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(54) **HIGH PERFORMANCE THREE-FLUID VEHICLE HEATER**

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F28D 7/10 (2006.01)

(52) **U.S. Cl.** **165/140**; 165/165; 165/174; 165/175

(58) **Field of Classification Search** 165/140, 165/165, 174, 175
See application file for complete search history.

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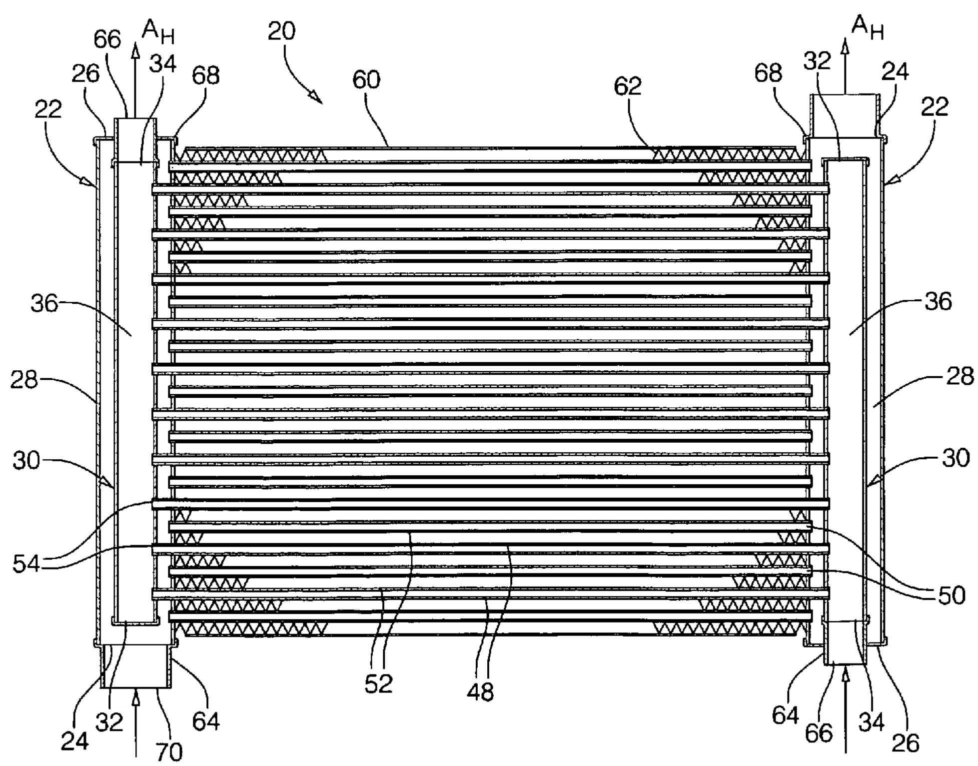
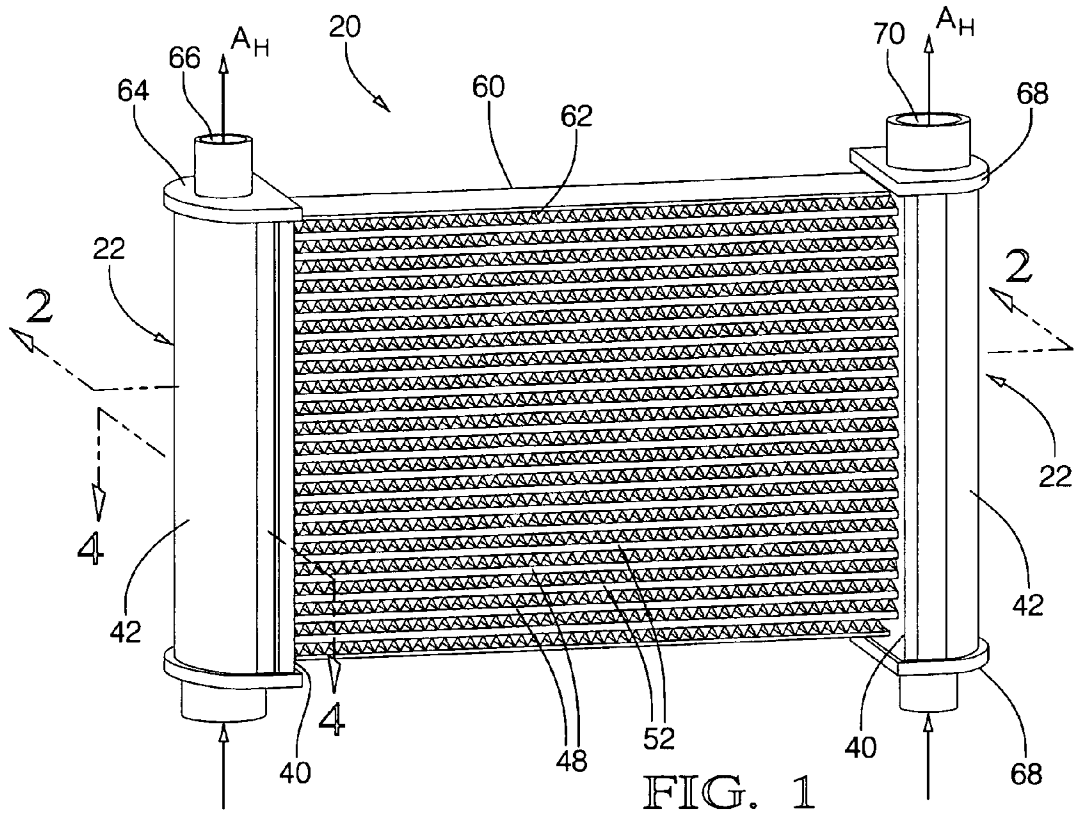
(57) **ABSTRACT**

