March 30, 1943. W. ASTLE 2,314,966

PLATE HEAT EXCHANGER

Original Filed March 29, 1937 10 Sheets-Sheet 1

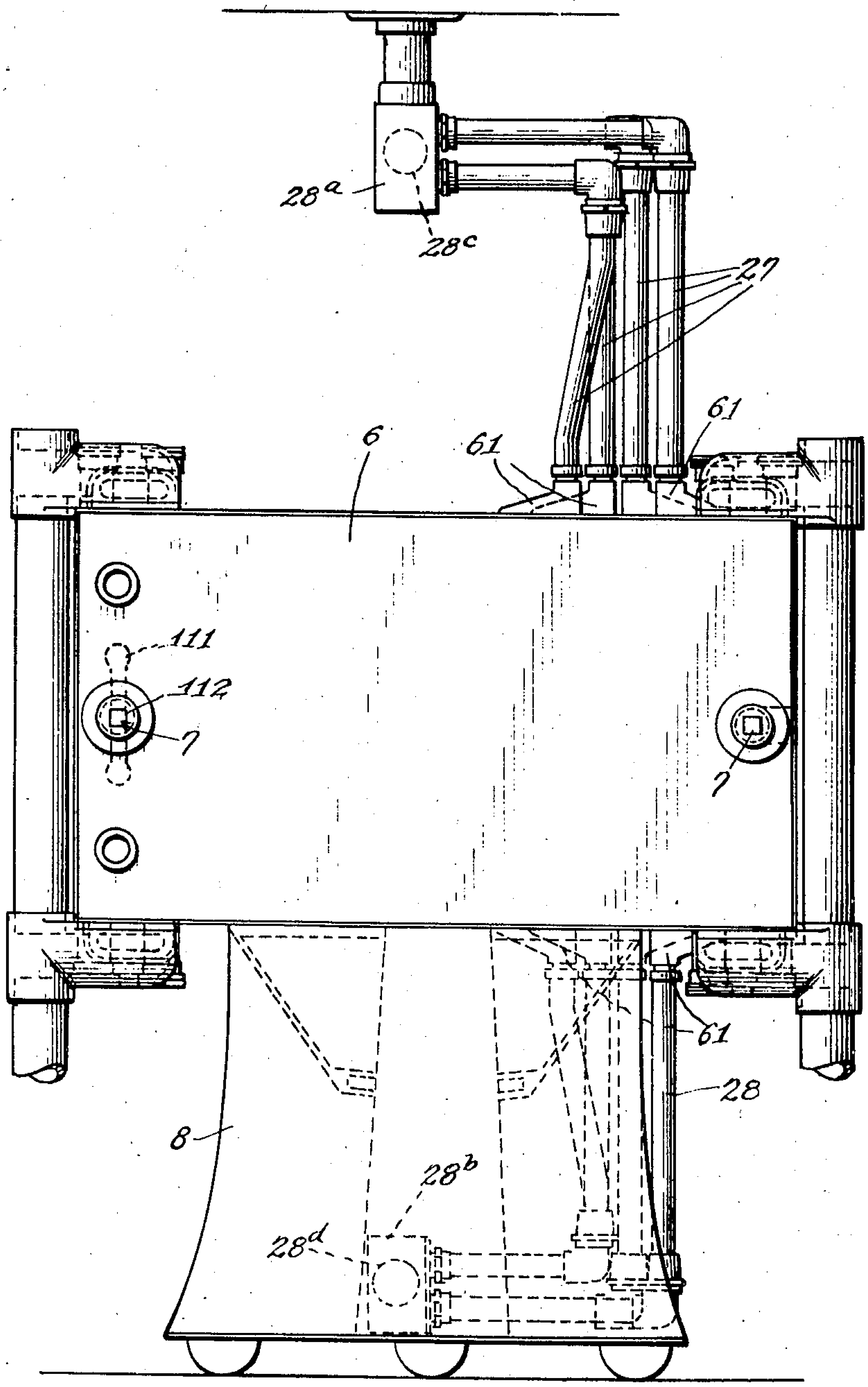

Fig. 1

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PLATE HEAT EXCHANGER

Original Filed March 29, 1937 10 Sheets-Sheet 2

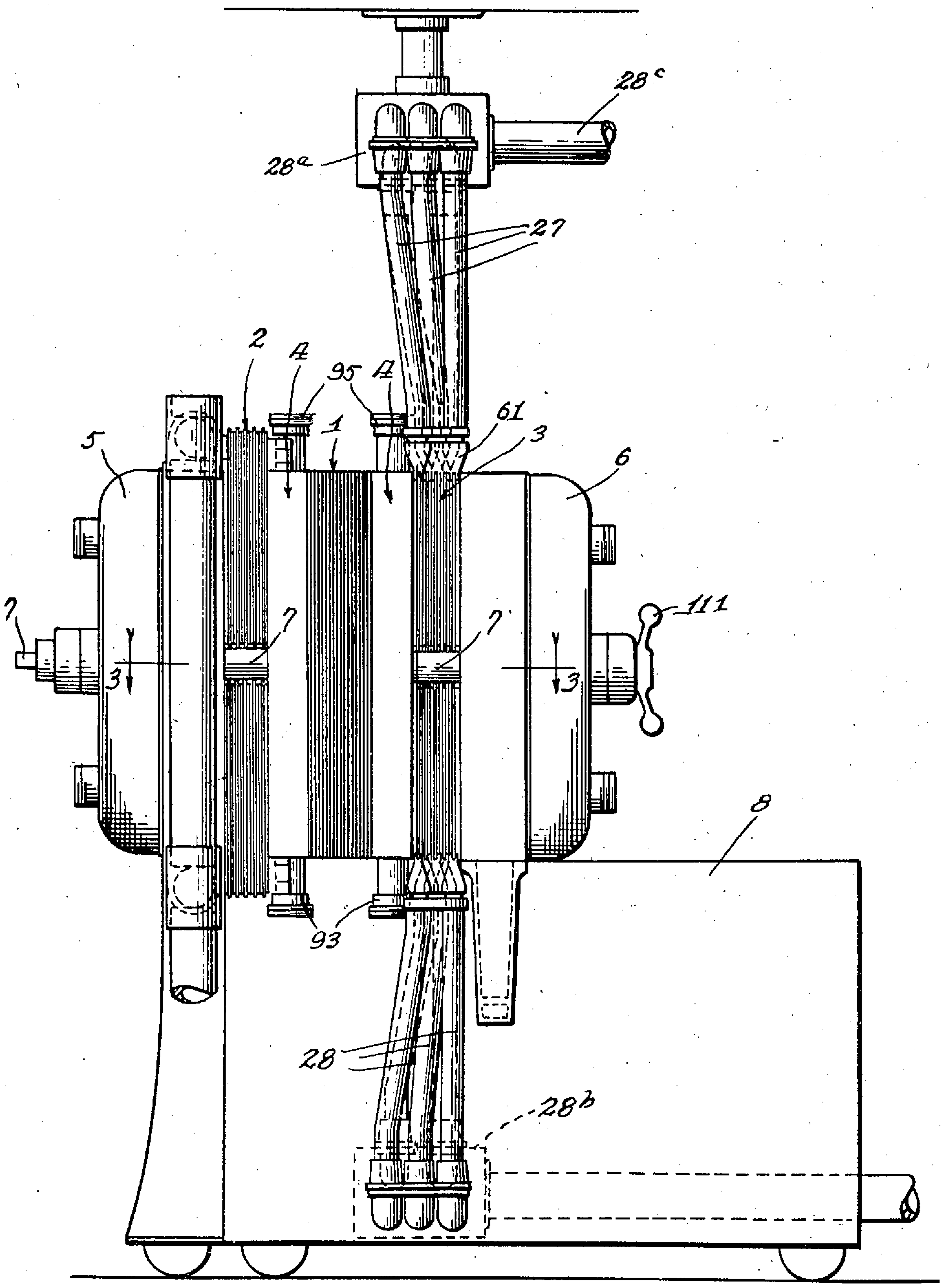

Fig. 2.

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March 30, 1943. W. ASTLE 2,314,966

PLATE HEAT EXCHANGER

Original Filed March 29, 1937 10 Sheets-Sheet 3

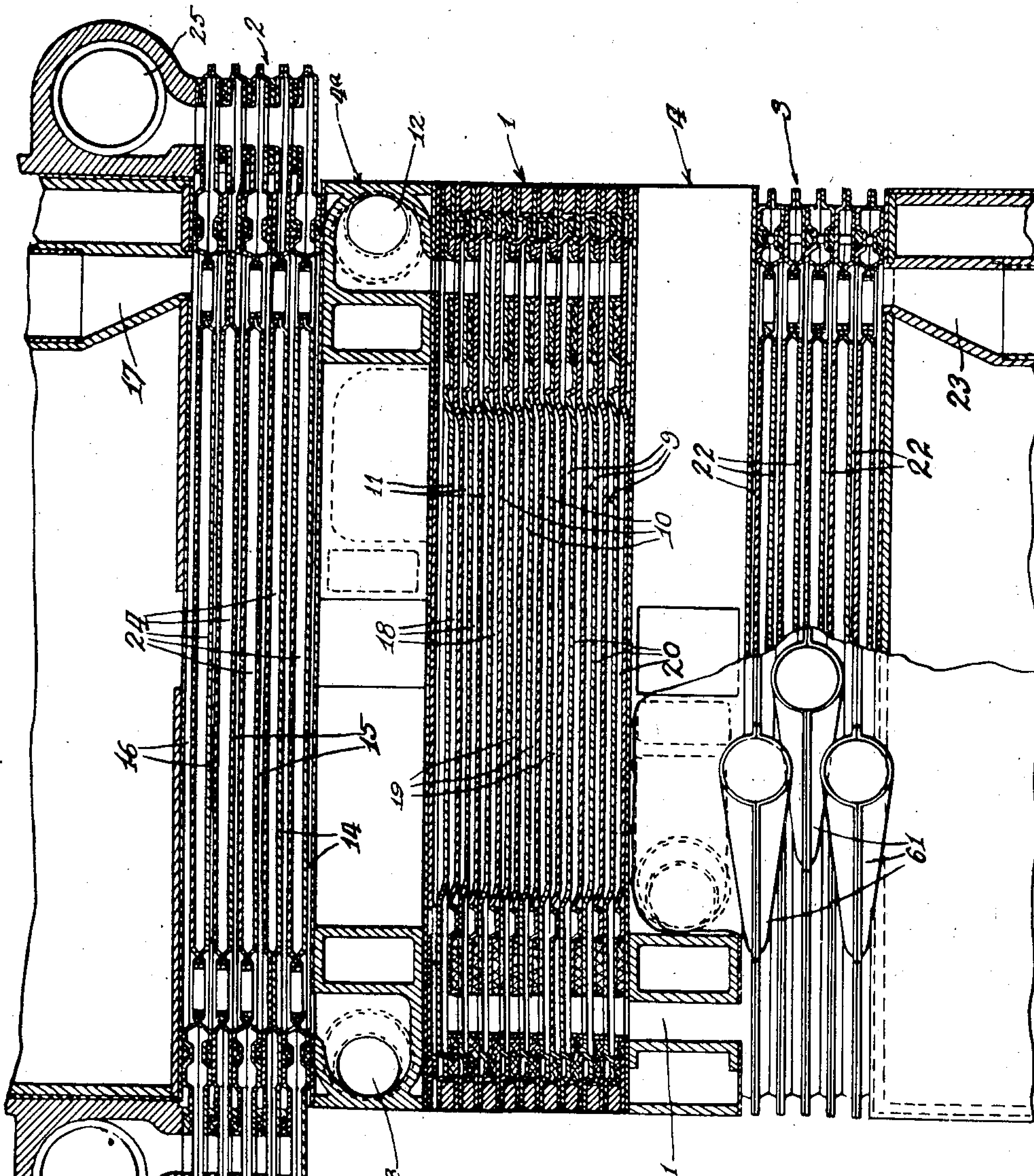

Fig. 3.

