Dec. 20, 1966 KEIICHI KIMURA 3,292,689

PLATEFIN-TYPE HEAT EXCHANGER AND METHOD OF MAKING SAME

Filed July 7, 1964 5 Sheets-Sheet 1

Fig 1

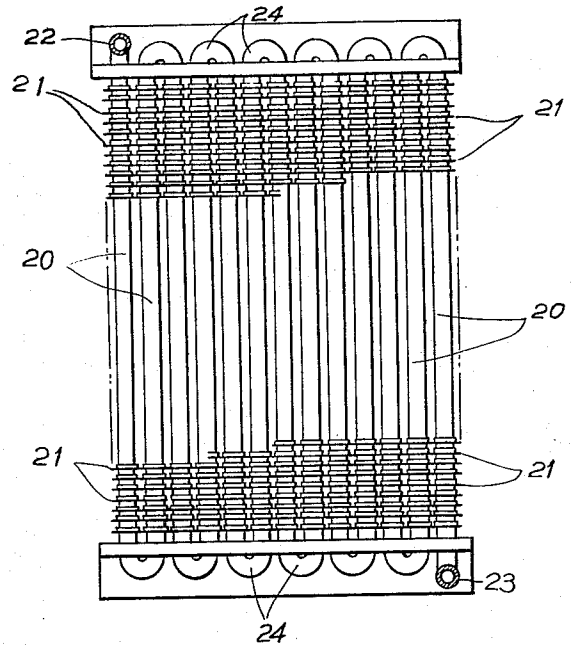


Fig 2

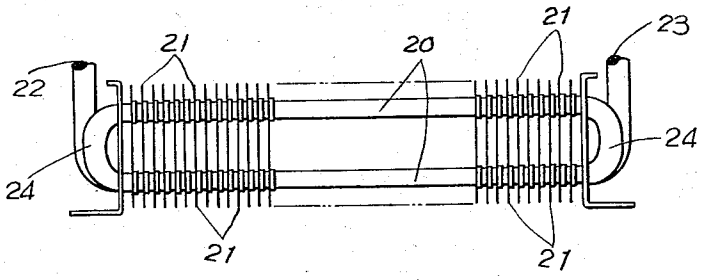
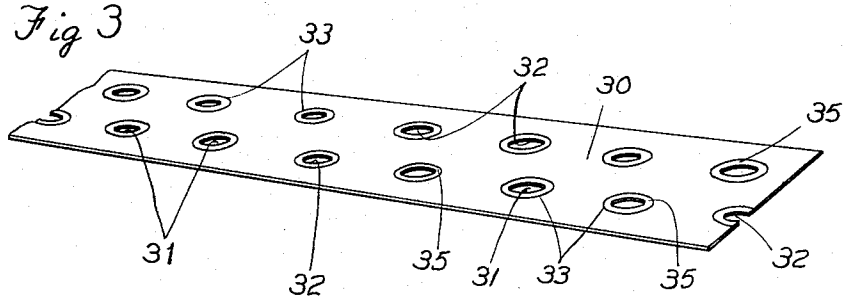


Fig 3



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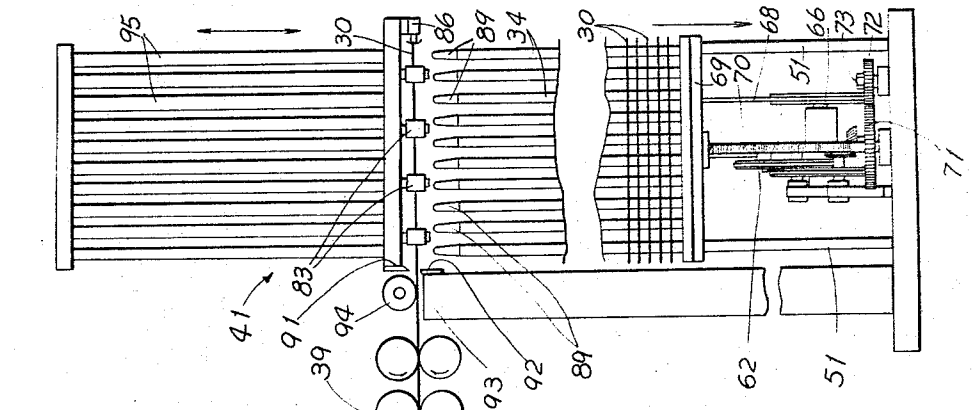
BY Keiichi Kimura

