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A HEAT EXCHANGER DEVICE FOR AN AIR CONDITIONING SYSTEM

The present invention relates to a heat exchanger device for an air conditioning system, especially for conditioning the air in cabins of cars or other vehicles.

Air conditioning systems for cars comprising thermoelectric cooling units are disclosed in US Patent No. 3.236.056 and in the published Swedish Patent Application No. 8704395. The air conditioning systems disclosed in these documents comprise one or more thermoelectric units which are sandwiched between straight water conduits having a rectangular cross-section and forming part of heat transfer circuits.

The known air conditioning systems have a relatively small cooling capacity and this may be the reason why the documents are silent about the source of the electric energy which has to be supplied to the thermoelectric units of the system. This energy source is apparently supposed to be the standard battery and electricity supply system already available in an existing standard car in which the air conditioning system is to be installed.

The object of the present invention is to provide a heat exchanger device for an air conditioning system of the above type by means of which the capacity and/or efficiency of the air conditioning system may be substantially increased.

The heat exchanger device according to the present invention comprises first and second heat exchanger elements defining separate first and second flow passages therein for heat transporting medium, and thermoelectric units, such as so-called Peltier elements, arranged between and having opposite heating and cooling surfaces in heat conductive contact with the first and second heat exchanger element, respectively, and the heat exchanger device according to the invention is characterised in that each heat exchanger element defines a tortuous flow passage therein having a length being several

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times the maximum dimension of the heat exchanger element or a plurality of coextending separate flow passages each having a small cross-sectional area.

The heat exchanger device according to the invention may secure an efficient cooling of the warm sides of the thermoelectric units and an efficient heating of the cold sides of these units, whereby the overall thermal efficiency of the air conditioning system may be increased. Furthermore, the capacity of the air conditioning system may be adapted to that desired by using a suitable number of thermoelectric units and by dimensioning the heat exchanger device correspondingly.

The flow passages formed in any of the heat exchanger elements may comprise two or more tortuous coextending flow passages or a plurality of substantially straight flow passages extending in the longitudinal direction of the heat exchanger. As an example, each heat exchanger element may define one or a few separate tortuous flow passages covering substantially the area contacting the thermoelectric units, or a plurality of separate adjacent flow passages extending in the longitudinal direction of the heat exchanger element. In order to obtain substantially the same effect, the total cross-sectional area or areas of the flow passage or passages should be substantially the same in either case.

The thermoelectric units may, for example, be of the type marketed by Marlow Industries Inc., such as Model SP1996.

In principle, the heat exchanger device may have any suitable shape allowing the selected number of thermoelectric units to become sandwiched between the heat exchanger elements. In the preferred embodiment, however, the heat exchanger element has a flat, block-like shape, so as to allow a maximum number of thermoelectric units to be included in the heat exchanger device in relation to the total volume of this device.

The heat exchanger elements may have any suitable shape in plan view. However, each heat exchanger element is preferably elongated and may, for example, be rectangular. It has been found that the efficiency of the heat exchanger is improved when the maximum longitudinal dimension of each element and, consequently, of the heat exchanger device substantially exceeds the maximum transverse dimension of the element or device. Thus, the length or longitudinal dimension may be about twice the transverse dimension or width, or more.

The best efficiency or coefficient of performance of the heat exchanger device is obtained when the cross-sectional area of the flow passage or passages (when each heat exchanger element defines two or more separate, coextending passages) and the area of the element contacting the thermoelectric units or Peltier elements is between 0.4×10^{-3} and 0.2 and preferably between 1×10^{-3} and 40×10^{-3}. In the presently preferred embodiment the said ratio is between 2.5×10^{-3} and 7.5×10^{-3}.

The tortuous flow passage may/, for example, be made in a block-shaped metal sample by drilling and by plugging some of the open ends of the passages drilled. Preferably, however, the flow passage in at least one of said first and second heat exchanger elements is a channel or groove formed in a side surface of the element. The side surface in which the channel or groove is formed may then be covered or closed in any suitable manner, for example by a film or a foil, so as to form the tortuous flow passage. Straight flow passages may be made in the same way or by extrusion of the heat exchanger element.

