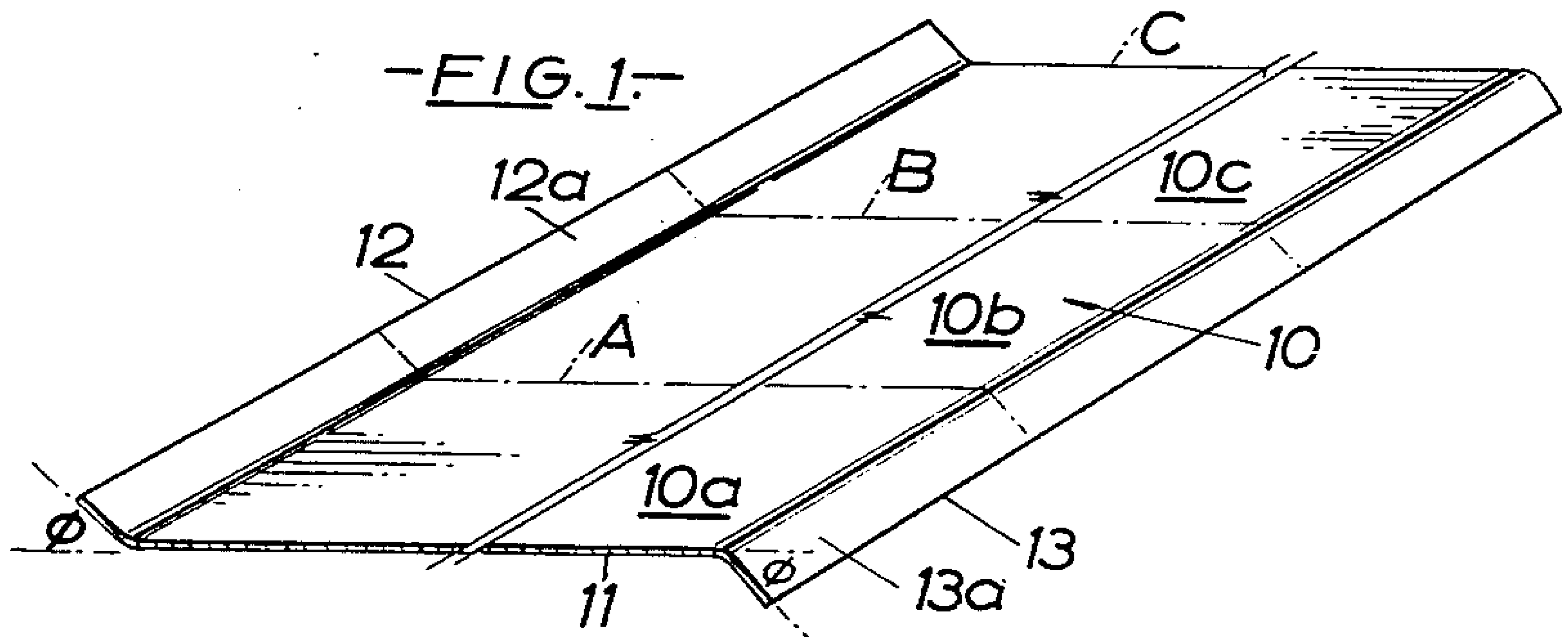
Sept. 20, 1960 G. ETHERIDGE 2,953,110

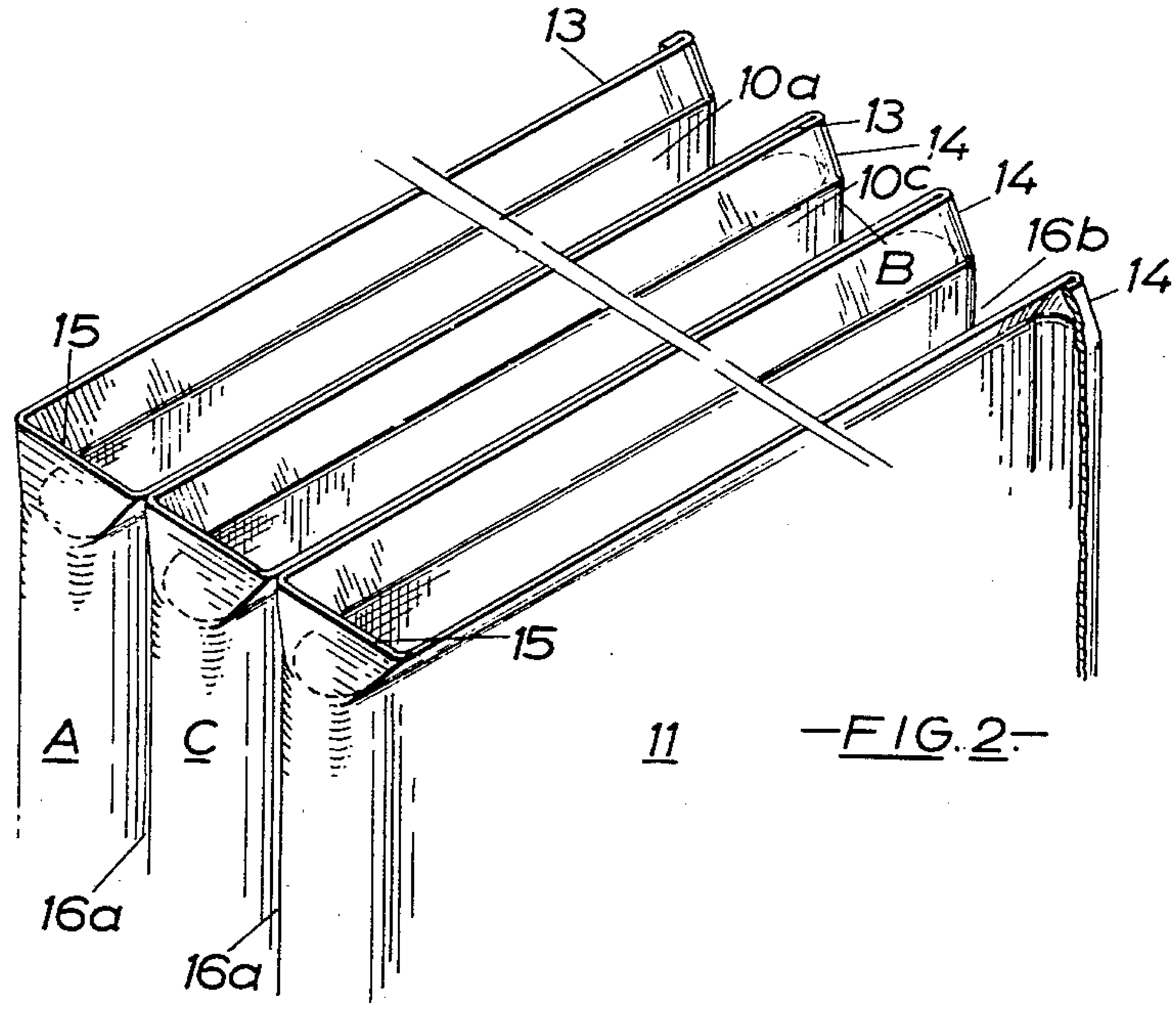
RECIPROCALLY FOLDED SHEET METAL STRUCTURES