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McGlew and Toren
ATTORNEYS

Dec. 20, 1966 KEIICHI KIMURA 3,292,689

PLATEFIN-TYPE HEAT EXCHANGER AND METHOD OF MAKING SAME

Filed July 7, 1964 5 Sheets-Sheet 2



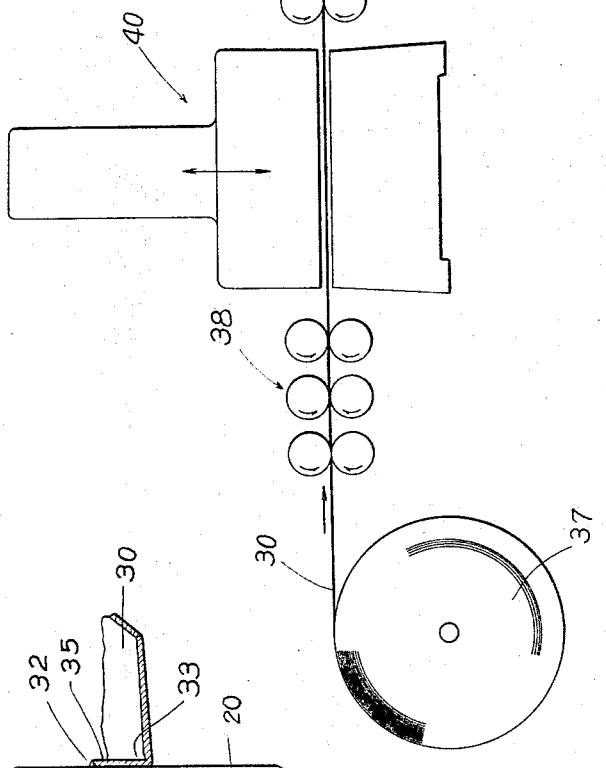


Fig 5

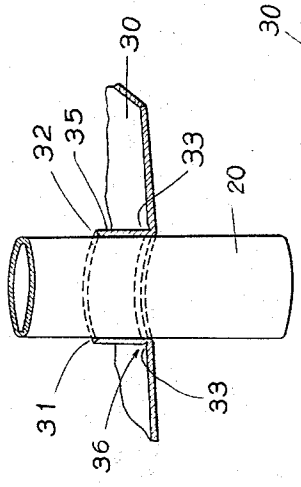


Fig 4

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PLATEFIN-TYPE HEAT EXCHANGER AND METHOD OF MAKING SAME

