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(54) ALUMINUM HEAT EXCHANGER AND METHOD OF MAKING THEREOF

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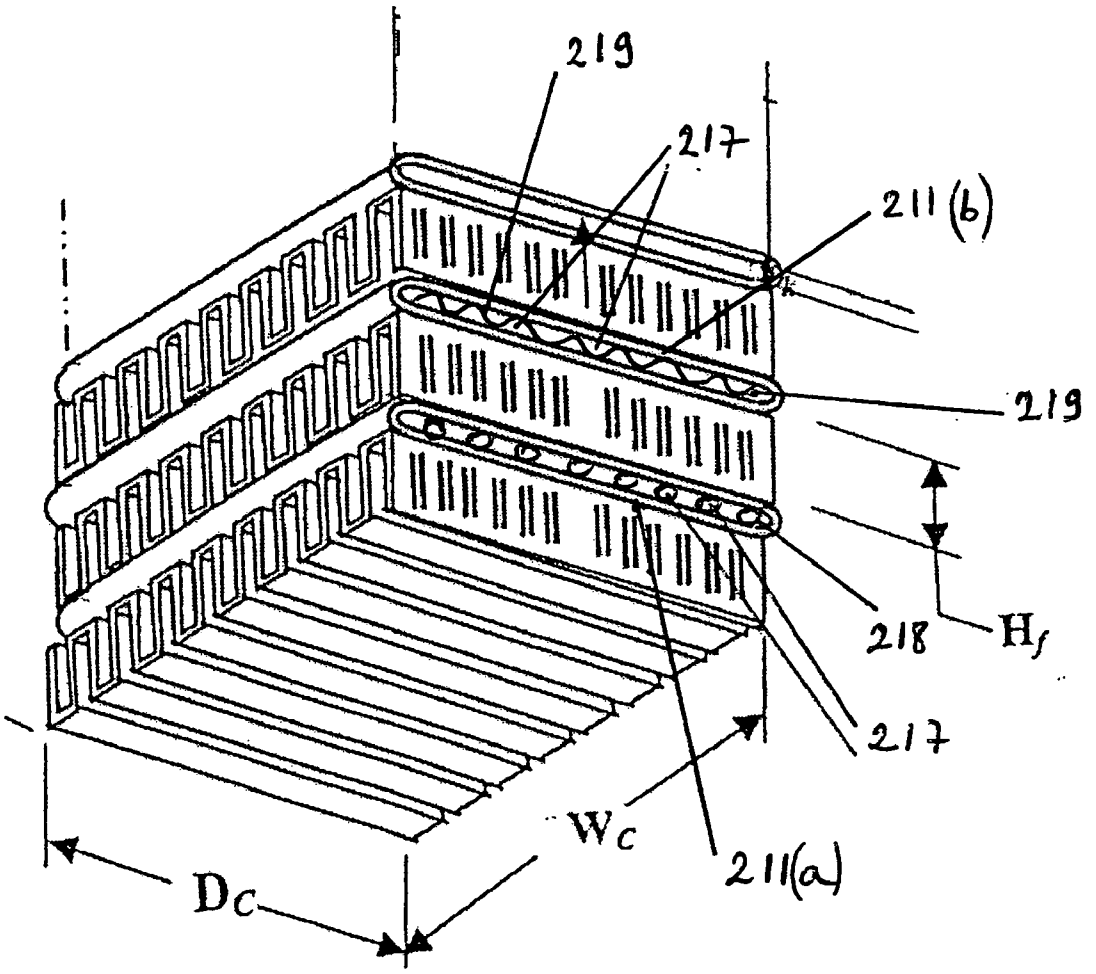
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(57) **ABSTRACT**

The present invention relates to an aluminum heat exchanger. More particularly, the present invention relates to an aluminum heat exchanger useful for motorized power systems similar to those utilized in the automotive industry for engine heat exchange, including, in particular, radiators. In a preferred method, the flat tubes of the heat exchanger are formed from flat sheet braze material and at least one portion is formed approximately normal to the wide portion (major axis) and parallel to the minor axis of the tube.