Filed Jan. 18, 1955

4 Sheets-Sheet 1

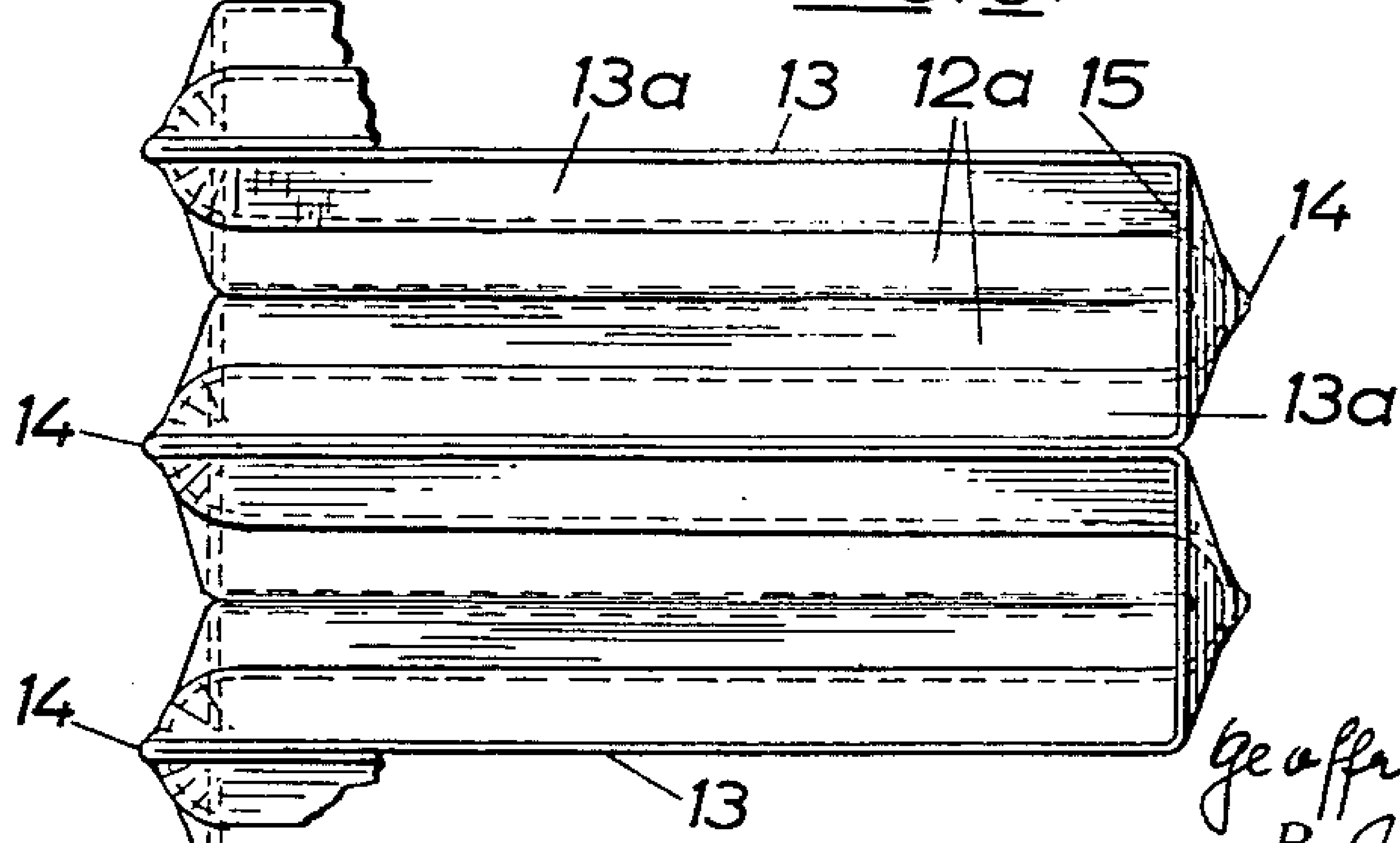
—FIG. 1—





—FIG. 2—

—FIG. 3—



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Filed Jan. 18, 1955 4 Sheets-Sheet 2

