United States Patent

Albright et al.

[15] **3,645,330**

[45] **Feb. 29, 1972**

[54] FIN FOR A REVERSIBLE HEAT EXCHANGER

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[52] **U.S. Cl.** **165/151**, 165/181

[51] **Int. Cl.** **F28d 1/00**

[58] **Field of Search** 165/151–153, 181, 165/182

[56] **References Cited**

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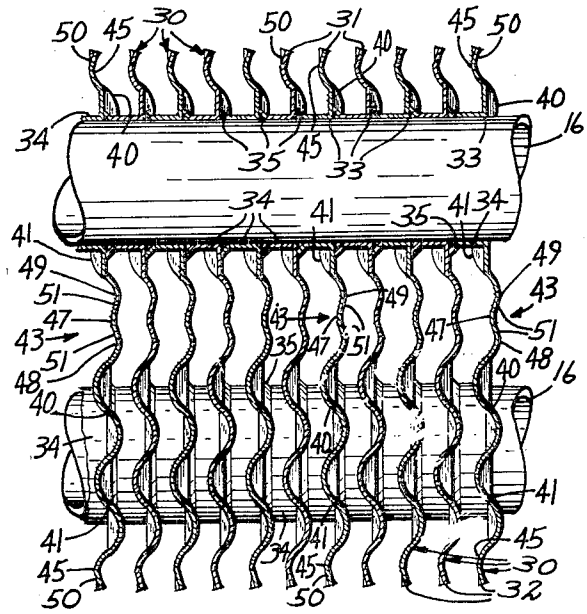
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[57] **ABSTRACT**

A sheet of material defining a pair of parallel opposed edges adapted to be positioned generally transverse to the direction of airflow through the exchanger, said sheet of material having a plurality of corrugations therein extending parallel to the edges and a plurality of openings therethrough for receiving fluid conduits therein, and a portion of said sheet of material adjacent said opposed edges extending at an angle, relative to a plane including the sheet of material, greater than zero and less than 45°, such that for any given set of conditions for the heat exchanger (including rate of airflow, number of fins per inch, etc.) the exchanger is reversible in the airflow, without inflicting a loss in the heat transfer or an increase in the pressure differential across the exchanger, and the air deflection at the outlet of the exchanger is approximately zero in either direction.

