

HEAT PIPE SYSTEM HAVING COMMON VAPOR RAIL

CROSS REFERENCE TO RELATED APPLICATION

[0001] This application claims priority to U.S. application Nos. 13/247,707 and 13/247,714, each of which was filed September 28, 2011, and U.S. provisional application No. 61/436,076 filed January 25, 2011, the entire contents of which are each hereby incorporated by reference.

FIELD OF INVENTION

[0002] The present invention relates generally to passive heat transfer devices and more particularly to heat pipes, which are closed loop systems using the high heat of evaporation/condensation associated with a phase changing working fluid to efficiently transfer large amounts of heat and which require no or only small energy input.

BACKGROUND

[0003] Heat pipes are closed loop heat exchangers that rely on a phase change of a working fluid to absorb heat by evaporation and release heat by condensation. A liquid working fluid (e.g., water, Freon, or the like) is vaporized in the evaporator portion of a heat pipe using heat absorbed from the environment. The vapor flows into the condenser portion of the heat pipe where it is condensed, releasing heat into the environment. Liquid condensed in the condenser is returned to the evaporator (e.g., by gravity, capillary action, pump, etc.) where it is evaporated again. In use the working fluid is continuously vaporized in the evaporator portion of the heat pipe and continuously condensed in the condenser portion of the heat pipe such that heat is absorbed from the environment by the evaporator, transferred to the condenser, and then released into the environment by the condenser. This process cools the environment surrounding the evaporator and heats the environment surrounding the condenser. Heat pipes can be extremely efficient at transferring large amounts of heat and can operate with only a limited difference between the temperatures of the evaporator and condenser portions of the system. Heat pipes also require no moving parts and typically require little or no maintenance.

[0004] One practical application for heat pipes is in de-humidification systems that pre-cool air in the inlet stream of a cooling coil (e.g., in the HVAC system for a commercial or residential building) and re-heat the outlet air stream from the cooling coil. The heat pipe can be configured to extend from one side of the cooling coil to its opposite side so the evaporator portion is in the cooling coil inlet stream and the condenser portion is on the opposite side of the cooling coil in the cooling coil outlet stream. For example, heat pipes can wrap around the sides and/or over the top of the cooling coil so the evaporator portion of the heat pipe is in the inlet stream and the condenser portion of the heat pipe is in the outlet stream. Pre-cooling the air as it enters the cooling coil allows the cooling coil to cool the air to a significantly lower temperature without using much if any additional energy. The overly cooled output air stream from the cooling coil is then heated by the condenser portion of the heat pipe system to a comfortably cool temperature. Over cooling the air in this manner increases the amount of moisture condensed from the air stream as it flows through the cooling coil. This combination of heat pipe and cooling coil provides a low cost, low maintenance dehumidification system.

[0005] Heat pipes can also be used to recover heat that would otherwise be lost in exhaust from an HVAC system during cold weather. For example, a heat pipe can be installed in the duct system of an HVAC system so the heat pipe extends into two adjoining ducts, one of which is being used to exhaust warmer stale air from the building and the other of which is used to convey cooler fresh air from outside the building to the HVAC system. Heat from the warm exhaust is captured by evaporation of the working fluid in the part of the heat pipe exposed to the exhaust and transferred to the cool inlet air by condensation of the working fluid in the part of the heat pipe exposed to the inlet stream. Thus, heat that would otherwise be lost to the outside of the building is used to pre-heat the cool inlet air, which means less energy is required by the heater of the HVAC system to heat the fresh air to a comfortable temperature. The heat pipes can be designed so when the cooling coil is operating in warm weather heat is transferred from the relatively warm inlet air to relatively cool stale exhaust air. Using the heat pipes to recapture heat from the warm exhaust in cold weather and recapture coolness from the cool exhaust in warm weather reduces the load on the heater and cooling coil and reduces energy required by the HVAC.

[0006] Various improvements to the prior art heat pipes are been made and will be described in the detailed description below.

SUMMARY

[0007] One aspect of the invention is a heat pipe. The heat pipe includes a plurality of conduits. Each conduit has an evaporator section extending laterally from a first open end of the respective conduit, a condenser section extending laterally from a second open end of the respective conduit, and a liquid return section. The liquid return section for each conduit is connected to the evaporator section at a position away from the first open end and connected to the condenser section at a position away from the second open end so the evaporator and condenser section are in fluid communication with one another through the liquid return section for flow of liquid condensed in the condenser section to the evaporator section. The liquid return section of at least one conduit is distinct from the liquid return section of another of the conduits. The heat pipe has a common vapor manifold in fluid communication with and extending between the first and second open ends of each of said plurality of conduits so vapors produced in the evaporator sections can flow from the first open ends through the common vapor manifold to the second open ends without flowing through the conduits.