A heat exchanger assembly includes a pair of outer headers each defining an outer cavity and a pair of inner headers each defining an inner cavity. Each inner header is disposed in one of the outer headers, and each header defines a plurality of header slots. A plurality of first fluid tubes extend between the outer headers from one of the header slots of each outer header to fluidly interconnect the outer cavities defined by the outer headers and a plurality of second fluid tubes are interleaved with the first refrigerant tubes and extend between the outer headers and through one of the header slots of each outer header and through the associated outer cavities defined by the outer headers and to the one of the header slots of each inner header to fluidly interconnect the inner cavities defined by the inner headers.

12 Claims, 3 Drawing Sheets





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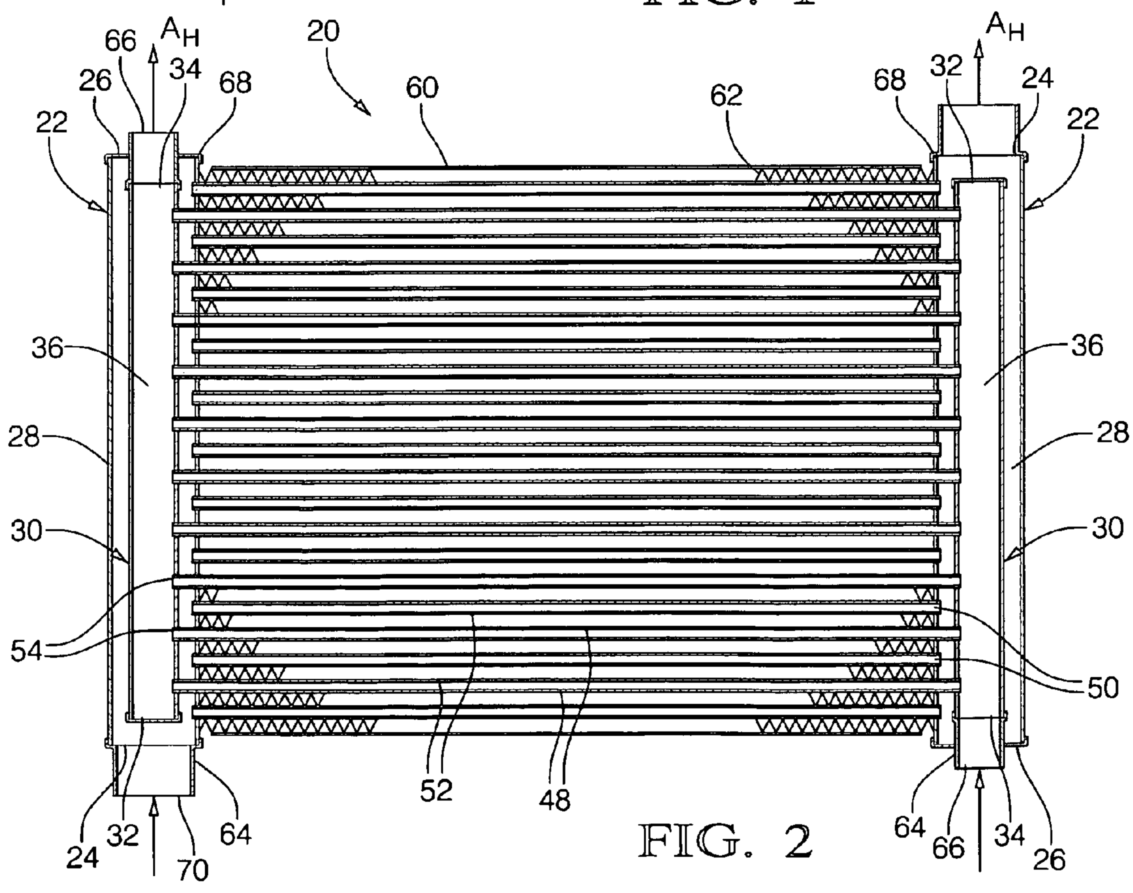
A_H