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2,314,966

PLATE HEAT EXCHANGER

Original Filed March 29, 1937

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Fig. 7

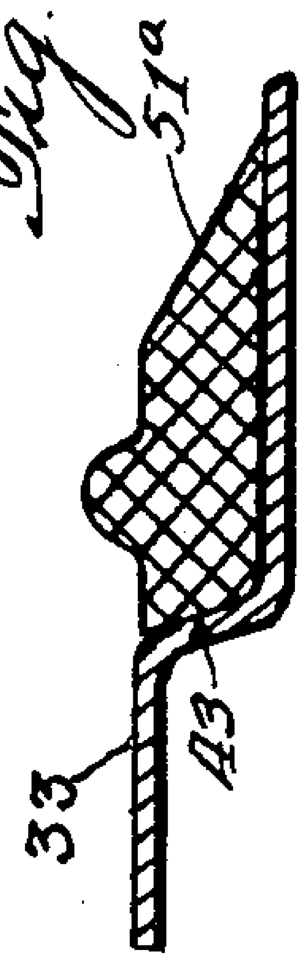

Fig. 8

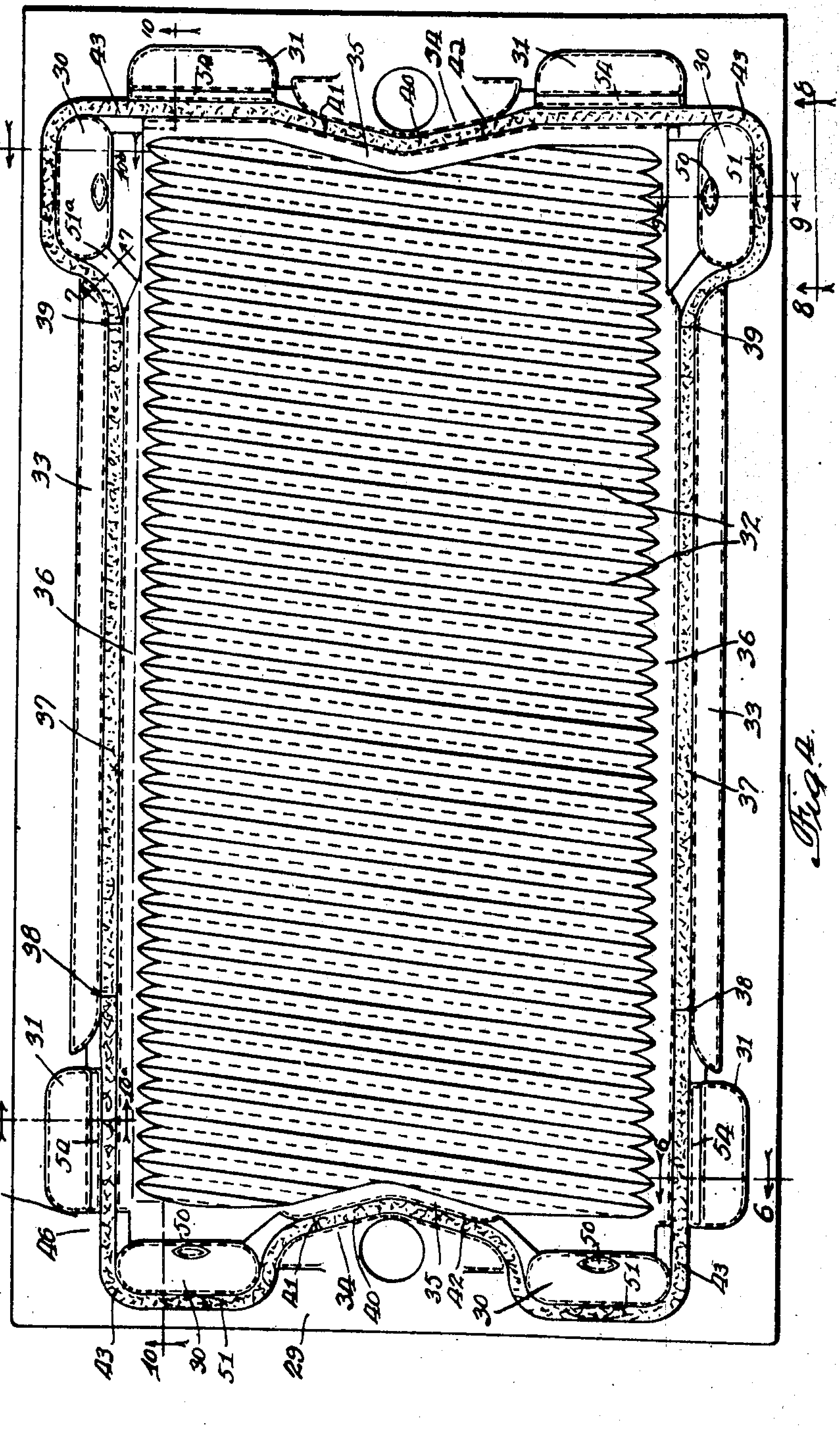

Fig. 4

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March 30, 1943. W. ASTLE 2,314,966

PLATE HEAT EXCHANGER

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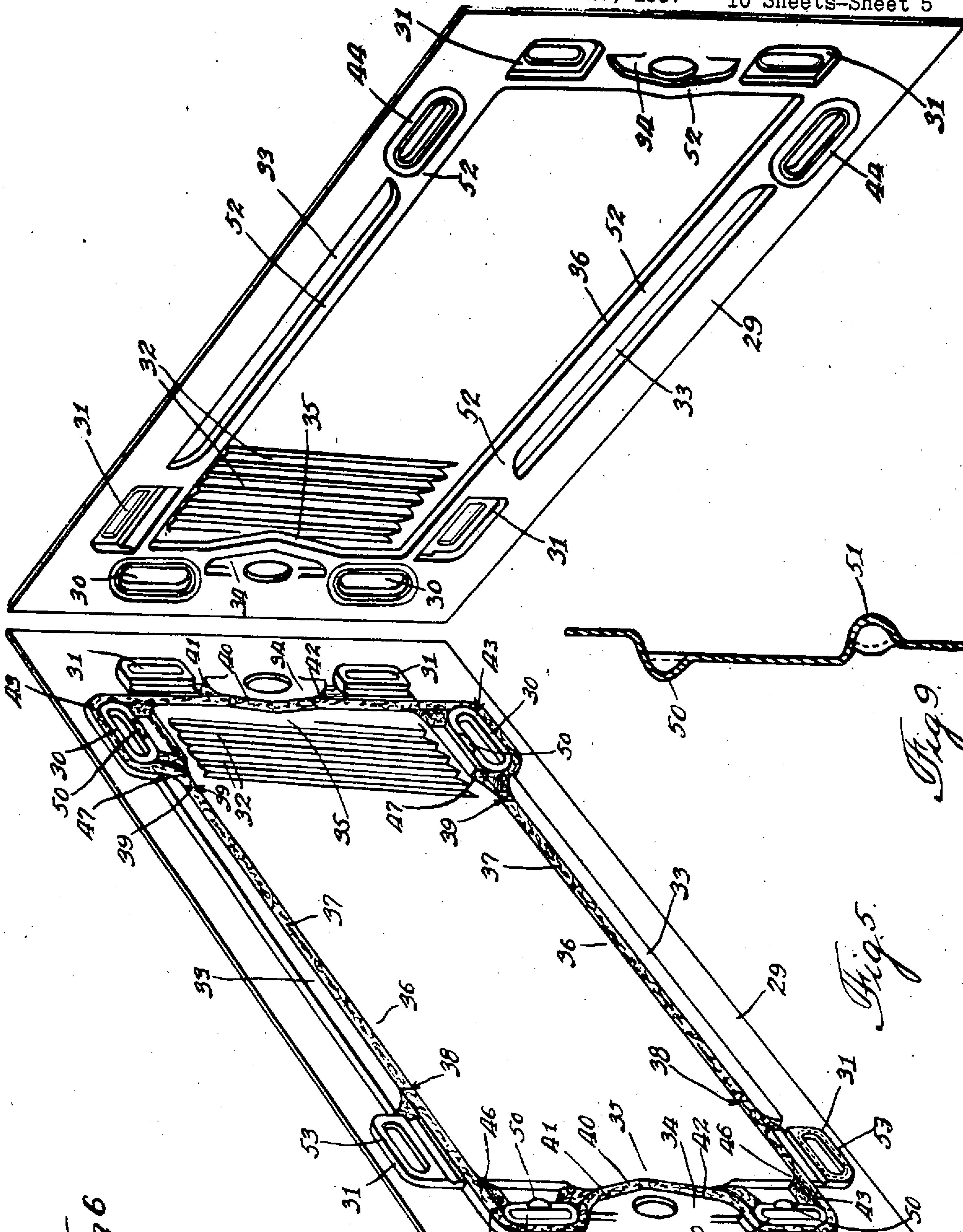

Fig. 5

Fig. 9

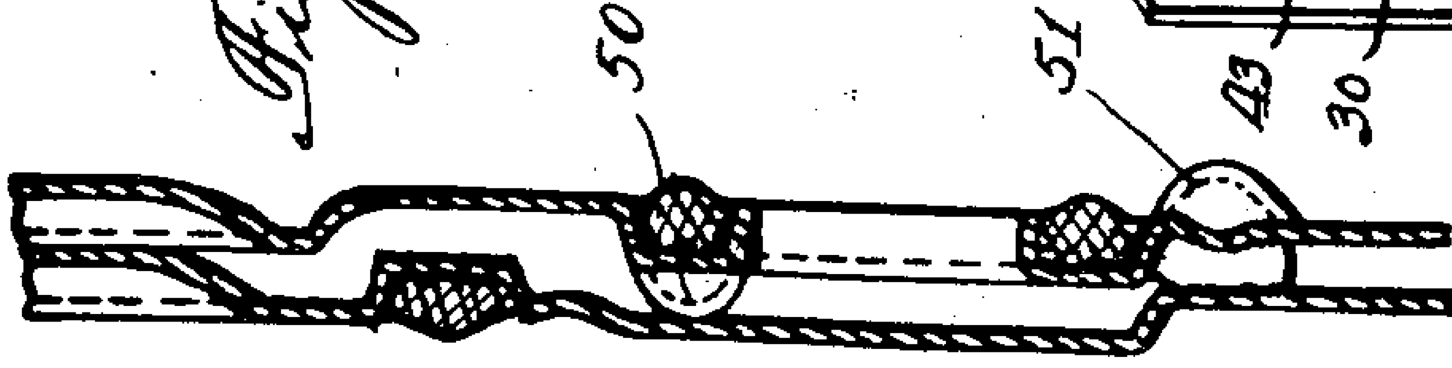

Fig 6

Inventor:
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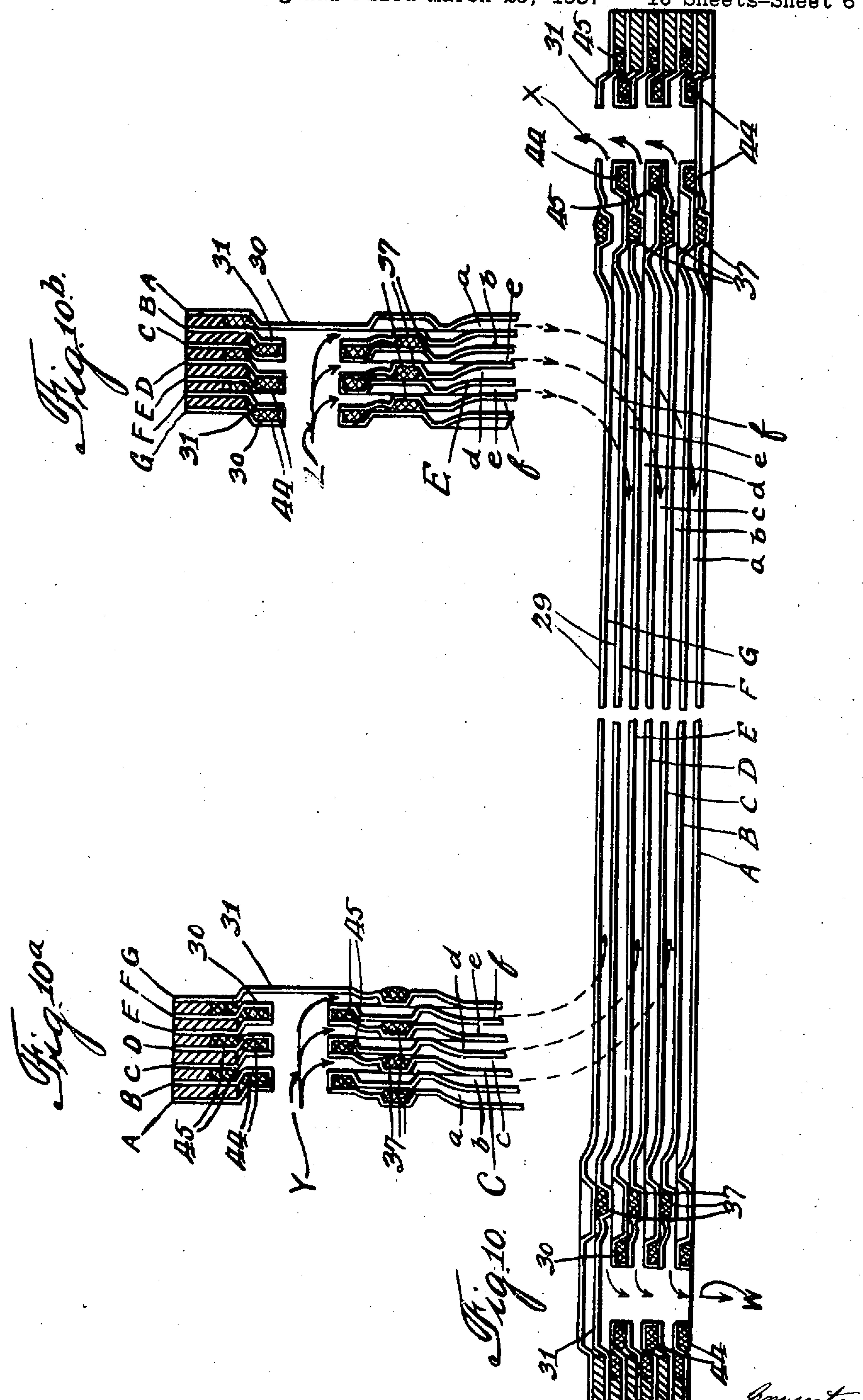
March 30, 1943. W. ASTLE 2,314,966

