the gases or heated fluid passing through the passages 5 can pass substantially directly to the outside of the envelope 1 without any abrupt change in direction of flow such as would obstruct the flow appreciably or cause undue turbulence. However, when the core sections are to be placed side by side in combination with others of similar construction, and like or different shape, to provide a larger over-all heat exchanger, as illustrated in Fig. 7, it may be desirable, though not necessary, to provide gradually curved vanes, indicated at 16 in Fig. 5, at the inlet end and outlet end of the low pressure passages 5. By providing vanes of this character, which, beginning at their inner ends, are substantially tangential to the rows of pins 7, and which, at their outer ends, are at an abrupt angle to the planes 15, the streams of heated fluid flowing through the passages 5 may be gradually deflected laterally from their normal direct straight flow endwise of the envelope to such a degree as is desired. In some instances, as mentioned, the vanes 16 may be omitted. At the ends of the envelope 1 the passages 5 are closed and blocked by walls 18 between the lateral limits of each of the manifolds or headers 10 and 11. A central vane 17 is provided to prevent right angular impingement of the low pressure fluid from the central ones of the passages 5 against the end walls 18 of the passages 5.

The arrangement of the inlet ends and outlet ends of the passages 5 on the bias, as indicated by the planes 15, has a distinct advantage in reducing the length of the entry and discharge paths to and from the extended surfaces or pins 7 within the core section envelope 1, and thus tends to equalize the flow between and along the different rows of pins 7. Different lateral spacing of the rows and of the pins along the rows can be used, also, for such flow equalization if desired. For example, more open or widely spaced rows of pins 7 at the transverse mid-portion of each passage 5 may be employed.

Good flow distribution in the high pressure passages can be obtained by proportioning the high pressure passages and inlet and outlet ducts so most of the pressure drop is from the flow through the core section itself. If desired, in the passages 6, suitable gradually convergent vanes 19 may be provided for directing the flow of high pressure fluid from the manifold 10 into the spaces between the fins 8 and therefrom into the manifold 11.

Referring next to Figs. 7 through 9, there is illustrated a large heat exchanger composed of a plurality of the smaller section type heat exchangers, such as hereinbefore described. The large composite heat exchanger there shown for purposes of illustration comprises four sections, with their adjacent side walls juxtaposed. The core sections are enclosed in an outer body, indicated generally at 20, which comprises side walls 21, end walls 22 and 23, and top and bottom walls 24.

The inlet pipes 12 for the high pressure fluid extend through the wall 22 and the outlet pipes 13 therefor extend through the wall 23. Throughout the major portion of the length of the body 20, its cross-section is substantially filled with the core sections which, in operative effect, isolate the two end portions of the body from each other and thus provide two internal end compartments or chambers, indicated generally as 26 and 27. The core sections are so arranged that, at most, only a limited amount of the low pressure fluid can pass from one compartment 26 or 27 to the other compartment around the outside of the sections. One side wall 21 is provided with an inlet passage 28 which opens into the compartment 26 and with an outlet passage 29 which opens into the compartment 27.

Low pressure fluid is thus supplied into the compartment 26 through the passage 28 and, being constrained by the core sections from passing around their exterior, passes into the open biased end portions of the passages 5, flows along the passages 5, and discharges at the biased portions at the opposite ends of the sections into the compartment 27.

At the same time, the high pressure fluid passes through the passages 6, being introduced through the pipe 12 and discharging through the pipe 13.

Actually the external walls of the core sections cannot fit with such precision as to exclude any filtration of air between adjacent core sections, but the amount so filtering does not appreciably affect the flow through the sections. A slight amount of filtration can help exchange heat through the exterior walls of the core section.

The core sections preferably are anchored in fixed position relative to the wall 22 at their high pressure inlet ends, but are free to float at the high pressure discharge ends so as to allow for the necessary elongation and contraction.

Expansion or slip joints 30 may be provided between the manifolds or headers 11 and the discharge pipes 13 to take care of the expansion and contraction, as the pipes 13 are fixedly mounted in the wall 23. The core sections can elongate and contract endwise relative to the wall 23.

Due to the bias areas at the ends of the core sections, ample spaces for the discharge and admission of low pressure fluid are provided at the ends of adjacent sections so that the admission and discharge of low pressure media to and from one section does not adversely affect or impede the admission and discharge of the low pressure media to and from an adjacent section alongside of it even through the sections are placed side by side with the side walls juxtaposed in face to face relation.

If desired, several layers of core sections may be stacked one on the other, thus providing a plurality of stacks of sections with the sections juxtaposed vertically and the stacks juxtaposed laterally.

Referring next to Fig. 10, the larger composite heat exchanger of Figs. 7 through 9 is shown in one condition in which it could be used. As there diagrammatically illustrated, a turbine T is shown, to which high pressure fluid in the form of air is to be supplied by an air compressor A, the air from the compressor A passing, in turn, first to the heat exchanger 20, then to a combustion chamber C, and then to the turbine T.