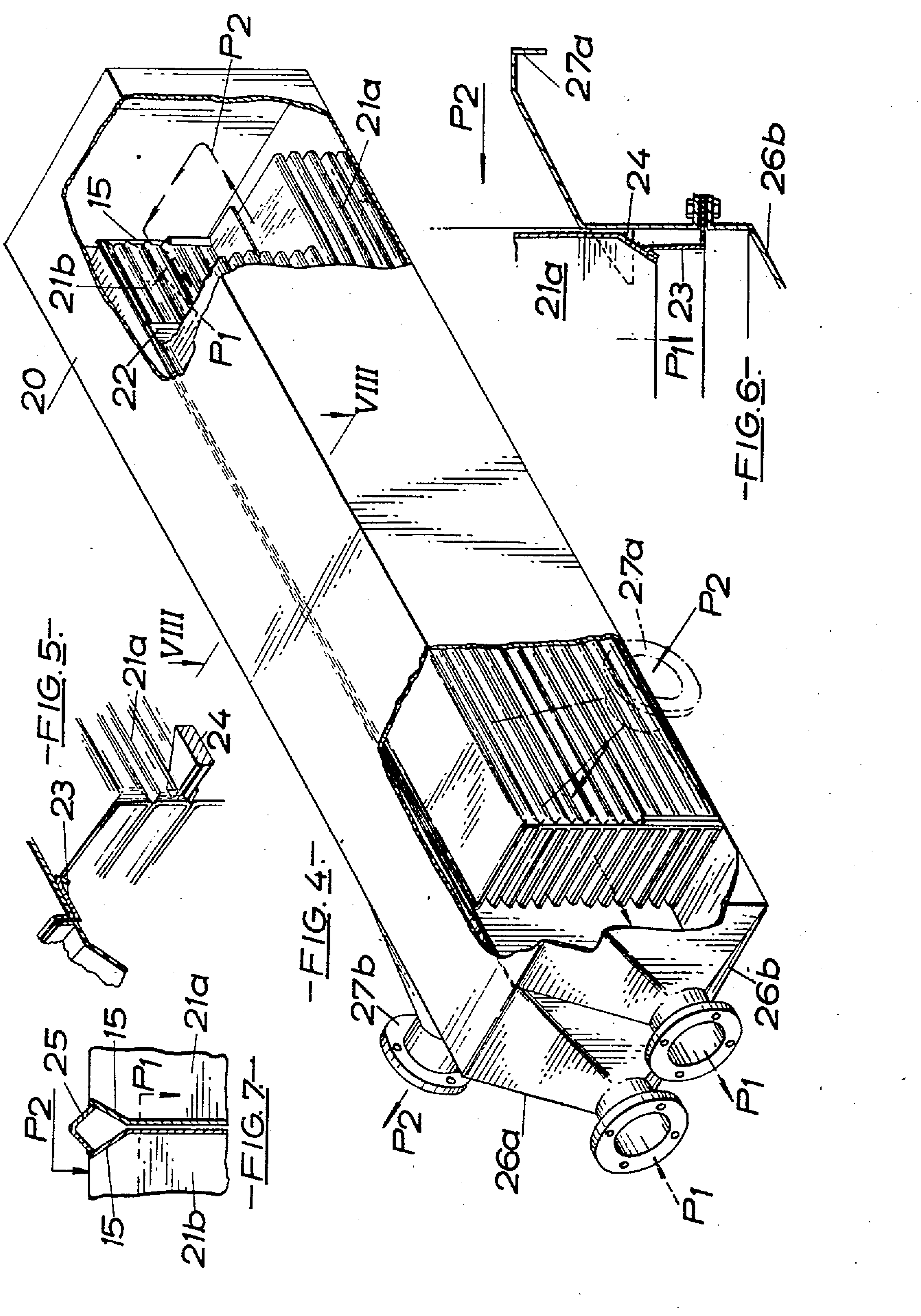

FIG. 4.

FIG. 5.

FIG. 6.

FIG. 7.