PLATE HEAT EXCHANGER

Original Filed March 29, 1937 10 Sheets-Sheet 6



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March 30, 1943. W. ASTLE 2,314,966

PLATE HEAT EXCHANGER

Original Filed March 29, 1937 10 Sheets-Sheet 7

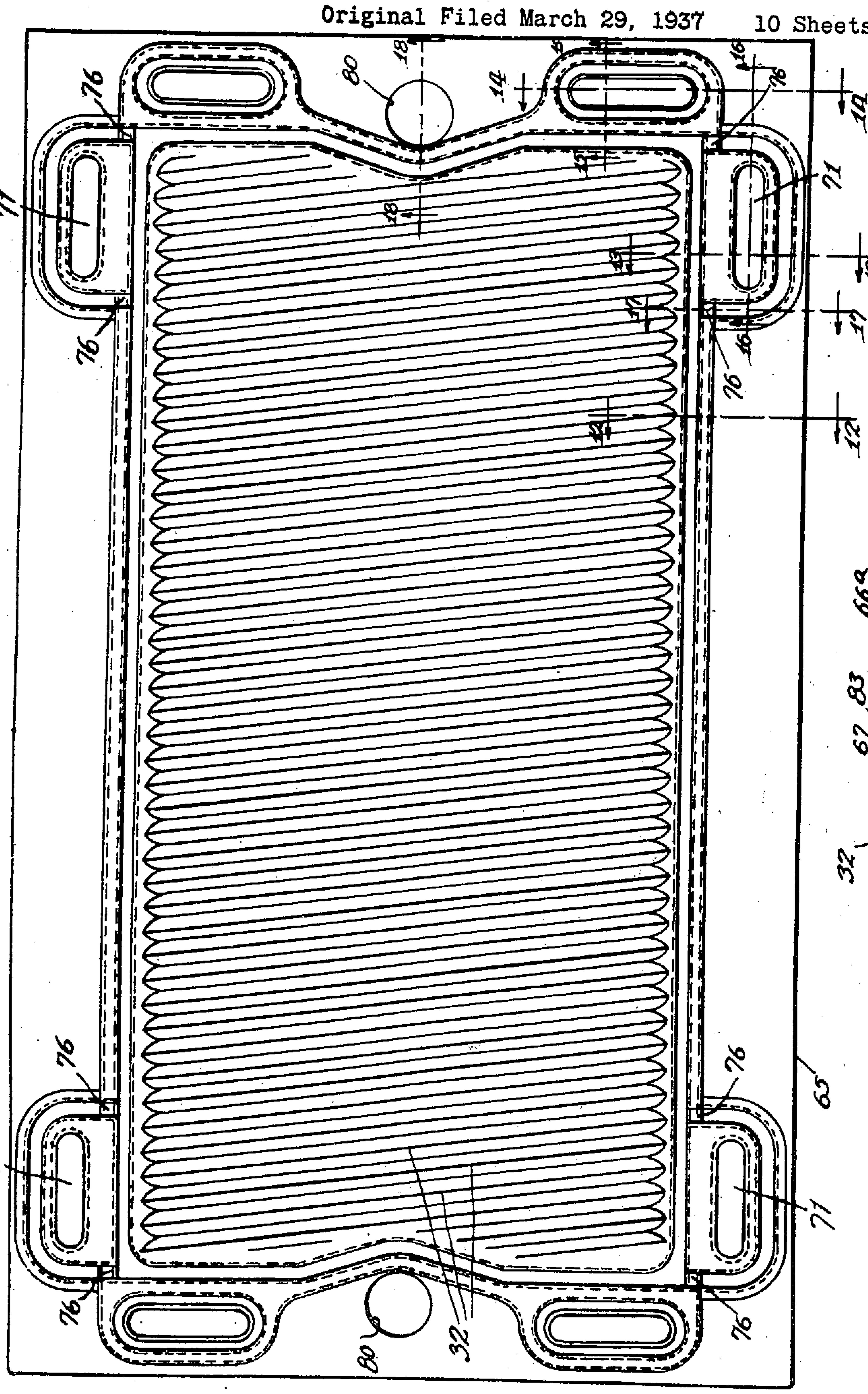

Fig. 11

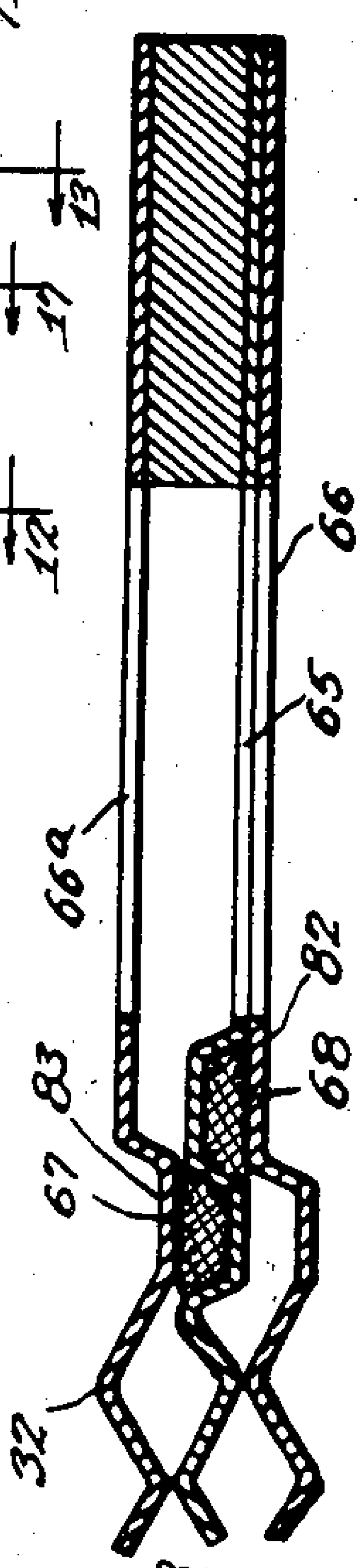

Fig. 18

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PLATE HEAT EXCHANGER

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Fig. 11a

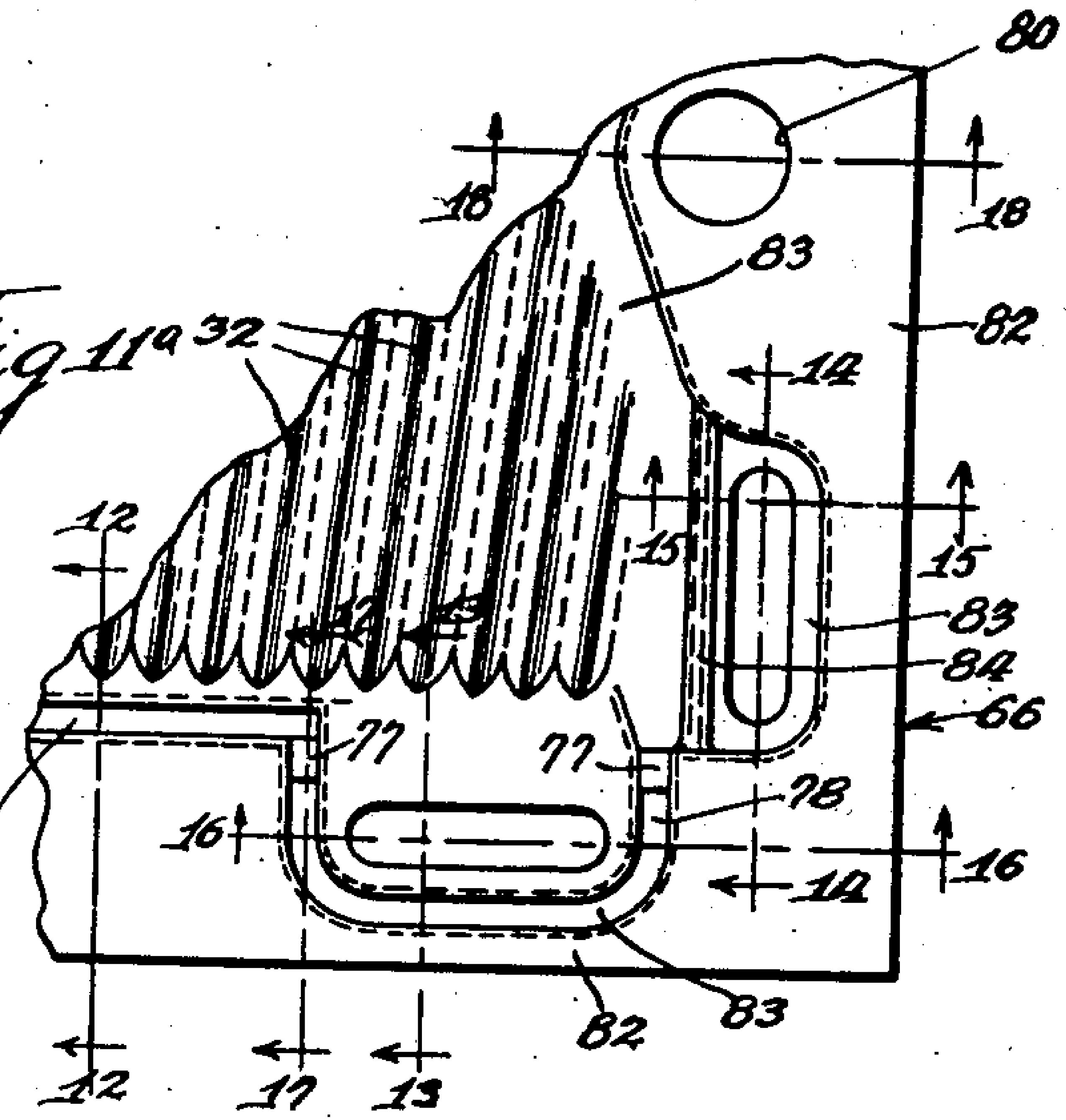
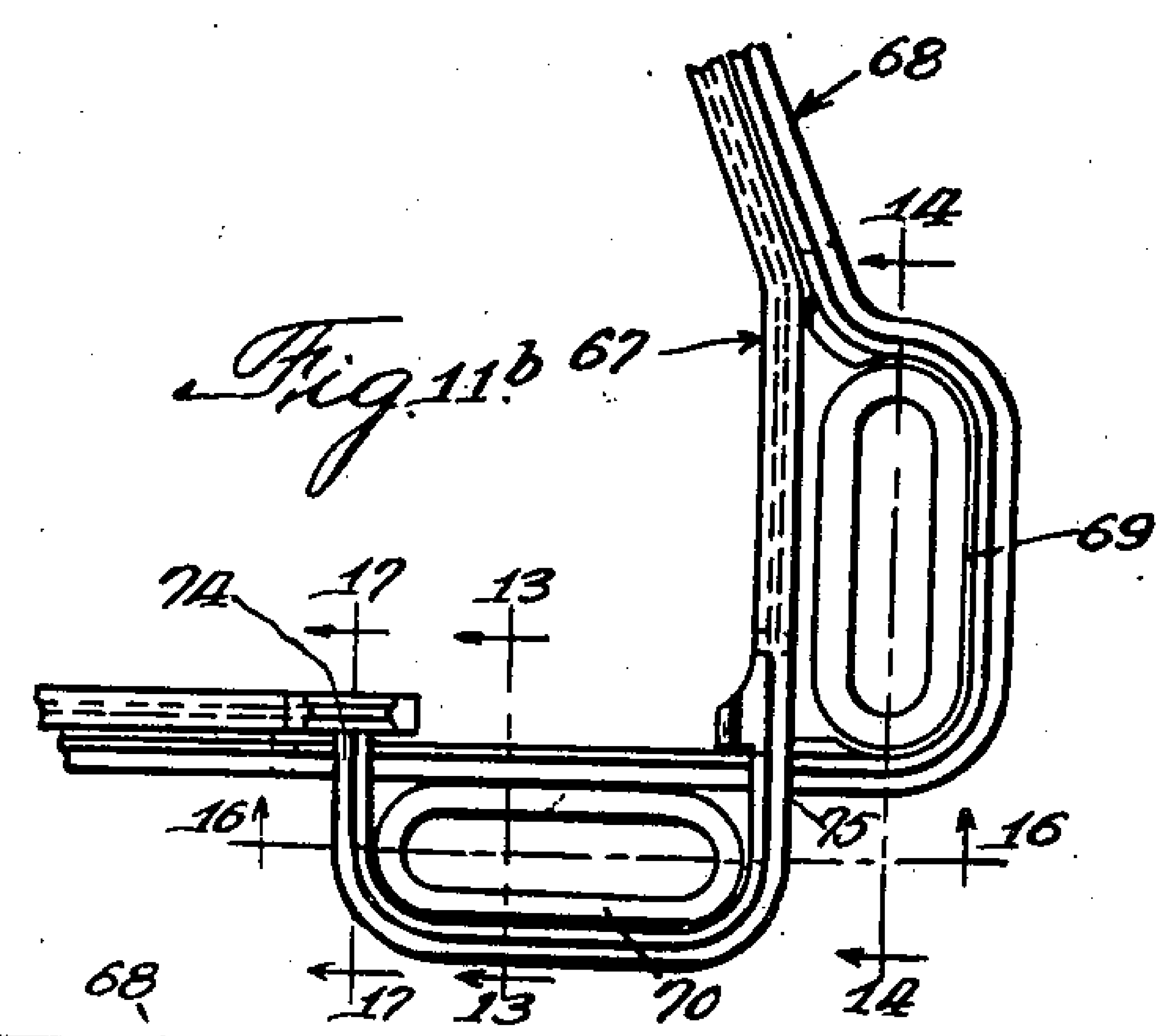