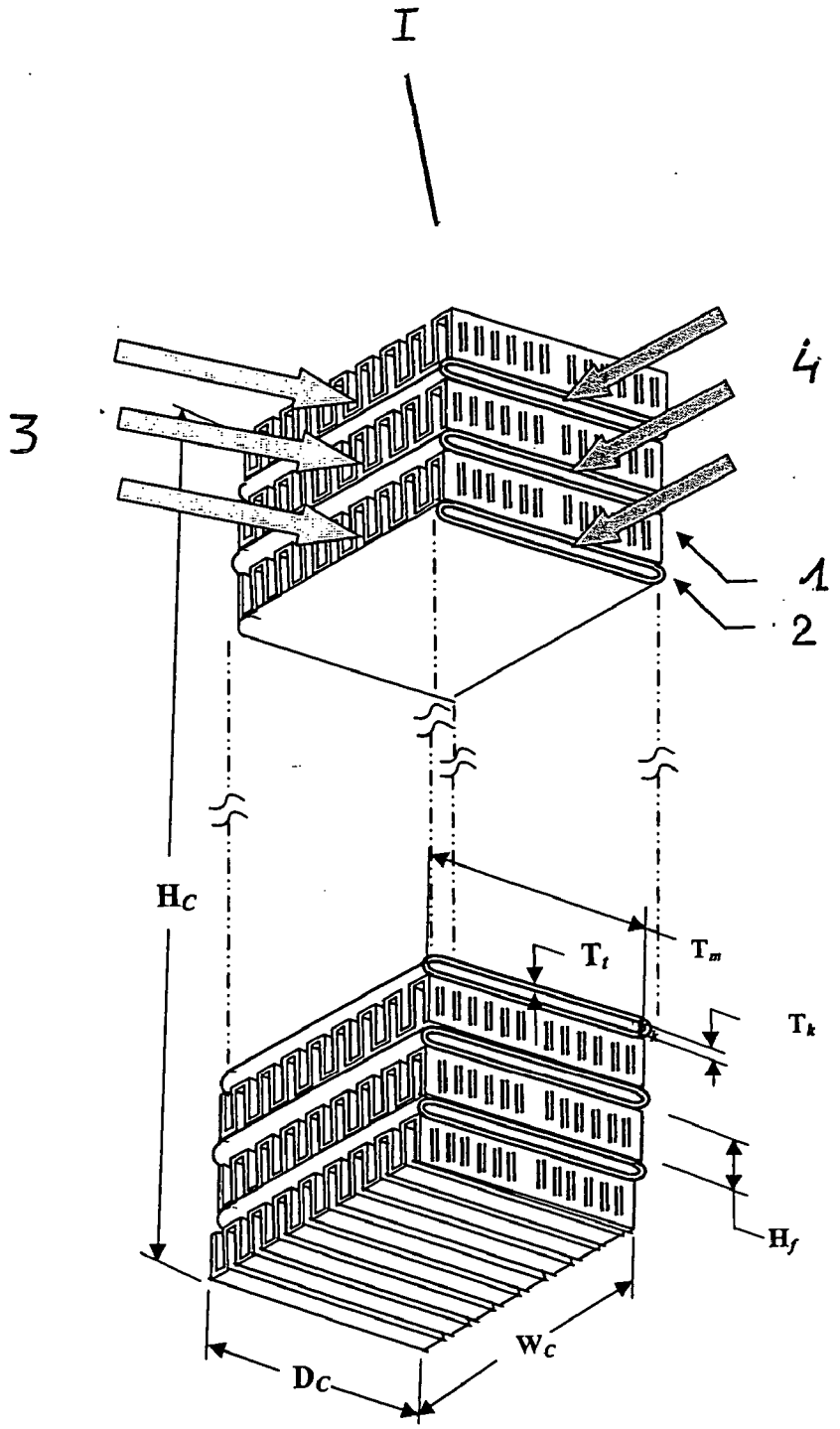



FIG. 1

PRIOR ART

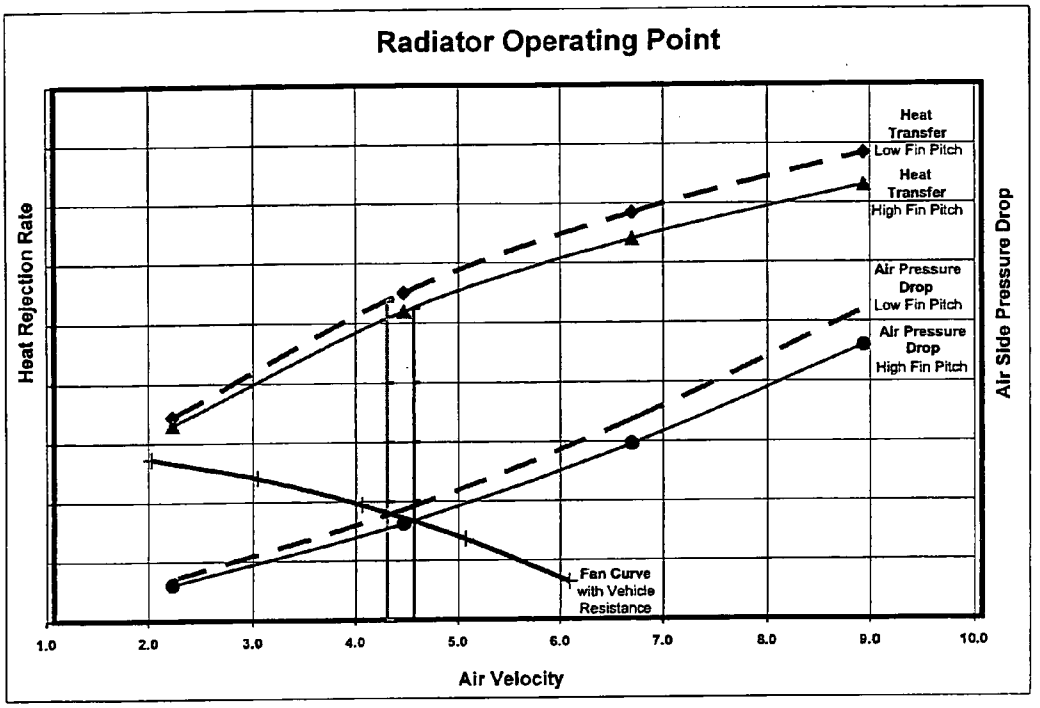

Radiator Operating Point
Heat Rejection Rate
Air Side Pressure Drop
Heat Transfer Low Fin Pitch
Heat Transfer High Fin Pitch
Air Pressure Drop Low Fin Pitch
Air Pressure Drop High Fin Pitch
Fan Curve with Vehicle Resistance
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
Air Velocity

FIG. 2

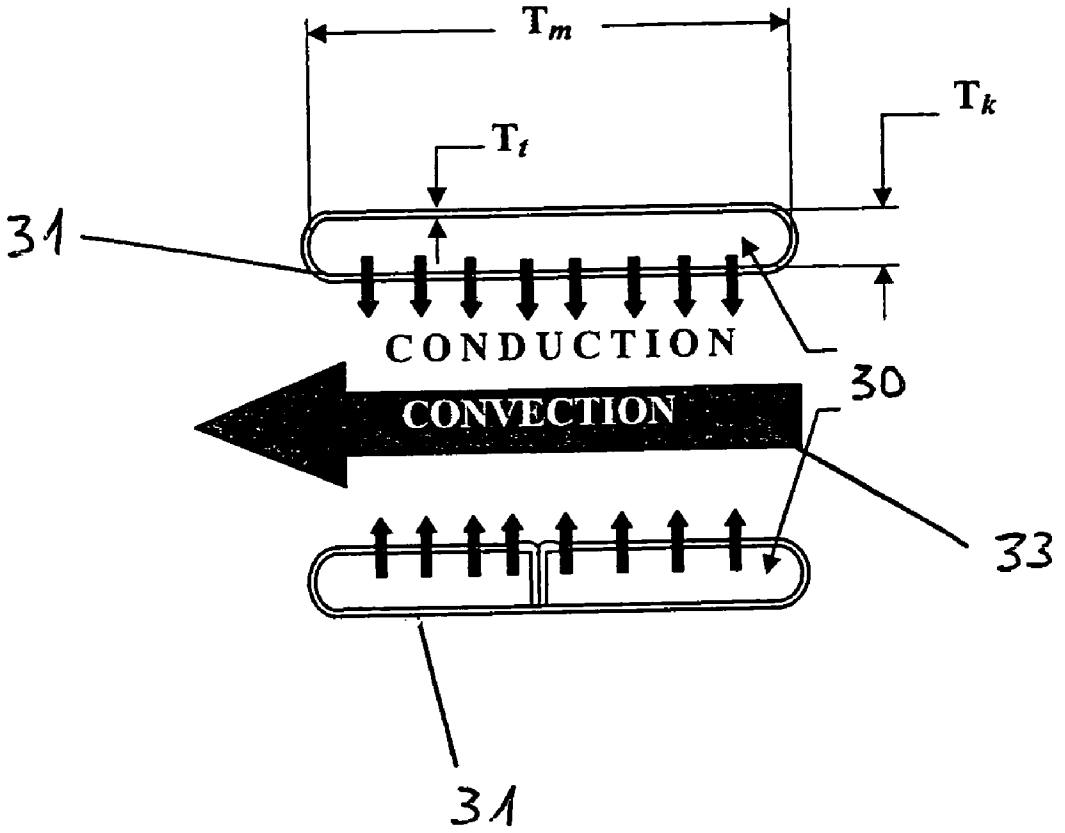



FIG. 3

PRIOR ART

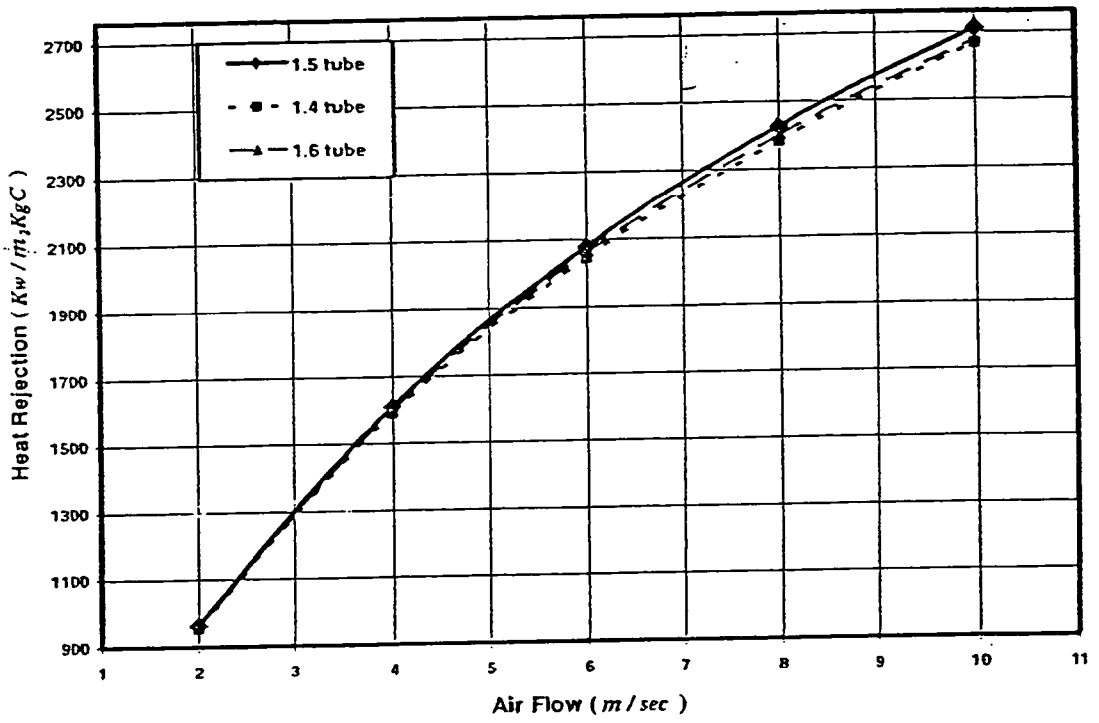

1.5 tube
1.4 tube
1.6 tube
Heat Rejection ( Kw / m³,KgC )
Air Flow ( m / sec )
2700
2500
2300
2100
1900
1700
1500
1300
1100
900
1
2
3
4
5
6
7
8
9
10
11

