An evaporator for use in car coolers.

An evaporator comprising a plurality of unit heat exchangers (A, B) each of which has a circuit formed therethrough for a heat exchanging medium and a connecting means (220, 230) for connecting the circuits in fluid communication with each other, each of the unit heat exchangers comprising a plurality of tubes (1) arranged in parallel with each other, a plurality of fins (2) each interposed between the two adjacent tubes (1) and a pair of hollow headers (3, 23 and 4, 24) to which both ends of each tube (1) are connected in fluid communication. The unit heat exchangers (A, B) are arranged fore and aft in a direction of air flow so that one of them faces windward, with the other lying leeward and unit air flow paths are defined between the adjacent tubes (1) and separated by the fins (2), such that a cross-sectional area of each unit air flow path in the leeward unit heat exchanger is larger than that in the windward one, whereby an amount of condensed water on the leeward unit heat exchanger is prevented from being scattered therefrom.
The present invention concerns an evaporator comprising a plurality of unit heat exchangers for use in car coolers.

EP-0 401 752 discloses a condenser for a refrigerant of a vehicle air conditioning system having adjacent assemblies which are mechanically connected via their ribbed portion, the mean thermal conductance \( \Lambda \) lies, however, 20% below the thermal conductance \( \Lambda \) of the material of the ribbed portion of the two adjacent assemblies in a connection zone between every two adjacent assemblies.

US-A-3229760 comprises a heat exchange apparatus more particularly a radiator structure provided with cooling fins mounted in a main housing provided with a plurality of spaced apart fluid conduits and a guard structure being provided to protect the fins.

US-A-4531574 provides a mounting for attaching an oil cooler to a radiator so as to be in series therewith in the path followed by the coolant air.

A multi-flow type heat exchanger is disclosed in Japanese Patent Publication Kokai 63-34468 and has a structure such that a plurality of parallel flat tubes are connected to a pair of hollow headers at their opposite ends, respectively, with a corrugated fin interposed between one such flat tube and the next. In operation, heat exchange occurs between coolant and ambient air which flows through spaces defined between the tubes while the coolant flows through a coolant circuit composed of the flat tubes. The known multi-flow type heat exchanger can be made thinner than the other known heat exchangers in its dimension in a direction of air flow, without affecting the efficiency of heat exchange. Therefore, the multi-flow type heat exchanger has proved itself better in performance than the other known heat exchangers of some types such as the serpentine type.

An object of the present invention is to provide an evaporator which is adapted to increase the heat transfer capacity thereof without necessitating an excessively wide space.

According to the present invention an evaporator comprises a plurality of unit heat exchangers, each of the unit heat exchangers having a circuit formed therethrough for a heat exchanging medium, and a connecting means for connecting the circuits in fluid communication with each other, each of the unit heat exchangers comprising a plurality of tubes arranged in parallel with each other, a plurality of fins each interposed between the two adjacent tubes and a pair of hollow headers to which both ends of each tube are connected in fluid communication, is characterized in that the unit heat exchangers are arranged fore and aft in a direction of air flow so that one of them faces the windward, with the other lying leeward and unit air flow paths are defined between the adjacent tubes and separated by the fins, such that a cross-sectional area of each unit air flow path in the leeward unit heat exchanger is larger than that in the windward one, whereby an amount of condensed water on the leeward unit heat exchanger is prevented from being scattered therefrom.

Each unit heat exchanger may be designed such that a fin pitch in the leeward unit heat exchanger is greater than the pitch in the windward one so that the cross-sectional area of each unit air flow path in the former heat exchanger is larger than that in the latter.

Advantageously the unit heat exchangers are arranged such that the headers of each unit heat exchanger are disposed horizontally on the upside and downside thereof.

Preferably the unit heat exchangers are connected parallel with each other so that the heat exchanging medium flows simultaneously through the unit heat exchangers.

The invention will now be described further, by way of example, with reference to the accompanying drawings, in which:-

Fig. 1 is a perspective view showing a duplex heat exchanger in a separated state of a forehead and a rearward unit heat exchanger;

Fig. 2 is a front elevation of the entirety of the duplex heat exchanger shown in Fig. 1;

Fig. 3 is a plan view of the entirety;

Fig. 4 is similarly a side elevation of the entirety;

Fig. 5 is a perspective view showing a separated state of a header, tubes and corrugated fins of the forehead or rearward unit heat exchanger;

Fig. 6 is a cross-section on a line 6 - 6 of Fig. 2;

Fig. 7 is an enlarged cross-section of the forehead or rearward unit heat exchanger, seen in the same direction as in Fig 6;

Fig. 8 is an enlarged front elevation showing the tubes and the corrugated fins;

Fig. 9 illustrates a coolant circuit in the duplex heat exchanger shown in Fig. 1;

Fig. 10 is a perspective view of a duplex heat exchanger;

Fig. 11 is a perspective view illustrating an essential part of the duplex heat exchanger shown in Fig. 1; and

Fig. 12 is a schematic plan view illustrating another embodiment of duplex heat exchanger.