9 Claims, 9 Drawing Figures



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SHEET 1 OF 2

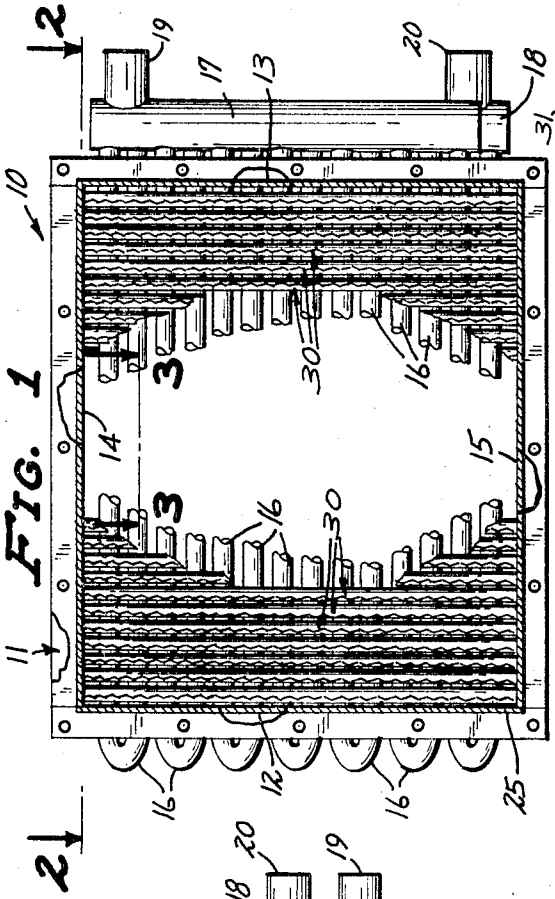


FIG. 1

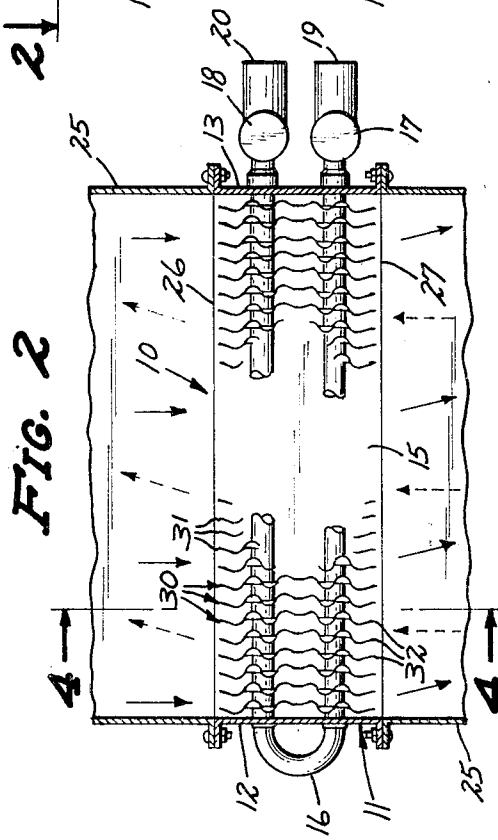


FIG. 2