FIG. 4

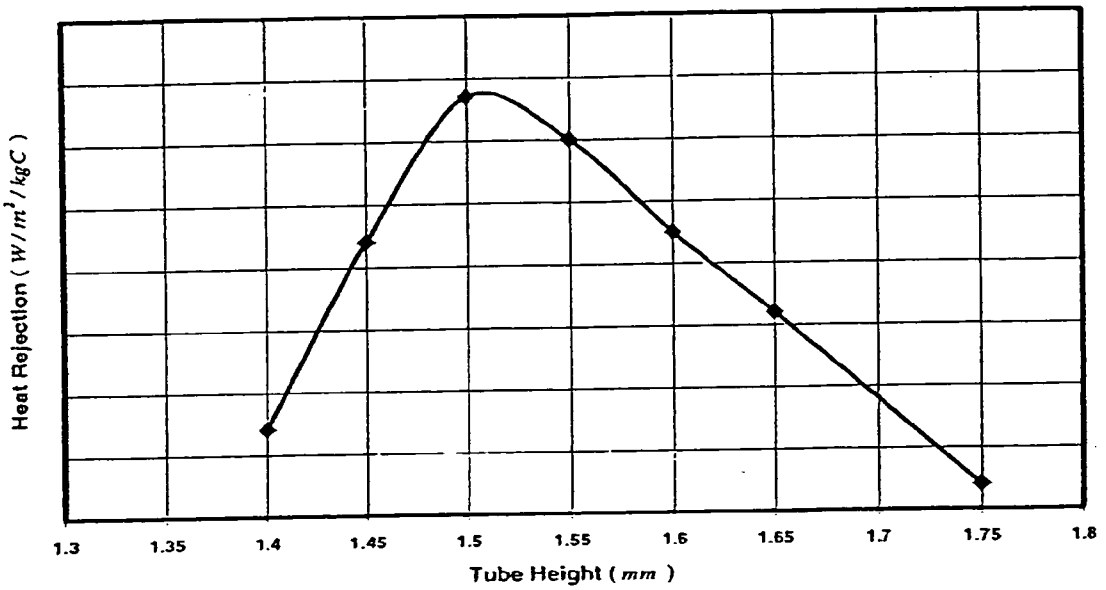

Heat Rejection ( W / m² / kgC )
1.3
1.35
1.4
1.45
1.5
1.55
1.6
1.65
1.7
1.75
1.8
Tube Height ( mm )

FIG. 5

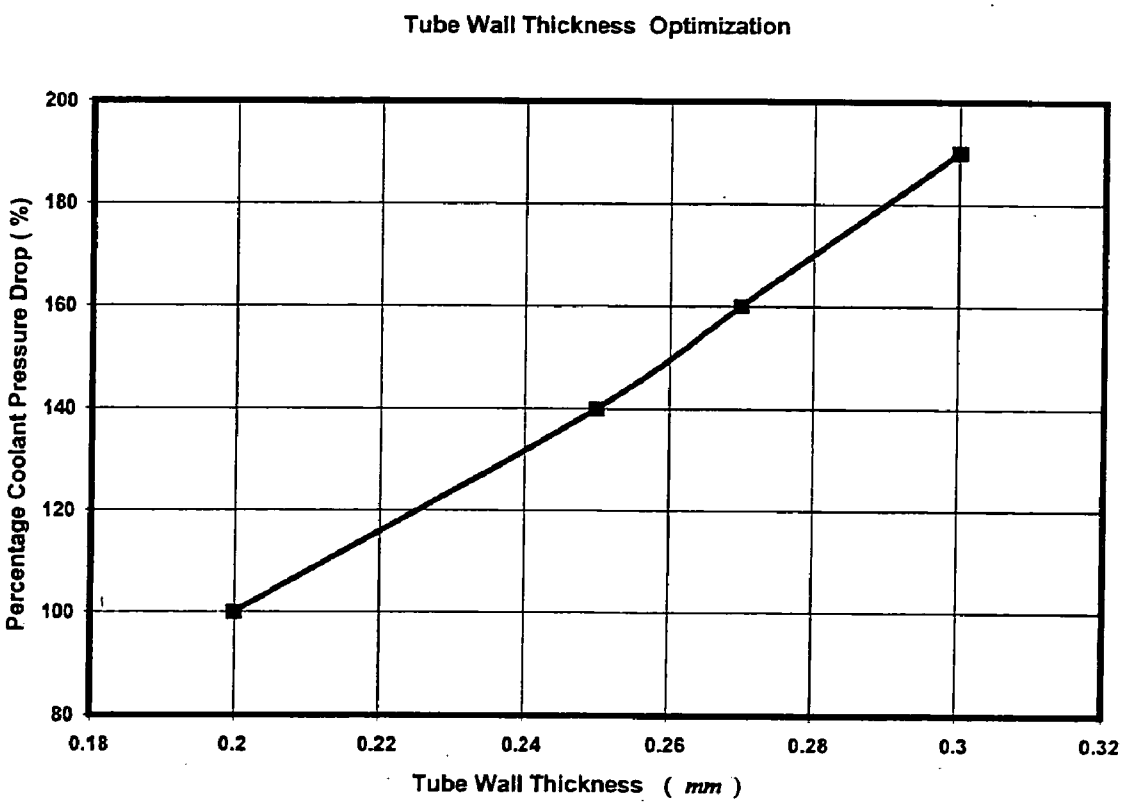

Tube Wall Thickness Optimization
Percentage Coolant Pressure Drop ( %)
200
180
160
140
120
100
80
0.18
0.2
0.22
0.24
0.26
0.28
0.3
0.32
Tube Wall Thickness ( mm )