FIG. 1



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A_H

FIG. 2

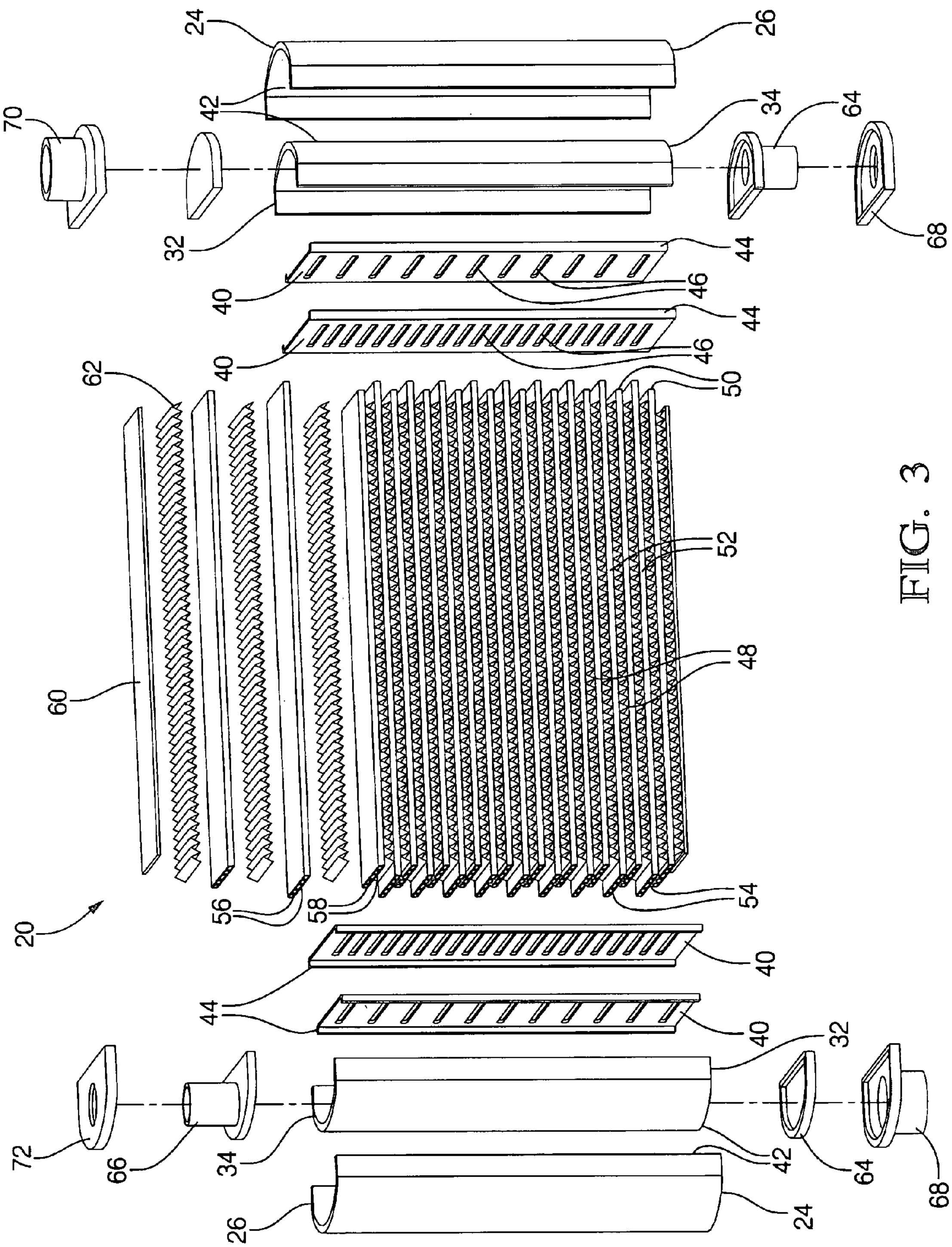

FIG. 3

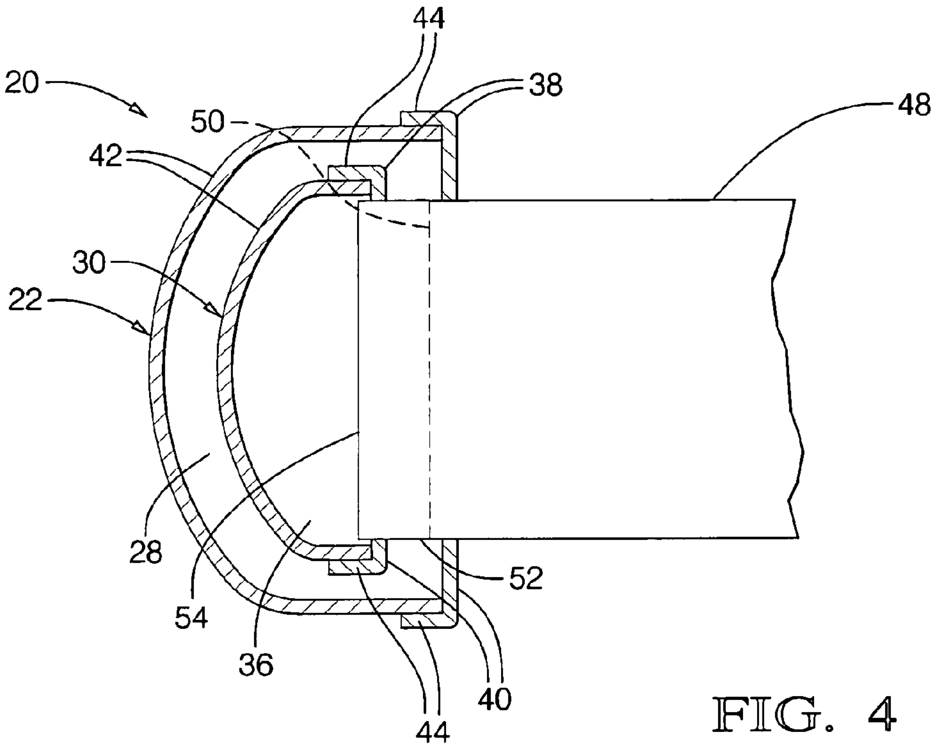

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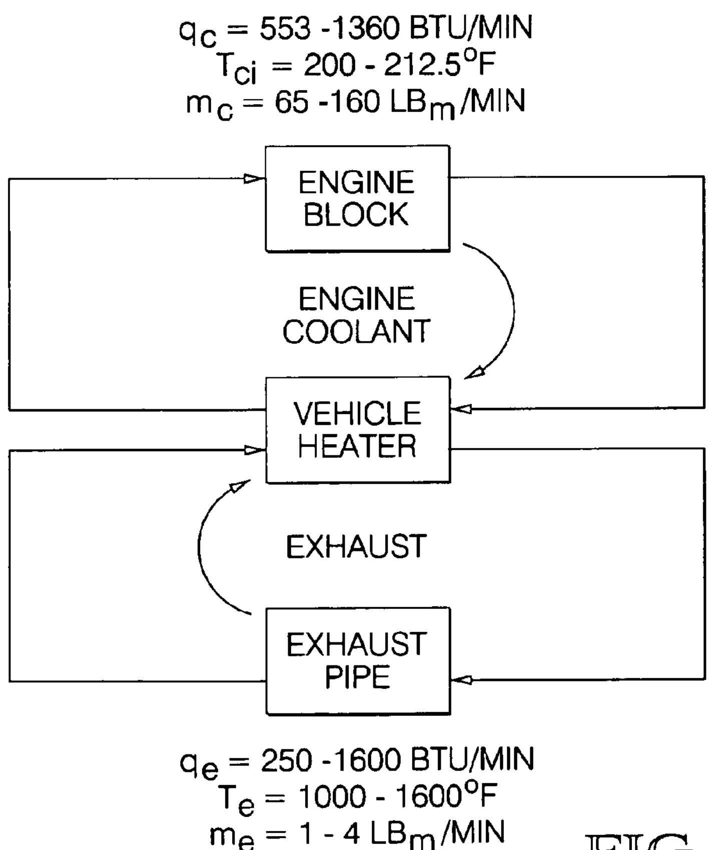
FIG. 4



q_c = 553 -1360 BTU/MIN
T_{ci} = 200 - 212.5°F
m_c = 65 -160 LB_m/MIN
ENGINE BLOCK
ENGINE COOLANT
VEHICLE HEATER
EXHAUST
EXHAUST PIPE
q_e = 250 -1600 BTU/MIN
T_e = 1000 - 1600°F
m_e = 1 - 4 LB_m/MIN

FIG. 5

HIGH PERFORMANCE THREE-FLUID VEHICLE HEATER

BACKGROUND OF THE INVENTION

1. Field of the Invention

The subject invention relates generally to a heat exchanger, and, more specifically, to a heat exchanger of the type including a plurality of fluid tubes extending between an inlet header and an outlet header for transferring fluid from the inlet header to the outlet header.

2. Description of the Prior Art

Heating systems for automobiles have traditionally relied upon engine coolant as the sole heat source for providing comfort heating to the occupants of a vehicle. In such heating systems, a heat exchanger is generally used to transfer heat from the engine coolant to a second fluid, generally air. An example of such a heat exchanger is disclosed in U.S. Pat. No. 1,684,083 to S. C. Bloom.

The Bloom patent discloses a pair of headers each extending between a pair of header ends and defining a cavity. Each of the headers defines a plurality of header slots spaced from one another between the header ends thereof. A plurality of fluid tubes each extend between the headers from one of the header slots of each header to fluidly interconnect the cavities defined by the headers. A first fluid, generally an engine coolant, may flow through one of the cavities defined by one of the headers and through the fluid tubes and through the other of the cavities defined by the other of the headers, and a second fluid, generally air, may flow across the fluid tubes for transferring heat from the first fluid to the second fluid.

