

IMPROVED WAVY HEAT TRANSFER SURFACE

The invention relates to wavy heat transfer surfaces of heat exchangers and in particular to the improvement of the heat transfer rate of such surfaces.

Heat transfer enhancement by louvering or slitting plate fin surfaces in heat exchangers has long been recognized as offering significant improvements in plate finned coil performance. The form and arrangement of the louvers are unique to the type of plate fin surface used in the particular heat exchanger since the airflow characteristics vary with the type of plate fin surface. The airflow characteristics of a surface depend upon whether the surface is flat, corrugated or wavy, and depend upon the arrangement of the heat transfer tubes. Most surfaces known today increase the heat transfer performance of the coil when the heat transfer surface is dry, such as when the coil is used as a refrigerant condenser. However, when the surfaces are wet, such as when the coil is used as an evaporator, the heat transfer performance is not improved by louvering or slitting the plate fin surface. Additionally, many previous plate fin surfaces suffer from high air-side pressure drop, which means that more power is required

to move air through the coil.

5 US Patent Number 4,860,822 discloses sinusoidal plate fin surfaces having lances located at each peak and trough in the area between the heat transfer tubes. Similarly, European patent application EP 0 325 553 A1 discloses sinusoidal plate fin surfaces having apertures located at each peak and trough in the area between the heat transfer tubes. U.S. Patents Numbers 4,817,709 and 4,787,442 clearly show 10 "delta wings" and "ramps" located after each peak and trough in the area between the heat transfer tubes. U.S. Patents Numbers 4,614,230 and 3,397,741 are examples of patents which show a slight gap between the heat transfer tubes but still disclose louvers 15 located in the areas between the heat transfer tubes. Neither of these last mentioned patents are directed to wavy plate fin surfaces, which means that their airflow characteristics will vary considerably from the airflow characteristics of a wavy plate fin 20 surface.

It is an object of the invention to solve the problems of the prior art plate fin heat exchangers.

Accordingly, the invention provides a heat exchange member for use in a refrigeration system:

25 said member having a wavy heat exchange surface having a series of alternating peaks and troughs

extending over the wavy surface in a direction substantially perpendicular to a direction of airflow;

the member including a plurality of holes aligned in first and second rows parallel to the peaks and troughs, where the first and second rows of aligned holes are staggered with respect to each other when viewed from the direction of airflow, where the first rows of aligned holes are located in alignment with every third peak of the wavy surface and the second rows of aligned holes are located in alignment with every third trough of the wavy surface such that the peaks aligned with the first rows of aligned holes are not immediately adjacent the troughs aligned with the second rows of aligned holes and where each adjacent pair of aligned holes within each row is separated by a respective portion of said surface in alignment with one of the third peaks or the third troughs;

the member further including means for enhancing heat transfer, where the enhancement means are located between the peaks and troughs on the wavy surface, but not in said respective portions.

The invention also includes a plate fin for use in a heat exchanger of a refrigeration system,

said plate fin having a predetermined thickness and comprising a wavy surface having a series of alternating parallel peaks and troughs, the plate fin

including apertures adapted to engage heat transfer tubes to be passed therethrough, said apertures being aligned in rows which are alternately aligned respectively with every third peak and every third trough of the wavy surface, each adjacent pair of aligned apertures within each row being separated by a respective portion of said surface in alignment with the respective peak or trough,

the plate fin including means for enhancing the heat transfer rate of the wavy surface, said heat transfer enhancing means being located between the parallel peaks and troughs on the wavy surface but not in said respective portions.

The invention also includes a method of forming a plate fin for a heat exchanger, the method comprising the steps of:

forming said plate fin to provide a surface having a wavy series of parallel peaks and troughs;

forming first and second staggered rows of apertures in the plate fin such that the first rows of apertures are aligned with every third peak of the surface and the second rows of apertures are aligned with every third trough of the surface; and

providing heat transfer enhancing means on said surface between adjacent peaks and troughs but not on respective portions of said surface which separate

each adjacent pair of apertures within each row and are aligned with a said peak or trough.