Filed July 7, 1964 5 Sheets-Sheet 3

Fig 6

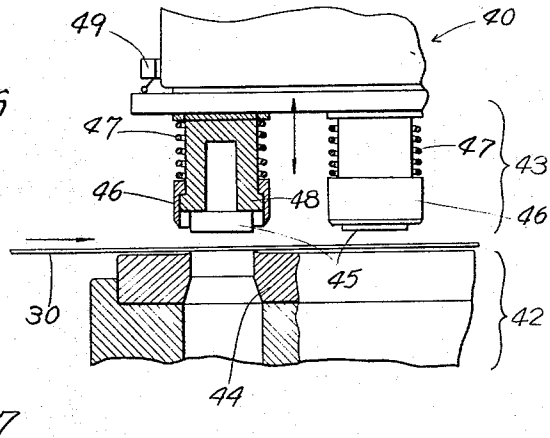
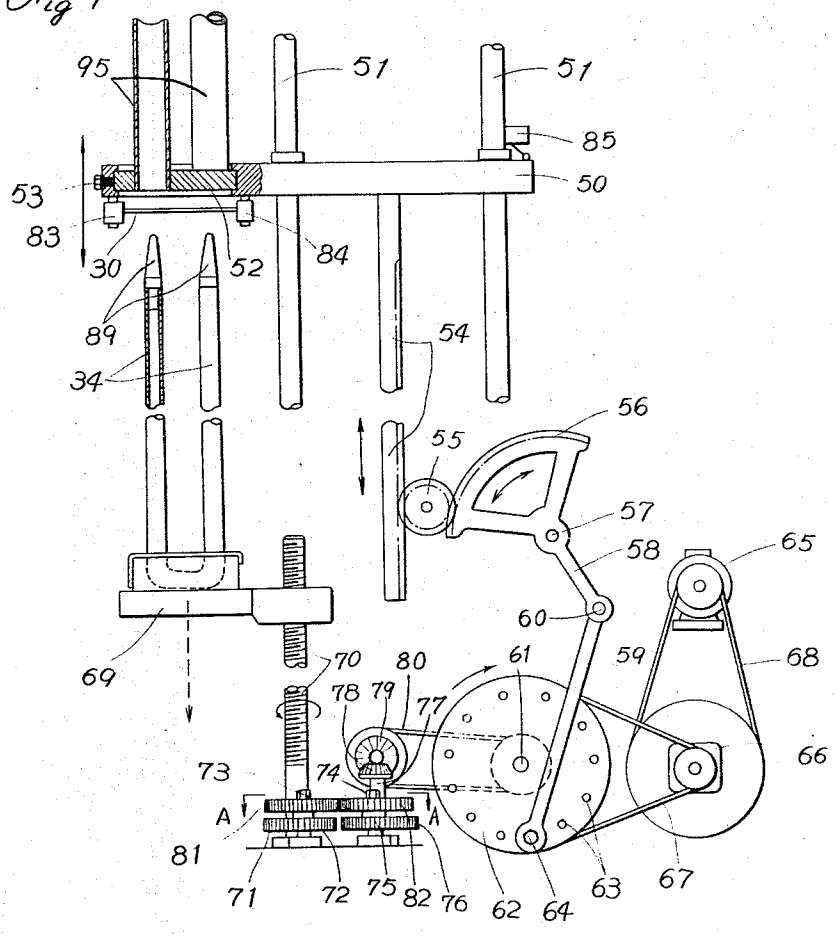


Fig 7



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PLATEFIN-TYPE HEAT EXCHANGER AND METHOD OF MAKING SAME

Filed July 7, 1964 5 Sheets-Sheet 4

Fig 8

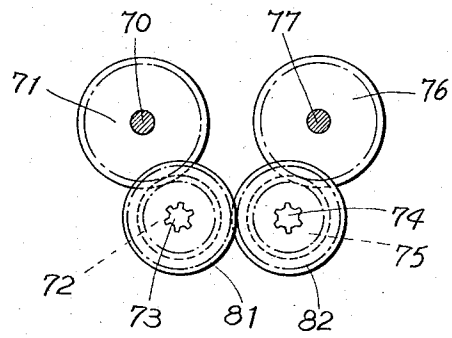


Fig 9

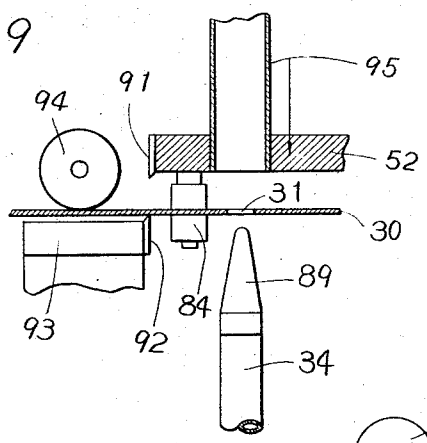
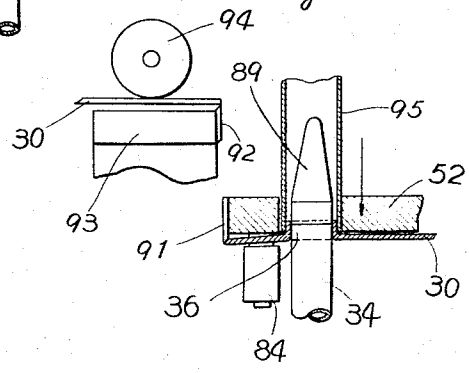


