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(54) **CONDENSER FOR AIR COOLED CHILLERS**

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(57) **ABSTRACT**

A heat exchanger comprising a first coil assembly including an inlet manifold; an outlet manifold parallel to and spaced from the inlet manifold; and a plurality of tubes each operably connected to and linking the inlet and the outlet manifolds, each tube having a multiplicity of flow paths and a hydraulic diameter in the range of $0.05 \leqq$ to $HD \leqq 0.30$.

FIG I

FIG. 2

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40

42

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FIG. 3

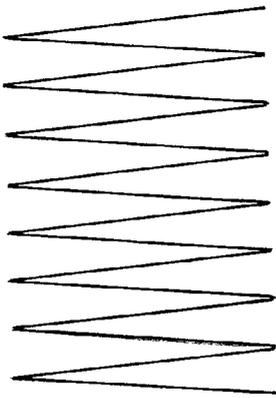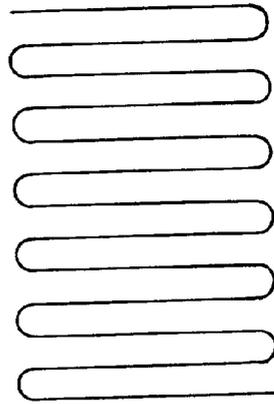32