The invention also includes a heat exchanger for a refrigeration system, the heat exchanger comprising:

5 first and second rows of heat transfer tubes which are staggered with respect to each other when viewed from a direction of air flow;

10 a series of plate fins having wavy surfaces which are substantially parallel to the direction of air flow, where each plate fin includes at least first and second rows of apertures which are sized and located to receive said heat transfer tubes;

15 the wavy surface of each plate fin having a series of alternating peaks and troughs extending over the wavy surface in a direction substantially perpendicular to said direction of air flow, the first rows of aligned apertures of each plate fin being located in alignment with every third peak of the wavy surface thereof and the second rows of aligned apertures of each plate fin being located in alignment with every third trough of the wavy surface thereof such that the peaks aligned with the first rows of aligned apertures are not immediately adjacent the troughs aligned with the second rows of aligned apertures and wherein each adjacent pair of aligned apertures within each row is separated by a respective

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portion of said wavy surface in alignment with one of the third peaks or the third troughs; and

each of the plate fins including means for enhancing heat transfer where the enhancement means are located between the peaks and troughs on the wavy surface thereof, but not in said respective portions.

In order that the invention may be well understood, an embodiment thereof, which is given by way of example only, will now be described with reference to the accompanying drawings, in which:

Figure 1 is a block diagram of a refrigeration system;

Figure 2 is a plan view of a wavy plate fin;

Figure 3 is a cross-sectional view of the plate fin taken along line 3-3 of Figure 2;

Figure 4 is a cross-sectional view of the plate fin taken along line 4-4 of Figure 2; and

Figure 5 is a combination of Figures 3 and 4.

Figure 1 shows a refrigeration system 10 which includes a compressor 12, a condenser 14, an expansion valve 16 and an evaporator 18. The compressor 12 compresses a refrigerant vapor and passes the compressed vapor to the condenser 14 by means of a hot gas line 20. The compressed refrigerant vapor enters the coils 22 of the condenser 14 and dissipates its heat through the coil walls into a plurality of plate

fins, or heat exchange members, 24. The heat from the refrigerant vapor is transferred from the coil walls and the plate fins 24 to a cooling medium such as air passing through the condenser 14. The compressed refrigerant vapor condenses to a liquid and passes along a refrigerant line 26 through the expansion valve 16 to the evaporator 18 which comprises a plurality of plate fins, or heat exchange members, 28. The expansion valve 16 maintains the pressure created by the compressor 12, and controls the amount of liquid refrigerant passed to the evaporator 18. A medium to be cooled such as air passes over the plate fins 28 and transfers heat to those plate fins 28. The heat is then conducted from the plate fins 28 into the evaporator coils 30 where the liquid refrigerant vaporizes in absorbing the heat. The vaporized refrigerant is then passed back to the compressor 12 by a suction line 32 connecting the evaporator 18 to the compressor 12.

Refrigerants contemplated for use in the refrigerant system 10 include R11, R22, R123, R134a as well as water and other common refrigerants used in multiple ton refrigeration systems.

Figure 2 shows a single plate fin 24, 28 for use in either the condenser 14 or the evaporator 18. As can be seen from Figures 3, 4 and 5, the plate fin 24,

28 comprises a wavy heat exchange surface having a series of alternating parallel peaks 34 and troughs 36. The plate fin 24, 28 includes a plurality of apertures 38 adapted to engage the respective heat transfer tubes 22, 30 of the condenser 14 and evaporator 18. The apertures 38 are aligned in alternating staggered first and second rows 42, 40, the rows 42, 40 being parallel to each other and alternately aligned with respective peaks 34 and troughs 36. Each of the peaks 34, troughs 36 and rows 40, 42 is perpendicular to the direction of airflow which is indicated by arrows in Figures 2-5.

The second rows 40 are aligned with every third trough 36, while the first rows 42 are aligned with every third peak 34. The arrangement is such that a peak 34 aligned with a first row 42 is not adjacent a trough 36 aligned with a second row 40. Figure 3 shows a cross-sectional profile where the rows 40 have apertures 38 aligned with the troughs 36. Figure 4 shows a cross-sectional profile of the plate fin 24, 28 where the apertures 38 of row 42 are aligned with the peaks 34. Figure 5 is a combination of Figures 3 and 4 showing more clearly the relationship between the second rows 40 and troughs 36 and the first rows 40 and peaks 34.