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RECIPROCALLY FOLDED SHEET METAL STRUCTURES

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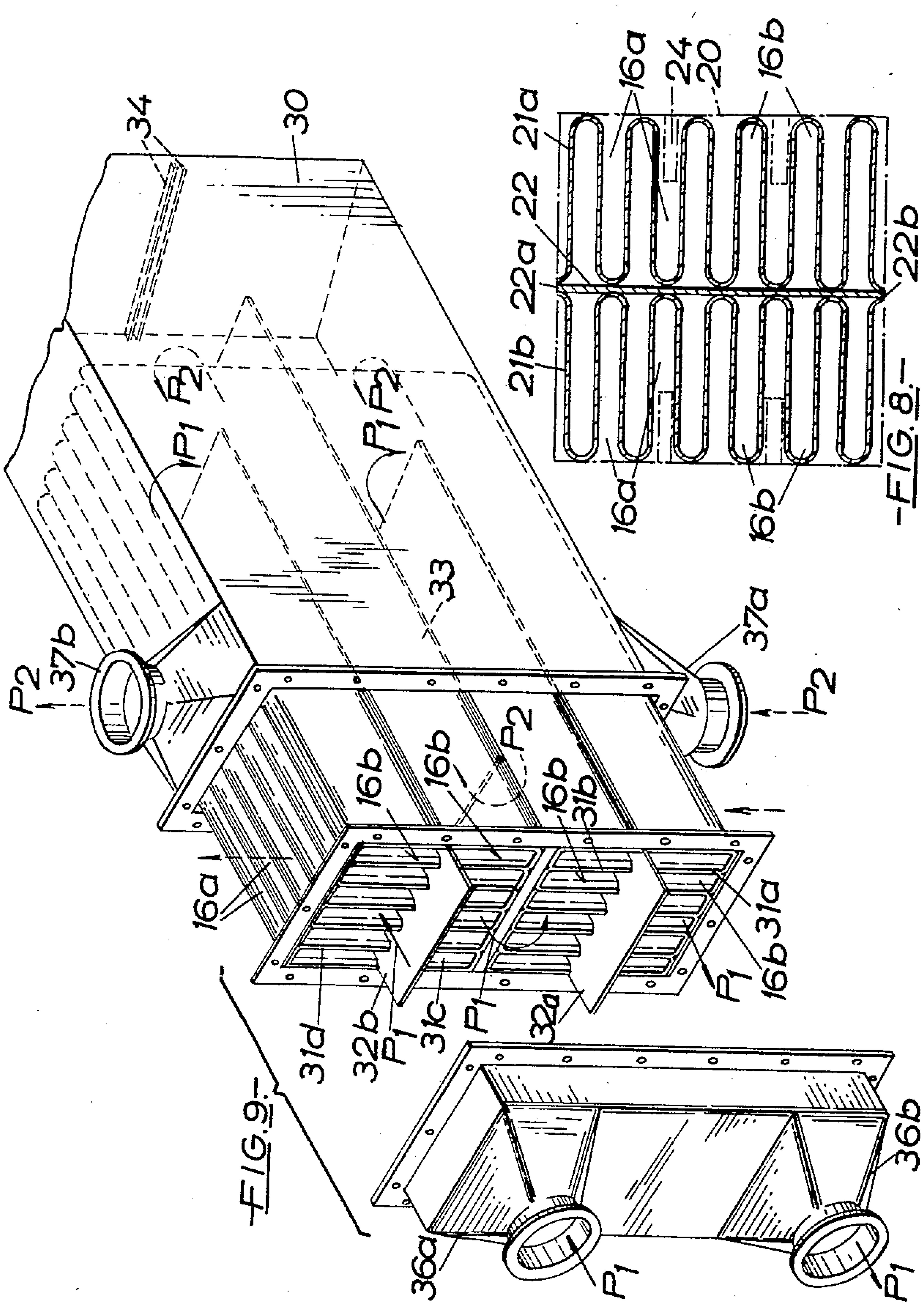