Fig 10



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Dec. 20, 1966 KEIICHI KIMURA 3,292,689

PLATEFIN-TYPE HEAT EXCHANGER AND METHOD OF MAKING SAME

Filed July 7, 1964 5 Sheets-Sheet 5

Fig 11

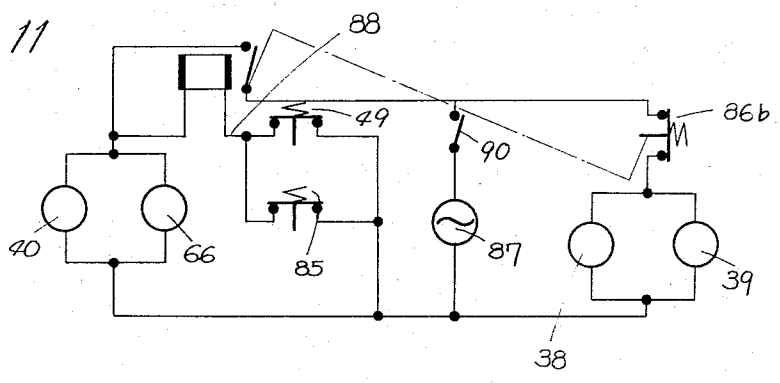


Fig 12

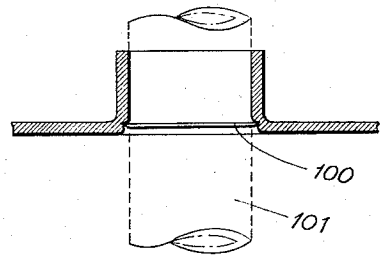
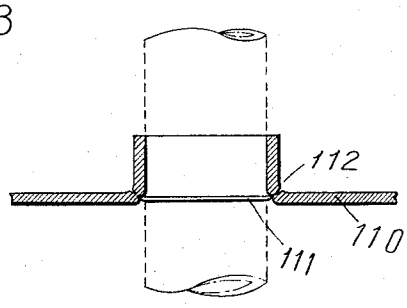


Fig 13



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PLATEFIN-TYPE HEAT EXCHANGER AND METHOD OF MAKING SAME

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Filed July 7, 1964, Ser. No. 380,776
5 Claims. (Cl. 165—151)

This invention relates to the method of manufacturing plate fin-type heat exchangers. More particularly, the invention pertains to a heat exchanger of the type having a plurality of spaced parallel plate fins mounted on a plurality of fluid conduit tubes or pipes.

It is one object of the present invention to provide a heat exchanger having a maximum heat exchanging area.

Another object of the invention is to provide a heat exchanger having the fluid conduit tubes mounted in the openings of the plate fins, which openings are smaller in diameter than the fluid conduit tubes.

A further object of the invention is to provide a heat exchanger having annular flanges or walls as heat transfer areas, said flanges being formed when the fluid conduit tubes are mounted in the openings of the fin plates.

A still further object of the invention is to provide a heat exchanger of the above character which is easy and simple in construction and yet remarkably efficient in operation and inexpensive of manufacture.

Other objects and specific features of the invention will become apparent in view of the following:

According to the principles of the present invention, the above objects and specific features are accomplished by mounting the fin plates on the fluid conduit tubes or pipes in such a manner that said fluid conduit tubes are tightly engaged in position by means of the flanges which are formed around the body of the tubes during the course of said mounting operation.