Means for enhancing the heat transfer rate of the

plate fin 24, 28 are provided by slitting and raising, or lowering, louvers 44 and 46 from the plate fin 24, 28 a distance at most four times the thickness of the plate fin 24, 28. Test data indicates that the louvers 44 and 46 should not be raised or lowered a distance from the plate fin 24, 28 which is more than three times the thickness of the plate fin 24, 28. As of the time of filing of this application, it is preferred to raise or lower the louvers 44, 46 a distance from the plate fin 24, 28 approximately 3.6 times the thickness of the plate fin.

Two sides of the louvers 44 and 46 are connected to the plate fin with the open sides facing the direction of airflow. The louvers 44 and 46 are located between the peaks 34 and troughs 36 on the wavy heat exchange surface of the plate 24, 28. Each louver 44 and 46 includes two oppositely directed portions 48, 50 extending from the plate fin 24, 28. Whichever portion 48 or 50 is closest the nearest peak 34 or trough 36 extends from the plate fin 24, 28 in a direction opposite to the direction of that nearest peak 34 or trough 36. Additionally, as shown in Figure 3, each pair of louvers 44 and 46 are mirror images of each other. The louvers 46 and 44 are arranged in alternating rows 54, 56 which are perpendicular to the direction of airflow and parallel

to the peaks 34 and troughs 36. The louvers 44 and 46 are mirror images of each other and are located on the sides of the peaks 34 and troughs 36.

5 It is critically important that the louvers 44, 46 are not located in portions 52 of the wavy heat exchange surface which separate each adjacent pair of aligned apertures 38 within each of the first 42 and second 40 rows of aligned apertures and are aligned with a respective peak or trough 34, 36. This
10 arrangement of the louvers 46 and 48 increases the heat transfer performance of the plate fin 24, 28 whether the wavy heat exchange surface is wet or dry and at the same time minimizes air side pressure drop. It will be understood that an advantage of the plate
15 fin 24, 28 is that it is suitable for use in a condenser or an evaporator.

Although the present invention has been described in connection with the preferred embodiment above, it is apparent that many alterations and modifications
20 may be made as long as the location of the heat transfer enhancing means remains substantially as described above.



CLAIMS:

1. A heat exchange member for use in a refrigeration system:

said member having a wavy heat exchange surface having a series of alternating peaks and troughs extending over the wavy surface in a direction substantially perpendicular to a direction of airflow;

the member including a plurality of holes aligned in first and second rows parallel to the peaks and troughs, where the first and second rows of aligned holes are staggered with respect to each other when viewed from the direction of airflow, where the first rows of aligned holes are located in alignment with every third peak of the wavy surface and the second rows of aligned holes are located in alignment with every third trough of the wavy surface such that the peaks aligned with the first rows of aligned holes are not immediately adjacent the troughs aligned with the second rows of aligned holes and where each adjacent pair of aligned holes within each row is separated by a respective portion of said surface in alignment with one of the third peaks or the third troughs;

the member further including means for enhancing heat transfer, where the enhancement means are located between the peaks and troughs on the wavy surface, but



not in said respective portions.

2. A heat exchange member according to claim 1, wherein said heat transfer enhancing means comprises louvers.

5 3. A heat exchange member according to claim 2, wherein each louver is paired with a second louver formed in its mirror image.

10 4. A heat exchange member according to claim 2 or 3, wherein each louver has two oppositely directed elements.

15 5. A heat exchange member according to claim 4, wherein the louver element of each louver closest to the nearest peak or trough extends from the member in a direction opposite the direction of the nearest peak or trough.

6. A heat exchange member according to any one of claims 2 to 5, wherein the amount of protrusion of each louver from the member is not greater than four times the thickness of the member.

20 7. A heat exchange member according to claim 6,



wherein said amount of protrusion is not greater than three times said thickness.

5 8. A heat exchange member according to claim 6, wherein said amount of protrusion is approximately 3.6 times said thickness.

9. A heat exchange member according to any one of claims 2 to 8, wherein two sides of each louver are attached to the member.