Fig. 11b



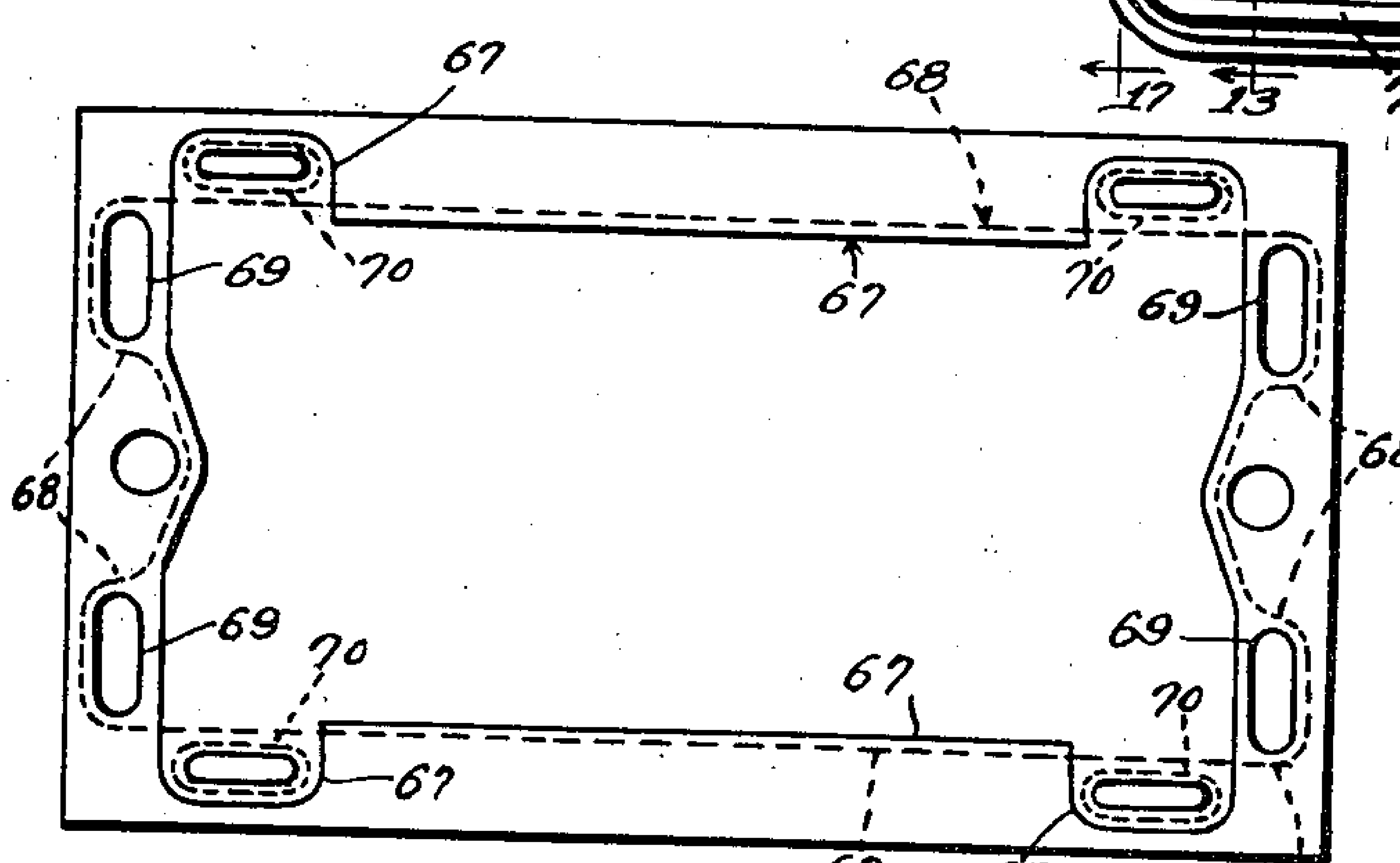


Fig. 11c

Inventor:
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PLATE HEAT EXCHANGER

Original Filed March 29, 1937 10 Sheets-Sheet 9

Fig. 12

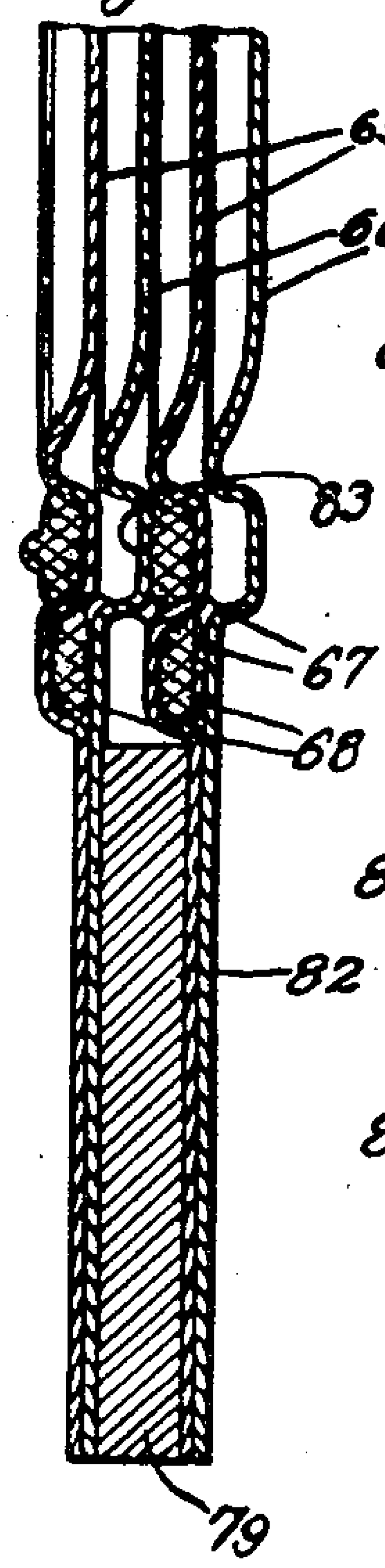


Fig. 13.

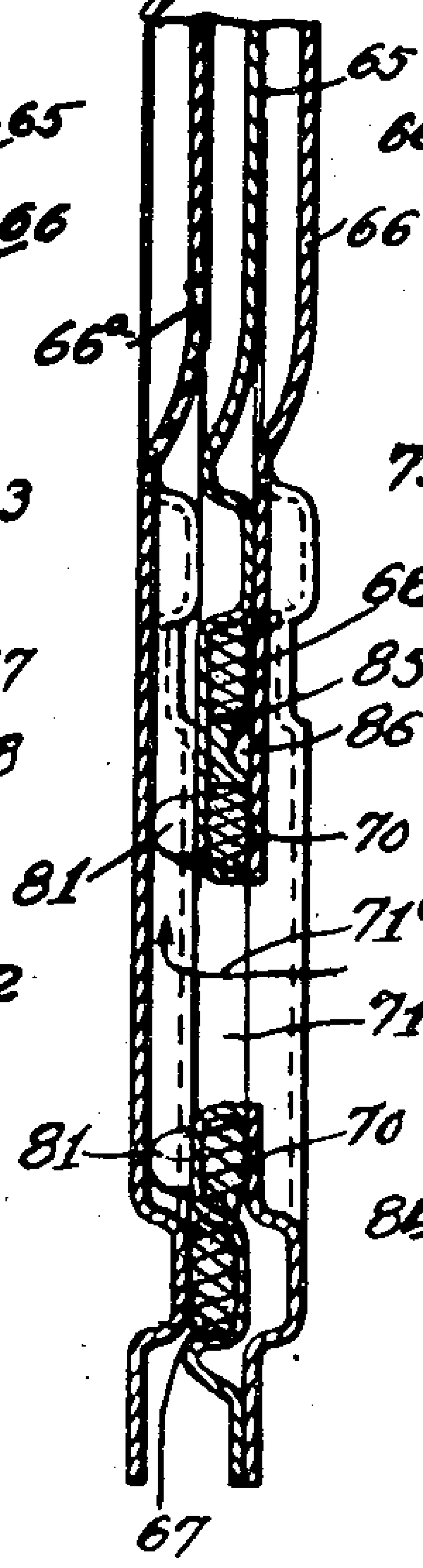


Fig. 14.

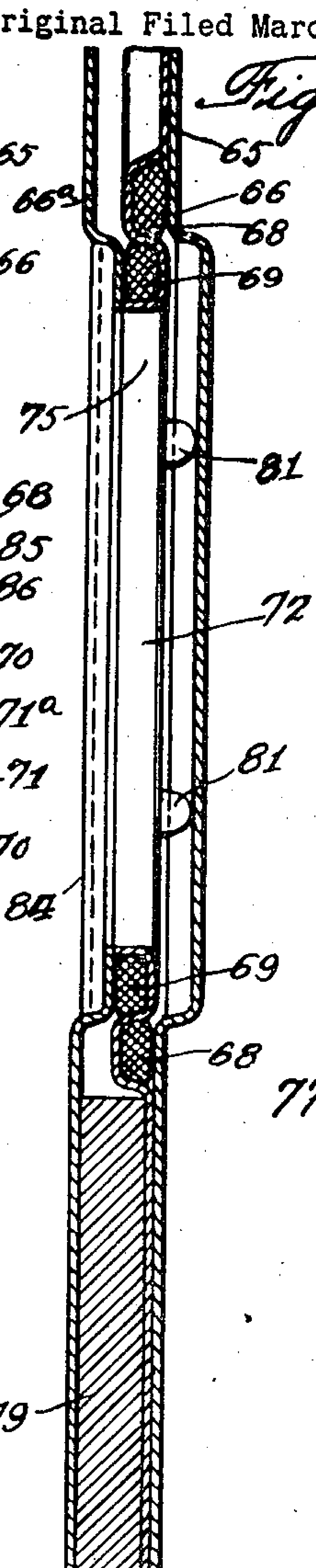


Fig. 17.