In more detail, there are provided, in each of the plates to be employed as fins constituting the heat exchange core of the present invention, a plurality of openings, each of which is smaller in diameter than the fluid conduit tubes to be mounted therein. There are further provided on each of said plates a plurality of folding lines or cuts, each of which is concentric with said openings and has a diameter substantially equal to that of the fluid conduit tubes.

Each of the plates thus prepared is engaged one by one with the fluid conduit tubes by mounting in such a manner that each of the peripheral portions of the openings is forced by the driving force applied to the plate to turn upward along the line demarcated by the folding cuts, whereby there is formed a cylindrical flange around each of the bodies of the fluid conduit tubes, tightly engaging in position said tubes and forming a maximum heat transfer area.

A fuller understanding of the present invention may be made by referring to the following description of some preferred typical embodiments of the principles of the present invention illustrated in the accompanying drawings, in which:

FIG. 1 is a front view, partly removed, of a heat exchanger embodying the principles of the invention;

FIG. 2 is a side elevation view of FIGURE 1, rotated 90°;

FIG. 3 is a magnified perspective view of a plate, partly removed, to be employed as a fin constituting the heat exchanger of FIGURE 1;

FIG. 4 is a magnified perspective view, partly removed, showing a manner of mounting the plate on a fluid conduit tube;

FIG. 5 is a schematic front view showing the assembly line embodying the principles of the invention;

FIG. 6 is a magnified front view, partly removed and partly in section of the forming press employed in the assembly line shown in FIGURE 5;

FIG. 7 is a side elevation, partly removed and partly in section, showing a mode of mounting the plates on the fluid conduit tubes;

FIG. 8 is an enlarged cross sectional view taken along the line A—A of FIGURE 7;

FIG. 9 and 10 are schematic front views illustrating the mode of mounting a plate fin on a fluid conduit pipe respectively.

FIG. 11 is a schematic diagram showing an electric circuit connecting the integral parts of the assembly line of FIGURE 5;

FIGURES 12 and 13 are magnified sectional views, partly removed, showing modified modes of mounting a plate on a fluid conduit tube in line with the principles of the invention.

Referring now to the drawings, there is shown in FIGURE 1 a heat exchanger of the present invention having spaced heat conductive fins **21** transversely mounted on spaced parallel fluid conduit tubes **20** with one end **22** serving as a fluid intake member and the other end **23** as a fluid outlet member, said fluid conduit tubes **20** being further connected with one another by means of end connections **24**.

What is inventive in this connection is the mode of mounting the cooling fins **21** on the fluid conduit tubes **20**. According to the principles of the invention, there is provided in a plate **30** to be employed as a fin a plurality of openings **31** having an internal diameter smaller than the external diameter of the fluid conduit tubes **20** to be mounted therein, said openings being formed at predetermined spaced interval by means of a forming press **40** as shown in FIGS. 3, 5 and 6.

There is further provided on said plate **30** a plurality of annular folding lines or cuts **33**, each of which is concentric with a respective one of said openings **31** and has an internal diameter substantially equal to the external diameter of the fluid conduit tubes **20**, said annular cuts **33** being formed by means of said forming press **40** simultaneously with the forming of openings **31** so as to provide an annular portion or section **35** surrounding the openings **31**. Each of the plates **30** thus prepared is then engaged one by one with the fluid conduit tubes **20** by mounting in such a manner that each of the annular portions **35** is forced by the longitudinal driving force applied to the plate **30** to turn upward along the folding lines **33**, whereby there are formed upturned cylindrical flanges **36**, as shown in FIG. 4, around each of the bodies of the fluid conduit tubes **20**, tightly engaging said tubes in position and forming a maximum heat transfer area.