10 10. A plate fin for use in a heat exchanger of a refrigeration system,

said plate fin having a predetermined thickness and comprising a wavy surface having a series of alternating parallel peaks and troughs, the plate fin including apertures adapted to engage heat transfer tubes to be passed therethrough, said apertures being aligned in rows which are alternately aligned respectively with every third peak and every third trough of the wavy surface, each adjacent pair of aligned apertures within each row being separated by a respective portion of said surface in alignment with the respective peak or trough,

20 the plate fin including means for enhancing the heat transfer rate of the wavy surface, said heat



transfer enhancing means being located between the parallel peaks and troughs on the wavy surface but not in said respective portions. --

5 11. A plate fin according to claim 10, wherein said heat transfer enhancing means comprises louvers arranged in pairs on each side of a peak or trough.

10 12. A plate fin according to claim 11, wherein each louver comprises a first portion extending from the plate fin in one direction and a second portion extending from the plate fin in a different direction.

13. A plate fin of claim 13, wherein said directions are opposite.

15 14. A plate fin according to any one of claims 10 to 13, wherein said heat transfer enhancing means extends from the plate fin a distance which is at most four times said predetermined thickness.

15. A plate fin according to claim 14, wherein said distance is approximately 3.6 times said thickness.

20 16. A plate fin according to claim 14, wherein said distance is at most three times said thickness.



17. A method of forming a plate fin for a heat exchanger, the method comprising the steps of:

forming said plate fin to provide a surface having a wavy series of parallel peaks and troughs;

5 forming first and second staggered rows of apertures in the plate fin such that the first rows of apertures are aligned with every third peak of the surface and the second rows of apertures are aligned with every third trough of the surface; and

10 providing heat transfer enhancing means on said surface between adjacent peaks and troughs but not on respective portions of said surface which separate each adjacent pair of apertures within each row and are aligned with a said peak or trough.

15 18. A method according to claim 17, wherein said heat transfer enhancing means are provided by forming louvers which extend from the plate fin a distance at most four times the thickness of the plate fin.

19. A method according to claim 18, wherein said
20 distance is approximately 3.6 times said thickness.

20. A method according to claim 18, wherein said distance is at most three times said thickness.



21. A heat exchanger for a refrigeration system, the heat exchanger comprising:

first and second rows of heat transfer tubes which are staggered with respect to each other when viewed from a direction of air flow;

a series of plate fins having wavy surfaces which are substantially parallel to the direction of air flow, where each plate fin includes at least first and second rows of apertures which are sized and located to receive said heat transfer tubes;

the wavy surface of each plate fin having a series of alternating peaks and troughs extending over the wavy surface in a direction substantially perpendicular to said direction of air flow, the first rows of aligned apertures of each plate fin being located in alignment with every third peak of the wavy surface thereof and the second rows of aligned apertures of each plate fin being located in alignment with every third trough of the wavy surface thereof such that the peaks aligned with the first rows of aligned apertures are not immediately adjacent the troughs aligned with the second rows of aligned apertures and wherein each adjacent pair of aligned apertures within each row is separated by a respective portion of said wavy surface in alignment with one of the third peaks or the third troughs; and



each of the plate fins including means for enhancing heat transfer where the enhancement means are located between the peaks and troughs on the wavy surface thereof, but not in said respective portions.

5 22. A heat exchanger according to claim 21, wherein said enhancement means comprises louvers.

23. A heat exchanger according to claim 22, wherein each louver is paired with a second louver formed in its mirror image.

10 24. A heat exchanger according to claim 22 or 23, wherein each louver has two oppositely directed elements.

15 25. A heat exchanger according to claim 24, wherein the element of each said louver closest to the nearest peak or trough of a respective wavy surface extends from the wavy surface in a direction opposite the direction of said nearest peak or trough.

20 26. A heat exchanger according to any one of claims 22 to 25, wherein the amount of protrusion of each louver from a said plate fin is not greater than four times the thickness of the plate fin.



27. A heat exchanger according to claim 26, wherein said amount of protrusion is approximately 3.6 times said thickness.

5 28. A heat exchanger according to claim 26, wherein said amount of protrusion is not greater than three times said thickness.

29. A heat exchanger according to any one of claims 22 to 28, wherein two sides of each louver are attached to a said plate fin.

10 30. A heat exchanger for use in a refrigeration surface substantially as hereinbefore described with reference to the accompanying drawings.

15 31. A plate fin substantially as hereinbefore described with reference to figures 2 to 5 of the accompanying drawings.