In a preferred embodiment the first as well as the second flow passage are channels or grooves formed in opposite, adjacent side surfaces of the first and second heat exchanger elements. The channel or groove in each heat exchanger element may then be covered by a cover plate or foil sealed

to the element at least along the contour of the element. The plate-like thermoelectric unit or Peltier element may then be arranged between the cover plates of the first and second heat exchanger elements, for example by means of thermo conductive paste or adhesive. Alternatively or additionally, the heat exchanger elements may be clamped together by releasable mechanical clamping means, such as screws or bolts, whereby an optimum specific contact pressure between the heat exchanger elements and the thermoelectric units sandwiched therebetween may be adjusted.

The tortuous flow passages defined in the heat exchanger elements may have any desired shape securing a good heat transfer between the heat transporting medium, usually water or an aqueous liquid, flowing through the flow passages and the adjacent side surfaces of the thermoelectric units. However, preferably at least one of the first and second flow passages defines one or more meander-shaped patterns which have been found to be especially efficient.

Each of the flow passages defined by the heat exchanger elements has an inlet and an outlet which may be located at any suitable position of the element. Preferably, each of the heat exchanger elements has the inlet as well as the outlet arranged at the same end. Thus, the first heat exchanger element may have its inlet and outlet positioned at one end while the first element may have its inlet and outlet positioned at the opposite end of the heat exchanger device. In such case each of the circuits of the air conditioning system for heat transporting medium has to be connected to only one end of the heat exchanger device.

Each of the heat exchanger elements may have a substantially rectangular outline, and the flow passage defined in each element may then comprise a transversely extending meander-shaped flow passage section at each end of the heat exchanger element interconnected by a longitudinally extending meander-

shaped flow passage section. This flow passage pattern has proved to be especially efficient.

The heat exchanger device according to the invention may be given any desired size and shape so that any desired number of thermoelectric units or Peltier elements may be sandwiched between the heat exchanger elements. Consequently, any desired cooling capacity of an air conditioning system including the heat exchanger may be obtained.

When the heat exchanger device comprises a plurality of thermoelectric units or Peltier elements these thermoelectric units are preferably divided into a number of groups, the thermoelectric units of each group being electrically connected in series and the groups of thermoelectric units being mutually electrically connected in parallel. This arrangement has the advantage that in case a thermoelectric unit belonging to one of the groups breaks down only that group to which it belongs becomes inefficient.

Even though the thermal efficiency of an air conditioning system including the heat exchanger device according to the invention is rather high, the standard electrical supply system in a standard car is usually not sufficient to supply electric energy also to the thermoelectric units of the heat exchanger device in cases where a good cooling capacity is required. Therefore, electric energy may be supplied to the thermoelectric units of the heat exchanger device from a separate electric supply system including a current generator driven by the engine of the vehicle being air conditioned.

In order to obtain maximum performance of the thermoelectric units the heat transporting capacity of the fluid flowing in the flow passage adjacent to the warm sides of the thermoelectric units should substantially exceed the heat transporting capacity of the medium flowing in the flow passage adjacent to the cold side of the thermoelectric units. This may, for example, be obtained by a heat exchanger

device being formed by three superposed heat exchanger elements, the flow passages formed in the outer elements being interconnected. Thermoelectric units may then be arranged between the inner heat exchanger element and any of the outer elements so that the warm sides of the thermoelectric units are in contact with the outer elements while the cold sides are in contact with the inner heat exchanger element. In the preferred embodiment, however, the heat exchanger device comprises only a pair of heat exchanger elements, and the length of the flow passage adjacent to the warm sides of the thermoelectric units may then be longer than that of the other flow passage adjacent to the cold side of the thermoelectric units.

The heat exchanger elements should be made from a material with good heat conductive characteristics. Thus, the first and second heat exchanger elements are preferably made from aluminum, copper and/or from alloys thereof.

The present invention further provides a system for conditioning air in a room, such as a cabin of a vehicle, such system comprising a heat exchanger device according to the invention as described above, the first and second passages of the heat exchanger device being included into first and second closed liquid circuits, respectively, each liquid circuit including a radiator and means for circulating liquid therethrough. One of these radiators may be arranged inside and one being arranged outside the room in which the air is to be conditioned. When the air conditioning system is used for conditioning the air of a vehicle cabin, one of the liquid circuits may include part of the liquid cooling system of a combustion engine for driving the vehicle. The radiator in the cabin may then selectively be provided with hot water from the driving engine or with cold water from the heat exchanger device.