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RECIPROCALLY FOLDED SHEET METAL STRUCTURES

Filed Jan. 18, 1955

4 Sheets-Sheet 4

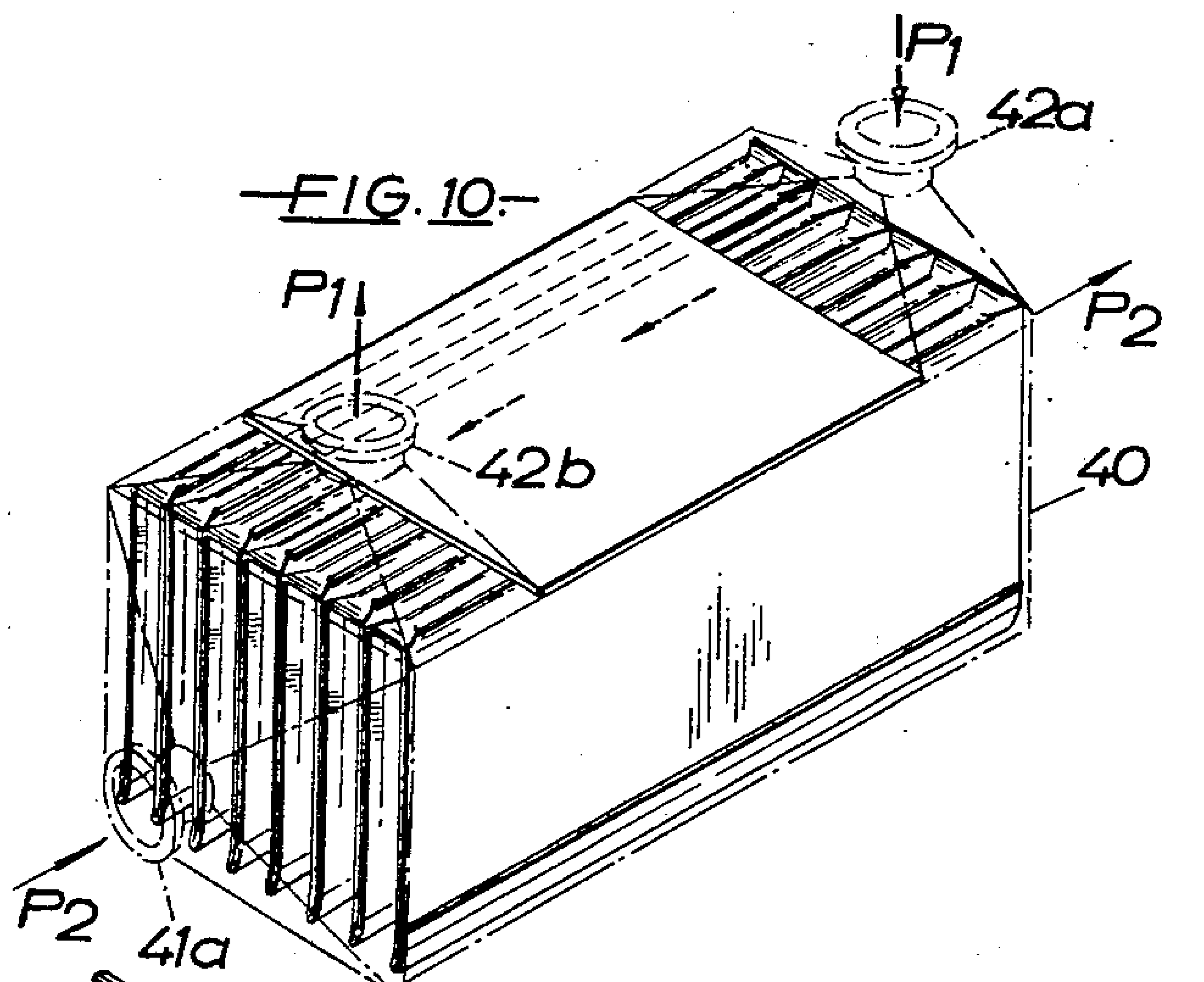

FIG. 10

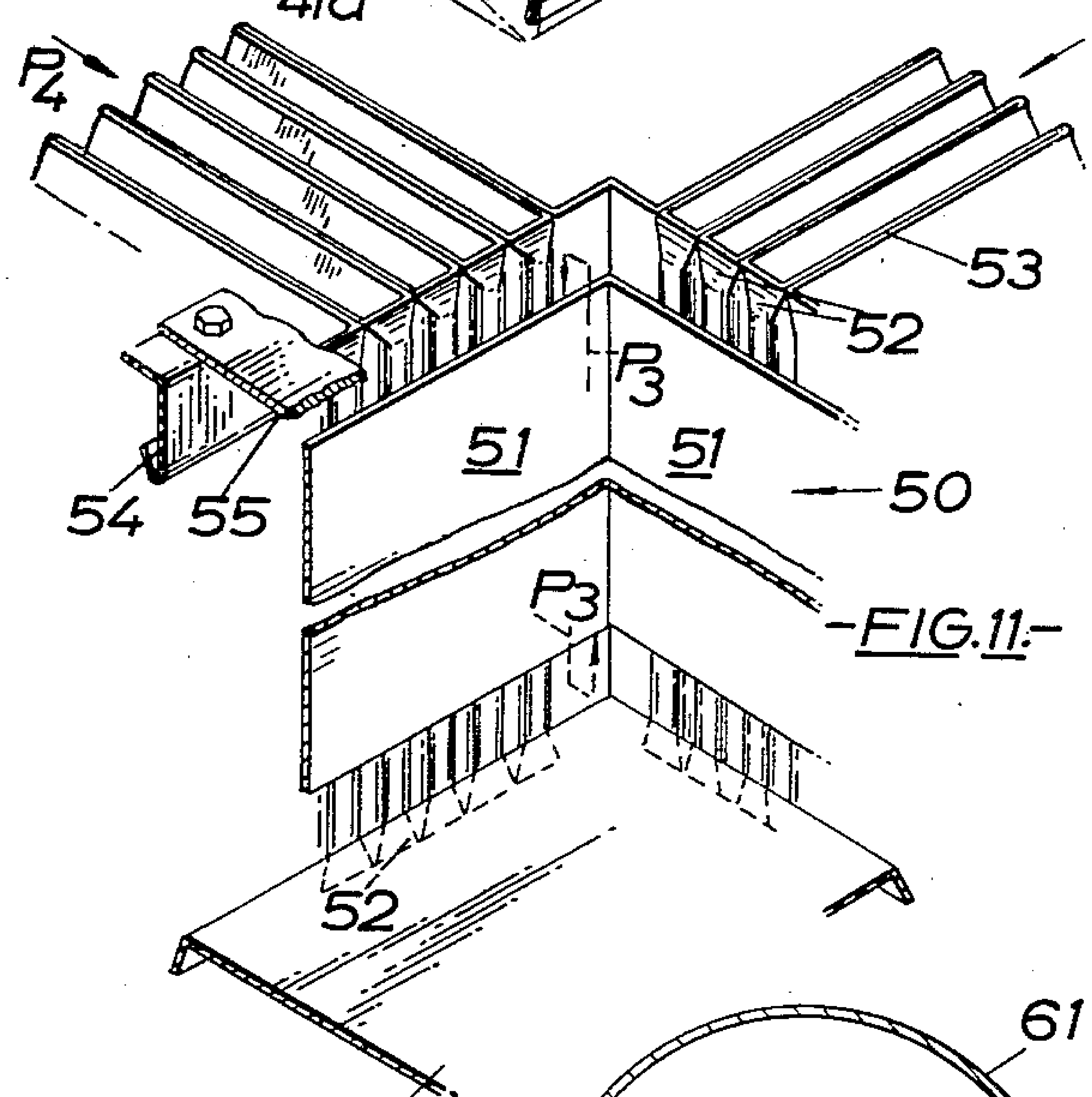

FIG. 11

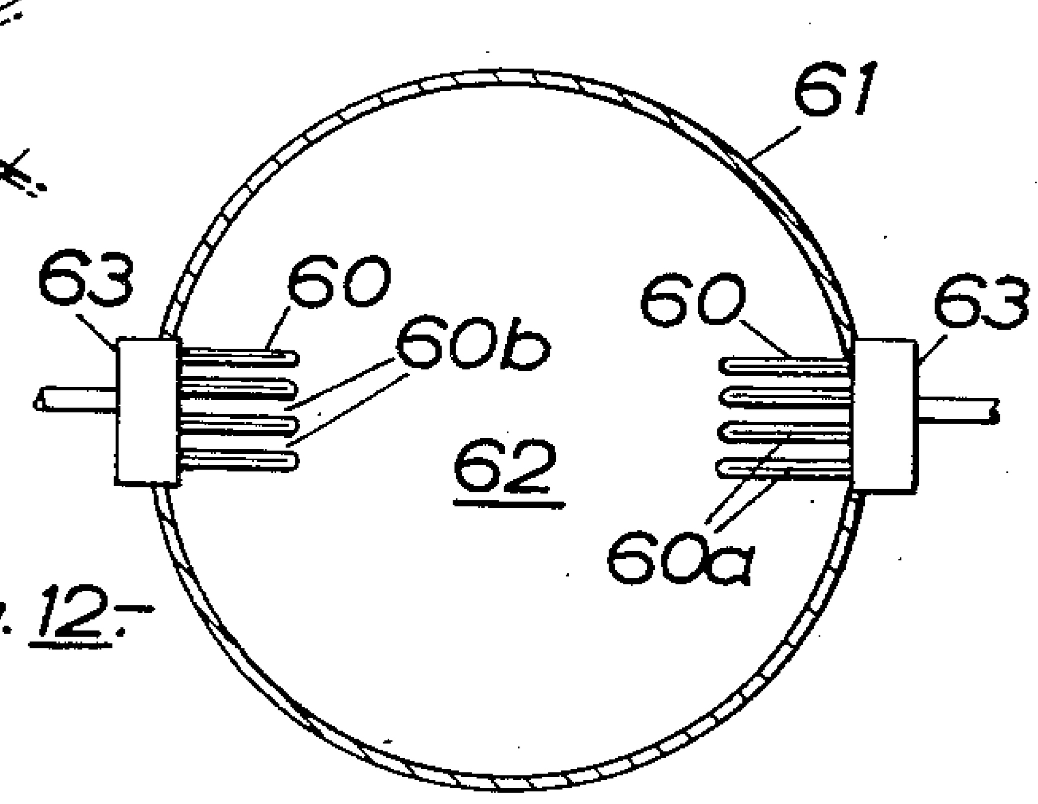

FIG. 12

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RECIPROCALLY FOLDED SHEET METAL STRUCTURES

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2 Claims. (Cl. 113—118)

The present invention concerns sheet metal structures, such as heat exchangers for effecting transfer of heat between two separated bodies of fluid, which include or consist of reciprocally folded sheets.

It has previously been the practice to close or seal the ends of reciprocally folded sheets by attachment thereto of a closure member, for instance a plate insert secured by welding; or alternately by clinching over the end regions so as to form smaller units which can be sealed separately.

An object of the present invention is to provide an improved end closure for such folded sheet metal portions, which enables their ready incorporation in a heat exchange installation.

Another object is to provide a construction which is especially suitable for incorporation in a container adapted to enclose a heated liquid and to be cooled by heat transfer to air or to another liquid surrounding such container which may for example be constituted by the tank of an electrical transformer.

According to the present invention a heat exchanger has two sets of interlaced contraflow passages, a plurality of mutually parallel wall portions formed by reciprocal folding of a piece of sheet metal transversely between its side edges, the side edge regions of successive pairs of wall portions being set over towards and substantially in contact with one another with the thus contiguous edges sealed together by metal fusion to form a passage end closure, each pair of adjacent wall portions thereby constituting a transversely open heat exchange passage.

The set may be of the order of 50° at a distance from the edge depending upon this angle and upon the desired width of flow passage.

For containers such as transformer or switch-gear tanks in which a liquid is required to dissipate its heat to air surrounding the container, the sets in the sheets, before folding, are arranged in the same direction relative to the plane containing the central or unset portion thereof, that is to say they are both to the same face of the sheet. The result of this is to provide a similar closure of both side edges of each pair of folded wall portions, thereby forming closed pockets.

If, however, a heat exchanger is required for contraflow action between two gases, or for other purposes where symmetrically closed pockets are unsuitable, it may be preferable to impart these sets in opposite directions, whereby after folding the contiguous edges of adjacent wall portions are staggered alternately at opposite side edges of the reciprocally folded portion.