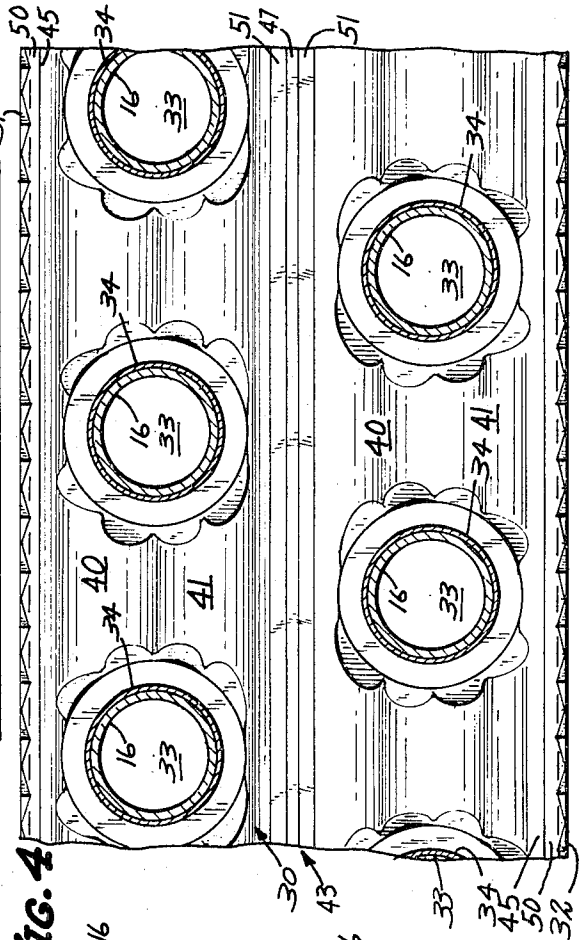


FIG. 4

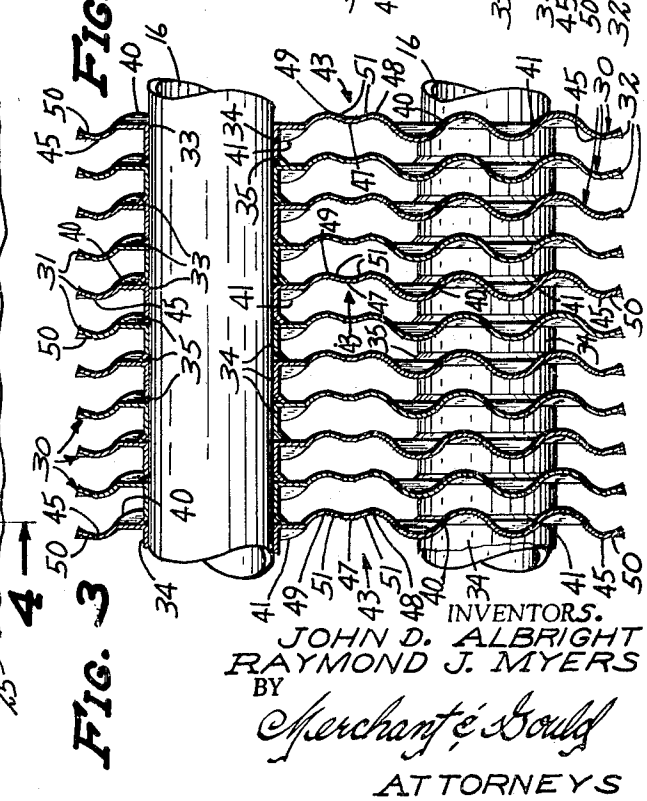


FIG. 3

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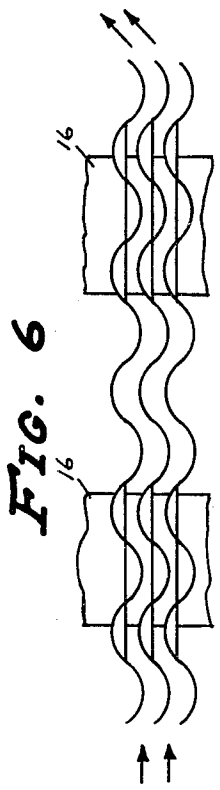