The invention will now be further described with reference to the drawings, wherein

Fig. 1 diagrammatically illustrates an air conditioning system according to the invention for use in a car,
Fig. 2 is a top plan view of a heat exchanger device shown in an enlarged scale,
Fig. 3 is a longitudinal sectional view along the line III-III shown in Fig. 2,
Fig. 4 is a transverse sectional view along the line IV-IV in Fig. 2,
Figs. 5 and 6 are plan views showing liquid passages formed in elements of the heat exchanger device shown in Figs. 2-4, and
Fig. 7 diagrammatically illustrates a modified embodiment of the system shown in Fig. 1.

Fig. 1 diagrammatically illustrates an air conditioning system which has been installed in a standard automobile having a driving combustion engine 10. The engine 10 drives an extra current generator 11 which is supplying current to an electric circuit 12 which comprises an on-off switch 13, a pair of relays 14, a pair of fuses 15, and an ignition lock 16. The cabin heating system of the automobile or car comprises a closed cooling water circuit 17 including the cooling jacket of the engine 10 and a radiator 18, which is arranged within the cabin of the car and which is associated with a blower or fan 19. The air within the car cabin may be heated in a conventional manner by controlling the fan 19 and the flow of hot cooling water circulating through the radiator 18.

A second water circuit 20 for cooled water including a water pump 21 and a solenoid valve 22 is connected to part of the water circuit 17 so as to include the cabin radiator 18. The second water circuit 20 also includes a cold flow passage of a heat exchanger device 23 illustrated if Figs. 2-6 and further described below.

The air conditioning system shown in Fig. 1 further comprises a third closed liquid circuit 24 comprising a hot flow pas-

sage of the heat exchanger device 23, a circulating pump 25, a radiator 26 arranged outside the car cabin and having an associated blower or fan 27, and a liquid expansion tank 28. The cabin radiator 18 may be disconnected from the water jacket of the engine 10 by means of solenoid valves 29.

The heat exchanger device 23 will now be described in more detail. The device 23 comprises a pair of plate-like elements 30 and 31 made from metal, such as aluminum. A tortuous channel or groove 32 and 33, respectively, is formed in a side surface of each of the elements 30 and 31. The channel 32 formed in the element 30 comprises a meander-shaped channel section 34 arranged at one end of the substantially rectangular element 30, a corresponding meander-shaped channel section 35 arranged at the opposite end of the element, and an interconnecting, longitudinally extending, meander-shaped channel section 36. The end channel section 35 is connected to a liquid inlet 37, and the end channel section 34 is connected to a liquid outlet 38 via a longitudinally extending straight channel segment 39. Through holes 40 are positioned along the periphery of the element 30 and through holes 41 are positioned along the central line of the element. A circumferential groove 42 for receiving a sealing ring or gasket is formed outside the channel sections 34-36 and 39.

Apart from the fact that the total length of the channel 33 in the plate-like element 31 is substantially greater than the total length of the channel 32 in the element 30, the elements 30 and 31 are alike. Therefore, the reference numerals used in Fig. 6 are the same as those of Fig. 5. However, in Fig. 6 a mark has been added to the reference numerals.

The channels or grooves 32 and 33 in each of the plate-like elements 30 and 31, respectively are covered by a thin, heat conductive cover plate 43 and 44, respectively, and each of the cover plates are in sealing engagement with a gasket or a

sealing ring positioned in the gasket grooves 42 and 42', respectively. As shown in Figs. 3 and 4 an arrangement of a plurality of plate-like Peltier elements 45 are sandwiched between the cover plates 43 and 44 so as to cover substantially the total area inside the gasket groove 42. The elements 30 and 31 with their cover plates 43 and 44 and with the Peltier elements 45 arranged therebetween are clamped together by means of bolts 46 or similar releasable fastening means extending through the aligned holes or bores 40, 40' and 41, 41'.