The treatment of the set portions around the 180° or other reciprocal bend will depend upon whether at that bend the set is in an inward or in an outward direction. If inward, the set portion may be bent round sharply by nipping, or a natural sharp bend may be used and the region may be bent around a mandrel of circular or other appropriate shape to avoid excessive curvature or stress. On the other hand, when the

flanging is outwardly directed at the bends the excess length of the edge may be shaped to leave the edge portion in the region of the bend lying at 90° to the adjacent contiguous edges.

For transformer casings or other containers for liquids the cover or base of the container to be sealed or joined to the ends of the reciprocally folded sheet metal portion may be bolted to a flange welded to the mutually parallel wall portions along the line of outwardly set bends lying, as described above, at 90° to the contiguous joined edges.

With these and other objects in view which will become apparent in the following detailed description, the present invention will be clearly understood in connection with the accompanying drawings, in which:

Figure 1 is a perspective view of part of a rectangular metal sheet having set edge regions substantially parallel one to the other and indicating the fold regions;

Fig. 2 is a perspective view of part of a folded metal sheet showing the end closures;

Fig. 3 is a plan corresponding to Fig. 2;

Fig. 4 is a perspective view of a heat exchange installation, the outer casing being broken away to expose its internal structure of mirror image folded metal sheets the set edge regions of which are as shown in Figs. 1 and 2;

Fig. 5 is a detail showing the flanging for sealing the folded metal sheet structure in the casing; and also a wedge-shaped supporting piece;

Fig. 6 is another detail of the flanging showing a connection between it and the outer casing;

Fig. 7 is a detail of an end closure between the mirror image folded metal sheets;

Fig. 8 is a section taken on the line VIII—VIII of Fig. 4;

Fig. 9 is a perspective view, with the front end of the casing displaced for clarity, of a heat exchange installation having an internal structure comprising double mirror image folded metal sheets; the set edge regions of which are as shown in Figs. 1 and 2;

Fig. 10 is a perspective view of a heat exchange installation showing a folded metal sheet internal structure the set edge regions of which are to the same face of the sheet;

Fig. 11 is a perspective view of part of the wall structure of a transformer tank including a folded metal sheet wall portion the set edge regions of which are to the same face of the sheet; and

Fig. 12 is a plan view of a tank the walls of which are fitted with one or more heating or cooling elements formed of a folded metal sheet the set edge regions of which are to the same face of the sheet.