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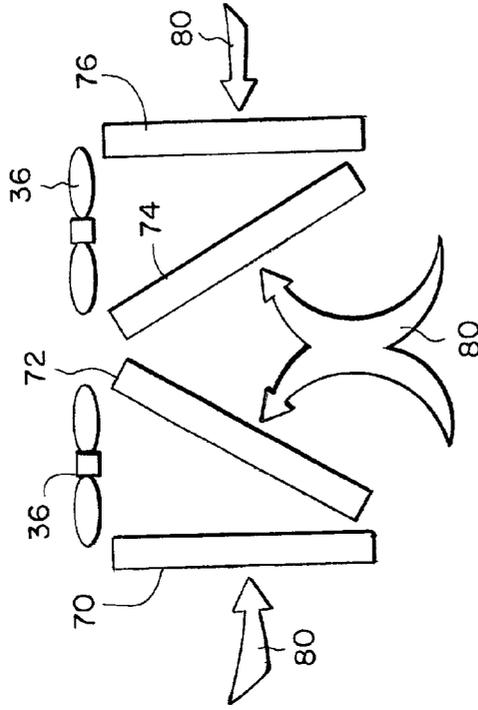
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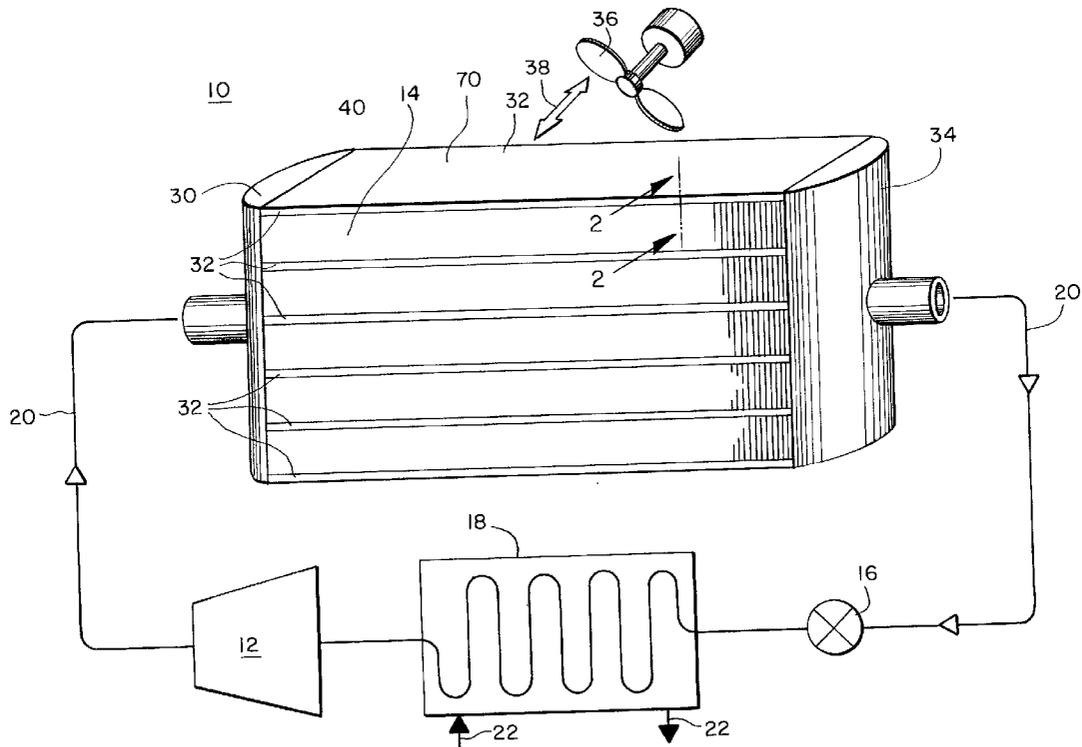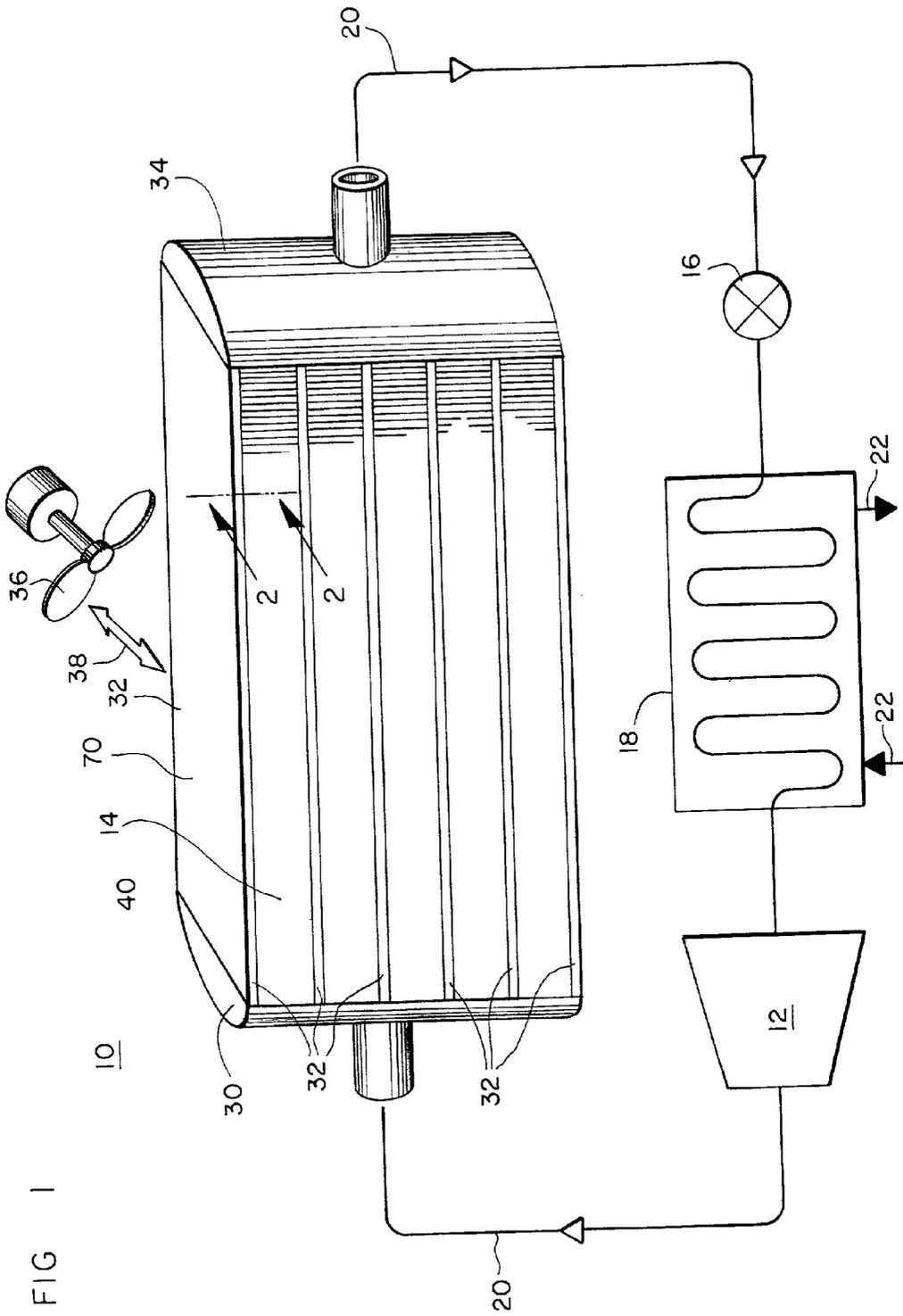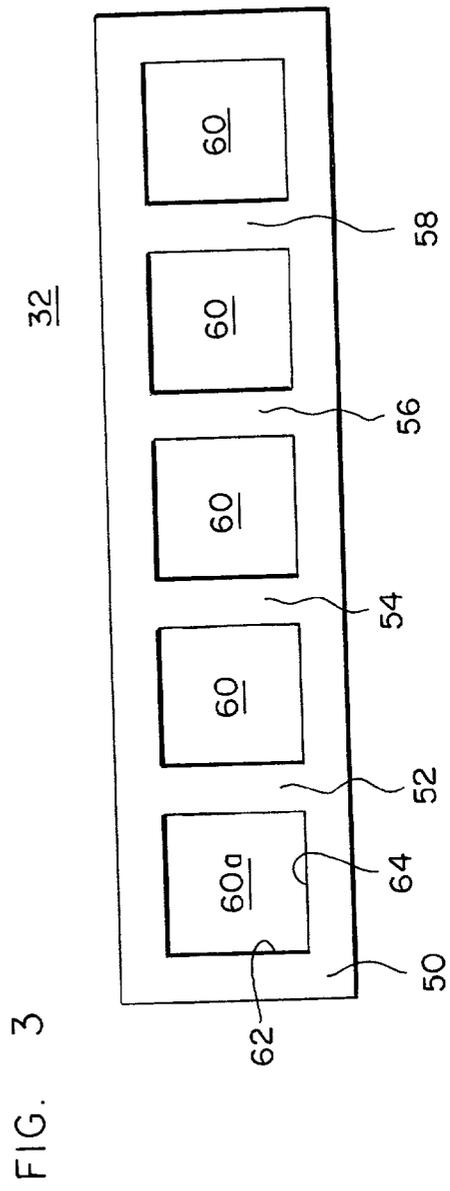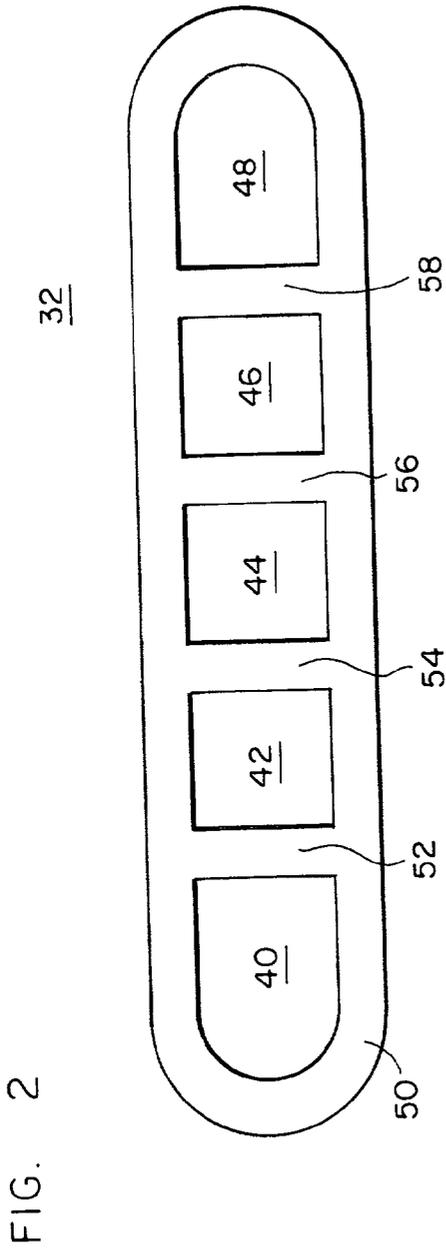
FIG. 5