The heating capacity of a heat exchanger as disclosed by the Bloom patent is generally limited by the temperature of the engine coolant. Accordingly, with the advent of more efficient internal combustion engines, the amount of heat available from the engine coolant for comfort heating is reduced. As a result, three-fluid heat exchangers have been developed to add another heat source to increase the amount of heat available for comfort heating. Examples of such three-fluid heat exchangers are disclosed in U.S. Pat. No. 4,002,201 to Donaldson and U.S. Pat. No. 5,884,696 to Loup.

The Loup patent discloses a pair of first headers each extending between a pair of first header ends and defining a first cavity. Each of the first headers are disposed in a spaced relationship to one another. A pair of second headers each extending between a pair of second header ends and defining a second cavity are each disposed adjacent one of the first headers. Each of the headers defines a plurality of header slots spaced from one another between the header ends thereof. A plurality of first fluid tubes each extend between the first headers from one of the header slots of each first header to fluidly interconnect the first cavities defined by the first headers. A plurality of second fluid tubes each extend between the second headers and adjacent the first fluid tubes from one of the header slots of each second header to fluidly interconnect the second cavities defined by the second headers. A first fluid may flow through one of the first cavities defined by the associated first header and through the first fluid tubes and through the other first cavity defined by the other first header, a second fluid may flow through one of the second cavities defined by the associated second header and through the second fluid tubes and through the other second cavity defined by the other second header, and a third fluid may flow across the fluid tubes for transferring heat from the first and second fluids to the third fluid.

The Donaldson patent discloses a heat exchanger similar to that as disclosed by the Loup patent except wherein the second fluid tubes are interleaved with the first fluid tubes.

The three-fluid heat exchangers as disclosed by the Loup patent and the Donaldson patent provide for an increased amount of heat for comfort heating by transferring heat from a first and second fluid to a third fluid, however, such patents essentially comprise two heat exchangers functioning independently of one another which are placed adjacent one another thereby increasing the size of the heat exchanger. Accordingly, there remains a need for a heat exchanger which provides an increased amount of heat but which does not have an increased size.

SUMMARY OF THE INVENTION AND ADVANTAGES

The invention provides such a heat exchanger assembly wherein the first headers are outer headers each defining an outer cavity and the second headers are inner headers each defining an inner cavity. Each inner header is disposed in one of the outer headers, and the heat exchanger assembly is improved by each second fluid tube extending through one of the header slots of each outer header and through the associated outer cavity and to one of the header slots of each inner header to fluidly interconnect the inner cavities defined by the inner headers whereby a first fluid may flow through one of the outer cavities defined by the associated outer header and through the first fluid tubes and through the other of the outer cavities defined by the other of the outer headers and a second fluid may flow through one of the inner cavities defined by the associated inner header and surrounded by the associated outer header and through the second fluid tubes and through the other of the inner cavities defined by the other of the inner headers and surrounded by the other of the outer headers and a third fluid may flow across the fluid tubes for transferring heat from the first and second fluids to the third fluid.

Accordingly, the present invention provides an improved heat exchanger for transferring heat by increasing the amount of available heat by providing for a three-fluid heat exchanger and by decreasing the overall size of the heat exchanger by providing for a single core construction.

BRIEF DESCRIPTION OF THE DRAWINGS

Other advantages of the present invention will be readily appreciated, as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

FIG. **1** is a perspective view of the heat exchanger assembly;

FIG. **2** is a cross-sectional, front view of the heat exchanger assembly shown in FIG. **1** vertically along **2-2**;

FIG. **3** is an exploded view of the heat exchanger assembly shown in FIG. **1**;

FIG. **4** is a cross-sectional, fragmentary, and side view of the heat exchanger assembly as shown in FIG. **1** horizontally along **4-4** showing an inner and outer header each having a generally semi-circular cross-section and including a curved wall arched upwardly between a pair of sides of a lanced wall; and

FIG. **5** is a schematic view of the first and second fluids of an embodiment of the heat exchanger assembly.

DETAILED DESCRIPTION OF THE INVENTION

Referring to the Figures, wherein like numerals indicate corresponding parts throughout the several views, a heat exchanger assembly **20** for transferring heat is shown generally in FIG. **1**.

The heat exchanger assembly **20** comprises a pair of outer headers **22** each extending between a first outer header end **24** and a second outer header end **26**. One of the outer headers **22** is for receiving a first fluid, and the other of the outer headers **22** is for exiting the first fluid from the assembly **20**. In an embodiment of the assembly **20** as shown in FIG. **4**, each outer header **22** is generally semi-circular in cross-section to define an outer cavity **28**. However, those skilled in the art appreciate that additional embodiments of the heat exchanger assembly **20** include outer headers **22** having various other cross-sections to define the outer cavities **28**.

Each of the outer headers **22** is disposed in a spaced relationship to one another and extends along a respective header axis A_H. In the embodiment of the assembly **20** as shown in FIG. **1**, the outer headers **22** are disposed in a parallel relationship to one another with the header axes A_H being parallel to one another.