FIG. 6

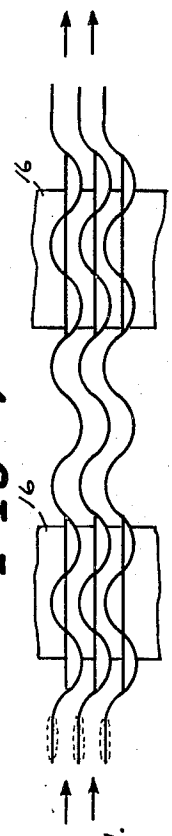


FIG. 7

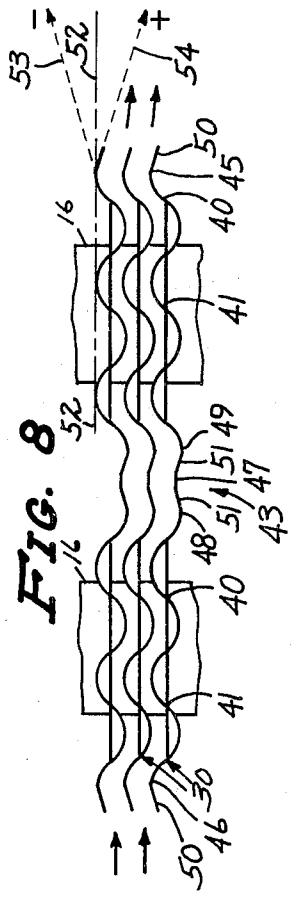


FIG. 8

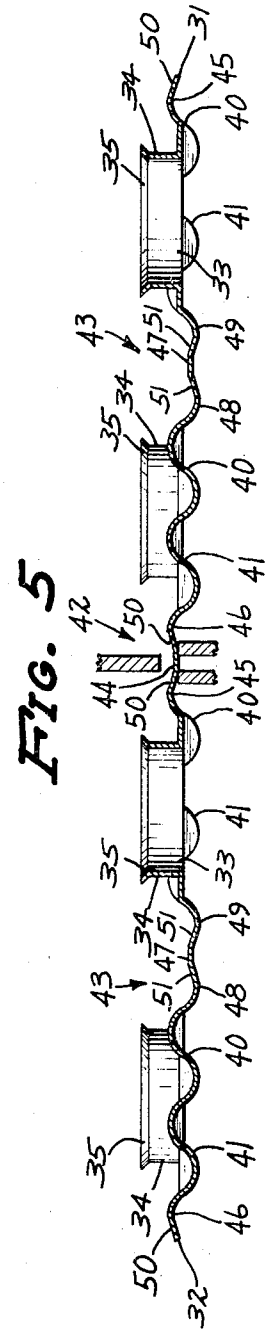


FIG. 5

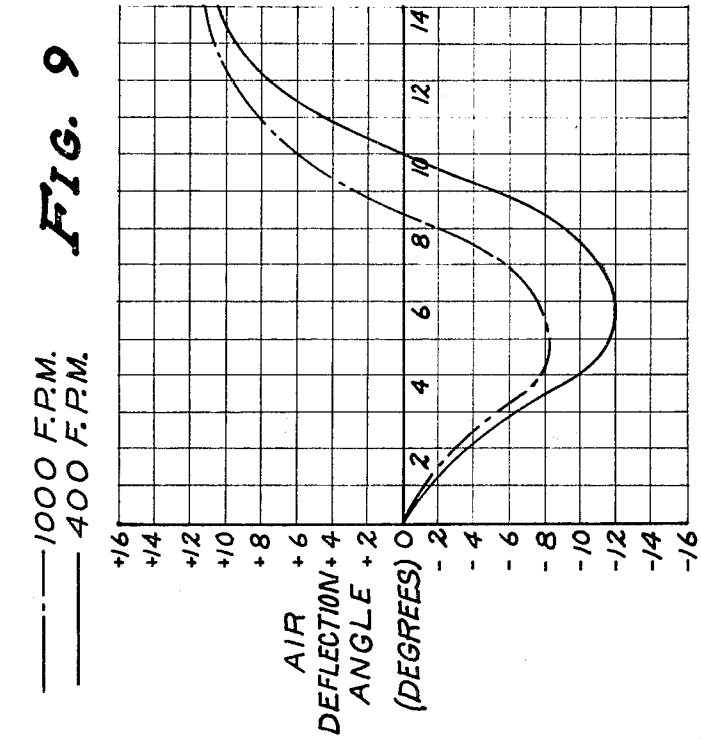


FIG. 9

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FIN FOR A REVERSIBLE HEAT EXCHANGER

BACKGROUND OF THE INVENTION

Field of the Invention:

The present invention applies specifically to the type of heat exchanger including a plurality of generally parallel fluid conduits connected to conduct a fluid medium, such as water or the like, and engaged through a plurality of generally parallel, spaced apart fins extending perpendicular to the conduits and especially to fins having severe undulations or waves therein. The fins and conduit are mounted in a tubular housing so that air or the like, upon being forced through the housing, contacts the fins and the conduits and exchanges heat, by giving up heat thereto or accepting heat therefrom. Such heat exchangers and housings are typically utilized in air conditioning units, industrial process equipment, etc. During installation, because of inadvertence or changed job conditions, it is not uncommon to reverse the position of the heat exchanger within the tubular housing, thereby, reversing the direction of airflow through the exchanger. Such a reversal of position generally radically changes the characteristics of the heat exchanger, thereby, substantially lowering the efficiency, and in some cases, rendering it impractical.

Description of the Prior Art:

It is well known in the prior art that fins of heat exchangers, which are constructed so that air is free to flow in a straight line therebetween, are extremely inefficient and provide a relatively low heat transfer. Because of this straight line flow, air immediately adjacent a fin, called a boundary layer, flows somewhat slower than air between the boundary layers due to resistance at the surface of the fins to air flow thereacross. This flowing of air through the exchanger in layers is known as laminar flow and reduces the heat transfer substantially.

Some prior art devices attempt to break up the laminar flow by creating turbulence in the air as it flows through the heat exchanger. One such prior art device is described in U.S. Pat. No. 1,557,467, entitled "Radiator," issued to A. B. Modine on Oct. 13, 1925. Modine discloses fins for a radiator wherein corrugations and other irregularities are provided to create turbulence in air flowing between the fins. However, because Modine's heat exchanger is utilized as a radiator in automobiles and the like, the amount of deflection of air at the outlet is not important and he simply terminates each of the fins in one of the hollows or grooves of the corrugations so that air leaving the heat exchanger is deflected downwardly at an angle of approximately 45°. Further, Modine describes a turned-over leading edge to provide strength and a pleasing appearance. This turned-over leading edge will greatly reduce the airflow through the heat exchanger as larger numbers of fins per inch are utilized. Further, if the heat exchanger is reversed the turned-over edge will produce a relatively large pressure differential across the heat exchanger as larger numbers of fins per inch are utilized. Thus, Modine's device is not reversible and causes an amount of air deflection at the outlet which is intolerable where heat exchangers are utilized in tubular housings, as in the presently described field.