FIG. 6

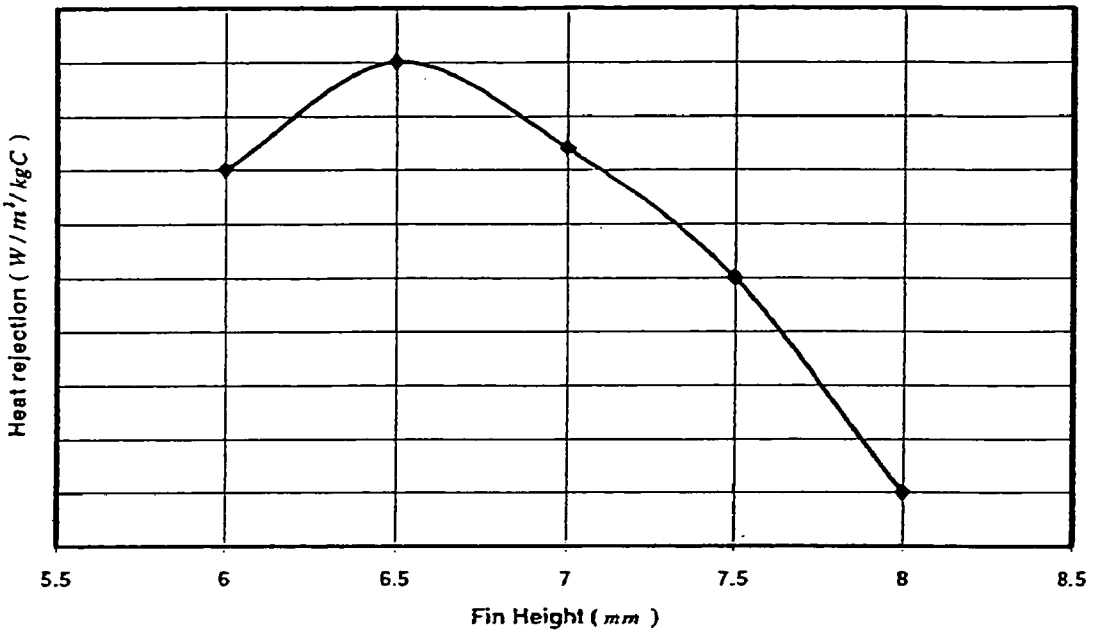



FIG. 7

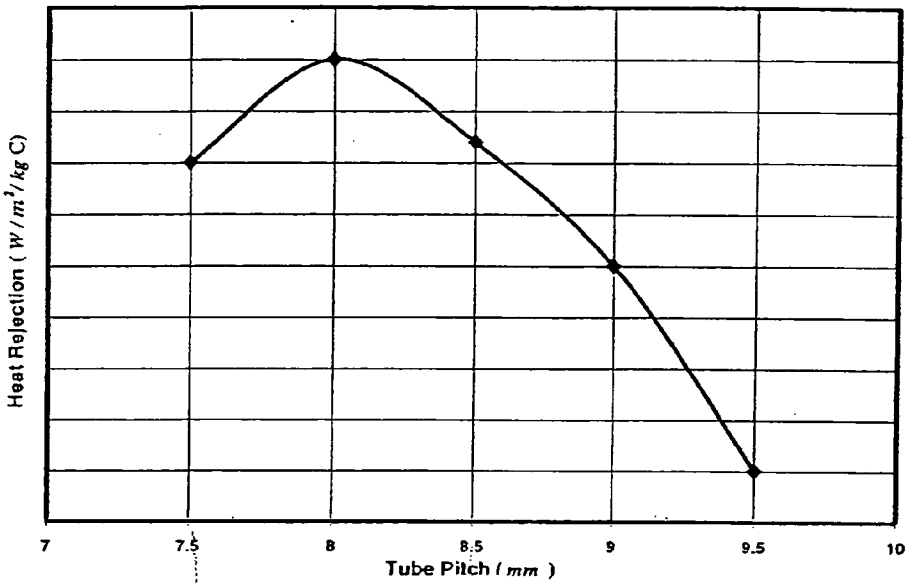



FIG. 8

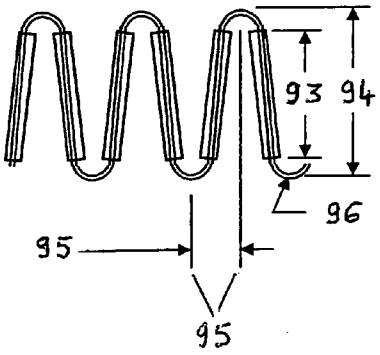



FIG. 9a

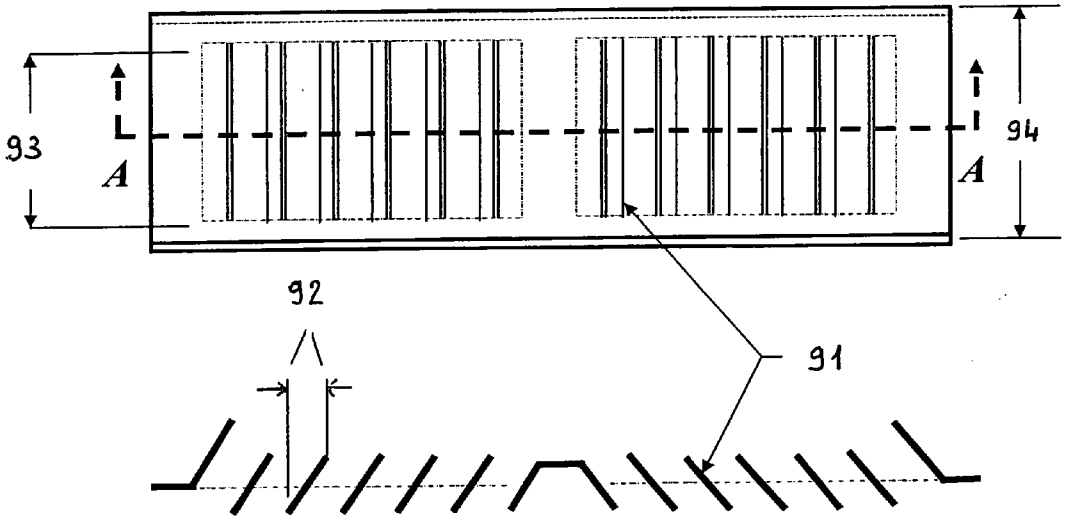



FIG. 9b

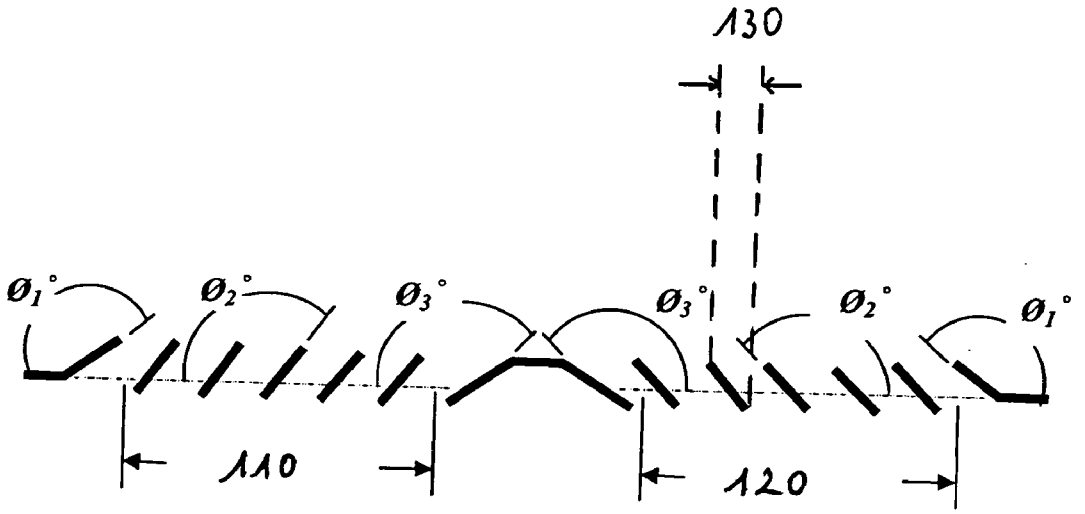



FIG. 10

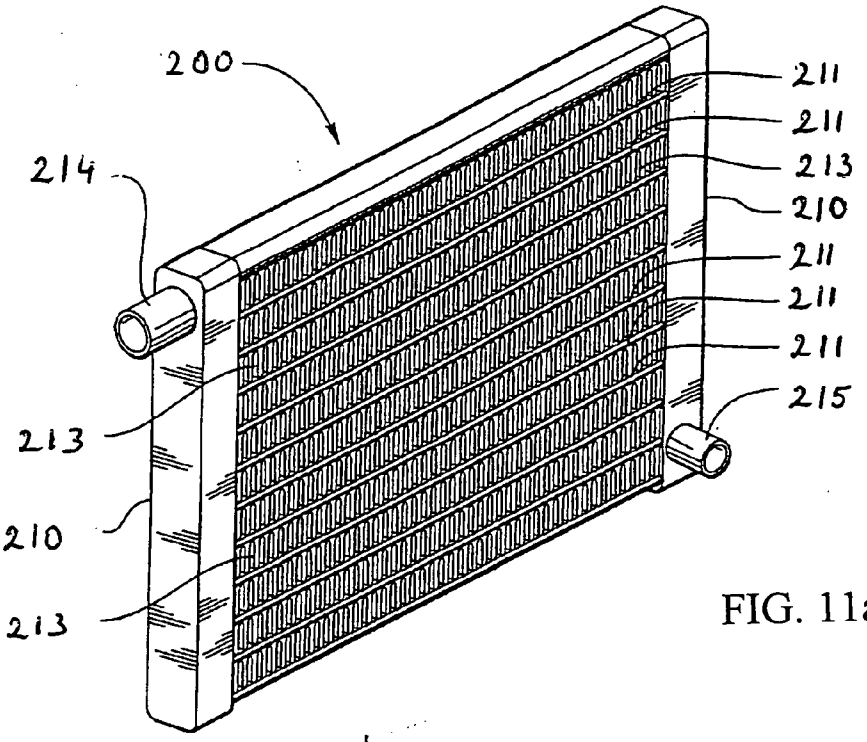



FIG. 11a

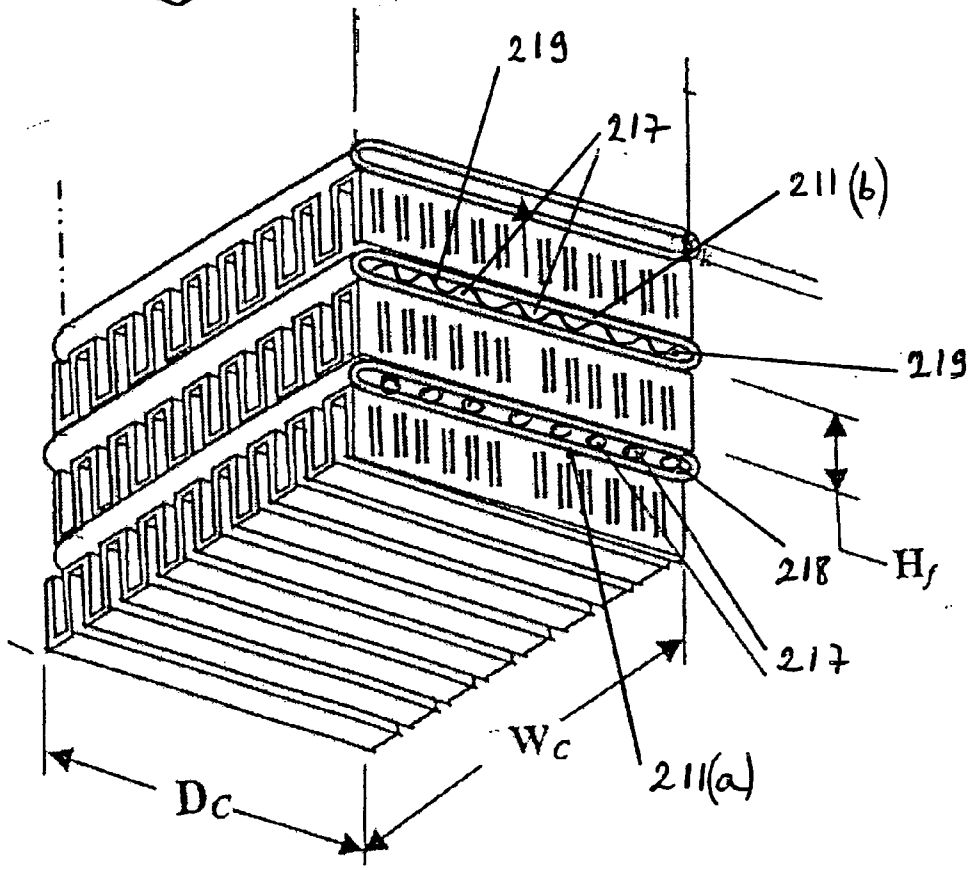



FIG. 11b

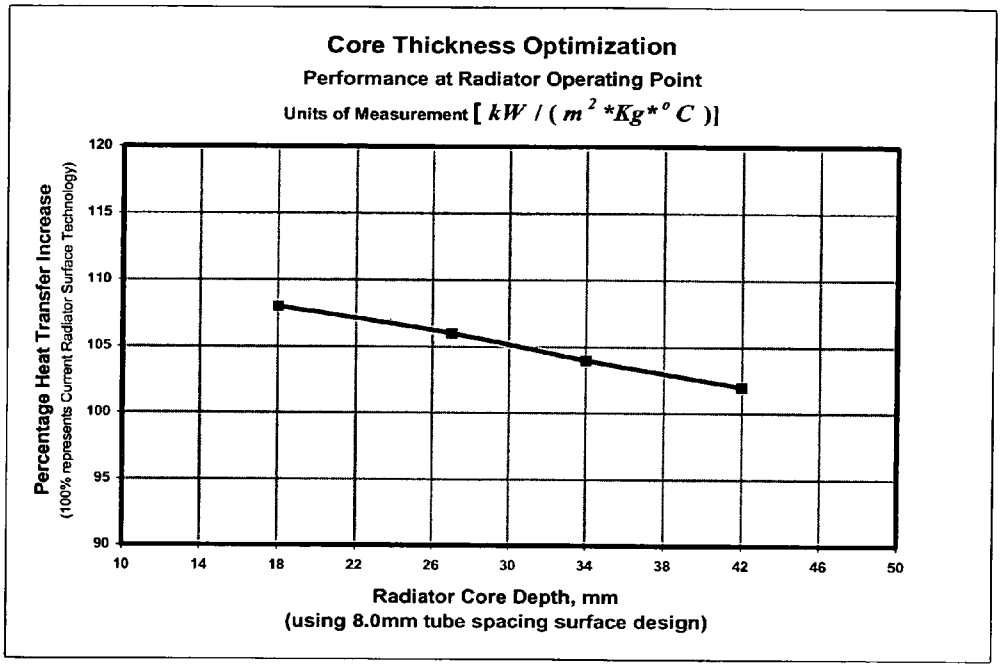

Core Thickness Optimization
Performance at Radiator Operating Point
Units of Measurement [ kW / ( m 2 *Kg* o C )]
Percentage Heat Transfer Increase
(100% represents Current Radiator Surface Technology)
120
115
110
105
100
95
90
10
14
18
22
26
30
34
38
42
46
50
Radiator Core Depth, mm
(using 8.0mm tube spacing surface design)

FIG. 12

# ALUMINUM HEAT EXCHANGER AND METHOD OF MAKING THEREOF

## FIELD OF THE INVENTION

[0001] The present invention relates to an aluminum heat exchanger. More particularly, the present invention relates to an aluminum heat exchanger useful for motorized power systems similar to those utilized in the automotive industry for engine heat exchange.

## BACKGROUND OF THE INVENTION

[0002] For a number of years now, industry has been concerned with designing heat exchangers made of various materials, particularly for combustion engines, for both practical and weight reasons. Such materials have included aluminum-based ones such aluminum, aluminum alloy and all-aluminum, in heat exchangers. However, these heat exchangers often have faced the problems of extreme 'tube side' or 'internal' or 'coolant' side pressure drops and manufacturing difficulties that have not been optimally solved or adequately adjusted for in heat exchanger applications.

[0003] Industry has also, more specifically, developed automobile heat exchangers employing such elements as flat tubes and corrugated fins. Problems have, just to the present, always existed due to the compromises necessary between the strength required to withstand thermal, pressure and vibration forces and the stresses that occur in the heat exchanger. In particular, heat exchangers inherently have core tube internal cross sectional limits that are largely based on coolant flow velocity. Tube walls, for example, have ultimate limitations based on internal corrosion and pressure issues. Other elements, such as the tubes and fin themselves, have limitations based materials that exhibit external corrosion and effect overall core strength, in addition to manufacturing issues based on airflow pressure drop concerns and the ultimate limits of fins placed between the tubes. The number of fin wall sections placed between the tubes also has limits because of manufacturing and airflow pressure drop issues.

[0004] **FIG. 1** shows a prior art heat exchanger core I with air flow **3** and coolant flow **4** noted at the area of the core fin **1** and core tube **2**. Core height Hc, fin height Hf, tube height minor axis Tk, core width Wc, tube wall thickness Tt, tube width major axis Tm and core depth Dc are shown. Traditional versions of such heat exchangers, without optimization of the basic parameters, do not correct the problems of tube side pressure drops or manufacturing difficulties or the like.