A pair of inner headers **30** each extend between a first inner header end **32** and a second inner header end **34**. One of the inner cavities **36** is for receiving a second fluid, and the other of the inner cavities **36** is for exiting the second fluid from the assembly **20**. In an embodiment of the assembly **20** as shown in FIG. **4**, each inner header **30** is generally semi-circular in cross-section to define an inner cavity **36**. However, those skilled in the art appreciate that additional embodiments of the heat exchanger assembly **20** include inner headers **30** having various other cross-sections to define the inner cavities **36**.

Each inner header **30** is disposed in one of the outer headers **22** and extends along the associated header axis A_H between the associated outer header ends **24**, **26**. In an embodiment of the assembly **20** as shown in FIG. **2**, each inner header **30** extends coaxial to the associated outer header **22** between the associated outer header ends **24**, **26**. The first inner header end **32** of each inner header **30** is preferably adjacent the first outer header end **24** of the associated outer header **22** and the second inner header end **34** of each inner header **30** is preferably adjacent the second outer header end **26** of the associated header. Additionally, as shown in FIG. **2**, the headers **22**, **30** preferably extend along the header axes A_H in opposite directions between the first and second header ends **24**, **26**, **32**, **34** thereof to align the input for the outer headers **22** and the input for the inner headers **30** on the same side **38** of the heat exchanger assembly **20** as shown in FIG. **2**.

In the embodiment of the assembly **20** as shown in FIG. **4**, the cross-section of each of the headers **22**, **30** includes a lanced wall **40** extending between a pair of sides **38** and a curved wall **42** arched upwardly between the sides **38** to define the headers **22**, **30** as being generally semi-circular in cross-section. Each lanced wall **40** includes a pair of flanges **44** each extending along one of the sides **38** of the lanced wall **40** with the flanges **44** in an overlapping relationship with the associated curved wall **42**. Each of the lanced walls **40** defines a plurality of header slots **46** spaced from one another between the header ends **24**, **26**, **32**, **34** thereof. The header slots **46** are preferably axially spaced on the headers **22**, **30** along the header axes A_H as shown in FIG. **2**.

Each of the header slots **46** is preferably elongated and extends transversely to the header axes A_H. The headers **22**, **30** are preferably punctured with a lance to define the header slots **46** to prevent the production of slugs, to provide easier bonding, and to add reinforcement, However, in additional embodiments of the assembly **20**, the headers **22**, **30** can be drilled, punched, or created by any other method known in the art to define the header slots **46**.

A plurality of first fluid tubes **48** each extend between a pair of first fluid tube ends **50** and transversely to the header axes A_H between the outer headers **22**. The first fluid tubes **48** are preferably in a spaced and parallel relationship with one another as shown in FIG. **1**. Each first fluid tube **48** extends from one of the header slots **46** of each outer header **22** to fluidly interconnect the outer cavities **28** defined by the outer headers **22**. In an embodiment of the assembly **20** as shown in FIG. **2**, the first fluid tube ends **50** of each first fluid tube **48** extend through one of the header slots **46** of each outer header **22** and into the outer cavity **28** thereof.

A plurality of second fluid tubes **52** each extend between a pair of second fluid tube ends **54** and transversely to the header axes A_H between the outer headers **22**. The second fluid tubes **52** are preferably in a spaced and parallel relationship with the first fluid tubes **48** as shown in FIG. **1**. The second fluid tubes **52** are also preferably interleaved with the first fluid tubes **48** as shown in FIGS. **1** and **2**.

Each of the fluid tubes **48**, **52** preferably have a generally elongated cross-section for being received by the elongated header slots **46**. Each of the fluid tubes **48**, **52** also preferably include at least one divider **56** extending within the associated fluid tube **48**, **52** along the length of the associated fluid tube **48**, **52** for reinforcing the fluid tube and defining a plurality of fluid passages **58** extending between the fluid tube ends **50**, **54** within the associated fluid tube **48**, **52** as shown in FIG. **3**.

As shown in FIG. **2**, a pair of core reinforcements **60** extend between the outer headers **22** outwardly of the fluid tubes **48**, **52** and interconnect the outer headers **22**. The core reinforcements **60** preferably extend in a parallel and spaced relationship to the fluid tubes **48**, **52**.

A plurality of cooling fins **62** are disposed between adjacent fluid tubes **48**, **52** and between the core reinforcements **60** and the next adjacent of the fluid tubes **48**, **52** for dissipating heat from the fluid tubes **48**, **52**. In the Figures, the cooling fins **62** are shown as serpentine fins, however, those skilled in the art appreciate that other types of cooling fins **62** can be used in additional embodiments of the heat exchanger assembly **20**.