In FIGURE 5 is shown the assembly line employed in association with the present invention, mainly consisting of sheet plate supply roll **37**, forming press **40** and mounting device **41**. The sheet plate **30** is first supplied to the forming press **40** by means of feed rolls **38** to be punched and demarcated with folding cuts in accordance with the principles of this invention, and the sheet plate thus prepared is fed into the mounting device **41** by means of feed rolls **39**, guide roll **94**, and other guide rolls **83** and **84** serving as a means to prevent lateral displacement of said sheet plate. Then the sheet plate driving table **52** (FIG. 7) constituting the mounting device **41** is energized to drive downward the punched sheet plate, whereby the sheet is cut into given size and shape, and mounted on the fluid conduit tubes **34** parallelly erected in position on the conduit tube support **69**.

The forming press **40** employed in the present invention is shown in FIGURE 6, mainly comprising a bed **42** having a plurality of dies **44**, and a movable frame **43** having

a plurality of punches **45** in a position facing said dies **44**, said dies **44** being spaced at predetermined distances in accordance with the desired arrangement or construction of the fluid conduit tubes **34** constituting the heat exchanger of the present invention. Members **46** are folding line cutters, each of which is provided with an inturned top flange **46***a* which is, when idle, movably pressed by a helical spring **47** onto the shoulder **48** of the punch holder **45***a*. Said dies **44**, punches **45** and folding line cutters **46** are of a size predetermined in association with the desired construction of the heat exchanger of this invention.

The construction of the mounting device **41** is shown in FIGURE 7, mainly comprising plate driving frame **50**, fluid conduit support **69** and driving motor **65**. In more detail, there is secured to one end of said plate driving frame **50** a plate driving table **52** by means of a bolt **53**. At right angle to said plate driving table **52** and passing therethrough, there are erected spaced parallel cylindrical guides **95** for passing therethrough fluid conduit tubes **34**. Plate guide members **83** and **84** are provided underneath plate driving frame **50**.

The plate driving frame **50** is further adapted to make a reciprocal movement, upward and downward, along guide shafts **51** by means of a rack **54** which is disposed substantially parallel to said guide shafts **51** and is associated via pinion **55** with a segment gear **56** which is adapted to be oscillated by integral lever **58** about fulcrum **57**. Lever **58** is pivotally connected by pin **60** with a link **59** having one end movably and selectively connected by means of a bolt **64** to one of the openings **63** spaced at predetermined distances along the peripheral portion of the pulley **62**. Pulley **62** is fixed to a shaft **61** and is driven by the shaft of the driving motor **65** via reduction belt **67**, magnetic control clutch **66** and another reduction belt **68**.

Member **69** is a fluid conduit tube support which is threadedly engaged with a screw shaft **70**, the downward longitudinal movement of said support **69** being controlled by a guide shaft (not shown) extending at right angles to support **69**. Screw shaft **70** is connected with a spline shaft **73** by means of gears **71** and **72**. Another spline shaft **74** in which is positioned in parallel to spline shaft **73**, is connected with the pulley shaft **61** via gears **75** and **76**, spindle **77**, bevel gears **78** and **79**, and belt **80**. Gears **81** and **82** are replaceably engaged with said spline shafts **73** and **74** and so adapted as to selectively control the transmission ratio of the movement of the pulley **62**. A changeover switch **85** is operated when the plate driving frame **50** reaches the upper limit of its reciprocal movement or stroke, and another change-over switch **86** is operated when the forward end of the punched plate **30** comes into contact therewith. Plate cutters **91** and **92** are shown in FIG. 5. Cutter **91** is fixed to one end of the plate driving frame **50** and the other cutter **92** is fixed to the top end portion of the supporter **93** in a position facing said cutter **91**.

In FIGURE 11 is shown a mode of electrical connection of the present embodiment. Transfer rolls **38** and **39** are connected in parallel with each other in association with the power source **87** via the contact **86***b* of the change-over switch **86**, said contact **86***b* being normally closed by means of a spring. The forming press **40** and the electromagnetic control clutch **66** are also joined in parallel in association with the power source **87** via the contact **86***a* of the change-over switch **86**, said contact **86***a* being normally open by means of a spring. Circuit **88** is a maintenance circuit of the contacting point **86***a* including parallel change-over switches **49** and **85** which are normally closed by a spring respectively. At **90** is indicated a hand switch.