Figs. 1 to 9 shows an embodiment in which the invention is applied to a condenser made of aluminum-based alloy for use as a car cooler. The reference symbol "H" denotes a duplex heat exchanger which comprises a forehead unit heat exchanger "A" located at an upstream side, as well as a rearward unit heat exchanger "B" located at downstream side with respect to a direction "W" of air flow.
The forehand unit heat exchanger "A" is composed of a plurality of horizontally disposed tubes 1 stacked in a vertical direction, of corrugated fins 2 interposed between two of such tubes adjacent to each other, and of a left-hand header 3 and a right-hand header 4. The tubes 1 are made of an extruded profile pipe of said aluminum-based alloy. Alternatively, the tubes 1 may be porous or perforated tubes such as "harmonica tubes" or may be made of an upset-welded pipe. The corrugated fins 2 are of substantially the same width as the tubes 1 and are soldered thereto. The corrugated fins 2 are made of the same or other aluminum-based alloy, and preferably are formed with louvers cut and raised from main bodies of the fins. A cylindrical pipe made of an aluminum-based alloy and having inner and/or outer surfaces coated with a soldering agent is used to manufacture the headers 3 and 4. Tube receiving apertures 5 are formed at regular intervals in a longitudinal direction of each header so that respective ends of each tube 1 are inserted in the tube receiving apertures and securedly soldered thereto. Cover plates 6 are fixed to an upper end and a lower end of the left-hand header 3, and other cover plates 7 are similarly fixed to an upper end and a lower end of the right-hand header 4. Side plates 8 are disposed outside of the outermost corrugated fins 2.

The rearward unit heat exchanger "B" comprises tubes 21, corrugated fins 22, a left-hand header 23 and a right-hand header 24 wherein tube receiving apertures 25, cover plates 26 and 27 and side plates 28 are provided in a manner similar to that in the forehand unit heat exchanger "A". However, a distance "LB" between the left-hand and the right-hand headers in the rearward unit heat exchanger "B" is greater than a similar distance "LA" in the forehand unit heat exchanger "A". By virtue of such a difference between the distances "LA" and "LB", the forehand and rearward headers do not overlap each other and the depth of the duplex heat exchanger as a whole is reduced to a significant degree. This enhances compactness of the heat exchanger so that space occupied by it in the automobiles or the likes is advantageously decreased.

Coolant paths of the forehand unit heat exchanger "A" are connected in series to those of the rearward one "B". In detail, a coolant inlet pipe 40 is connected to an upper portion of the left-hand header 23 of the rearward unit heat exchanger "B". A coolant outlet pipe 50 is connected to an upper portion of the left-hand header 3 of the forehand unit heat exchanger "A". Said left-hand headers 3 and 23 of the forehand and rearward unit heat exchangers "A" and "B" are interconnected by a joint pipe 60. The reference numerals 71 and 72 in Figs. 2 and 3 denote brackets for fixing said unit heat exchangers one to another.