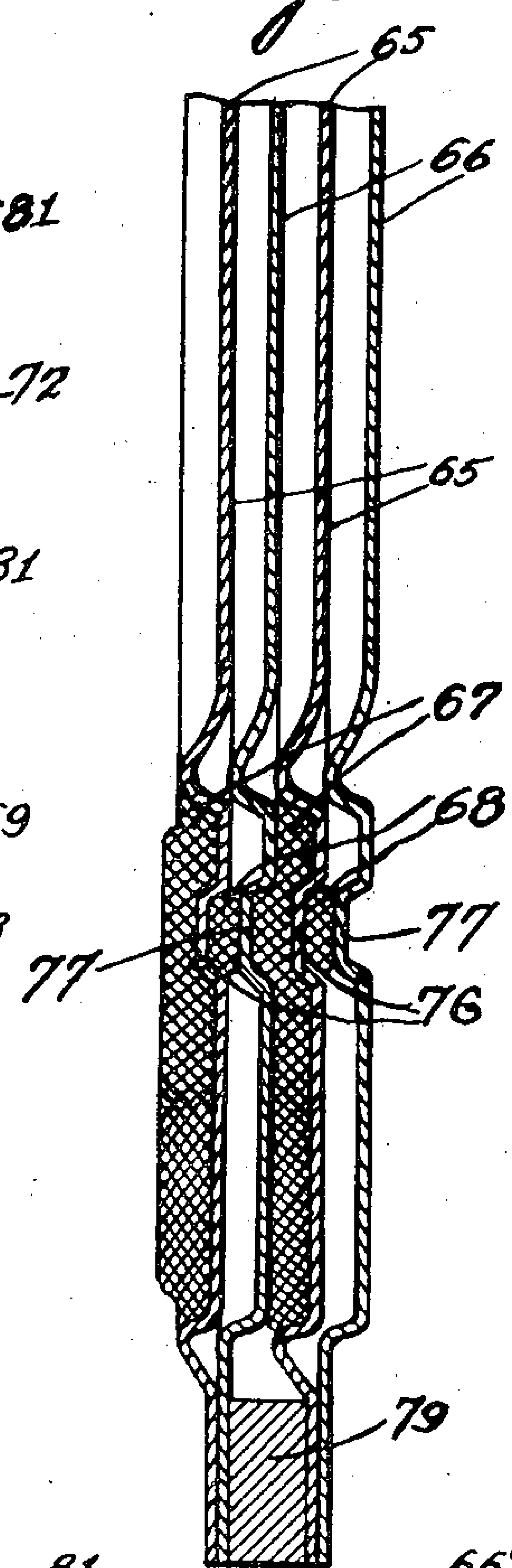
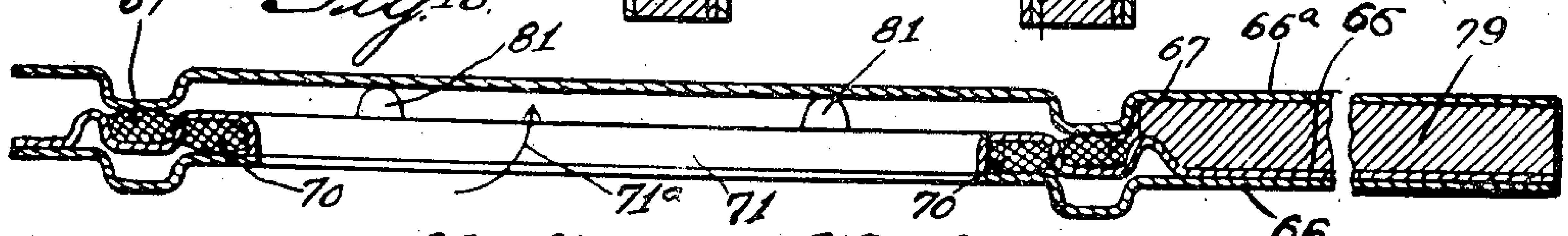


Fig. 16.



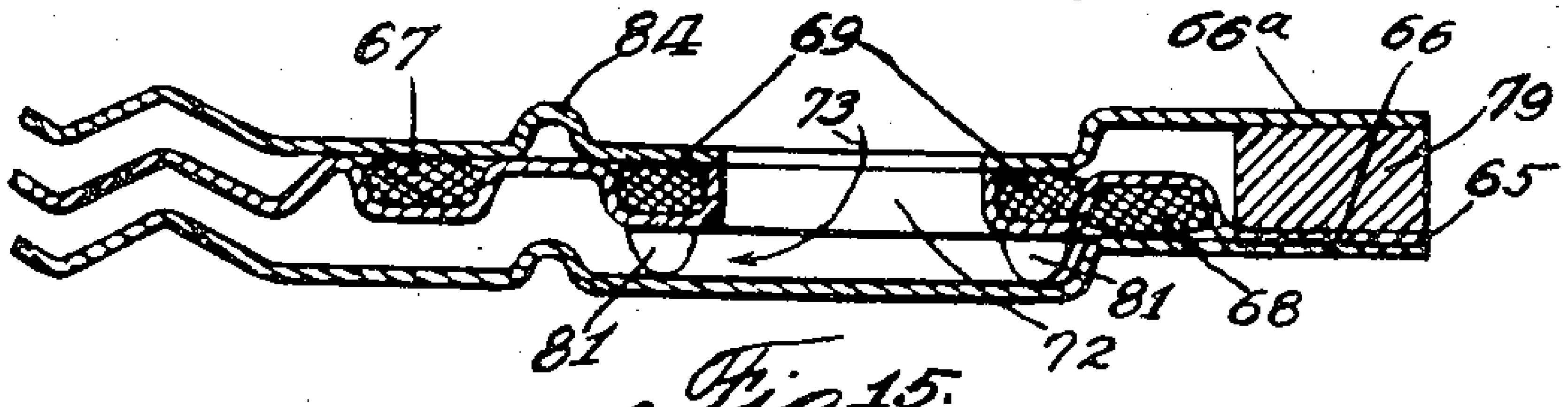


Fig. 15.

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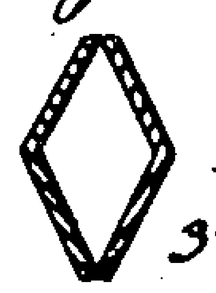
PLATE HEAT EXCHANGER

Original Filed March 29, 1937 10 Sheets-Sheet 10

Fig. 23



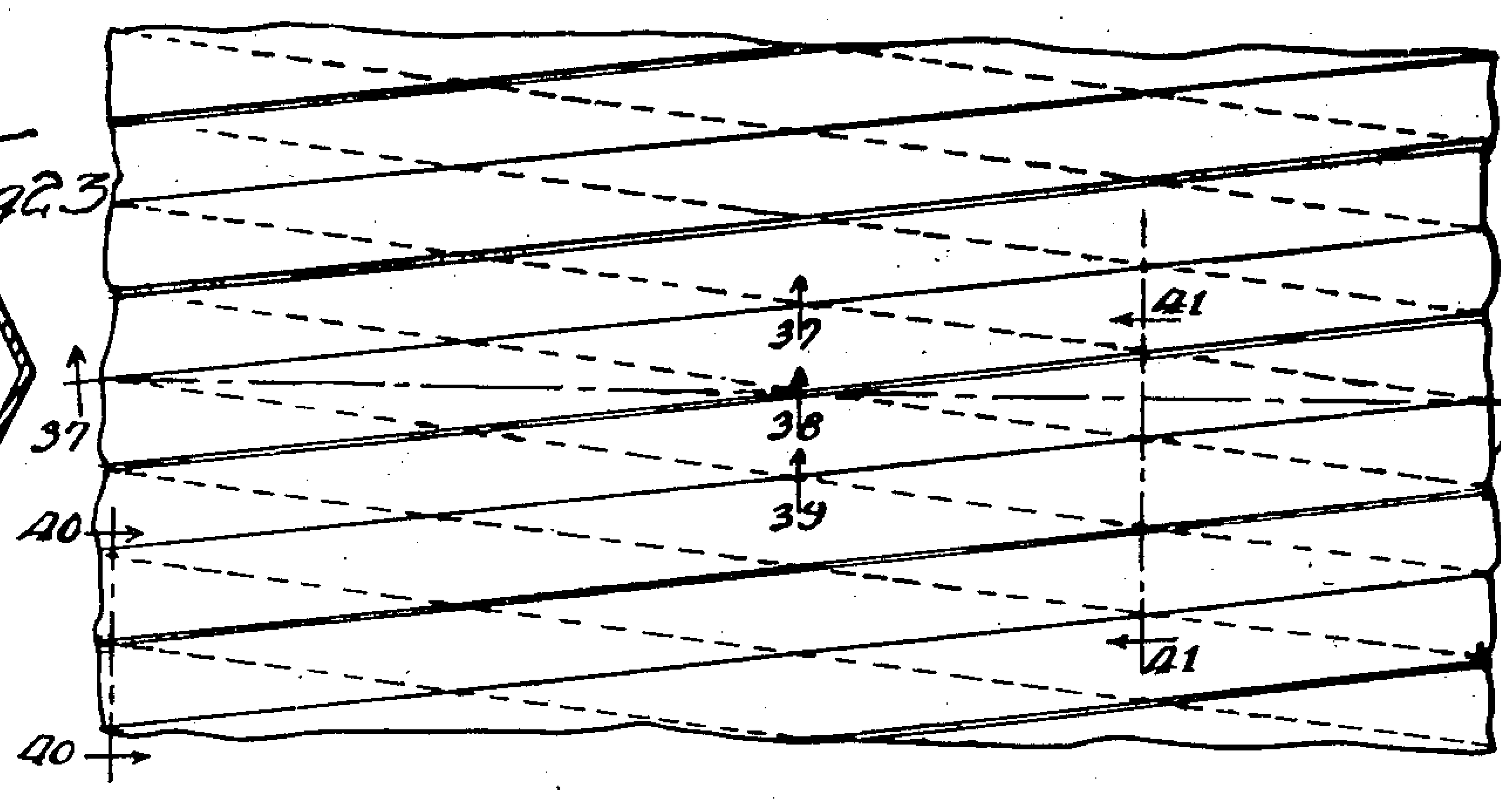


Fig. 24

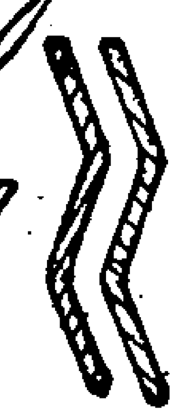


Fig. 19

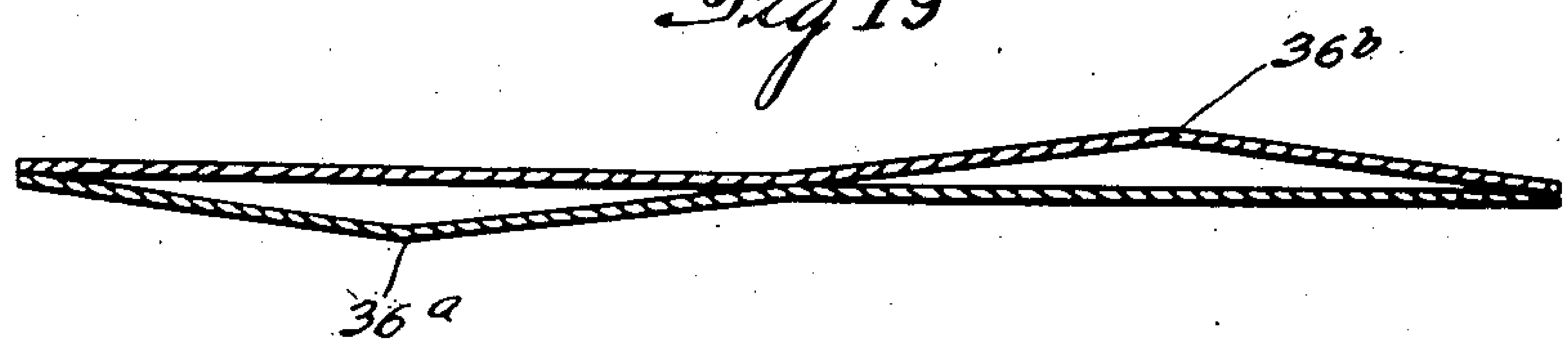


Fig. 20

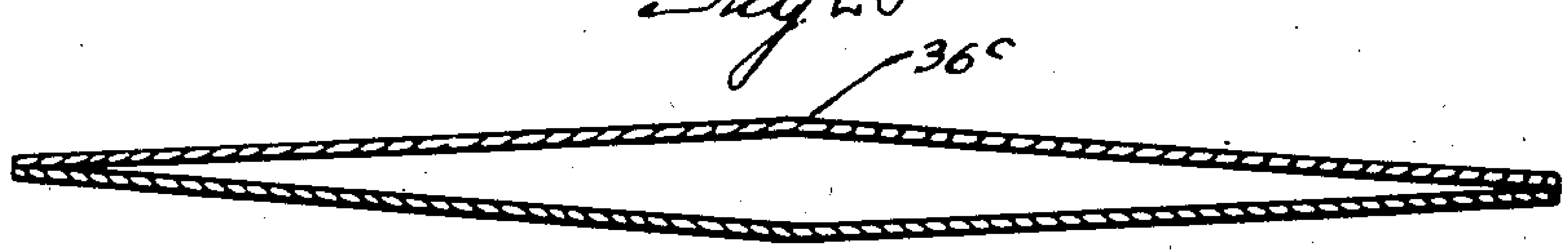


Fig. 21

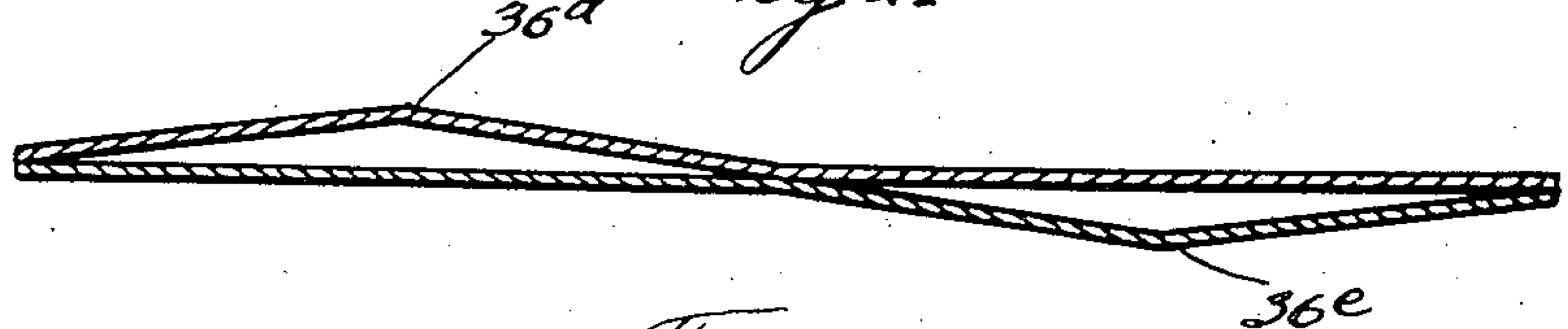


Fig. 22

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Patented Mar. 30, 1943

2,314,966

UNITED STATES PATENT OFFICE

2,314,966

PLATE HEAT EXCHANGER

William Astle, Chicago, Ill.