A pair of inner end caps **64** are each hermetically sealed to one of the inner header ends **32**, **34** of each inner header **30**. The inner end caps **64** sealed about the inner header ends **32**, **34** can be either internal or external end caps. The inner end cap **64** which is hermetically sealed to the second inner header end **34** of each inner header **30** defines an inner aperture **66** in fluid communication with the associated inner cavity **36**. One of the inner apertures **66** is an inlet for the associated inner cavity **36** defined by the associated inner header **30** for receiving the second fluid, and the other of the inner apertures **66** is an outlet for the other of the inner cavities **36** defined by the other of the inner headers **30** for exiting the second fluid from the assembly **20**.

A pair of outer end caps **68** are each hermetically sealed to one of the outer header ends **24**, **26** of each outer header **22**. The outer end caps **68** sealed about the outer header ends **24**, **26** can be either internal or external end caps. The outer end cap **68** which is hermetically sealed to the first outer header end **24** of each outer header **22** defines an outer aperture **70** in fluid communication with the associated outer cavity **28**. One of the outer apertures **70** is an inlet for the associated outer cavity **28** defined by the associated outer header **22** for receiving the first fluid, and the other of the outer apertures **70** is an outlet for the other of the outer cavities **28** defined by the other of the outer headers **22** for exiting the first fluid form the assembly **20**.

The heat exchanger assembly **20** is distinguished by each of the second fluid tubes **52** extending through one of the header slots **46** of each outer header **22** and through the associated outer cavity **28** and to one of the header slots **46** of each inner header **30** to fluidly interconnect the inner cavities **36** defined by the inner headers **30**. In an embodiment of the assembly **20** as shown in FIG. **2**, the second fluid tube ends **54** of each second fluid tube **52** extend through one of the header slots **46** of each outer header **22** and through the associated outer cavity **28** and through one of the header slots **46** of each inner header **30** and into the associated inner cavity **36**.

The assembly **20** is further distinguished by the outer end cap **68** which is hermetically sealed to the second outer header end **26** of each outer header **22** defining a receiving aperture **72** aligned and in fluid communication with the inner aperture **66** of the inner end cap **64** hermetically sealed to the second inner header end **34** of the associated inner header **30**.

In operation, a first fluid may flow through one of the outer apertures **70** and through the associated outer cavity **28** defined by the associated outer header **22** and through the first fluid tubes **48** and through the other of the outer cavities **28** defined by the other of the outer headers **22** and through the other of the outer apertures **70**, and a second fluid may flow through one of the inner apertures **66** and through the associated inner cavity **36** defined by the associated inner header **30** and surrounded by the associated outer header **22** and through the second fluid tubes **52** and through the other of the inner cavities **36** defined by the other of the inner headers **30** and surrounded by the other of the outer headers **22** and through the other of the inner apertures **66**. A third fluid may flow between the fluid tubes **48**, **52** and across the cooling fins **62** for transferring heat from the first and second fluids to the third fluid.

In the preferred embodiment, the heat exchanger assembly **20** is a vehicle heater **20** and draws its thermal energy from two sources in a fuel powered motor vehicle. One of the first and second fluids of the vehicle heater **20** is the engine coolant abstracting heat from the engine block, and the other of the first and second fluids is the exhaust gas abstracting heat from the combustion of fuel in the internal combustion engine and discharging it to the ambient air through the exhaust pipe as shown in FIG. **5**. The engine coolant generally flows directly into the vehicle heater **20** while the exhaust gas, on the other hand, preferably does not flow into the vehicle heater **20** for safety reasons. The exhaust gas is preferably used to generate steam in a separate heat exchanger, and this steam flows into the vehicle heater **20**.

In the preferred embodiment, as shown in FIG. **5**, the rate of abstraction of heat from the engine coolant ($\dot{q}_c$) is generally 553-1360 Btu/min, the engine coolant inlet temperature into the vehicle heater **20** (T_{ci}) is generally 200-212.5° F., and the mass flow rate of the engine coolant ($\dot{m}_c$) is generally 65-160 lb_m/min. The rate of abstraction of heat by the exhaust gas from the combustion of fuel ($\dot{q}_e$) is generally 250-1600 Btu/min, the exhaust gas temperature in the exhaust pipe (T_e) is generally 1000-1600° F., and the mass flow rate of the exhaust gas in the exhaust pipe ($\dot{m}_e$) is generally 1-4 lb_m/min. Accordingly, depending on the amount of heat derived from the two heat sources in the motor vehicle, varying discharge air temperatures (T_d) can be attained in the vehicle heater **20**. If T_d is the desired discharge air temperature, then the fraction of the heat to be drawn by the vehicle heater **20** from the exhaust gas via steam (x) can be controlled with a valve and determined using the relation:

$$x = \frac{T_d - \varepsilon_c T_c - (1-\varepsilon_c)T_a}{(\dot{m}_e c_{pe}/\dot{m}_a c_{pa})\varepsilon_e(T_e - T_s) - \varepsilon_c(T_c - T_a)} \quad (1)$$

wherein:

T_d is the discharge air temperature of the vehicle heater **20**;

T_c is the incoming temperature of the coolant into the vehicle heater **20**;

T_a is the temperature of incoming air into the vehicle heater **20**;

ϵ_c is the effectiveness of the coolant portion of the vehicle heater **20**;

ϵ_e is the effectiveness of the exhaust gas portion of the vehicle heater **20**;

$\dot{m}_a$ is the mass flow rate of air into the vehicle heater **20**;

$\dot{m}_e$ is the mass flow rate of exhaust gas from the internal combustion engine;

c_{pa} is the isobaric specific heat of air; and

c_{pe} is the isobaric specific heat of exhaust gas.