## SUMMARY OF THE INVENTION

[0005] It is an object of the present invention to provide a heat exchanger, and, in particular, an aluminum-based heat exchanger, wherein the use of specific materials, weights, heights and thicknesses leads to fewer side pressure drop and other issues affecting the efficiency of exchangers. Therefore, it is a further object of the present invention to provide an aluminum heat exchanger that performs at optimized levels under normal conditions of use. It is a further object of the present invention to provide an aluminum heat exchanger that has maximum performance in automotive applications with minimized manufacturing difficulty. It is a further object of the present invention to provide a heat exchanger with optimized performance related to tube side or internal pressure drop. It is a further object of the present invention to provide a brazed aluminum heat exchanger with optimized parameters related to tube characteristics such as tube height and tube thickness. The present invention also provides for increased ability to standardize core tubes and fins for many different vehicle applications, thereby reducing production costs.

[0006] According to one aspect of the present invention, the embodiment provides a "high heat exchanging efficiency" heat exchanger that utilizes an optimized fin height, at a specific tube height or tube minor axis, to create an optimized core tube pitch.

[0007] Also highly preferred are embodiments of the present invention wherein the heat exchanger is a radiator or similar cooling system for an internal combustion engine; even more preferred wherein the heat exchanger is an automotive radiator.

[0008] The present invention, in more preferred embodiments, optimizes the heat exchange, for example, from coolant to air for vehicle engine radiators in the core depth or core thickness, (dimension measured in the direction of the air flow path), with a typical range from about 12 to 44 millimeters. The tube height and tube wall thickness in the heat exchanger, and, particularly, in an aluminum or aluminum alloy radiator, are found to optimize coolant flow and internal heat transfer at appropriate levels. For example, prior art heat exchangers with tubes on 9.25 millimeter, as well as heat exchangers with 6.0 millimeter tube centers that have a higher air pressure drop across the core for a similar fin, do not maximize the specific heat transfer (heat rejection/core weight) for efficient heat exchangers. In addition, prior art cores often have higher weight for a similar core face area and thickness than provided for in the present invention. In the most preferred embodiments, surprisingly, the present invention provides maximum heat transfer for the given parameters of an aluminum heat exchanger, and, in particular, an aluminum radiator. Present invention embodiments further may provide enhanced air side heat transfer with new fin technology as a part of heat exchanger fin configurations with variable louver angles and louver widths. Most preferred embodiments of the present invention allow adjustment for face area or core depth or fin pitch required to meet the needs of different engine cooling requirements.

## BRIEF DESCRIPTION OF THE DRAWINGS

[0009] The features and inventive aspects of the present invention will become more apparent upon reading the following detailed description, claims and drawings, of which the following is a brief description:

[0010] **FIG. 1** is a schematic view of a prior art heat exchanger with a core section and comprising of flat tubes and corrugated fins;

[0011] **FIG. 2** is a graphic representation of radiator operating point definition in accordance with an exemplary aspect of the present invention;

[0012] **FIG. 3** is a cross-sectional view of prior art flat tube of electrowelded or folded tube construction employed in a heat exchanger;

[0013] **FIG. 4** is a graphic representation of optimized tube height based data at constant coolant flow and fin density related to heat capacity at various tube height levels in accordance with an exemplary aspect of the present invention;

[0014] **FIG. 5** is a graphic representation of optimized tube height based on heat rejection data at radiator operating point and constant coolant flow and fin pitch in accordance with an exemplary aspect of the present invention;

[0015] **FIG. 6** is a graphic representation of side wall thickness resistance characteristics for 1.5 mm minor axis tubes, with 190% representing current practice percentage coolant pressure drop and the other points in accordance with an exemplary aspect of the present invention;

[0016] **FIG. 7** is a graphic representation of a fin height optimization curve based on heat rejection data at radiator operating point in 1.5 mm height tubes with constant coolant flow and core fin pitch in accordance with an exemplary aspect of the present invention;

[0017] **FIG. 8** is a graphic representation of a radiator tube spacing optimization curve based on heat rejection data at constant radiator operating point with constant coolant flow and fin pitch with 1.5 mm tubes in accordance with an exemplary aspect of the present invention;

[0018] **FIGS. 9***a* and **9***b* show a typical prior art fin louver arrangement in which all fin louvers are typically positioned at the same relative angle position;

[0019] **FIG. 10** is a schematic representation of a high performance radiator fin louver arrangement in accordance with an exemplary aspect of the present invention.

[0020] **FIG. 11** is a schematic representation of a radiator in accordance with an aspect of the present invention.

[0021] **FIG. 12** is a graphic representation of a radiator core thickness optimization curve as it relates to percentage heat transfer increase in accordance with an aspect of the present invention.

## DETAILED DESCRIPTION OF THE INVENTION

[0022] The present invention describes a heat exchanger wherein one of the preferred embodiments includes an optimized tube height at about 1.5 millimeters, matched with fins at an height of about 6.5 millimeters and establishment of a tube pitch of about 8.0 millimeters for cores with an approximate depth range of about 12 to 44 millimeters. In general, tube optimization may be evaluated in one variable module and fin optimization in a separate module. The fin louvers may vary such that, in preferred aspects of the present invention, the louvers have variable louver angles or widths within an angular range of about 18° to 35°, preferably of about 18° to 28°, with an approximate louver width of about 0.9 millimeters. The fin density range is, preferably, less than or equal to 25 fins per inch.

[0023] In its preferred embodiments, the present invention provides for heat exchangers, and, in particular, engine cooling heat exchangers, with an optimized heat transfer for such exchangers, and, in particular, engine cooling heat exchangers, with a core thickness of about 12 millimeters to about 44 millimeters that are made with standard braze materials and braze practices. More preferred engine cooling heat exchangers in embodiments of the present invention are radiators. In further preferred embodiments, the tubes are relatively flat tubes, i.e. tubes whose width or major axis is significantly greater than its height or minor axis, and whose shape has opposing sides which are essentially parallel to one another. In more preferred embodiments, variable angled louvers are also used and tested using a constant airflow and a constant coolant flow. In the present invention, fin height is optimized for maximization of both conductive and convective heat exchange, preferably using a fin material thickness of about 0.03 to 0.12 millimeters, more preferably from about 0.05 to 0.12 mm, even more preferably from about 0.07 to 0.12 mm, at a maximum fin pitch of 25 fins per inch or spacing of 1.02 fins per millimeter. Also, preferably, is a tube 'spacing' or tube 'pitch' from about 7.0 to 9.0 mm, more preferably from about 7.5 to 8.5 mm, even more preferably around about 8.0 millimeters from center to center, with approximately 1.5 mm high tubes.

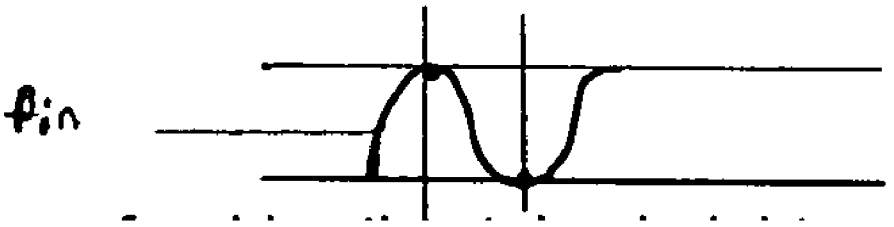
[0024] Preferably, heat exchangers of the present invention are aluminum-based, more preferably made from aluminum or aluminum alloy, resulting in most efficient heat transfer from the tube and fin, particularly in a radiator core, for a given coolant flow. Computational Fluid Dynamics Models and Calorimeter Testing exemplify highly efficient cores. Coolant velocity in testing normally varies at a rate of approximately one (1) meter per second to three (3) meters per second. Models used may employ varying core height (HC), core width (WC), core depth (DC), fin height (Hf) and tube height (Tk) in their calculations. The tube height (Tk) was measured at the minor axis. Test coolant flow through the tubes was kept constant and airflow through the fins was kept constant. The fins were of the corrugated type and had louvers. (Tm=tube width major axis; Tt=tube wall thickness).