SUMMARY OF THE INVENTION

The present invention pertains to fin construction for a reversible heat exchanger wherein the fin includes a piece of sheet material defining a pair of opposed edges extending generally transverse to the direction of airflow through the exchanger with a plurality of corrugations formed between the edges and a plurality of corrugations formed between the edges and a plurality of apertures through the material for receiving fluid conduits therethrough and said piece of material further defining longitudinally extended edge angle portions adjacent each of said opposed edges and disposed at an acute angle greater than zero degrees and less than 45° relative to a plane extending tangent to an adjacent corrugation and other like formed corrugations, said edge angle portions cooperating with edge angle portions of adjacent fins to provide an optimum amount of air deflection at the outlet and an optimum amount of differential pressure across the exchanger regardless of the direction of air flow through the heat exchanger.

It is an object of the present invention to provide improved fins for reversible heat exchanger whereby the characteristics of the heat exchanger are substantially identical in either direction of airflow.

It is a further object of the present invention to provide improved fins which produce optimum heat exchanger characteristics, such as air deflection at the outlet, pressure differential thereacross, heat transfer, etc., while rendering the heat exchanger reversible within an airflow.

These and other objects of this invention will become apparent to those skilled in the art upon consideration of the accompanying specification, claims and drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Referring to the drawings, wherein like characters indicate like parts throughout the figures:

FIG. 1 is a view in transverse section of an air duct showing an end elevation of a heat exchanger having the improved fins therein, portions thereof removed;

FIG. 2 is a sectional view as seen from the line 2-2 of FIG. 1, portions thereof removed;

FIG. 3 is an enlarged fragmentary sectional view as seen from the line 3—3 in FIG. 1;

FIG. 4 is an enlarged sectional view as seen from the line 4—4 in FIG. 2;

FIG. 5 is an enlarged view in transverse section of a sheet of material, prior to separation into a pair of improved fins;

FIGS. 6 and 7 are somewhat schematic views in transverse side elevation of prior art heat exchangers;

FIG. 8 is a semischematic view in transverse side elevation of the present heat exchanger including the improved fins; and

FIG. 9 is an approximate graphic representation of the outlet air deflection angle relative to the number of fins per inch in a heat exchanger utilizing the improved fins, with two different airflow rates specified.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to the drawings the numeral **10** generally designates a heat exchanger including a generally rectangularly shaped casing **11** having sidewalls **12** and **13** and upper and lower walls **14** and **15**, respectively. A plurality of generally U-shaped conduits or tubes **16** are engaged through the sidewall **12**, with the bight remaining on the exterior of the sidewall **12**. The tubes **16** extend across the casing **11** in transversely spaced apart relationship and are engaged through the sidewall **13** with the two open ends of each of the tubes **16** extending a short distance to the exterior of the sidewall **13**. A corresponding first open end of each of the tubes **16** is sealingly engaged in communication with a first header **17** mounted parallel with and exterior of the sidewall **13**. The opposite corresponding open ends of each of the tubes **16** are sealingly engaged in communication with a second header **18** extending parallel with and exterior of the sidewall **13**. The headers **17** and **18** have ports **19** and **20**, respectively, for the ingress and egress of water or other heat-transferring fluid through the system.