Original application March 29, 1937, Serial No. 133,621. Divided and this application August 23, 1940, Serial No. 353,967

9 Claims. (Cl. 257—245)

My invention relates to plate heat exchangers.

This application is a division of my co-pending application Serial No. 133,621, filed March 29, 1937, which became Patent No. 2,248,933, issued July 15, 1941.

An object of my invention is to provide a plate heat exchanger in which the plates are provided with corrugations formed in general transversely to the direction of flow, with the corrugations of one plate extending at an angle to the corrugations of the adjacent plate, whereby the fluid velocity varies from point to point and whereby turbulent action of the fluid results, bringing substantially all of the fluid particles into continuously repeated contact with the heat exchange surface, resulting in high heat exchange values at low operating pressures.

A further object of my invention is to provide a plate heat exchanger having an improved port and gasket construction which lends itself readily to the building up of different flow circuits.

A further object of my invention is to provide an improved plate heat exchanger in which the plates are readily accessible for cleaning.

Further objects and advantages of the invention will be apparent from the description and claims.

In the drawings, in which several embodiments of my invention are shown,

Figure 1 is a front elevational view of a plate heat exchanger embodying my invention;

Fig. 2 is a side elevational view of the construction of Fig. 1;

Fig. 3 is a horizontal sectional view substantially on the line 3—3 of Fig. 2; the section line of the regenerative plates being substantially the same as the line 15—15 of Fig. 11.

Fig. 4 is a plan view of a sheet metal heat transfer plate;

Fig. 5 is a somewhat diagrammatic perspective view showing two of the heat transfer plates and a gasket construction used therewith;

Fig. 6 is a section substantially on the line 6—6 of Fig. 4;

Fig. 7 is a section on the line 7—7 of Fig. 4;

Fig. 8 is a side elevational view on the line 8—8 of Fig. 4;

Fig. 9 is a sectional view on the line 9—9 of Fig. 4;

Fig. 10 is a diagrammatic sectional view of a plate construction showing the interplate flow on the line 10—10 of Fig. 4;

Fig. 10*a* is a diagrammatic sectional view on the line 10*a*—10*a* of Fig. 4;

Fig. 10*b* is a diagrammatic sectional view on the line 10*b*—10*b* of Fig. 4;

Fig. 11 is a plan view of a heat transfer plate having provisions on both sides for holding gaskets against movement along a face of the plate;

Fig. 11*a* is a plan view of a corner portion of a plain heat transfer plate which cooperates with the plate of Fig. 11;

Fig. 11*b* is a plan view of portions of the gaskets used on the front and rear faces of the gasket plate of Fig. 11;

Fig. 11*c* is a diagrammatic view showing the outline of the heat transfer plates and center lines of the cooperating gaskets;

Fig. 12 is a section on the line 12—12 of Figs. 11 and 11*a*;

Fig. 13 is a section on the line 13—13 of Figs. 11 and 11*a*;

Fig. 14 is a section on the line 14—14 of Figs. 11 and 11*a*;

Fig. 15 is a section on the line 15—15 of Figs. 11 and 11*a*;

Fig. 16 is a section on the line 16—16 of Figs. 11 and 11*a*;

Fig. 17 is a section on the line 17—17 of Figs. 11 and 11*a*;

Fig. 18 is a section on the line 18—18 of Figs. 11 and 11*a*;

Fig. 19 is a plan view showing portions of two superposed corrugated heat transfer plates;

Fig. 20 is a section on the line 37—37—37 of Fig. 19;

Fig. 21 is a section on the line 37—38—37 of Fig. 19;

Fig. 22 is a section on the line 37—39—37 of Fig. 19;

Fig. 23 is a sectional view substantially on the line 40—40 of Fig. 19; and

Fig. 24 is a section substantially on the line 41—41 of Fig. 19.

The particular construction disclosed as illustrative of my invention is an apparatus including a regenerative circuit in which raw milk first receives heat from warm milk from a holder, or the like, the raw milk being thereafter heated to a still higher temperature by heat supplied from hot water, or the like, and the warm milk from the holder being thereafter further cooled by transferring heat to a cooling fluid, such as ammonia or the like. The construction shown for this purpose comprises a set 1 of regenerative plates providing thin substantially rectangular flow spaces between adjacent plates for the passage of the raw milk and of the pasteurized milk, a set 2 of heating plates providing thin substantially rectangular flow spaces for the raw warm milk and the heating fluid, such as hot water, a set 3 of heat transfer plates providing thin substantially rectangular flow passages for the pasteurized milk from the regenerator and for the cooling fluid, such as ammonia, and suitable terminal plates 4 and passages for controlling the flow of the various fluids to and from different sets of heat transfer plates. The entire group of heat transfer plates and terminal plates may be clamped together to effect fluid-tight connections by means of two clamping heads 5 and 6 which may be drawn together to effect the clamping action by means of a pair of clamping rods 7 extending through the heat exchange plates and terminal plates and through the clamping heads. The assembly of plates and clamping heads may be mounted on a suitable support 8, one of the clamping heads 5 being stationary with respect to the support and the other 6 being slidably mounted thereon to facilitate the clamping and unclamping of the plates and the separation of the plates from each other for cleaning, etc.

As indicated above, in the particular apparatus disclosed, there are four different fluids being handled; the raw milk which is to be heated; the pasteurized milk which is to be cooled; the heating fluid, such as hot water for further heating the raw milk after it has passed through the regenerative plates; and the cooling fluid such as ammonia or the like for further cooling the pasteurized milk after it has passed through the regenerative plates. In the apparatus shown, raw milk enters the regenerative set 1 at the left side, as viewed in Fig. 3; flows through three parallel interplate flow spaces 9 to the right-hand side of the regenerative plate; thence from the right-hand side of the regenerative set to the left-hand side of the regenerative set through three other parallel interplate flow spaces 10, and thence from the left-hand side to the right-hand side of the regenerative set through three other parallel interplate flow spaces 11; thence from the regenerative set to an outlet passage 12 in the terminal plate 4*a*; thence (usually through a pump) to a passage 13 in the left-hand side in the terminal plate 4*a*; thence from left to right through two parallel interplate flow spaces 14, from right to left through two parallel interflow spaces 15, and again from left to right through two parallel interplate flow spaces 16 in the heating plate set and from this heating plate set through suitable passages 17 to the pasteurizer.

The pasteurized milk is supplied to a passage in the right-hand side of the terminal plate, as viewed in Fig. 3, from which it flows through the regenerative set of plates, first from right to left through three parallel interflow spaces 18; then from left to right through three parallel interflow spaces 19, and again from right to left through three parallel interplate flow spaces 20; thence through a passage 21 at the left-hand side of the terminal plate, and thence from left to right in parallel through the interplate flow spaces 22, and thence through the discharge passage 23 leading through the front clamping head. The heating liquid, such as hot water for the heating set of plates 2, may be supplied to the interplate flow spaces 24 of the heating plates from a supply conduit 25 on the right-hand side of the set of plates, flowing from right to left in parallel through the interplate flow spaces 24 to the left-hand side of the set of heating plates and from thence to the hot water outlet passage 26 at the left-hand side of the set of heating plates.

Suitable conduits 27 and 28 (Figs. 1 and 2) are provided for the entrance and discharge of ammonia with respect to the cooling plates. The conduits connected with the movable terminal plates may be made flexible so that these terminal plates can be shifted without disconnecting them from their supply and discharge conduits. The conduits 27 and 28 for the entrance and discharge of ammonia may be connected with suitable headers 28*a* and 28*b* in communication with the pipes 28*c* and 28*d*, respectively.

Plate and gasket constructions

The construction of the plates used for the above described regenerative system is different in some respects from the construction used for the heating plate system and also from the construction used for the cooling plate system. The construction of the plates for the regenerative set will first be described.

In the construction shown, the plates 29 (Figs. 3, 4, and 5) used in the regenerative set may be made from similar sheet metal blanks, the port and gasket arrangement, however, being changed to suit requirements for effecting the desired flow circuit arrangements. These plates are in general rectangular in form and are provided with plate gasket constructions which in general outline the extent of the broad, thin flow passages between adjacent plates, and the plates are also provided with port gasket constructions, the port gasket constructions serving in general when provided to prevent a certain fluid from entering the space between two adjacent plates with respect to which space it is desired to maintain a fluid separation.

Referring to Figs. 4 and 5, it will be noted that the plate shown is provided with four embossed portions 30 of a general oval formation and with four embossed portions 31 which in general are in the form of a half oval. Any desired ones of these eight embossed portions may be punched out to provide port openings as desired and any desired ones of them may also be provided with a port gasket groove surrounding the port to effect a sealing engagement with an opposing embossment on an adjoining plate to prevent fluid which may be flowing through the ports from escaping into the space between the adjacent plates. The upper faces of all eight of the bosses lie in the same general plane.

The main central portion of the plate is provided with corrugations 32, the purpose and details of construction of which will be described hereinafter. The plate is also suitably embossed or pressed to provide retaining means for portions of the plate gasket construction, as indicated at 33, 34, 35, and 36.

In general, it will be noted that the horizontally extending pair of oval embossments 30 is located at one end of the plate, and the pair of vertically extending oval embossments 30 is located at the other end of the plate. It will also be noted that one of the horizontally extending oval embossments 30 is above the corrugated portion of the plate, and the other horizontally extending oval embossment 30 is below the corrugation of the plate, and the two vertically extending oval port embossments 30 are located laterally beyond the end of the corrugated portion of the plate.

Similarly, with respect to the two pairs of semi-oval embossments 31, one of the horizontally extending pair is above the corrugated portion of the plate and the other is below the corrugated portion of the plate, while the two vertically extending semi-oval embossments are located laterally beyond the end of the corrugated portion of the plate.

In general, the flow over the corrugated portion of the plate is between a pair of horizontally extending ports and a pair of vertically extending ports. Either pair may be used as the ports of entry and the other pair may be used as the ports of discharge. If, for example, two oval horizontally extending ports in one of the plates are used as the ports of entry, and two vertically extending oval ports in the adjacent juxtaposed plate are used as the ports of discharge, the fluid entering both at the top and bottom of the interplate space through the entry ports will distribute itself over the adjacent corrugated plate portion, which in general lies in a vertical plane, and will flow laterally along this corrugated surface without any substantial rise or fall as it flows and will leave the interplate space through the upper and lower vertically extending discharge ports.

In building up a nest or set of regenerative plates shown in Fig. 10, alternate plates are reversed end for end so that a pair of oval port bosses **30** will be juxtaposed with respect to a pair of semi-oval port bosses **31** so that a gasket surrounding the oval port will rest snugly in fluid-tight engagement with the adjacent portion of a semi-oval port boss. Thus the oval gasket will prevent fluid flowing through the ports in the adjacent plates from entering the space between the adjacent plates.

The construction of the plates being cross corrugated, the fluid flowing over its surface is in the form of a wide thin film which is caused to flow in a plurality of converging streams of varying velocity at low cumulative pressure.

The corrugations **32** are pitched at such an angle that the tops of the corrugations in alternate plates cross and rest against each other at predetermined distances to properly support the plates against any diaphragmatic action and to create high velocities of the fluids, which vary from the maximum at the point of contact to a minimum at the center between any two points of contact.