FIG. 4A

FIG. 4B

CONDENSER FOR AIR COOLED CHILLERS

BACKGROUND OF THE INVENTION

[0001] The present invention is directed to air cooled condensers for heating, ventilating and air conditioning (HVAC) systems. More specifically, the present invention is directed to aluminum heat exchangers for use in large air cooled air conditioning chillers, such chillers cooling a transport fluid for use in air conditioning elsewhere. In particular the present invention applies to a condenser using microchannel tubing, also known as parallel flow tubing or multi-path tubing.

[0002] HVAC condensers presently use fin and tube coils, primarily with copper tubes and aluminum fins. A significant weight reduction of the overall unit could be accomplished if the tubes were also formed of aluminum and then brazed or glued to the fins. Small sized brazed aluminum heat exchangers as microchannel tubing are used in the automotive industry. However, the application and the sizes are distinct. Automobile radiators are not as concerned about efficiency as the HVAC industry is. Also, simply resizing an automotive heat exchanger does not provide an optimum solution.

[0003] In order to accomplish this, the design of an aluminum heat exchanger with microchannel tubing must be analyzed and optimized.

[0004] U.S. Pat. No. 4,998,580 to Guntly et al. and U.S. Pat. No. 5,372,188 to Dudley et al. are directed to a condenser with a small diameter hydraulic flow path where hydraulic diameter is conventionally defined as four times the cross sectional area of the flow path divided by the wetted perimeter of the flow path. The Guntly et al. patent requires hydraulic diameters of about 0.07 inches and less while the Dudley et al. patent requires a hydraulic diameter in the range of 0.015 to 0.040 inches. This technology is used in the automotive industry and is not optimum for an air cooled chiller application.

SUMMARY OF THE INVENTION

[0005] The present invention is directed to solving the problem in the prior art systems.

[0006] It is an object, feature and advantage of the present invention to provide an aluminum heat exchanger with multiple parallel flow paths for use in a large chiller for air conditioning purposes. It is a further object, feature and advantage of the present invention to significantly reduce the weight of a large chiller.

[0007] It is an object, feature and advantage of the present invention to provide a heat exchanger with multiple parallel flow paths having a hydraulic diameter greater than 0.07 inches and less than 0.30 inches. It is a further object, feature and advantage of the present invention to provide a hydraulic diameter in the range greater than 0.07 inches and less than or equal to 0.26 inches. It is yet a further object, feature and advantage of the present invention to provide a hydraulic diameter in the range greater than 0.07 inches and less than or equal to 0.14 inches. It is a still further object, feature and advantage of the present invention to provide a hydraulic diameter in the range of 0.14 inches less than or equal to 0.26 inches. Finally, in the preferred embodiments of the present invention the hydraulic diameter is either 0.07 inches or 0.14.

[0008] The present invention provides a heat exchanger. The heat exchanger comprises a first coil assembly including an inlet manifold, an outlet manifold parallel to and spaced from the inlet manifold; and a plurality of tubes each operably connected to and linking the inlet and the outlet manifolds. Each tube has a multiplicity of flow paths and a hydraulic diameter in the range of $0.05 \leqq$ to $HD \leqq 0.30$.

[0009] The present invention also provides an air conditioning system including a compressor, a first heat exchanger, a fan motivating air across the first heat exchanger, an expansion device and a second heat exchanger serially linked into an air conditioning cycle by tubing. The first heat exchanger includes an inlet manifold, an outlet manifold, and a multiplicity of adjacent flow paths surrounded by a common tube wall and interconnecting the inlet manifold with the outlet manifold.

[0010] The present invention further provides a method of manufacturing an air cooled chiller. The method comprises the steps of: forming a first heat exchanger to include a multiplicity of adjacent flow paths wherein the flow paths are sized and shaped to a preferred hydraulic diameter within the range of $0.7 \leqq$ the hydraulic diameter is <0.30 inches where hydraulic diameter=4 times the cross sectional area divided by the total wetted perimeter; providing a fan to move air across the multiplicity of adjacent flow paths; providing a compressor, a second heat exchanger, and an expansion device; and linking the compressor, the first heat exchanger, the expansion device, and the second heat exchanger serially into an air conditioning cycle by tubing.