The casing **11** is designed to be fitted into and form part of a tubular housing, such as air ducts **25** (illustrated in FIG. **2**), although exchanges not associated with ducts are also included in this disclosure. The tubular housing or air ducts **25** direct air through the casing **11** and over the tubes **16** from one end **26** to the other end **27** of the casing **11**. The normal airflow through the casing **11** from end **26** to end **27** is illustrated in FIG. **2** by the solid arrows. However, in some instances the direction of airflow with respect to the heat exchanger **10** may be reversed so that the air flows from the end **27** to the end **26**, as illustrated by the dotted arrows in FIG. **2**, or the heat exchanger **10** may be installed in the air ducts **25** in a reverse direction. In either case the flow of air through the heat exchanger **10** is reversed.

A plurality of cooling or heating fins **30** are positioned in parallel spaced apart relationship between the sidewalls **12** and **13** of the casing **11** and in engagement with the tubes **16**. Each of the fins **30** is formed from a piece of sheet material having good heat conducting characteristics, and the desired strength, durability, weight, etc., such as aluminum or the like. Each of the fins **30** is formed in a generally rectangular shape with opposed longitudinally extending edges **31** and **32** and two rows of longitudinally spaced apart openings **33** extending generally parallel with the edges **31** and **32** and spaced therebetween. The openings **33** in one of the rows are staggered or misaligned with the openings in the adjacent row for reasons which will become apparent presently. Each of the openings **33** has a generally cylindrical collar **34** extending outwardly from a side of the fin **30** generally coaxial with the associated opening **33**. The outermost edge of the collar **34** is flanged outwardly at **35** to aid in assembly of the heat exchanger **10**. In assembly, the tubes **16** are inserted through the openings **33** and a plurality of fins **30** are equally spaced thereon. The tubes **16** are then radially expanded by internal pressure or the like to firmly, frictionally engage the fins **30** and prevent relative movement thereof.

A plurality of longitudinally extending corrugations are formed between the edges **31** and **32** in each of the fins **30**. In the present embodiment the corrugations are formed in a continuous sequence in a sheet of material and a piece of the material is removed along a specific line to form a fin **30**. Referring to FIG. **5**, which is a cross-sectional or end view of a sheet of material including two of the present fins **30**, the sequence of corrugations can be seen. The sequence includes two corrugations **40** and **41**, each having a generally sinusoidally shaped cross section or each including a rounded valley and hill. At one end of the two corrugations **40** and **41** a somewhat wider high area or hill **42** is formed and at the opposite end of the two corrugations **40** and **41** a somewhat wider low area or valley **43** is formed. The high area **42** has a small dip **44** at the center thereof to provide a double peak **45** and **46** configuration and the low area **43** has a small peak **47** at the center thereof to provide a double dip **48** and **49** arrangement. The sequence of two corrugations **40** and **41**, a high area **42**, two corrugations **40** and **41**, a low area **43**, two corrugations **40** and **41**, a high area **42**, continues across the sheet of material. To form a fin **30** from the sheet of material a piece is removed by cutting the sheet along the dips **44** of the high areas **42** and/or the peaks **47** of the low areas **43**. As illustrated in FIG. **5**, a row of openings **33** is positioned between adjacent high areas **42** and low areas **43**. Thus, if a heat exchanger **10** is to be constructed with a single row of openings **33**, the pieces of material are severed from the sheet of material along each high area **42** and adjacent low area **43**. In the present embodiment two rows of openings **33** are provided in each of the fins **30** so that the sheet of material is severed along the dips **44** in each of the high areas **42**.

In the present embodiment the low portion of the dip **44** in the high area **42** and the high portion of the peak **47** in the low area **43** are separation portions or portions along which the sheet of material can be separated into fins **30**. When the sheet of material is separated along either of these portions the angularly disposed portions forming the sides of the dip **44** and/or the peak **47** form edge angle portions **50** and **51**, respectively. As illustrated in FIG. **5**, the fins **30** are cut so that an edge angle portion **50** is adjacent each of the edges **31** and **32**. In the present embodiment the dip **44** in the high area **42** and the peak **47** in the low area **43** are formed so that the edge angle portions **50** and **51** form an angle of approximately 17° with reference to a plane tangent to the peaks of the corrugations and to the dips of the corrugations, respectively. It has been found that an angle of between 15° and 20° for the edge angle portions **50** or **51** is optimum when nine or tens fins per inch are utilized with an air flow velocity of between 400 and 1,000 feet per minute.