[0025] In preferred embodiments of the present invention, preferred tube design uses a wall thickness of about 0.20±0.04 millimeters and an approximate tube height of about 1.5+0.2 millimeters. This height is identified as the optimized height for the about 0.2 millimeter wall thickness. The preferred fin design uses an approximate fin stock thickness of about 0.07±0.01 millimeters and an approximate fin height of about 6.50±0.25 millimeters. In this design, the optimized height for conducting heat to the center of this about 0.07 millimeter fin, i.e. the resulting center to center tube pitch is most preferably about 8.0 millimeters. The preferred fin louver design is the variable fin louver angle or width used to optimize heat transfer across the surface of the fin. The preferred fin louver design uses an approximate width of from about 0.9 to 1.0±0.2 millimeters. As seen in **FIG. 10**, fin louver arrangement angles vary as follows:

[0026] Angle $\phi 1 \approx \phi 2$; $\phi 1 < \phi 2$

[0027] More preferably, the present invention comprises an aluminum-based heat exchanger having a plurality of flat tubes disposed in parallel with respect to the direction of the air flow with at least one corrugated fin disposed between and connected to each pair of flat tubes composing the core portion; the flat tubes with an approximate height across the minor axis of from about 1.4 to 1.6 millimeters. One or more of the plurality of tubes of the present invention may contain sub-passageways or 'ports' that extend along a length of the

tube. Preferred hydraulic diameter of the tubes are between about 1 to 3 $mm^2$, more preferably from about 1.8 to 1.9 $mm^2$. The corrugated fins preferably have a thickness of about 0.03 to 0.12 millimeters, more preferably of about 0.05 to 0.12 mm, also more preferably from about 0.07 to 0.12 mm. Also, preferably, tube wall thickness (Tt) is between about 0.15 to 0.3 millimeters, more preferably from between about 0.20 to about 0.3 mm, even more preferably between about 0.23 and 0.27 millimeters. Even more preferably, the aluminum-based heat exchanger embodiments of the present invention have flat tubes with a spacing or tube pitch of about 7.5 to 8.5 millimeters between the tube centers at the center of the minor axes. Also preferred are heat exchanger embodiments wherein the fin density is less than or equal to about 25 fins per inch or 1.02 fins per millimeter as measured from center to center of each of the adjacent fin portions, i.e. from one upturn of the fin to one downturn of the fin, as exemplied in **FIG. 9*a*, 95**, and below:


$\beta_{in}$

[0028] Even more preferably, th tube heights across the minor axis is about 1.5 millimeters.

[0029] As describes herein, preferred embodiments of the present invention also include at least one fin louver. The aluminum-based heat exchanger with fin louvers, preferably, have fin louvers with specific louver openings. More preferred are fins with fin louver openings that are disposed approximately normal to the air flow and angled to the air stream between the fin portions and the length of the louver. Even more preferred are fin louvers wherein the openings are disposed approximately normal to the flat of the core tubes and have a louver width of about 0.8 to 1.2 millimeters.

[0030] Most preferably, the aluminum-based heat exchangers are 'brazed' or employ brazing technology. In terms of a method of producing exchangers in accordance with embodiments of the present invention, preferred is a method wherein the flat tube is formed from flat sheet braze material and has at least one portion formed approximately normal to the wide portion (major axis) and parallel to the minor axis of the tube.

## PREFERRED EMBODIMENTS OF THE INVENTION

[0031] In one of the preferred embodiments of the present invention, an aluminum-based heat exchanger comprises: a plurality of flat tubes disposed in parallel with respect to the direction of the air flow with at least one corrugated fin disposed between and connected to each pair of flat tubes composing the core portion; the flat tubes having an height across the minor axis of from about 1.4 to about 1.6 millimeters; the corrugated fin having a thickness of about 0.03 to 0.12 millimeters; and a tube wall thickness of between about 0.15 to 0.30 millimeters. Also in preferred embodiments, the flat tubes have a spacing or tube pitch of about 7.5 to 8.5 millimeters between the tube centers at the center of the minor axes. Also preferred is when the fins have a density that is less than or equal to about 25 fins per inch or 1.02 fins per millimeters as measured from center to center of each of the adjacent fin portions. Also, in preferred embodiments, fin height is less that about 8.00 mm, more preferred between about 6.00 to 7.00 mm, even more preferred between about 6.25 to 6.75 mm.

[0032] In a particularly preferred embodiment of the present invention, an aluminum alloy or aluminum radiator comprises a plurality of flat tubes disposed in parallel with respect to the direction of the air flow with at least one corrugated fin disposed between and connected to each pair of flat tubes composing the core portion; flat tubes having an height across the minor axis of from about 1.4 to 1.6 millimeters; corrugated fin having a thickness of about 0.03 to 0.12 millimeters; a tube wall thickness of between about 0.15 to 0.30 millimeters; and tube spacing or tube pitch from between about 7.5 to 8.5 millimeters. More preferred embodiments of the present invention have heat exchanger core thicknesses of between about 12 to 20 millimeters, 25 to 29 millimeters, 32 to 36 millimeters, or 40 to 44 millimeters, depending on the vehicle application.

[0033] In particularly preferred embodiments, the tube height is between about 1.2 and 1.6 millimeters, even more preferred between 1.4 and 1.6 millimeters, most preferred around about 1.5 millimeters.

[0034] In preferred embodiments of the present invention, the flat tube is formed from flat sheet braze material. In preferred embodiments, relatively flat tube has at least one portion formed approximately normal to the wide portion major axis and parallel to the minor axis of the tube, and, in particularly preferred embodiments, forms one or more tube passages. Also in preferred embodiments, the tube spacing or tube pitch is between about 7.0 and 9.0 millimeters, more preferably between about 7.5 and 8.5 millimeters, even more preferably about 8.0 millimeters.

[0035] Referring to **FIG. 2**, a graphic representation is shown showing the air side pressure drop, heat rejection rate and air velocity variables related to radiator operating point, in support of an aspect of the present invention.

[0036] Referring to **FIG. 3**, tubes **31**, coolant flow area **30**, and the effect of conduction and convection are shown, as it relates to the tube width Tm, tube height Tk and tube wall thickness Tt in a prior art flat electrowelded or folded tube.

[0037] Referring to **FIG. 4**, is a graphic representation of air flow in meters/second versus heat rejection showing optimized tube heights as found in preferred aspects of the present invention.

[0038] **FIG. 5** shows graphic data of optimized tube height in mm, in accordance with the present invention, versus heat rejection levels ($w/m^2/KgC$).

[0039] **FIG. 6** shows graphic data including optimized tube wall thickness leading to reduce percentage coolant pressure drop, in accordance with preferred embodiments of the present invention.

[0040] **FIG. 7** shows graphic data including optimized fins heights in mm versus heat rejection, in accordance with preferred embodiments of the present invention.

[0041] **FIG. 8** shows graphic data related to optimized tube pitch in mm versus heat rejection, in accordance with preferred embodiments of the present invention.

[0042] Referring to **FIG. 9***a*, a prior art corrugated fin is shown. **FIG. 9***b* shows an overhead view of the exchanger with fin louver (**91**), with louver width (**92**), louver opening (**93**), fin height (**94**), fin pitch **95**, and end radius (**96**).

[0043] Referring to **FIG. 10**, in preferred embodiments with louvers, the fin louver openings are disposed approximately normal to the air flow and angled to the air stream between the fin portions and the length of the louver. More preferably, the openings are disposed approximately normal to the flat of the core tubes and have a fin louver width (**130**) of about 0.8 to 1.2 millimeters. In embodiments where lead and trailer fin louvers are present, even more preferred are fin louvers wherein the lead and trailing louver angles $\phi 1$ are approximately equal to the center neutral area louvers and the louver angles $\phi 2$ are less than the common louver angles $\phi 3$ relative to the fin face parallel to the air stream.