[0011] The present invention still further provides a method of transferring heat in a heat exchanger. The method comprises the steps of: forming a first heat exchanger to include a multiplicity of adjacent flow paths wherein the flow paths are sized and shaped to a preferred hydraulic diameter HD within the range of $0.7<HD<0.30$ inches where hydraulic diameter HD as defined as four times a cross sectional area divided by a total wetted perimeter; and transferring heat thru a wall enclosing said flow paths and to a fluid contained therein.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] FIG. 1 is a block diagram of an air cooled chiller system in accordance with the present invention.

[0013] FIG. 2 shows a first preferred embodiment of the present invention taken along lines 2-2 of FIG. 1.

[0014] FIG. 3 is an alternative embodiment of the multi-path tubes shown in FIG. 2.

[0015] FIGS. 4a and 4b are diagrams of fins used in the heat exchanger shown in FIG. 1.

[0016] FIG. 5 is a block diagram of a multiple coil assembly configuration as a preferred embodiment of FIG. 1.

DETAILED DESCRIPTION OF THE DRAWING

[0017] FIG. 1 shows an air conditioning system 10 including a compressor 12, a first heat exchanger 14 functioning as a condenser, an expansion device 16 such as an expansion valve, and a second heat exchanger 18 functioning as an evaporator. The compressor 12, the first heat exchanger 14, the expansion device 16, and the second heat exchanger 18

are serially linked in an air conditioning cycle by tubing **20**. The first heat exchanger **14** functions as a condenser in releasing heat from the system, while the second heat exchanger **18** functions as an evaporator in cooling a fluid transported to and from the heat exchanger **18** by means of conduit **22**. Such systems are generally well known and are sold by The Trane Company, a Division of American Standard Inc., under the registered trademarks CenTraVac and Series R.

[0018] The present invention is directed to an improved condenser **14**. This improved condenser **14** is preferably formed of aluminum and has an inlet manifold **30** receiving hot gaseous refrigerant from the conduit **20** and the compressor **12**. This hot gaseous refrigerant is distributed by the inlet manifold **30** to a plurality of tubes **32**. These tubes **32** conduct the hot gaseous refrigerant from the inlet manifold **30** through the tubes **32** to an outlet manifold **34**. In the process, the hot gaseous refrigerant is condensed and returns to the conduit **20** as a liquid where it is modulated through the expansion device **16** to the second heat exchanger **18**. The tubes **32** are preferably microchannel or parallel flow tubing. Microchannel tubing is shown by applicant's U.S. Pat. No. 5,967,228 to Bergman et al. which is assigned to the assignee of the present invention and hereby incorporated by reference.

[0019] Air is moved over the tubes **32** by an air moving device **36** such as a fan either to or away from the fan **36** as indicated by arrow **38**. To enhance heat transfer from the tubes **32**, fins **40** are provided to enhance the heat transfer. These fins **40** will be subsequently described with reference to **FIG. 4**.

[0020] The preferred embodiment of the tubes **32** is shown in **FIG. 2** and an alternative embodiment is shown in **FIG. 3**. The heat transfer tube **32** shown in **FIG. 2** includes a multiplicity of adjacent flow paths **40, 42, 44, 46** and **48** throughout the length of the tube **32** and surrounded by a common tube wall **50**. The adjacent flow paths **40** through **48** are separated by barrier walls **52, 54, 56** and **58** respectively.

[0021] In **FIG. 2**, the flow paths **40** and **48** are of similar shape and cross sectional area and the flow paths **42, 44** and **46** are of similar shape and cross sectional area. The flow paths **40, 42, 44, 46** and **48** are sized and shaped to form a preferred hydraulic diameter HD within the range of:

[0022] 0.7<HD<0.30 inches.