Referring to FIG. **9**, a graph illustrates the variations in deflection angle of the outlet air from the heat exchanger **10** (ordinate) for variations in the number of fins per inch (abscissa) and for variations of air velocity. In reviewing the graph of FIG. **9**, it will be seen that the air flowing through the heat exchanger **10** has a tendency to follow the corrugations, for less than six fins per inch and, consequently, the air is deflected substantially in a first direction or the direction of the last corrugation. This corresponds somewhat to the prior art type of fins which simply stopped at the end of a corrugation, as shown in FIG. **6**. In FIG. **6**, the outlet and inlet edges are directed at an angle of approximately 45° to the plane of the fins and the deflection angle of the outlet air is so large as to be objectionable. This amount of deflection is intolerable in most heat exchangers utilized in the present field because it tends to create distortions in air distribution in the tubular housing or air ducts **25** rather than a uniform flow. Because of the large number of variables in the heat exchanger **10** and the system in which it is utilized, the actual angle of the edge angle portion **50** or **51** may vary between an angle greater than 0° and less than 45°. As previously stated and illustrated in FIG. **9**, for an edge angle portion **50** or **51** having an angle of approximately **17** degrees an outlet air deflection angle of approximately zero can be obtained with an air velocity of 400 to 1,000 feet per minute by installing between eight and ten fins per inch. Similarly, if any of the variables are altered, the angle of the edge angle portions **50** or **51** can be altered to return the outlet air deflection angle to approximately zero or the desired angle.

Referring to FIG. **7**, heat exchanger fins are illustrated wherein the edges and the portions adjacent thereto are parallel to the air flow. This has been found to be undesirable because a laminar flow is set up at the inlet edge and adjacent parallel portions so that a relatively large differential pressure is produced between the inlet and outlet and the heat transfer is significantly reduced. Laminar flow development is retarded by the edge angle portions **50** or **51** of the present invention, so that the differential pressure across the heat exchanger **10** is substantially reduced and a high heat transfer is maintained. FIG. **8** illustrates a semischematic view of a heat exchanger **10** incorporating the improved fins **30**. A broken line **52** represents a plane extending tangent to the adjacent portion **45** or **46** and other like formed portions of corrugations **40** and **41**. A dotted arrow **53** indicates generally the first direction of air at the outlet, which first direction is represented in the graph of FIG. **9** as negative. A second dotted arrow **54** indicates generally the second direction of air at the outlet, which second direction is represented in the graph of FIG. **9** as positive.

In general, the angle of the edge angle portions **50** or **51** should be adjusted so that the optimum desired outlet air deflection angle and differential pressure are obtained. While the angle of the edge angle portion **50** adjacent the edge **31** of the fin **30** may vary somewhat from the angle of the edge angle portion **50** adjacent the edge **32**, in general these angles will be substantially equal since the various characteristics of the system in which the heat exchanger **10** is mounted remain equal. Further, to simplify manufacturing of the fins **30** the angles of the edge angle portions **50** adjacent each of the edges **31** and **32** should be substantially equal.

Because there is an edge angle portion **50** or **51** adjacent the inlet edge of each of the fins **30** to break up the laminar flow at the inlet of the heat exchanger **10** and because there is an edge angle portion **50** or **51** adjacent the outlet edge of each of the fins **30** to provide the correct air deflection at the outlet of the heat exchanger **10**, the heat exchanger **10** is reversible within the air ducts **25** or the flow of air therethrough can be reversed. If desired, the edges **31** and **32** can be rippled to give added strength thereto, with little or no effect on the overall operation of the edge angle portions **50** or **51**. The ripple is constructed so that the average angle of the edge portions **50** or **51** is the desired angle.