The Peltier elements are preferably of the type marketed by Marlow Industries Inc., Model SP1996. The heat exchanger device may, for example include twelve Peltier elements which may be divided into six groups each including a pair of elements connected in series. Each of the six groups of Peltier elements may be connected mutually in parallel into the current supply circuit 12 so that the plate-like element 30 is positioned on the cooling side of the Peltier elements 45 while the plate-like element 31 is positioned on the heating side of the Peltier elements.

The meander-shaped channels or grooves 32 and 33 shown in Figs. 5 and 6 may be replaced by a plurality of straight, substantially parallel, separate channels or grooves extending in the longitudinal direction of each of the elements. In such case, the cross-sectional area of each channel or groove as shown in Fig. 4 would be substantially smaller. When the channels or grooves are straight, each element 30 and 31 and the corresponding cover plate 43 or 44 may be formed by extrusion as a coherent part.

The heat exchanger device 23 is preferably heat insulated and supported by shock absorbing means. The heat insulating means may, for example, be foamed plastic which also functions as a shock absorber.

The air conditioning system illustrated in Fig. 1 operates as follows. When the on-off switch 13 is in its off position the solenoid valves 29 are open while the valve 22 is closed. In this state the cabin radiator 18 and the blower 19 may heat the air in the car cabin in a conventional manner.

When the switch 13 is moved to its on position the valves 29 are closed while the valve 22 is opened and electric current is supplied to the Peltier elements 45 of the heat exchanger device 23, to the pumps 21 and 25 and to the fan 27. Water in the second water circuit 20 will now be circulated through the flow passage defined by the channel 32 in the heat exchanger device 23 whereby the water will be efficiently cooled by the Peltier elements 45 in a manner known per se. The cold water flowing through the cabin radiator 18 will now cool the cabin air being circulated in the cabin by means of the blower 19. At the same time the warm side of the Peltier elements 45 will be cooled by water or another liquid being circulated in the third water circuit 24 which includes the channel 33 of the heat exchanger device 23, by means of the pump 25. The heat removed from the heat exchanger device 23 will be given off to the outside air via the outside radiator 26.

In the air conditioning system shown in Fig. 7 the parts similar to those shown in Fig. 1 has been indicated by the same reference numerals.

In the embodiment shown in Fig. 7 the second water circuit has been made independent of the cooling water circuit 17 and comprise a separate radiator 47 arranged opposite to the blower 19 and a liquid expansion tank 48. Furthermore, the operation of the various electrical devices of the system is controlled by an electric control unit 49. It is appreciated that the air conditioning system shown in Fig. 7 may be installed in a car without interfering with the existing electrical and cooling systems of the car.

EXAMPLE

A heat exchanger device as that illustrated in Figs. 2-6 has a length of 330 mm, a width of 152 mm and a total thickness of 51 mm. The cross-sectional dimensions of the channel 32 in the plate-like element 30 is 9 x 14 mm, while the cross-sectional dimensions of the channel 33 in the plate-like member 31 is 6 x 14 mm. The heat exchanger device contains twelve Peltier elements Model SP1996 from Marlow Industries Inc. These elements are divided into six pairs which are mutually connected in parallel while each pair is connected in series.

During cooling down from a temperature in the cabin of a car substantially above ambient temperature, the device is operating at an electric direct current of 42.1 ampere at a voltage of 27.2 volts is supplied to the Peltier elements. Thus, the power consumption is 1145 W/h. Water or water containing glycol is circulated in the circuits 20 and 24 and through the associated channels or grooves 32, 33 of the heat exchanger device. The flow rate through the channels 32 at the cold side of the Peltier elements is 6 l/min at a pressure of 0.6-0.8 bar. The cooling rate of the cabin by means of the radiator 18 corresponds to 1000 W/h.

The liquid is forced through the liquid circuit 24 including the channels 33 by means of the pump 25 at a rate of 6 l/min at a pressure of 0.6-0.8 bar.

The coefficient of performance of the system may be calculated as follows:

$$\frac{1000\ W \times 100}{1145\ W} = 87{,}4\%.$$

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CLAIMS

1. A heat exchanger device for an air conditioning system, said heat exchanger device (23) comprising first and second heat exchanger elements (30, 31) defining separate first and second flow passages (32, 33) for heat transporting medium, and thermoelectric units (45) arranged between and having opposite heating and cooling surfaces in heat conductive contact with the first and second heat exchanger elements, respectively,
characterised in that each heat exchanger element (30, 31) defines a tortuous flow passage (32, 33) therein having a length being several times the maximum dimension of the heat exchanger element, or a plurality of coextending separate flow passages each having a small cross-sectional area.