A partition plate 29 in the left-hand header 23 is located at a middle portion thereof so that said header 23 of the rearward unit heat exchanger "B" is partitioned into an upper and a lower chamber. On the other hand, other partition plates 9 in the left-hand header 3 are positioned respectively above and below a middle portion thereof, thus partitioning said header 3 of the forehand unit heat exchanger "A" into three chambers. Further, still another partition plate 10 in the right-hand header 4 at a middle portion thereof partitions same into two chambers for the forehand unit heat exchanger "A". Due to the partitions 29, 9 and 10, coolant flows in such a manner as illustrated in Fig. 9 wherein the coolant enters the left-hand header 23 of the rearward heat exchanger "B" through the coolant inlet pipe 40 so that it makes a U-turn within said heat exchanger before flowing into the lower chamber of said header 23. The coolant then advances through the joint pipe 60 into the lower chamber of the left-hand header 3 of the forehand heat exchanger "A". Subsequently, the coolant makes U-turn three times from one group of tubes to the next group of tubes within the forehand heat exchanger "A" so as to rise from a bottom thereof. Upon arrival at the upper chamber of said left-hand header 3, the coolant leaves it through the coolant outlet pipe 50. Heat transfer occurs between an air flow indicated by an arrow "W*" and the coolant flowing through the tubes of said unit heat exchangers "A" and "B". A sufficient difference is assured between the coolant temperature and the air flow temperature in the embodiment because the coolant is flowed from the rearward heat exchanger lying leeward to the forehand one standing to the windward. It is also an important feature that the times of coolant U-turn between the groups of tubes in the forehand heat exchanger "A" is more than that in the rearward heat exchanger "B". Such a structure makes less a total cross-sectional area of coolant paths in the forehand heat exchanger "A" than that in the rearward one "B" in correspondence with a change in volume of the coolant flowing through the duplex heat exchanger employed as a condenser. It is to be noted in this connection that the coolant flowing into the rearward heat exchanger "B" is still in its gas state of a larger volume but it is gradually cooled down there-into in its liquid state of a smaller volume. Therefore, the larger cross-sectional area of coolant paths in the rearward heat exchanger "B" is useful for sufficient heat transfer of the coolant in its gas state in said heat exchanger. At the same time, undesirable pressure loss is diminished to a minimum though the cross-sectional area in the forehand heat exchanger "A" is decrease corresponding to shrinkage of the coolant therein, thereby improv-
ing heat transfer efficiency of the duplex heat exchanger as a whole. The cross-sectional area in the forehand heat exchanger "A" is set at 30 to 60 % of that in the rearward heat exchanger "B". In a case wherein the area in forehand heat exchanger "A" adapted to the supercooling of coolant is below 30%, this excessively decreased area brings about an undesirable great pressure loss in said heat exchanger "A" on one hand, and a superfluously large area of coolant paths in the rearward heat exchanger "B" adapted to condense the coolant will on the other hand undesirably decrease a flow rate of coolant to lower the heat transfer efficiency. In another case wherein the coolant path area in the forehand heat exchanger "A" is above 60% of that in the rearward heat exchanger "B", such a small area in "B" will increase the pressure loss of coolant therein and lower the heat transfer capacity due to insufficient area of heat transfer surfaces. Therefore, it is desirable to set the cross-sectional area of coolant paths in the forehand heat exchanger "A" to be 30 to 60 %, and more preferably 35 to 50 % of that in the rearward heat exchanger "B" in order for the duplex heat exchanger to perform efficient heat transfer under a lower pressure loss.

Other parameters for better performances of the forehand and rearward heat exchangers "A" and "B" are as follows.

The aforementioned tubes 1 and 21 may preferably be 6 to 20 mm in width "Wt", 1.5 to 7 mm in height "Ht", and 1.0 mm or more in an inner height "Hp" of coolant path. The corrugated fins 2 and 22 may preferably be 6 to 16 mm in height "Hf" (that is, a distance between two adjacent tubes 1 or 21), and 1.6 to 4.0 mm in fin pitch "Fp". Reasons for such dimensions will be given below.

Tube width "Wt" less than 6 mm will make too narrow the width of the corrugated fins 2 and 22 which are interposed respectively between the two adjacent tubes 1 or 21. A larger tube width above 20 mm will cause an excessively large width of said fins 2 and 22, which in turn causes an increased resistance against air flow therethrough in addition to an overweight of the condenser. This, the range of 6 to 20 mm is desirable, and a range of 10 to 20 mm is more desirable.

Tube height "Ht" above 7 mm will increase the resistance of the tubes against air flow, and said height below 1.5 mm will make it difficult to obtain the inner height "Hp" of coolant path greater than 1.0 mm with a sufficient wall thickness of the tubes. The range of 1.5 to 5 mm, or more particularly a range 2 to 4 mm is preferable.

If said inner height "Hp" of coolant path were less than 1.0 mm, then the loss in coolant pressure would undesirably increase lowering the heat transfer efficiency. A range of 1.0 to 3.0 is preferable.

Fin height "Hf" less than 6 mm will bring about an increased pressure loss of air flow penetrating through the fins, though fin height of 16 mm or more will reduce the number of mounted fins, reducing the "fin effect" and making worse the heat transfer performance. Therefore, fin height is selected from the aforementioned range of 6 to 16 mm, or more preferably from a range of 6 to 12 mm is selected.

As for the fin pitch "Fp", the air flow pressure loss increases with its value below 1.6 mm whereas heat transfer performance becomes worse with its value above 4.0 mm. The most preferable range is from 2.0 to 3.6 mm.