[0044] Referring to **FIG. 11**, in embodiments where a plurality of flat tubes is disposed in parallel with respect to the direction of the air flow with at least one corrugated fin disposed between and connected to each pair of flat tubes composing the core portion; the flat tubes preferably have a height across the minor axis of from about 1.4 to 1.6 millimeters. Also in such preferred embodiments, the corrugated fin having a thickness of from between about 0.03

to 0.12 millimeters; and, preferably, a tube wall thickness of from between about 0.15 to 0.30 millimeters. In preferred embodiments, the heat exchanger has at least one fin louver. Also in more preferred embodiments, the fin height is between about 6.25 to about 6.75 mm.

[0045] The heat exchanger **200** has a pair of header or manifolds **210** interconnected by a plurality of tubes **211**. Fins **213** are located between adjacent tubes to enhance heat exchange between the tubes and external atmosphere, such as air.

[0046] An inlet **214** and outlet **215** are normally attached to the headers as shown or otherwise to ensure correct flow of fluid within the heat exchanger. The tube **211**(*a*) and **211**(*b*) has a means for forming a plurality of fluid paths **217** which generally traverse the tube. The fluid paths can be formed as discrete passageways or ports **217** or can be formed via use of an insert **219** or other such means.

[0047] In more preferred embodiments, the common louvers have at least two distinct angle groups in each fore and aft set, (e.g. the first and second sets or angle groups **110**, **120**, of **FIG. 10**).

[0048] Again, referring to **FIG. 10**, in preferred embodiment of the present invention, angle group one (**110**) and angle group two (**120**) are shown with: $\phi 1$ representing the leading and trailing fin louver angle; $\phi 2$ representing the common fin louver angle; $\phi 3$ representing the central neutral fin louver angle; $\phi 1$ is approximately=$\phi 3$ and $\phi 1$ & $\phi 3 < \phi 2$.

[0049] Tube spacing may vary in embodiments of the present invention. Particularly preferred is spacing wherein the tube spacing or tube pitch is about 8.0 millimeters. Core thickness may also vary in accordance with the present invention. More preferred are aluminum-based heat exchangers wherein the core thickness is from about 12 to 20 millimeters, more preferably, from about 16 to 20 mm. Also preferred are aluminum-based heat exchangers wherein the core thickness is between from about 25 to 29 millimeters. Also preferred are aluminum-based heat exchangers wherein the core thickness is between from about 32 to 36 millimeters. Also preferred are aluminum-based heat exchangers wherein the core thickness is between from about 40 to 44 millimeters.

[0050] The initial four preferred core thicknesses (depth) targets for this core thickness series are about 18.0 millimeters, 27.0 millimeters, 34.0 millimeters and 42 millimeters. These core thickness series would use similar tube pitch, tube and fin technologies.

[0051] Referring to **FIG. 12**, an examination of the core thickness indicates that as the core approaches 50 millimeters thickness and above, the "heat transfer increase per unit of core material weight" is almost equal to the capability of current technology (100%). In the preferred embodiments of the present invention, and, particularly in radiator applications, the core is preferably less than 50 millimeters in thickness, more preferably the core thickness range is between about 12 and 44 millimeters for most vehicle applications. The heat transfer increase was examined at the fan operating point taking into account the air side pressure drop for a standardized comparison of the core thicknesses.

[0052] In a preferred method of making the heat exchangers of the present invention, the flat tubes of the heat exchanger are formed from flat sheet braze material and at least one portion is formed approximately normal to the wide portion (major axis) and parallel to the minor axis of the tube.

[0053] Unless stated otherwise, dimensions and geometries of the various structures depicted herein are not intented to be restrictive of the invention, and other dimensions or geometries are possible. In addition, while a feature of the present invention may have been described in the context of only one of the illustrated embodiments, such feature may be combined with one or more other features of other embodiments, for any given application. It will also be appreciated from the above that the fabrication of the unique structures herein and the operation thereof also constitute methods in accordance with the present invention.

[0054] The preferred embodiments of the present invention has been disclosed. A person of ordinary skill in the art would realize, however, that certain modifications would come within the teachings of the invention. Therefore, the following claims should be studied to determine the true scope and content of the invention.

What is claimed is:

**1**. A heat exchanger comprising:

a plurality of flat tubes disposed in parallel with respect to the direction of the air flow with at least one corrugated fin disposed between and connected to each pair of flat tubes composing the core portion;

the flat tubes having an height across the minor axis of from about 1.4 to 1.6 millimeters;

the corrugated fin having a thickness of about 0.03 to 0.12 millimeters; and

a tube wall thickness of between about 0.15 to 0.30 millimeters.

**2**. A heat exchanger as in claim 1 wherein the flat tubes have a spacing or tube pitch of about 7.5 to 8.5 millimeters between the tube centers at the center of the minor axes.

**3**. A heat exchanger, as in claim 1, further having fin density less than or equal to about 25 fins per inch or 1.02 fins per millimeter as measured from center to center of each of the adjacent fin portions.

**4**. A heat exchanger as in claim 1 wherein the tube corrugated fin has a thickness of about 0.05 to 0.12 mm.

**5**. A heat exchanger as in claim 4 wherein the tube height is about between about 1.3 to 1.7 mm, and the fin height from about 6.25 to 6.75 mm.

**6**. A heat exchanger, as in claim 2, wherein the fin density is less than or equal to about 25 fins per inch or 1.02 fins per millimeter as measured from center to center of each of the adjacent fin portions.

**7**. A heat exchanger as in claim 2 wherein the flat tube is formed from flat sheet braze material and has at least one portion formed approximately normal to the wide portion major axis and parallel to the minor axis of the tube, forming one or more tube passages.

**8**. A heat exchanger as in claim 3, wherein the corrugated fin has a thickness of about 0.05 to 0.12 millimeters.

**9**. A heat exchanger as in claim 2 wherein the tube spacing or tube pitch is about 8.0 millimeters.

**10**. An aluminum-based heat exchanger comprising:

a plurality of flat tubes disposed in parallel with respect to the direction of the air flow with at least one corrugated fin disposed between and connected to each pair of flat tubes composing the core portion;

the flat tubes having an height across the minor axis of from about 1.4 to 1.6 millimeters;

the corrugated fin having a thickness of about 0.03 to 0.12 millimeters;

a tube wall thickness of between about 0.15 to 0.30 millimeters; and

at least one fin louver.

**11**. An aluminum-based heat exchanger as in claim 10 such that the fin louver openings are disposed approximately normal to the air flow and angled to the air stream between the fin portions and the length of the louver.

**12**. A heat exchanger as in claim 10 wherein the openings are disposed approximately normal to the flat of the core tubes and have a fin louver width of about 0.8 to 1.2 millimeters.

**13**. A heat exchanger as in claim 12 wherein the lead and trailing fin louver angles are approximately equal to the center neutral area fin louvers and the louver angles are less than the common louver angles relative to the fin face parallel to the air stream.

**14**. A heat exchanger as in claim 10 wherein the common louvers have at least two distinct angle groups in each fore and aft set and wherein the common louver groups increase in angle as they are near the common center neutral area relative to the fin face parallel to the air stream.

**15**. An aluminum alloy or aluminum radiator comprising:

a plurality of flat tubes disposed in parallel with respect to the direction of the air flow with at least one corrugated fin disposed between and connected to each pair of flat tubes composing the core portion;

the flat tubes having an height across the minor axis of from about 1.4 to 1.6 millimeters;

the corrugated fin having a thickness of about 0.03 to 0.12 millimeters;

a tube wall thickness of between about 0.15 to 0.30 millimeters; and

wherein the tube spacing or tube pitch is about 7.5 to 8.5 millimeters, the fin height is less than 8.00 mm, and the core portion has a thickness of less than 50 mm.

**16**. An aluminum alloy or aluminum radiator, as in claim 15, wherein the fin density is less than equal to 25 fins per inch or 1.02 fins per millimeter.

**17**. A heat exchanger as in claim 15 wherein the core thickness is between about 12 to 20 millimeters.

**18**. A heat exchanger as in claim 15 wherein the core thickness is between about 25 to 29 millimeters.

**19**. A heat exchanger as in claim 15 wherein the core thickness is between about 32 to 36 millimeters.

**20**. A heat exchanger as in claim 15 wherein the core thickness is between about 40 to 44 millimeters.

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