The air supplied to the combustion chamber C by the air compressor A is under relatively high pressure and is conducted by one or more suitable conduits 31 to the inlet pipes 12 of the high pressure passages 6 of the heat exchanger. It travels through the passages 6 and out of the high pressure discharge pipes 13 through one or more suitable conduits 32 and thence passes to the combustion chamber C. From the combustion chamber C it passes through one or more conduits 33 to the turbine T. The expanded gas from the turbine T, which comprises the low pressure fluid, is discharged through suitable conduit means 34 and is conducted thereby into the inlet 28 of the body 20 of the heat exchanger.

Being blocked from flowing directly from the compartment 26 to the compartment 27, this fluid is constrained to flow through the low pressure passages 5 of the core sections and discharge therefrom into the compartment 27 and thence along through conduit means 35 to the outside air, usually to a suitable stack.

Referring next to Figs. 11 and 12, there is shown a diagrammatic fragmentary view of a core section type exchanger employing core sections 36 like those heretofore described. The core sections are arranged in a hollow body 37, similar to the body 20. For purposes of illustration, the end of the exchanger at which the discharge ends of the high pressure passages are located is illustrated, it being apparent from that illustration that the other end of the exchanger can be similarly arranged. In this form, instead of the high pressure exhaust pipe, such as 13, each of the exchangers 36 is arranged without any separate manifold and the end portion on which a separate manifold would normally be secured is directly connected to a shell wall 39 of the hollow body or envelope such as heretofore described.

A suitable opening 40 is provided directly in the wall 39 and is of sufficient size so that the high pressure media exhausting from all of the high pressure passages, such as indicated at 6, pass directly therethrough.

It is apparent from the foregoing examples that a heat exchanger in the form of a single core section, or a larger heat exchanger formed of a hollow body or envelope enclosing a plurality of core sections, provides effective flow and well proportioned heat exchange relation such that objectionable opposition to flow therethrough is very greatly reduced.

The arrangement of a number of the sections in a single envelope or hollow body also has distinct advantages. For example, let it be assumed that a number of the sections are installed within the single hollow body or envelope 20, hereinbefore described. If, in such case, the low pressure fluid is fed into the envelope or body 20 and the low pressure passages 5 are at the top and bottom of the core sections, then the top and bottom walls of the envelope 1 of the core sections are not subjected to any pressure. As to the side walls of the envelope 1, those of the low pressure passages 5 are not subjected to any pressure and those of the high pressure passages 6 are subjected only to the differential between the high pressure within the passages or envelope 1 and the lower pressure within the hollow body 20.

If the high pressure passages are provided at the top and bottom of each core section, then, of course, the top and bottom walls of the sections would be subjected to the differential between the high pressure and the low pressure fluids if low pressure is maintained in the body **20**, and subjected to zero pressure if high pressure instead of low is maintained in the body **20** and the passages **5** are used as high pressure passages or the passages **6** are disposed at the top and bottom. Thus, by virtue of the fact that the walls are subjected at most only to the differential in the pressures of the fluids both within and outside of the core sections, the forces tending to separate and tear apart the parts of the core sections are greatly reduced or eliminated.

By arranging at the top and bottom passages for pressure fluid at the pressure maintained within the envelope **20** outside of the core sections, lower strength material with higher conductivity may be used as the extended surface material and as the walls of the core sections.

The bias areas or faces at the ends of the core sections provide a large flow area for the entrance and exit of pressure fluids, such as the products discharged by the turbine, and make it possible to keep the dimensions of the core section between the ends of the biased faces at a minimum. This results in a maximum length of the true counter flow section between the adjacent limits of the biased faces at one end and those at the other end. The loss of flow head due to turns required for the fluids to enter and leave the core sections is less, due to the biased faces, as the turn angle is considerably larger than 90 degrees.

Again, the core sections can be placed close together without reducing the frontal area on the low density fluid side. It is to be noted also that when a very dense fluid is to be used on the high pressure side, such as liquid metal, then the liquid or gaseous fluid used on the low pressure side also may be considerably pressurized so as to provide a larger volume in proportion to the amount of dense high pressure fluid and to reduce the pressure differential.

Further, it is apparent that by providing a large number of small core sections, such as the single core section illustrated, with biased faces at the ends, an effective means is provided for permitting the admission, flow, and discharge of the low pressure fluid without any substantial interference with the introduction and discharge of the high pressure fluid, and without the necessity for complicated manifolding structures where a number of core sections are arranged and combined in close proximity to each other. The heat exchange fluid which may be used for the high pressure or that which may be used for the low pressure can be selected to suit the needs of the particular installation.

In Fig. 13, there is shown a number of core sections arranged in an annular space, which arrangement may be advantageous for a heat exchanger built around other components of a plant, such as a combustion chamber or compressor.