Thus, an improved cooling fin for heat exchangers is disclosed which is constructed so that the heat exchanger is reversible. Further, other characteristics of the heat exchanger, such as heat transfer, the pressure differential

thereacross, etc., have optimum values while providing a desired or optimum outlet air deflection angle along with the reversibility. While a preferred embodiment has been described and illustrated, it should be understood that many variations, such s the type of corrugations, the direction of the angle of the edge angle portions, the spacing and positioning of the openings **33**, etc., may be operatively incorporated into the structure.

We claim:

1. Fin construction for a reversible heat exchanger adapted to be positioned with opposite ends thereof in a flow of air, the heat exchanger having a plurality of generally parallel fluid conduits connected to conduct a fluid medium through the heat exchanger and a plurality of fins arranged in side-by-side relationship to dissipate heat from the fluid conduits by the flow of air, each of said fins comprising:

a. a piece of sheet material defining a pair of generally parallel, opposed substantially identical edges disposed adjacent the opposite ends of the heat exchanger and extending generally transverse to the direction of air flow through the exchanger;

b. a plurality of corrugations formed between said opposed edges and extending longitudinally with respect to said opposed edges;

c. a plurality of apertures formed in said sheet material between said opposed edges to provide a row of apertures extending longitudinally of said corrugations and adapted to one each frictionally receive one of the fluid conduits;

d. said piece of material further defining longitudinally extended generally planar edge angle portions adjacent each of said opposed edges and disposed at acute angles greater than 0° and less than 45° relative to a plane extending tangent to an adjacent portion of a corrugation and other like portions of said corrugations;

e. said edge angle portions cooperating with edge angle portions of adjacent fins to deflect the air entering and leaving the heat exchanger whereby to create air turbulence at said edge angle portions and provide a heat exchanger having a heat transfer rate and a pressure differential between opposite ends thereof of a substantially equal amount regardless of the direction of air flow through the heat exchanger without deflecting air leaving the heat exchanger an excessive amount.

2. The structure of claim **1** wherein said apertures are formed in said sheet material to provide a plurality of spaced rows of apertures extending longitudinally of said corrugations, said apertures in each row of apertures adapted to frictionally receive one each one of the fluid conduits.

3. The structure of claim **2** wherein the piece of sheet material defines between adjacent rows of said apertures a separation portion extending longitudinally of said corrugations and in which said separation portion is flanked by said edge angle portions whereby separation of said sheet material along said separation portion provides a plurality of fins having said opposed edge angle portions.

4. The structure of claim **3** wherein said planar edge angle portions each extend from an adjacent corrugation at an acute angle relative to a plane lying tangent to said adjacent corrugation and other like formed corrugations.

5. The structure of claim **1** wherein said acute angle is between approximately 15° and 20°.

6. The structure of claim **1** in further combination with means formed peripherally of each aperture of said fin for frictionally engaging a respective fluid conduit and spacing said fin from an adjacent fin.

7. The structure of claim **6** wherein said means formed peripherally of each aperture is a collar and in which each of said collars terminates in a radially outwardly flared end portion.

8. A heat exchanger adapted to be positioned in a tubular housing having a flow of air therethrough, said heat exchanger comprising:

a. a plurality of conduits adapted to conduct a fluid medium through said heat exchanger;

b. a plurality of fins spaced transversely of said housing whereby air flowing in said housing passes between said fins, each of said fins comprising:

1. a piece of sheet material having opposite longitudinally extended side edges extending transversely of the tubular housing;

2. said opposite side edges defining corrugations therebetween which extend longitudinally and generally parallel to said side edges;

3. said fin having a plurality of openings formed therein between said opposite side edges and spaced longitudinally of said corrugations to form a row of openings adapted to frictionally engage one each one of said plurality of conduits;

4. a generally planar edge angle portion generally coextensive with and proximate each opposite side edge;

5. said edge angle portions cooperating with adjacent edge angle portions to deflect air passing through said heat exchanger a given angular amount as it leaves said heat exchanger relative to the direction of air flow through said heat exchanger whereby the heat transfer rate and the pressure differential between opposite sides of said heat exchanger, regardless of the direction of air flow through said heat exchanger, is approximately equal.

9. The structure of claim **8** wherein said edge angle portion is rippled.

* * * * *