It therefore follows that when x=0, i.e., when the exhaust gas heat source is cut off, the following expression for the discharge air temperature is obtained from Eq. (1):

$$T_d=(1-\epsilon_c)T_a+\epsilon_c T_c \quad (2)$$

Additionally, when x=1, i.e., when the engine coolant heat source is cut off, the following expression for the discharge air temperature is obtained from Eq. (1):

$$T_d = T_a + \frac{\dot{m}_e c_{pe}\varepsilon_e(T_e - T_s)}{\dot{m}_a c_{pa}} \quad (3)$$

While the invention has been described with reference to an exemplary embodiment, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing form the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this invention, but that the invention will include all embodiments falling within the scope of the appended claims.

What is claimed is:

1. A heat exchanger assembly for heat transfer comprising;

a pair of outer headers each extending between a first outer header end and a second outer header end and defining an outer cavity,

each of said outer headers disposed in spaced relationship to one another,

a pair of inner headers each extending between a first inner header end and a second inner header end and defining an inner cavity,

each inner header disposed in one of said outer headers,

each of said headers defining a plurality of header slots axially spaced from one another between said header ends thereof,

a plurality of first fluid tubes each extending between said outer headers from one of said header slots of each outer header to fluidly interconnect said outer cavities defined by said outer headers,

a plurality of second fluid tubes each extending between said outer headers, and

each of said second fluid tubes extending through one of said header slots of each outer header and through the associated outer cavity and to one of said header slots of each inner header to fluidly interconnect said inner cavities defined by said inner headers,

a pair of inner end caps each hermetically sealed to one of said inner header ends of each inner header wherein said inner end cap hermetically sealed to said second inner header end of each inner header defines an inner aperture in fluid communication with the associated inner cavity,

a pair of outer end caps each hermetically sealed to one of said outer header ends of each outer header wherein said outer end cap hermetically sealed to said first outer header end of each outer header defines an outer aperture in fluid communication with the associated outer cavity,

whereby a first fluid flow through one of said outer cavities defined by the associated outer header and through said first fluid tubes and through the other of said outer cavities defined by the other of said outer headers and a second fluid flow through one of said inner cavities defined by the associated inner header and surrounded by the associated outer header and through said second fluid tubes and through the other of said inner cavities defined by the other of said inner headers and surrounded by the other of said outer headers and a third fluid flow across said fluid tubes for transferring heat from the first and second fluids to the third fluid,

wherein said first fluid tubes extend in a spaced relationship with one another and wherein said second fluid tubes are interleaved with said first fluid tubes such that said second fluid tubes and said first fluid tubes are arranged in an alternating arrangement

wherein said second fluid tubes includes opposing second fluid tube ends terminating in said inner cavities.

2. An assembly as set forth in claim **1** wherein said outer end cap hermetically sealed to said second outer header end portion of each outer header defines a receiving aperture aligned and in fluid communication with said inner aperture of said inner end cap hermetically sealed to said second inner header end of the associated inner header.

3. An assembly as set forth in claim **2** wherein said first inner header end of each inner header is adjacent said first outer header end of the associated outer header and said second inner header end of each inner header is adjacent said second outer header end of the associated header.

4. An assembly as set forth in claim **3** wherein each header extends along a respective header axis in opposite directions between said first and second header ends thereof.

5. An assembly as set forth in claim **1** wherein each of said inner headers extends coaxial to the associated outer header between the associated outer header ends.

6. An assembly as set forth in claim **1** wherein said outer headers extend in a parallel relationship to one another.

7. An assembly as set forth in claim **1** wherein each of said second fluid tubes extends through one of said header slots of each inner header and into the associated inner cavity.

8. An assembly as set forth in claim **7** wherein each of said first fluid tubes extends through one of said header slots of each outer header and into the associated outer cavity.

9. An assembly as set forth in claim **1** wherein each header is generally semi-circular in cross-section to define said cavities.

10. An assembly as set forth in claim **9** wherein the cross-section of each header includes a lanced wall extending between sides and a curved wall arched upwardly between said sides to define said headers as being generally semi-circular in cross-section.

11. An assembly as set forth in claim **10** wherein each lanced wall defines said header slots.

12. An assembly as set forth in claim **10** wherein each lanced wall includes a pair of flanges each extending along one of said sides with said flanges in an overlapping relationship with the associated curved wall.

* * * * *