Referring now to the drawings, and in particular to Fig. 1, a rectangular metal sheet has an upper surface **10** and an under surface **11**. A preliminary set is given to one edge region **12***a* of the sheet **10**, **11** by bending it adjacent and parallel to a first side edge **12** through an acute angle ϕ in an upward direction. Similarly a preliminary set is given to an opposite edge region **13***a*, of the sheet **10**, **11** by bending it adjacent and parallel to a second side edge **13** through an acute angle ϕ in a downward direction. The sheet is then successively folded alternately in opposite directions through approximately 180° about equally spaced fold regions A, B, C, . . . etc., which extend transversely between the edges **12** and **13** of the sheet.

The folding of the flat portion of the sheets may be effected in a conventional folding machine. The set edges, which are outside the folding tool limits, assume a curved contour at the fold regions which are shaped in the manner described hereunder.

Wall portions **10***a*, **10***b*, **10***c* etc., are thus formed and the side edges **12** or **13** of each alternate pair of adjacent wall portions are substantially contiguous and can now be united by welding, brazing or other suitable process of metal fusion without the use of filler pieces.

At the 180° bends, inwardly directed set portions **14** of edge regions **13***a* are bent round sharply by nipping or a natural sharp bend may be used and the region **14** may be bent around a mandrel of circular or other appropriate shape to avoid excessive curvature or stress. The excess lengths of the outwardly directed set portions at the 180° bends, are shaped to leave the edge portion **15** of the edge regions **13***a* lying at 90° to the adjacent contiguous edges **12** or **13**.

The edge portions **15** are thus substantially in one plane thus facilitating the attachment, by welding, of a metal strip such as a flange.

Passages **16***a* are thus formed having fluid-tight joints at one of their ends and openings at their other ends and these passages **16***a* are interlaced with passages **16***b* which have fluid-tight joints at the ends adjacent the open ends of passages **16***a* and openings at their other ends.

The sets of both edge regions **12** and **13** may, however, be to the same face of the sheet and the resulting passages **16***a* have fluid-tight joints at both ends, these passages **16***a* being interlaced with passages **16***b* which are open at both ends.

The folded metal structure, hereinafter referred to as a "pack," which is described above can be incorporated in a heat exchange installation of the type diagrammatically illustrated in Figs. 4 to 8 which utilizes two mirror image packs. Two packs **21***a* and **21***b* are provided with a continuous flange **23** disposed about the four peripheral side edges of the combined packs and attached thereto by welding; a dividing wall **22** separates the two packs **21***a* and **21***b* along the major part of their length. A return portion of the flange **23** is bolted or otherwise secured to a casing **20** as shown in Fig. 6, gaskets being provided between the casing and the flange as required. The packs are not attached to the shell except by way of the flange, in order to allow for expansion along their length. Wedge shaped support members **24** are provided on the casing **20** which project into the transverse openings of the fluid passages, these support members being provided at intervals along the length of the casing. At the free floating end of the packs a connecting means is provided consisting of a sheet metal angle **25** welded to the adjacent edge portions **15** of the two packs as shown in Fig. 7 thereby preventing the intermingling of the two fluid systems; such a metal angle is slightly deformable to ensure sealing between the two packs. The upper ends of both metal sheets are welded at **22***a* to the dividing wall **22** and the lower ends of both metal sheets are similarly welded thereto at **22***b*. Alternate passages **16***a* and **16***b* are isolated from each other but similar passages **16***a* and **16***b* of the two packs **21***a* and **21***b* are connected to each other.

Entrance nozzle **26***a* and exit nozzle **26***b* are provided for a higher pressure fluid **P1**. Similarly entrance and exit nozzles **27***a* and **27***b* respectively are provided for a lower pressure fluid **P2**.

The higher pressure fluid **P1** enters the pack through nozzle **26***a* and passes into alternate passages **16***b* of pack **21***b*. As these passages are closed at their other extremities and the dividing wall **22** stops short of such extremities the fluid **P1** passes into corresponding passages **16***b* of pack **21***a* and from thence out of the casing by way of exit nozzle **26***b*. The lower pressure fluid **P2** enters the casing at nozzle **27***a* and passes into alternate passages **16***a* of pack **21***a*. These passages **16***a* are open at the free floating extremities of the pack and the fluid **P2** is guided by the back wall of the casing **20** and is diverted into corresponding passages **16***a* of pack **21***b* and from there out of the casing by way of exit nozzle **27***b*.

Fluid **P1** and fluid **P2** enter and leave the packs substantially at right angles but once inside the fluid flows

in their respective interfaced passages are parallel and in opposite directions.

Fig. 9 shows how a double mirror image pack, similar to the mirror image pack shown in Figs. 4 to 8, can be assembled. Mirror image packs **31***a* and **31***b* are separated by dividing wall **32***a* and packs **31***c* and **31***d* are separated by dividing wall **32***b*. These two sets of mirror image packs are separated by dividing wall **33**. The packs are secured to a casing **30** in the same manner as that described for the embodiment shown in Figs. 4 to 8, the isolation of the alternate fluid passages and also the free floating end closure between the two mirror image packs being performed substantially in the same manner.

The higher pressure fluid **P1** enters at nozzle **36***a* and passes into alternate passages **16***b* of pack **31***d*. The free floating extremities of these passages **16***b* being closed and as the dividing plate **32***b* is curtailed in this region, the fluid **P1** passes into corresponding alternate passages **16***b* of pack **31***d*; at the nozzle end of the pack **31***c* the fluid passes through the open ends of passages **16***b* striking the front wall and being diverted into the corresponding open ends of the alternate passages **16***b* of pack **31***b*. A similar operation now takes place for the flow of fluid through the alternate passages **16***b* of packs **31***b* and **31***a*, the fluid **P1** finally emerging from the casing through nozzle **36***b*.