2. A heat exchanger device according to claim 1, wherein each heat exchanger element (30, 31) has a flat, block-like shape.

3. A heat exchanger device according to claim 1 or 2, wherein each heat exchanger element has an elongated, preferably substantially rectangular shape.

4. A heat exchanger device according to claim 3, wherein the maximum longitudinal dimension of each heat exchanger element substantially exceeds the maximum transverse dimension thereof.

5. A heat exchanger device according to any of the claims 1-4, wherein the ratio between the cross-sectional areas of the flow passage or the sum of the cross-sectional areas of the flow passages, and the areas of the heat exchanger surface being in contact with the thermoelectric units is between 0.4×10^{-3} and 0.2, and preferably between 1×10^{-3} and 40×10^{-3}.

6. A heat exchanger according to claim 5, wherein said ratio is between 2.5×10^{-3} and 7.5×10^{-3}.

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7. A heat exchanger device according to any of the claims 1-6, wherein the flow passage in at least one of said first and second heat exchanger elements (30, 31) is a channel or groove (32, 33) formed in a side surface of the element.

8. A heat exchanger device according to claim 7, wherein said first and second flow passages are channels or grooves (32, 33) formed in opposite, adjacent side surfaces of the first and second heat exchanger elements (30, 31).

9. A heat exchanger device according to claim 7 or 8, wherein the channel or groove (32, 33) in each heat exchanger element (30, 31) is covered by a cover plate (43, 44) sealed to the element along the contour of the element.

10. A heat exchanger device according to claim 8 and 9, wherein the plate-like thermoelectric units (45) are arranged between the cover plates (43, 44) of the first and second heat exchanger elements (30, 31).

11. A heat exchanger device according to any of the claims 1-10, wherein the heat exchanger elements (30, 31) are clamped together by releasable clamping means, such as screws or bolts (46).

12. A heat exchanger device according to any of the claims 1-11, wherein at least one of the first and second flow passages (32, 33) defines one or more meander-shaped patterns (34-36).

13. A heat exchanger device according to any of the claims 1-12, wherein the flow passage (32, 33) of each heat exchanger element (30, 31) has an inlet and an outlet (37, 38) arranged at one end of the heat exchanger element (30, 31).

14. A heat exchanger device according to claim 12 and 13, wherein each of the heat exchanger elements (30, 31) has a

substantially rectangular outline, the flow passage (32, 33) being defined in each element comprising a transversely extending meander-shaped flow passage section (34, 35) at each end of the heat exchanger element interconnected by a longitudinally extending meander-shaped flow passage section (36).

15. A heat exchanger device according to any of the claims 1-14, comprising a plurality of thermoelectric units (45) which are divided into a number of groups, the thermoelectric units of each group being electrically connected in series and the groups of thermoelectric units being mutually electrically connected in parallel.

16. A heat exchanger device according to any of the claims 1-15, wherein the length of the flow passage (33) adjacent to the warm side of the thermoelectric units (45) is longer than that of the other flow passage (32) adjacent to the cold side of the thermoelectric units.

17. A heat exchanger device according to any of the claims 1-16, wherein the first and second heat exchanger elements (30, 31) are made from a heat conductive material, such as aluminum, copper, and/or from alloys thereof.

18. A heat exchanger according to any of the claims 1-17 adapted for conditioning the air of a vehicle cabin.

19. A system for conditioning air in a room, such as the cabin of a vehicle, said system comprising a heat exchanger device (23) according to any of the claims 1-18, the first and second passages (32, 33) of the heat exchanger device being included into first (20) and second (24) closed liquid circuits, respectively, each liquid circuit including a radiator (18, 27) and means (21, 25) for circulating liquid therethrough.

20. A system according to claim 19 for conditioning the air of a vehicle cabin, wherein the first liquid circuit (20) includes part of the liquid cooling system (17) of a combustion engine (10) for driving the vehicle.