[0023] Hydraulic diameter is conventionally calculated according to the following formula:

$$\text{Hydraulic Diameter (HD)} = \frac{\text{cross sectional area} \times 4}{\text{total wetted perimeter}}$$

[0024] Empirical study shows that a **100** ton air cooled chiller should have a hydraulic diameter of at least 0.07 whereas a 240 ton air cooled chiller should have a hydraulic diameter of about 0.14 inches. Linear extrapolation shows that a 480 ton air cooled chiller should have a hydraulic diameter of about 0.26 inches. Thus, the preferred range of hydraulic diameters is 0.07<HD<0.30 with an intermediate range of 0.07<HD≦0.26. An optimum range appears to be 0.07<HD<0.14, with preferred hydraulic diameter of 0.14.

[0025] In determining the hydraulic diameter, the total cross sectional area of the flow paths **40, 42, 44, 46** and **48** is either measured or calculated, and the total wetted perimeter for those same flow paths is determined in a similar manner.

[0026] For the sake of expediency, exemplary calculations are performed for the alternative embodiment shown in **FIG. 3**. In this **FIG. 3**, like reference numerals are used to denote like elements.

[0027] In the tube **32** shown in **FIG. 3**, each of the multiplicity of flow paths has an identical size and shape **60**. The cross sectional area for these multiplicity of flow paths **60** can be determined by taking an individual flow path **60***a*, determining a height **62** and a width **64**, and multiplying the height **62** and width **64** together to determine an area for a single flow path **60***a*. The total cross sectional area for the tube **32** is determined by multiplying by the number of flow paths, in this case **5**, by the cross-sectional area per flow path leading to the calculation that the total cross sectional area equals 5 times the height **62** time the width **64**.

[0028] The wetted perimeter for any individual flow path **60** can be calculated as two heights (**62**) plus two widths (**64**). Total wetted perimeter can be determined by multiplying the wetted perimeter for any particular flow path by the number of individual flow paths **60**, in this case **5**, to result in a total wetted perimeter of 5 times (2H plus 2W). This results in a hydraulic diameter according to the following formula:

$$HD = 10(H \times W) \times \tfrac{4}{20}(H+W)$$

[0029] which reduces to:

$$HD = 2H \times W/(H+W)$$

[0030] **FIG. 4***a* shows a first fin embodiment where a corrugated fin **40***a* is used. Similarly, **FIG. 4***b* shows the use of a sinusoidal fin **40***b*.

[0031] **FIG. 5** is directed to a multiple coil assembly embodiment of the invention in contrast to **FIG. 1** which shows a single coil assembly **70**. In practice, multiple coil assemblies **70, 72, 74** and **76** might be used. The arrangement shown in **FIG. 5** is described in applicant's previous U.S. Pat. No. 5,067,560 to Carey et al. which is assigned to the assignee of the present invention and hereby incorporated by reference. The control of such a condenser is described in applicant's U.S. Pat. No. 5,138,844 to Clanin et al. which is assigned to the assignee of the present invention and also incorporated by reference.

[0032] In **FIG. 5**, the first coil assembly **70** is basically perpendicular to ground and a second coil assembly **76** is spaced from the first coil assembly **70** and is generally arranged in a parallel plane. A third coil assembly **72** is positioned between the first and second coil assembly **70, 76** and lying in a plane which is not parallel to the planes of first and second coil assemblies **70, 76**. A fourth coil assembly **74** also lies between the first and second coil assembly **70, 76** at a line in a plane which is not parallel to the planes of the first and second coil assembly **70, 76**. The fourth coil assembly **74** preferably is at a complimentary angle to the third coil assembly **72**. The potential airflow paths are shown by arrows **80**.

[0033] What has been described is a condenser for use in the large air cooled chiller. It will be apparent to a person of ordinary skill in the art that many alterations and modifications are readily apparent. Such modifications include varying the material from aluminum to other light weight mate-

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rials having a good heat transfer coefficient as well as modifying the number and shape of the multiple flow paths within each tube. All such modifications and alterations are contemplated to fall within the spirit and scope of the following claims.

1. A heat exchanger comprising:

a first coil assembly including an inlet manifold;

an outlet manifold parallel to and spaced from the inlet manifold; and

a plurality of tubes each operably connected to and linking the inlet and the outlet manifolds, each tube having a multiplicity of flow paths and a hydraulic diameter HD in the range of 0.07<HD<0.30.