The assembly line thus constructed operates in the following manners:

Fluid conduit tubes **34** are erected on the fluid conduit tube support **69** in complete agreement with the spacing of the dies **44** and punches **45** of the forming press **40**, each of the top ends of said fluid conduit tubes **34** being protected with a tapered cap **89**. When the hand switch **90** is closed, the transfer rolls **38** and **39** are energized to feed, at a predetermined constant velocity, the punched portion of the plate **30** into the plate driving frame via guide roll **94** and supporter **93** and then guide rolls **83** and **84**. Incidentally the initial portion of said plate **30** is punched by operating the punch forming press **40** by hand. When the forward end of said plate **30** abuts against the change-over switch **86**, the switch **86** closes the contact **86***a* and opens the contact **86***b*, interrupting the transferring operation of the transfer rolls **38** and **39**, and allowing the forming press **40** to make punching operation by one stroke via the electromagnetic control clutch **66**. During the operation of said stroke, the electromagnetic control clutch **66** also operates so that the rotating movement of the driving motor **65** is transmitted to the screw shaft **70** via pulley **62**, belt **80**, bevel gears **79** and **78**, shaft **77**, and gears **76**, **75**, **82**, **81**, **72** and **71** to adjust the position of the fluid conduit tube support **69**.

The rotating movement of the driving motor **65**, on the other hand, is transferred to the plate driving frame **50** via pulley **62**, link **59**, lever **58**, segment gear **56**, pinion **55** and rack **54**, allowing the frame **50** to make a downward drive, whereby the punched portion of the plate **30** is cut into a desired size by means of cutters **91**, and **92** and the portion thus cut away is further driven downward until said cut plate is mounted as a fin at the predetermined space intervals on the fluid conduit tubes **34**, allowing the caps **89** and the bodies of said tubes **34** to pass through the openings of said cut plate and into the cylindrical guide shafts **95**, whereby the plate is tightly engaged as a fin with the bodies of the fluid conduit tubes **34** in such a manner as shown in FIGURE 4 by means of cylindrical flanges formed by the peripheral portions surrounding the openings **31**, which portions are forced to turn upward by the driving force applied to the plate.

When the sheet plate driving table **52** reaches the lowest limit of its drive, the motion of frame **50** is reversed so that it moves upwardly, releasing the fin **30** from the contact with the change-over switch **86**, whereas both of contacts **86***a* and **86***b* are maintained at the former operating position by means of the maintenance circuit **88** until the plate driving frame **50** reaches the upper limit of its reciprocal movement. At the same time, the fluid conduit tube support **69** and accordingly the fluid conduit tubes **34** are gradually shifted downward by the constant rotating action of the screw shaft **70**, and the sheet plate **30** fed into the forming press **40** is punched and demarcated with folding lines by means of dies **44**, punches **45** and folding line cutters **46** provide the plate with concentric openings and folding lines for mounting therein fluid conduit tubes **34**, the groove cutter **46** being so adapted as not to cut through the plate in association with the helical spring **47**. When the pressing operation of the forming press **40** is finished and the plate driving frame **50** reaches the upper limit of its reciprocal movement, the change-over switches **49** and **85** operate again to release the contacts **86***a* and to close the contact **86***b* so as to convert the entire system to the next stroke of mounting operation, wherein the transfer rolls **38** and **39** are again energized to feed a fresh portion of the plate **30** into the forming press **40** the punched portion of the plate **30** into the plate driving frame **50**. When the forward end of the punched portion of the plate **30** thus comes into contact with the changeover switch **86**, said switch operates again to start a second mounting operation as described hereinbefore.