This varying velocity fluid is also caused to receive turbulent action as it rapidly passes over the heat exchange surface in the troughs of the corrugations. These varying actions of the fluid result in the continuously repeated contact of all particles of the fluid with the surface of the heat exchange material and cause high heat exchange values at low operating pressures.

Alternate plates have the angle of the corrugations rising from left to right and right to left to cause these conditions.

The flow passages are so located as to create lateral flow to and from the troughs of the corrugations and then to follow the convergent flow noted, to the end of the plate when it passes through the elongated ports running lengthwise with the flow. This port arrangement causes a straight line flow which does not permit the creation of dead pockets of air or fluids, and insures proper draining.

It will be noted that the port bosses **30** and **31** are so positioned with respect to the flow spaces on opposite sides of the plate that a heat exchange apparatus, built up of a multiplicity of these plates positioned to lie in vertical planes, can be drained and vented completely without loosening and separating the plates. As shown in Figs. 4 and 5, the positioning of the bosses **30** and **31** is such that a plate may be provided with four pairs of transfer ports, one pair in the upper right-hand quadrant of the plate, one pair in the upper left-hand quadrant, one pair in the lower right-hand quadrant, and the other pair in the lower left-hand quadrant, all of the four lower bridging transfer ports having an effective drainage port area not substantially above the horizontal plane of the lower edges of the flow spaces and all of the four upper bridging transfer ports having an effective air vent port area not substantially below the horizontal plane of the upper edges of the flow spaces.

This positioning of the ports, in combination with film flow spaces having laterally extending upper and lower edges, prevents any possibility of any substantial liquid pockets forming in the lower part of the film flow spaces and prevents any possibility of any substantial air pockets forming in the upper part of the film flow spaces, thus enabling the entire series of film flow spaces to fill up at once when liquid is supplied through a supply passage in a terminal plate **4** and enabling the entire series of film flow spaces to be drained completely by opening a drain passage in a terminal plate.

The angular cross section of the corrugations is such as to create a varying Venturi effect throughout the plates, and to insure a maximum efficiency of fluid flowing over its surface. The angle of this surface is most efficient between 25° and 30°. As shown in Figs. 19 to 24, inclusive, the corrugations in two adjacent plates may be so designed as to provide a change in the effective cross-sectional area for the flow between the plates and so as to cause a somewhat tortuous or zigzag flow, causing a change of velocity of the flow stream and a tubulence of flow resulting in a high heat transfer efficiency of the plates. Figs. 20, 21, and 22 show successive cross-sections of the flow space between the plates of Fig. 19. It will be noted that in passing from the effective area along the section line **37—37—37**, as shown in Fig. 20, to the effective area along the section line **37—38—37**, as shown in Fig. 21, the effective area is doubled, thus reducing the velocity, and that in passing from the section line **37—38—37** to the section line **37—39—37**, as shown in Fig. 22, the effective area is reduced to one-half, thus doubling the velocity. This alternating decrease and increase of the velocity results in a turbulence of the flowing fluid, which brings all parts of the flowing liquid repeatedly into contact with the heat transfer plates, thus making for efficient heat transfer. It will also be noted that in the section indicated in Fig. 20, the greatest cross-sectional area is at the points **36*a*** and **36*b***, whereas in the section of Fig. 21 the greatest cross-sectional area is at the point **36*c*** and that in the cross-section shown in Fig. 22 the greatest effective areas are at the points **36*d*** and **36*e***. This shifting of the maximum effective area has a tendency to cause a zigzag current which further increases the turbulence and adds to the heat-transferring efficiency of the heat transfer plates.

The plates are so constructed as to be operable in either horizontal or vertical position, being oblong in form.

Cellular plates are also proposed for water, brine or ammonia use through the inside.

For ammonia, the corrugations are formed with a flat surface of approximately $\frac{3}{16}$'' width so that the two plates may be spot welded at spaced distances where the corrugations are made to cross in order to insure these plates against distortion at exceptionally high pressures, say, of one thousand pounds.

While these corrugations are laid parallel they are also pressed at an angle to the edge of the plates so that the corrugations in alternate enclosed plates cross each other as before, causing the fluid to be treated to flow in convergent streams over its surface, as previously described. In this case, the refrigerant is caused to flow at right angles to the fluid being treated by passing it through the troughs of the corrugations.

In order to facilitate maintenance and cleaning of the apparatus, means are provided whereby the plate gaskets can be readily removed and replaced. For this purpose, the gaskets, before being secured to the heat transfer plates, may be provided with an adhesive coating which dries and loses its adhesiveness but which can be made adhesive at the time when it is to be applied to the heat transfer plate by applying to the portion of the gasket which is to engage the plate a coating of a solvent which will render the gasket again adhesive. For this purpose the adhesive coating may be some non-vulcanized rubber composition which becomes nonadhesive on drying but which is again rendered adhesive on the application of a suitable hydrocarbon solvent.

As an example of the use of this gasket construction, the method of removing and replacing the gaskets after using the apparatus will be described. When the plates carrying the gaskets are removed after use for cleaning, inspection, etc., the gaskets may be forcibly separated from the sheet metal plates and replaced by new gaskets kept in stock by the user of the apparatus. In applying the new gaskets, the sheet metal heat transfer plates are first carefully cleaned to remove any adhesive or gasket portions which may have adhered to the plate, the solvent is applied to the adhesive coating on the new gasket to render this coating again adhesive, and the gasket is then pressed into place with respect to the sheet metal plate, causing the gasket to adhere to the plate. In a short time the plate with the gasket in place is ready to be placed in position and clamped in the apparatus.

Terminal plates

The terminal plates **4** which will be described more in detail hereinafter are provided with eight possible port locations spaced and arranged to correspond with the eight port embossments on the heat exchange plates so that fluid can be supplied from the terminal plate to any desired ones of the ports in the adjacent heat exchange plate and so that fluid may be discharged from any desired ones of the ports in the heat exchange plate to the corresponding ports in the terminal plate.

Heat exchange flow

Before describing in further detail the construction and operation of the particular apparatus shown, I will describe in general what may be accomplished by the use of a set of plates, such as shown in Figs. 4 to 10*b*, suitable for use as the regenerative plates of set **1**.

In order to make clear the construction by means of which the various arrangements of interplate flow may be obtained, reference is made first to Fig. 5, which shows in perspective two plates which are to be swung together in juxtaposition to each other to provide an interplate flow space. In Fig. 5, the left hand plate **29** has two horizontal port bosses **30** at the right hand end of the plate perforated and provided with oval gaskets on the back side of the plate. The two vertically extending port bosses **30** at the left hand side of the plate are imperforate. The two right hand vertically extending, semioval port bosses **31** are imperforate, and the two left hand horizontally extending semioval port bosses **31** are perforated but not gasketed. In the right hand plate **29** the horizontally extending oval port bosses at the right hand end of the plate **29** are perforated and provided with gaskets on the obverse side of the plate. The vertically extending oval port bosses **30** at the left hand end of the plate are imperforate. The vertically extending semioval port bosses **31** at the right hand end of the plate are perforated but not gasketed. The horizontally extending semioval port bosses **31** at the left hand end of the plate are imperforate.

The plate gasket construction comprises two similar, horizontally extending gasket strips **37** extending from **38** to **39**, two similar, substantially vertically extending gasket strips **40** extending from **41** to **42**, and four shaped, molded gasket sections **43** for the corners of the plate, respectively, extending between the horizontally extending gasket strips and the vertically extending gasket strips. The port gaskets **44** are oval in shape and are seated in correspondingly shaped oval channels **45** which may be formed in any desired ones of the bosses **30** or **31**. The embossments **33** serve to support one side of the gasket strips **37** and also serve to support portions of the corner gaskets **43**, as indicated in Figs. 4 and 5. The embossments **34** serve to support one side of the gasket strips **40** and also serve to support portions of the corner gaskets **43**. The embossments **36**, extending from **46** to **47**, serve to support one side of the horizontally extending gasket strips **37** and also portions of the corner gasket pieces **43**. The embossments **35** serve to support one side of the vertically extending gasket strips **40** and also portions of the corner gaskets **43**. The semioval embossments **31** and the oval embossments **30** serve to support portions of the corner gaskets **43**.

In order to prevent springing of the plate **29** under pressure and thus to prevent danger of leakage, the plates may be embossed as indicated at **50** and **51** in Figs. 4, 5, 6, and 8. These embossments **50** and **51** bear against the adjacent plates and effectively support the plates against distortion due to fluid pressure on the plates, thus preventing danger of leakage. In order to make the plates and gaskets easy to clean, the gaskets **43** may be beveled as indicated at **51***a* in Figs. 4 and 7, thus providing a smooth surface for brushing.

It will be understood, of course, that the above described porting and gasketing arrangement is illustrative only and may be varied to take care of different situations. With the porting and gasketing arrangement described, when the two plates shown in Fig. 5 are swung together and pressed tightly in engagement with each other, the plate gasket construction, including the gasket members **37**, **40** and **43**, carried by the left hand plate, will lie in sealing engagement against flat portions of the right hand plate along the broken line indicated at **52**. The oval port gaskets **44** carried by the right hand plate **29** will lie in sealing engagement against flat portions of the semioval port bosses 31 of the left hand plate 29, as indicated by the broken lines 53. This construction provides for an interplate flow for a fluid entering the ports 30 at the right hand end of the left hand plate and leaving the interplate flow space through the right hand end ports in the bosses 31 of the right hand plate. The fluid entering the aforesaid ports 30 will first flow downwardly from the upper port 30 and upwardly from the lower port 30 along the corrugations in the plate, distributing itself over the area between the plates 29, and will thence flow transversely with respect to the corrugations toward the exit ports 31 without any substantial rise or fall in its passage between the corrugated portions of the juxtaposed plates.

The through plate flow for the fluid which is to be excluded from the aforesaid interplate flow space is effected by means of the port gaskets 44 in the right hand plate 29 which lies snugly against and in fluid tight relation with respect to the apertured port bosses 31 at the right hand end of the left hand plate 29. It will be noted that the area included by the plate gasket construction takes in the interplate flow ports 30 of the left hand plate and the interplate flow ports 31 of the right hand plate.

Figs. 10, 10*a* and 10*b* are views showing the relation of the interplate flow spaces with respect to the porting arrangement of the plates. These views show only the porting arrangement for the upper half of the plate but of course the porting arrangement of the lower half of the plate may be substantially the same as that shown. In these views seven plates are shown, indicated as A, B, C, D, E, F and G, the corresponding interplate flow spaces being indicated by reference characters *a*, *b*, *c*, *d*, *e* and *f*. For the sake of clarity, the plate corrugations are not shown. The porting arrangement shown in these views provides for parallel flow of a fluid in one direction through three of the interplate flow spaces *b*, *d* and *f* and for parallel flow of a separate fluid in the opposite direction through the three interplate flow spaces *a*, *c*, and *e*. A fluid entering the set of plates at Y will flow downwardly through the interplate flow spaces *b*, *d* and *f* into the space between the corrugated portions of the plates and thence laterally along the aforesaid interplate flow spaces, escaping from the set of plates at the point X. The separate fluid entering the set of plates at Z will flow downwardly along the interplate flow spaces *a*, *c* and *e* into the space between the corrugated portions of the plates and thence to the left between the corrugated portions of the plates, leaving the set of plates at W.

As indicated above, this construction provides for parallel counterflow in opposite directions of the separate fluids. Many different flow arrangements may be secured by varying the porting arrangement. For instance, if plate C is made imperforate at the position Y, plate E made imperforate at the position Z, plate C made imperforate at the position W, and plate E made imperforate at position X, the flow of the fluids will be in series rather than in parallel. The fluid entering position Y will flow through the interplate flow space *b* to position X, thence through interplate flow space *d* back to position Y, and thence through interplate flow space *f* back to position X where it will leave the set of plates. The separate fluid entering position Z will flow through the interplate flow space *e* to position W, thence through interplate flow space *c* back to position Z, thence through interplate flow space *a* to position W where it leaves the set of plates.

For the sake of convenience in description, it may be assumed that the fluid entering at Y in Fig. 10*a*, leaving at X in Fig. 10, is raw milk, and that the fluid entering at Z in Fig. 10*b* and leaving at W in Fig. 10 is pasteurized milk. With this construction, it will be noted that the raw milk flows in the interplate flow spaces *b*, *d* and *f* and that the pasteurized milk flows through the interplate flow spaces *a*, *c* and *e* countercurrent to the flow of the raw milk. The port gaskets 44 at Y and X prevent the raw milk from escaping and entering the spaces *a*, *c* and *e* reserved for the pasteurized milk, and the port gaskets 44 at Z and W prevent the pasteurized milk from entering the flow spaces *b*, *d* and *f* reserved for the flow of the raw milk. The plate gasket constructions, including the gaskets 37 at Z and W, prevent the raw milk in the interplate flow spaces *b*, *d* and *f* from escaping from the flow space outlined by these gasket constructions. The plate gasket constructions, including the gaskets 37 at Y and X, prevent the pasteurized milk from escaping from the flow spaces *a*, *c* and *e* outlined by these gasket constructions.