2. The heat exchanger of claim 1 wherein the multiplicity of flow paths are in a parallel arrangement.

3. The heat exchanger of claim 2 further including fins arranged in heat transfer relation between adjacent tubes of the plurality of tubes.

4. The heat exchanger of claim 3 wherein the fins have a sinusoidal shape.

5. The heat exchanger of claim 3 wherein the fins have a corrugated shape.

6. The heat exchanger of claim 3 wherein the multiplicity of flow paths have a similar cross sectional shape.

7. The heat exchanger of claim 3 wherein the multiplicity of flow paths has at least first and second cross sectional shapes.

8. The heat exchanger of claim 3 further including a device moving air across the first coil assembly and the heat exchanger is primarily formed of aluminum.

9. The heat exchanger of claim 3 further including a second coil assembly parallel to and spaced from the first coil assembly, each oil assembly lying in first and second respective planes which are substantially parallel to each other.

10. The heat exchanger of claim 9 including a third coil assembly located between the first and second coil assemblies and lying in a third plane not parallel to the first and second planes.

11. The heat exchanger of claim 10 further including a fourth coil assembly between the first and second coil assemblies and lying in a fourth plane not parallel to the first and second planes wherein the angle of the fourth plane is complementary to the angle of the third plane.

12. An air conditioning system comprising:

a compressor,

a first heat exchanger,

a fan motivating air across the first heat exchanger,

an expansion device and

a second heat exchanger serially linked into an air conditioning cycle by tubing;

the first heat exchanger including an inlet manifold, an outlet manifold, and a multiplicity of adjacent flow paths surrounded by a common tube wall and interconnecting the inlet manifold with the outlet manifold.

13. The system of claim 12 wherein the multiplicity of adjacent flow paths are of similar cross sectional area and are formed of aluminum.

14. The system of claim 13 wherein the flow paths are sized and shaped to form a preferred hydraulic diameter HD within the range of 0.7<HD<to 0.30 inches where hydraulic diameter HD is defined as four times the cross sectional area of the flow paths divided by the total wetted perimeter of the flow paths.

15. The system of claim 14 wherein the first heat exchanger includes first, second, third and fourth coil assemblies, each coil assembly including the multiplicity of flow paths, and said first, second, third and fourth coil assemblies each having a planar dimension such that the coil assemblies form a W shape when viewed in a direction perpendicular to a common plane to first, second, third and fourth coil assemblies.

16. The system of claim 14 wherein the multiplicity of flow paths are of identical size and shape.

17. The system of claim 14 wherein the multiplicity of flow paths are in first and second differing shapes.

18. The system of claim 17 wherein the first shape is rectangular and the second shape includes an arced surface.

19. A method of manufacturing an air cooled chiller comprising the steps of:

forming a first heat exchanger to include a multiplicity of adjacent flow paths wherein the flow paths are sized and shaped to a preferred hydraulic diameter HD within the range of 0.7<HD<0.30 inches;

providing a fan to move air across the multiplicity of adjacent flow paths;

providing a compressor, a second heat exchanger, and an expansion device; and

linking the compressor, the first heat exchanger, the expansion device, and the second heat exchanger serially into an air conditioning cycle by tubing.

20. The method of claim 19 including the further step of:

adaptively configuring the second heat exchanger to chill the temperature of a liquid.

21. The method of claim 19 including the further step of:

forming the first heat exchanger from aluminum.

22. The method of claim 21 including the further step of interconnecting adjacent ones of the multiplicity of flow paths with a corrugated or sinusoidal fin.

23. The method of claim 22 including the step of arranging the multiplicity of flow paths in a common plane.

24. A method of transferring heat in a heat exchanger comprising the steps of:

forming a first heat exchanger to include a multiplicity of adjacent flow paths wherein the flow paths are sized and shaped to a preferred hydraulic diameter HD within the range of 0.7<HD<0.30 inches; and

transferring heat thru a wall enclosing said flow paths and to a fluid contained therein.

25. The method of claim 24 including forming the wall from aluminum.

26. The method of claim 25 including forming the flow paths into first and second distinct cross-sectional shapes.

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