The lower pressure fluid **P2** enters the casing **30** at nozzle **37***a* and passes into alternate passages **16***a* of pack **31***a*. The alternate passages **16***a* are open at the free floating extremities of the packs **31***a* and **31***b* and the fluid **P2** thus strikes the back wall of the casing **30** and is diverted into corresponding passages **16***a* of pack **31***b*. The dividing wall **33** is supported in guides **34** on the internal back wall of the casing thus preventing fluid **P2** from by-passing alternate passages **16***a* of pack **31***b*. The dividing wall **33** is however curtailed at the nozzle end of the casing to allow fluid **P2** to pass into alternate passages **16***a* of pack **31***c*; these alternate passages **16***a* of packs **31***c* and **31***d* are closed at the nozzle end of the casing and a similar operation now takes place for the flow of fluid through the alternate passages **16***a* of packs **31***c* and **31***d*, the fluid **P2** finally emerging from the casing through nozzle **37***b*.

As in the example illustrated in Figs. 4 to 8 the paths of the two fluids **P1** and **P2** in their respective interlaced passages are always substantially parallel and in opposite directions to each other.

Fig. 10 illustrates diagrammatically a further embodiment of a heat exchange installation in which the pack is formed from a folded metal sheet, the set edge regions of which are to the same face of the sheet, whereby one set of passages have fluid-tight joints at both ends formed by the set edges, these passages being interlaced with passages which are open at both ends.

A container **40** is provided with an entrance nozzle **41***a* at one end and an exit nozzle (not shown) at the opposite end for a low pressure fluid **P2**. One side wall of the container has an entrance nozzle **42***a* and an exit nozzle **42***b* for a higher pressure fluid **P1**.

Low pressure fluid **P2** is admitted through nozzle **41***a*, passes through the open ended passages and is discharged at the opposite end of the container **40** through the exit nozzle (not shown). The higher pressure fluid **P1** is admitted to the closed ended passages by way of nozzle **42***a* and is discharged at nozzle **42***b*. The two fluids are thus admitted to their respective interlaced passages at right angles to each other and the two fluid flows within their respective passages are parallel and in opposite directions.

Reciprocally folded metal sheets having set edges to the same face of the sheet, forming a plurality of mutually parallel wall portions and having end closures of the type previously described may be used to form part of a transformer wall, the mutually parallel wall portions projecting outwardly from the transformer container **50** as shown diagrammatically in Fig. 11. Partition walls or baffle plates **51** can be welded to some of the interiorly disposed bends of the mutually parallel wall portions. A flange **54** is welded to both the upper and lower edge portions **52** of ther mutually parallel wall portions, which edge portions, as previously described, are substantially in one plane and are shaped to lie at 90° to the adjacent contiguous edges **53**. A cover **55** and a base **56** may now be bolted to the return part of flange **54** as shown. The baffle plates **51** are curtailed both at the top and the bottom leaving a gap in these regions between them and the upper and lower flanges, **54**.

Cooling air **P4** may enter the open ended flow passages from below and has a straight run through. Hot circulating oil **P3** from the transformer container **50** enters the closed ended passages through the gap between the top of the baffle plate **51** and the upper flange **54**, as shown by the broken arrow. The oil **P3** is cooled by the air **P4** and falls down to the bottom of the closed ended passages whilst the air is heated and rises to the top of the open ended passages. The cooled oil **P3** re-enters the container **50** between the gap formed between the lower edge of the partition wall at the lower flange **54**. The directions of entry of the two fluids into their respective interlaced passages are thus at right-angles to each other and the two flows within their respective passages are parallel and in opposite directions.

A folded metal structure of this type may also be used for vessel heating or cooling purposes as shown diagrammatically in Fig. 12. Mutually parallel wall portions **60**, formed in the same manner as described for the embodiment shown in Fig. 11, form part of a vessel wall **61** and are directed toward the interior **62** of such a vessel. Open-ended passages **60*b*** are interlaced with closed-ended passages **60*a***, which latter convey heat from a heating source **63**, the walls of these passages thus forming the heating elements.

When used for heating a hot fluid enters the closed-ended passages **60*a*** horizontally and is conveyed downwardly along these passages. Cold fluid, in the interior **62** of the vessel, due to the transfer of heat through the walls to the passages **60*b***, moves upwardly along the open-ended passages **60*b***. The two fluids enter their respective passages at substantially right angles and the two fluid flows in their respective passages are parallel and in opposite directions.

I have disclosed several embodiments of the present invention, it is to be understood that these embodiments are given by example only and not in a limiting sense, the scope of the present invention being determined by the objects and the claims.

I claim:

1. In a method of making a heat exchanger having a front and a rear, from a rectangular metal sheet having a first edge and an opposite second edge, the steps of bending a first edge region of said metal sheet adjacent and parallel to said first edge through an acute angle, bending a second edge region of said metal sheet adjacent and parallel to said second edge through an acute angle, and successively folding said metal sheet alternately in opposite directions through about 180° along substantially equally spaced fold regions extending transversely between said first and second edges into a succession of mutually parallel wall portions spaced apart at a distance, whereby the edges of alternate pairs of said wall portions are brought into abutting relationship to form contiguous edges thereof and to deform simultaneously said contiguous edges into a curved portion at the rear of said heat exchanger, forming said contiguous edges into a substantially straight line at the front of said heat exchanger, the straight line of said contiguous edges of all said wall portions being disposed in one continous straight line along the front of said heat exchanger, and metal fusing said contiguous edges in order to produce a series of substantially fluid-tight parallel heat exchange passages.

2. The method of making a heat exchanger, as set forth in claim 1, wherein said step of forming said contiguous edges into a substantially straight line is performed in a manner to arrange said straight line at an angle of about 90° to said parallel wall portions.

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