In order to prevent any possibility of fluid seeping past both the port gasket construction and the plate gasket construction, the semioval port bosses are relieved, as indicated at 54 (Fig. 10) to provide gutters or drain channels along which any fluid escaping past either the port gasket or the plate gasket may drain off readily, thus preventing any possibility of leakage of a fluid past both gaskets which might result in raw milk being mixed with the pasteurized milk.

In the construction shown in Figs. 10, 10*a* and 10*b*, three passages in parallel are provided for the raw milk and three passages in parallel are provided for the pasteurized milk, the raw milk passages alternating with the passages of the pasteurized milk so that the flow may be made countercurrent. It will be apparent that many different flow circuits may be secured by varying the port arrangements. The transverse passage through the plates may be blocked off at any desired points simply by leaving the port embossments imperforate. It will be understood, of course, that the flow with respect to the upper ports of the set, indicated in Figs. 10, 10*a* and 10*b*, may be duplicated through the lower sets of ports.

In Figs. 11 to 18, inclusive, is shown a plate and gasket construction which may, in general, be used in place of that shown in Figs. 5 to 10*b*, inclusive, in the regenerative set 1. This construction comprises a set of sheet metal plates which may be termed gasket plates 65 having provisions on both faces for holding gaskets against displacement in planes parallel to the sheets, a set of plain plates 66 alternating and interspaced between the gasketed plates 65 and cooperating with the gasketed plates 65 to provide interplate flow spaces, a plate gasket construction 67 in general lying in grooves on the front side of the gasket plate, as viewed in Fig. 11, a plate gasket construction 68 in general lying in grooves on the rear face of the gasket plate of Fig. 11, port gaskets 69 at the ends of the gasket plates in general lying in grooves in the front side of the gasket plate 65, and port gaskets 70 adjacent the upper and lower edges of the gasket plates in general lying in grooves in the rear side of the gasket plate **65**. The front and rear plate gaskets **67** and **68** in general outline interplate flow spaces between the gasket plate and the front and rear plain plates, and the port gaskets **69** and **70** in general serve to provide for the flow of liquid through the gasket plate and an adjacent plain plate without allowing the liquid flowing through the port to enter the space between the two plates. Any desired arrangement of interplate flow space may be provided by suitably perforating the plates and providing suitable port gaskets.

In the construction shown (referring particularly to Figs. 13 to 16, inclusive), liquid may be caused to enter or leave the interplate space between the gasketed plate **65** and the front plain plate **66***a* through the laterally extending ports **71** adjacent an edge of the plate, as indicated by the arrow **71***a* (Figs. 13 and 16) and to leave or enter this interplate flow space through the laterally extending ports, adjacent the opposite side edge of the plates. Liquid may be caused to enter or leave the interplate flow space between the gasketed plate **65** and the rear plain plate **66** through the vertically extending ports **72** adjacent a side edge of the plates, as indicated by the arrow **73** (Figs. 14 and 15), and to leave or enter this interplate flow space through the vertically extending ports **71** adjacent the opposite side edge of the plates.

It will be noted that all of the gaskets **67**, **68**, **69**, and **70** lying between a gasket plate **65** and a plain plate **66** lie in the same general plane and that the front gasket construction **67** and the rear gasket construction **68** cross each other at the two points **74** and **75** on each corner, as indicated in Fig. 11*b*. This crossing of the gaskets necessitates a special construction, both in the gasket plate **65** and in the plain plate **66**, in order to prevent undue distortion of the gaskets and to insure tight joints. To take care of this crossing of the gaskets, the gasketed plate has portions of the front gasket channel bumped forwardly, as indicated at **76** (Figs. 11 and 17), to about half the depth of the gasket groove, so that the front gasket construction **67** will be pressed forwardly, as indicated in Fig. 17. In order to hold the rear gasket snugly up into the bumped-up portion **76** of the gasket plate, the rear plain plate **66** is provided with embossed portions **77** (Figs. 11*a* and 17) extending across the channel formed by the gasket engaging embossment **78**, these portions being deep enough to substantially half fill the channels of the embossments **78**. These portions **77** lie against the adjacent portions of the gasket **67** and hold them snugly against the bumped-up embossments **76** in the gasket plate **65**.

It will be seen that the portions **76** and **77** serve to deflect both the front gasket **67** and the rear gasket **68** at their crossing points, the gasket **67** being deflected to the right, as seen in Fig. 17, and the gasket **68** being deflected to the left.

Suitable spacer plates or frames **79** may be provided between the peripheral portions of the plates in order to prevent crushing and maintain the proper plate spacing. The plates may be provided with openings **80** at their opposite ends for the passage of the clamping rods **7**. In order to prevent crushing or distortion of the plates when clamped, the gasketed plate may be provided with a plurality of bumped-up portions **81** (Figs. 11, 13, 14, 15 and 16), which will engage and lie against the adjacent portions of the plain plates **66**. In order to prevent any liquid which may leak past the port gaskets from entering the space between the plates, drain constructions may be provided so that if any liquid does escape past one of the port gaskets, it will be drained out from between the plates rather than be forced past the plate gasket into the interplate flow space. It will be noted that the rear gasket **68** in general lies outside of the front gasket except those portions of the front gasket **67** which extend outwardly to embrace the ports. The rear gasket constructiton **68**, which may be termed the outer gasket construction, in general lies against the peripheral flange portion **82** of the plain plate **66**, and the front gasket construction **67**, which may be termed the inner gasket construction, in general lies against the ridge or embossment **83** formed in the plain plate. The main portions, both of the gasketed plates and of the plain plates lying between the plate gaskets, are corrugated in general substantially in the manner previously described, the corrugated portions of the gasketed plates lying in the same general plane as the gaskets of the corresponding plates.

Two somewhat different constructions are provided for draining the leakage past the port gaskets, one construction involving an embossment **84** in the plain plate (Figs. 11*a*, 14 and 15) and the other involving the provision of drainage partitions **85**, as shown in Fig. 13. Where the embossment **84** is used, it provides a channel between the gaskets **67** and **69**, as shown in Fig. 15, enabling any liquid escaping past the gasket to flow off between the plates to the outside of the flow spaces. Similarly, when the drainage partition **85** is used in Fig. 13, the channel **86** in the drainage partition enables any liquid escaping past the port gasket **70** to flow out through this channel **86** and escape from between the two plates without escaping past the plate gasket **68** into the interplate flow space.

Further modifications will be apparent to those skilled in the art and it is desired, therefore, that the invention be limited only by the prior art and the scope of the appended claims.

In the specification and claims where the terms "quadrant" and "quadrantal space" are used (referring to the plates), it is to be understood that the quadrants and quadrantal spaces are defined by a horizontal plane dividing the flow spaces equally, and a vertical plane dividing the flow spaces equally.

Having thus described my invention, what I claim and desire to secure by Letters Patent is:

1. A plate and gasket construction for use in a heat exchange apparatus of the juxtaposed plate type comprising a sheet metal heat exchange plate embossed to provide portions lying in offset parallel planes, a plate gasket for bounding the film flow space along a face of said plate, and a transfer port gasket bounding the liquid flow passage between a pair of film flow spaces, the rear face of said plate gasket lying against the front face of the rear one of said offset portions, the front face of said port gasket lying against the rear face of the front one of said offset portions, and at least a portion of each gasket lying between the parallel planes bounding said offset portions.

2. A plate and gasket construction for use in a heat exchange apparatus of the juxtaposed plate type comprising a sheet metal heat exchange plate embossed to provide portions lying in offset parallel planes, a plate gasket for bounding the film flow space along a face of said plate, and a transfer port gasket bounding the liquid flow pas-

sage between a pair of film flow spaces, one face of said plate gasket lying against the obverse face of one of said offset portions, one face of said port gasket lying against the reverse face of the other offset portion, at least a portion of each gasket lying between the parallel planes bounding said offset portions, adjacent portions of the two gaskets being held against lateral displacement by a portion of the plate connecting said offset portions.

3. A plate and gasket construction for use in a heat exchange apparatus of the juxtaposed plate type comprising a sheet metal heat exchange plate embossed to provide portions lying in offset parallel planes, a plate gasket for bounding the film flow space along a face of said plate, and a transfer port gasket bounding the liquid flow passage between a pair of film flow spaces, one face of said plate gasket lying against the obverse face of one of said offset portions, one face of said port gasket lying against the reverse face of the other offset portion, at least a portion of each gasket lying between the parallel planes bounding said offset portions, a portion of said plate gasket being held in place against lateral movement by engagement of the edge of the gasket with a portion of the plate connecting said offset portions.

4. A plate and gasket construction for use in a heat exchange apparatus of the juxtaposed plate type comprising a sheet metal heat exchange plate embossed to provide portions lying in offset parallel planes, a plate gasket for bounding the film flow space along a face of said plate, and a transfer port gasket bounding the liquid flow passage between a pair of film flow spaces, one face of said plate gasket lying against the obverse face of one of said offset portions, one face of said port gasket lying against the reverse face of the other offset portion, at least a portion of each gasket lying between the parallel planes bounding said offset portions, a portion of said port gasket being held in place against lateral movement by engagement of the edge of the gasket with a portion of the plate connecting said offset portions.

5. A plate and gasket construction for use in a heat exchange apparatus of the juxtaposed plate type comprising a sheet metal heat exchange plate embossed to provide portions lying in offset parallel planes, a plate gasket for bounding the film flow space along a face of said plate, and a transfer port gasket bounding the liquid flow passage between a pair of film flow spaces, one face of said plate gasket lying against the obverse face of one of said offset portions, one face of said port gasket lying against the reverse face of the other offset portion, at least a portion of each gasket lying between the parallel planes bounding said offset portions, a portion of said port gasket being held in place against lateral movement by engagement of the edge of the gasket with a portion of the plate connecting said offset portions, the opposite edge of said port gasket engaging a collar portion of the plate surrounding the port.

6. A plate and gasket construction for use in a heat exchange apparatus of the juxtaposed plate type comprising a sheet metal heat exchange plate embossed to provide portions lying in offset parallel planes, a plate gasket for bounding the film flow space along a face of said plate, and a transfer port gasket bounding the liquid flow passage between a pair of film flow spaces, the rear face of said plate gasket lying against the front face of the rear one of said offset portions, the front face of said plate gasket lying in front of the space between the parallel planes bounding both offset portions, the front face of said port gasket lying against the rear face of the front one of said offset portions, the opposite face of said port gasket lying in the rear of the space between the parallel planes bounding both offset portions, at least a portion of each gasket lying between the parallel planes bounding said offset portions.

7. A plate and gasket construction for use in a heat exchange apparatus of the juxtaposed plate type comprising a sheet metal heat exchange plate embossed to provide portions lying in offset parallel planes, a plate gasket for bounding the film flow space along a face of said plate, and a transfer port gasket bounding the liquid flow passage between a pair of film flow spaces, one face of said plate gasket lying against the obverse face of one of said offset portions, one face of said port gasket lying against the reverse face of the other offset portion, at least a portion of each gasket lying between the parallel planes bounding said offset portions, said plate being formed to provide a shoulder lying against the inner edge of said plate gasket throughout the major portion of the length of the gasket.

8. A plate and gasket construction for use in a heat exchange apparatus of the juxtaposed plate type comprising a sheet metal heat exchange plate embossed to provide portions lying in offset parallel planes, a plate gasket for bounding the film flow space along a face of said plate, and a transfer port gasket bounding the liquid flow passage between a pair of film flow spaces, one face of said plate gasket lying against the obverse face of one of said offset portions, one face of said port gasket lying against the reverse face of the other offset portion, at least a portion of each gasket lying between the parallel planes bounding said offset portions, said plate having its film flow space embossed to provide corrugations extending transversely of the film flow, said corrugations having their major portions lying between said planes.

9. A plate and gasket construction for use in a heat exchange apparatus of the juxtaposed plate type comprising a sheet metal heat exchange plate embossed to provide portions lying in offset parallel planes, a plate gasket for bounding the film flow space along a face of said plate, and a transfer port gasket bounding the liquid flow passage between a pair of film flow spaces, one face of said plate gasket lying against the obverse face of one of said offset portions, one face of said port gasket lying against the reverse face of the other offset portion, at least a portion of each gasket lying between the parallel planes bounding said offset portions, said plate being formed to provide a shoulder lying against the inner edge of said plate gasket throughout the major portion of the length of the gasket, and having its film flow space embossed to provide corrugations extending transversely of the film flow, said corrugations having their major portions lying between said planes.

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