As described above, the most adequate dimensions are selected as to the shapes of tubes 1 and 21 and the corrugated fins 2 and 22 which give important influences on the performance of condenser. Selection of the dimensions of tube width, tube height, inner height of coolant path, fin height and fin pitch respectively from the ranges referred to above will provide the condenser which can be operated efficiently in an optimal manner wherein a good balance is realized between the pressure loss of coolant or air flow and the heat transfer characteristics, without being accompanied by any significant increase in the weight of condenser.

Figs 10 and 11 show an embodiment which is applied to an evaporator for car coolers. In this embodiment, which is suited to reduce coolant pressure loss in evaporators, tubes 1 of a forehand heat exchanger "A" as well as tubes 1 of a rearward heat exchanger "B" are vertical and parallelly arranged in a right-to-left direction. Corrugated fins 2 are interposed between adjacent tubes 1. Upper headers 3 and 23 and lower headers 4 and 24 disposed horizontally. A bifurcate inlet pipe 220 for coolant is connected to left ends of the upper headers 3 and 23. Likewise, a bifurcate outlet pipe 230 is connected to right ends of the lower headers 4 and 24, coolant paths of the two heat exchangers "A" and "B" thereby running parallel with each other. Coolant flows into the heat exchangers "A" and "B" through the inlet pipe 220, descends to the lower headers 4 and 24 and then flows out of the heat exchangers through the outlet pipe 230. As shown in Fig. 11, fin pitch "FpB" of corrugated fins 22 in the rearward heat exchanger "B" is made greater than that "FpA" in the forehand heat exchanger "A". Such a greater fin pitch "FpB" in the rearward heat exchanger prevents the so-called water-drop-flying which would otherwise be caused by air flow forcing toward a cabin of the automobile such condensed water that is retained between the fins in the rearward heat exchanger due to the capillary phenomenon. Some partition plates may be fixed inside the upper and lower headers to cause coolant to meander along zigzag paths.
Three unit heat exchangers "A", "B" and "C" as shown in Fig. 12 may be combined though two unit heat exchangers are arranged fore and aft. Further, four or more unit heat exchangers may be combined in the invention.

As will be apparent from the above description, the duplex heat exchanger is constructed such that the fins are each interposed between two adjacent tubes each having ends respectively connected to the hollow headers in fluid connection therewith. A plurality of the unit heat exchangers are aligned with each other in the direction of air flow and the coolant paths of said heat exchangers are connected in series or parallel with each other. Therefore, the capacity of heat transfer can be increased for the duplex heat exchanger as a whole because each unit heat exchanger contributes to the heat transfer therein. Such a combination of two or more unit heat exchangers provides a higher degree of freedom in selecting the number and/or location of the partition plates in order to form a desired coolant flow circuit. Thus, an optimal design of the duplex heat exchanger can be employed for a higher heat transfer efficiency and for a lower pressure loss which are indispensable to a good heat exchanger.

Claims

1. An evaporator comprising a plurality of unit heat exchangers (A, B) each of the unit heat exchangers having a circuit formed therethrough for a heat exchanging medium and a connecting means (220, 230) for connecting the circuits in fluid communication with each other, each of the unit heat exchangers comprising a plurality of tubes (1) arranged in parallel with each other, a plurality of fins (2) each interposed between the two adjacent tubes (1) and a pair of hollow headers (3, 23 and 4, 24) to which both ends of each tube (1) are connected in fluid communication, characterized in that the unit heat exchangers (A, B) are arranged fore and aft in a direction of air flow so that one of them faces windward, with the other lying leeward and unit air flow paths are defined between the adjacent tubes (1) and separated by the fins (2), such that a cross-sectional area of each unit air flow path in the leeward unit heat exchanger is larger than that in the windward one, whereby an amount of condensed water on the leeward unit heat exchanger is prevented from being scattered therefrom.

2. An evaporator according to claim 1, characterized in that each unit heat exchanger (A, B) is designed such that a fin pitch (FP_B) in the leeward unit heat exchanger is greater than the pitch (FP_A) in the windward one so that the cross-sectional area of each unit air flow path in the former heat exchanger is larger than that in the latter.

3. An evaporator according to claim 1 or 2, characterized in that the unit heat exchangers (A, B) are arranged such that the headers (3, 23 and 4, 24) of each unit heat exchanger are disposed horizontally on the upside and downside thereof.

4. An evaporator according to claim 1, 2 or 3, characterized in that the unit heat exchangers (A, B) are connected parallel with each other so that the heat exchanging medium flows simultaneously through the unit heat exchangers.