The fin mounted on the fluid tubes **34** by said second mounting operation, however, is spaced a distance higher than the first fin mounted by the first mounting operation, because the position of the fluid conduit tube support **69** and according that of the fluid conduit tubes **34** are shifted downward at a synchronized ratio by the constant rotating

movement of the screw shaft **70**. The desired heat exchanger shown in FIGURE 1 is thus obtained by repeating said punching and mounting operations stroke by stroke. Namely, upon completion of the mounting operation, the resultant fabric is removed from the support **69** by manually opening the switch **90**, and subjected to further finishing treatments, such as taking off the tapered caps **89**, associating the conduit tubes **34** by means of connecting pipes, and the like. The empty support **69** is restored to the starting position by a reversible means, not shown. The spacing ratio of the fins can be varied by changing the rotating velocity of the screw shaft **70** by replacing the gears **81** and **82** with new ones having the desired gearing ratio.

In view of the foregoing, it may be apparent that the plate fin-type heat exchanger of the present invention can be constructed in an easy and a simple manner with markedly improved heat exchanging efficiency. For the major principle of this invention comprises merely mounting heat conductive tubes in the openings provided in the plates, each of said openings being further provided with a concentric peripheral portion which is demarcated with a folding line or cut substantially equal in diameter with the body of the conductive tubes, so that there is erected in tight engagement with each of the conductive tubes an annular flange which is integral not only with the resultant plate fin but substantially with the body of the conductive tubes.

According to the principles of the invention, it is most profitable to carry out the folding line demarcating, punching and mounting operations on an assembly line as shown hereinbefore.

But these operations may also be performed by hand either one by one or in combination as the case may permit.

Furthermore, folding lines **33** may be formed either on the top surface of the plate as shown in FIG. 4 or on the bottom surface of the plate as shown in FIG. 12 at **100**. In the latter case, particularly, it is possible to connect the plate and fluid conduit tubes with less amount of force than in the former case. Alternatively, said folding lines **33** may be formed on both surfaces of the plate as shown in FIG. 13 at **111** and **112**, in which case the connection of the plate and fluid conduit tubes can be effected with minimum amount of force.

Instead of the annular folding cuts employed in the present invention, there may further be employed shaped folding cuts with the same improved effects as described hereinbefore.

While the present invention has been shown and described in association with the preferred embodiments hereinbefore it is to be understood that the same is not so limited but shall cover and include any and all modifications of the invention which fall within the scope thereof.

I claim:

1. A plate-fin heat exchanger comprising, in combination, a plurality of spaced, substantially parallel, heat exchanging plate-fins mounted on plural substantially parallel fluid conduit tubes; each tube extending through a respective opening in each plate-fin and being tightly embraced by a one-piece cylindrical flange which encircles the tube and extends from the surface of each plate concentric with the respective opening; each cylindrial flange extending from a circular depression in at least one surface of the associated plate, the circular depression being concentric with the associated opening and having a diameter substantially equal to the outer diameter of the tube extending through the associated opening.

2. A method of constructing a plate-fin heat exchanger of the type having plural spaced substantially parallel heat exchanging plate-fins mounted on plural substantially parallel fluid conduits, said method comprising the steps of forming plural openings in the plates to be used as fins, each opening having a diameter of appreciably less than that of the fluid conduit to be extended therethrough; forming, in at least one surface of each plate, plural circular depressions each concentric with a respective opening and each having a diameter substantially equal to the outside diameter of a fluid conduit to be extended through the associated opening, whereby to demarcate, between the periphery of each opening and the associated depression, an annular zone of the associated plate; and forcing fluid conduits through said plates in substantially coaxial alignment with each opening to deform said annular zones out of the planes of the plates to form substantially cylindrical flanges tightly engaging the tubes extending through the associated openings.

3. The method of constructing a plate fin heat exchanger as claimed in claim **2**, wherein said depressions are formed in one surface of the plates and the fluid conduit tubes are mounted into the openings from said one surface.

4. The method of constructing a plate fin heat exchanger as claimed in claim **2**, wherein said depressions are formed in one surface of the plates and the fluid conduit tubes are mounted into the openings from the opposite surface.

5. The method of constructing a plate fin heat exchanger as claimed in claim **2**, wherein said depressions are formed in both surfaces of the plates and the fluid conduit tubes are mounted into the openings from one of said surfaces.

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