In this form, the sections **42** are arranged in an annular row between inner and outer concentric tubular walls **43** and **44** of a cylindrical envelope or shell. The bias faces of the sections discharge one fluid into the space between the walls **43** and **44**. The ends of the sections are connected to manifolds which receive the other fluid. An annular partition wall **45** may be arranged between the walls **43** and **44** at a location between the ends of the sections for constraining the fluid entering the spaces between the sections to flow through, and not around the outsides of, the sections.

Referring next to Fig. 14, a plurality of the sections, indicated at **46**, are arranged in face to face relation in stacks, the stacks are arranged in lateral face to face relation, and the group is enclosed in a body or shell **47**, comparable to the hollow body or envelope **20**, and having an inlet and an outlet. The manifolding may be such as described in connection with Figs. 7 and 8, if desired.

In this form, a partition wall, such as the wall **45**, is not required as the core section faces fit closely enough to limit the amount of fluid passing between adjacent sections so that almost all of it passes through the sections. Thus the core sections perform the additional function of a means for constraining the fluid introduced in the outer envelope **47** to flow through, and not around the outside of, the core sections.

In the description, and in some of the claims, the structure is described as though in the position illustrated in Fig. 1, using such terms as "above," "top," "bottom," and the like. Such terms are not used as absolutes, but merely as a convenient datum for describing the position of the parts relative to each other, regardless of the position in which the heat exchanger as a whole is disposed when in use.

Furthermore, either set or group of passages may be used for high density fluid, the other set or group being used for low density fluid.

Having thus described my invention, I claim:

1. A heat exchanger comprising an envelope having a top wall, a bottom wall, and side walls, a plurality of partition walls in the envelope, said walls being of heat conducting material, said partition walls being spaced apart from each other flatwise and dividing the interior of the envelope into a plurality of passages, the sides of the envelope, beginning at locations near each of the ends, respectively, and extending toward the adjacent end, being relatively convergent and terminating at their closest location to each other in spaced relation to each other laterally of the envelope and thereby providing biased faces for the passages, which faces extend from the sides of the envelope to the adjacent ends of the envelope, alternate ones of the passages providing a group, bias wall means for said group, each passage of said group being open at the ends of the envelope and closed by said bias wall means and side walls uninterruptedly throughout its length, including its biased faces, and the other of said passages providing a second group each of which is closed at its sides by said side walls, additional wall means closing the ends of each passage of the second group, and each passage of the second group being open at its biased faces.

2. A heat exchanger according to claim 1 characterized in that, in a plane parallel to the partition walls, each end portion of the envelope, from the extreme end of the envelope to the most widely spaced ends of its associated biased faces, is trapezoidal with the small base of the trapezoid at the said end of the envelope.

3. A heat exchange apparatus comprising means forming a closed compartment, a plurality of hollow heat exchange envelopes arranged in the compartment in side by side relation, each envelope having a plurality of passages extending endwise therethrough, each envelope having bias areas at each side near each end, part of the passages in each envelope providing one group in which the passages are closed at the sides and ends of the envelope and are open at the bias areas, the others of the passages of each envelope providing another group in which the passages are closed at the sides and bias areas and open at the ends, conduit means connected with the inlets and outlets of those passages of all of the envelopes belonging to the same type of group, and uncommunicated with the passages of the other type of group.

4. A heat exchange apparatus according to claim 3 characterized in that the group to which the conduit means are connected is the said other group.

5. A heat exchange apparatus according to claim 3 characterized in that means divide the compartment into end chambers substantially isolated from each other, one chamber having a wall with an inlet passage therein and the other chamber having a wall with an outlet passage therein, and said one chamber is common to, and in communication with, the inlet ends of said one

group through the bias areas in said one chamber and the other chamber is common to, and in communication with, the outlet ends of said one group through the bias areas in said other chamber.

6. A heat exchange apparatus according to claim 5 characterized in that the bias areas of the said one group are open directly into their associated chambers.

7. A heat exchanger according to claim 6 characterized in that said chambers are the end portions of a hollow shell in which all of the envelopes are contained.

8. A heat exchanger according to claim 7 characterized in that means in the compartment substantially block any longitudinal passages between the outsides of the envelopes.

9. A heat exchanger according to claim 8, characterized in that the last mentioned means are provided by the

juxtaposition of the side, top, and bottom walls of adjacent envelopes.

10. A heat exchanger according to claim 3 wherein additional conduit means extraneously of the envelopes are uncommunicated with the first mentioned conduit means and are in communication with the passages of the other type of group.

References Cited in the file of this patent

UNITED STATES PATENTS

2,395,543	Gallaher	Feb. 26, 1946
2,456,455	Simpson	Dec. 14, 1948
2,487,626	Wittman	Nov. 8, 1949
2,697,588	Jensen	Dec. 21, 1954

FOREIGN PATENTS

30,363	Great Britain	Dec. 29, 1909