[0008] Another aspect of the invention is a heat transfer system adapted for transferring heat between two different ducts in a ventilation system. The system comprising a heat pipe. The heat pipe has a plurality of conduits. Each conduit includes an evaporator section extending laterally from a first open end of the respective conduit, a condenser section extending laterally from a second open end of the respective conduit, and a liquid return section. The liquid return section for each conduit is connected to the evaporator section at a position away from the first open end and connected to the condenser section at a position away from the second open end so the evaporator and condenser section are in fluid communication with one another through the liquid return section for flow of liquid condensed in the condenser section to the evaporator section. The liquid return section of at least one conduit is distinct from the liquid return section of another of the conduits. The heat pipe includes a common vapor manifold in fluid communication with and extending between the first and second open ends of each of said plurality of conduits so vapors produced in the evaporator sections can flow from the first open ends through the

common vapor manifold to the second open ends without flowing through the conduits.

[0009] Another aspect of the invention is a heat transfer system adapted for transferring heat between two different ducts in a ventilation system. The system includes a heat pipe. The heat pipe has first and second sets of conduits. Each set of conduits includes a plurality of conduits extending between open ends and spaced vertically from one another. The conduits of the first set are in generally side-by-side relation with the conduits of the second set and spaced laterally from the conduits of the second set. The heat pipe a first vapor manifold comprising a leg at one end of the conduits of the first set, another leg at an opposite end of the conduits of the second set, and a vapor passage extending between and in fluid communication with the legs of the first manifold. The vapor passage of the first vapor manifold extends between the first and second sets of conduits so vapor can flow between the ends of the conduits of the first set and the opposite ends of the conduits of the second set through the first vapor manifold without flowing through any conduits of said first and second set of conduits. The heat pipe has a second vapor manifold comprising a leg at one end of the conduits of the second set, another leg at an opposite end of the conduits of the first set, and a vapor passage extending between and in fluid communication with the legs of the second manifold. The vapor passage of the second vapor manifold extends between the first and second sets of conduits so vapor can flow between the ends of the conduits of the first set and the opposite ends of the conduits of the second set through the second vapor manifold without flowing through any conduits of said first and second set of conduits.

[0010] Other objects and features will in part be apparent and in part pointed out hereinafter.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] FIG. 1 is a perspective of one embodiment of a heat pipe;

[0012] FIG. 2 is front elevation of the heat pipe;

[0013] FIG. 3 is a right side elevation of the heat pipe with a portion of a conduit broken away to show a phase changing working fluid;

[0014] FIG. 4 is a left side elevation of the heat pipe with a portion of a conduit broken away to show the phase changing working fluid;

[0015] FIG. 5 is a top plan view of the heat pipe in combination with a cooling coil;

[0016] FIG. 6 is perspective of one embodiment a heat pipe nested within another heat pipe;

[0017] FIG. 7 is a perspective of a heat pipe having a common vapor manifold configured to wrap around the side of a cooling coil;

[0018] FIG. 8 is a perspective of a heat pipe having evaporator sections and condenser sections configured to double back on themselves;

[0019] FIG. 9 is a perspective of another embodiment of a heat pipe;

[0020] FIG. 10 is a perspective of a system including a plurality of heat pipes;

[0021] FIG. 11 is a perspective of the system illustrated in Fig. 10 in a frame with fins;

[0022] FIG. 12 is a schematic illustrating the system of Figs. 10 and 11 installed in the duct system of an HVAC system;

[0023] FIG. 13 is a perspective of another embodiment of a heat pipe;

[0024] FIG. 14 is a top plan view of a set of heat pipes including the heat pipe illustrated in Fig. 13;

[0025] FIG. 14A is a top plan view of another embodiment of set of heat pipes including the heat pipe illustrated in Fig. 13; and

[0026] FIG. 15 is a schematic illustrating a system having the set of heat pipes in Fig. 14 installed in the duct system on an HVAC system.

[0027] Corresponding reference characters indicate corresponding parts throughout the drawings.

DETAILED DESCRIPTION

[0028] Referring to Figs. 1-5, one embodiment of a heat pipe, generally designated 101, includes a plurality of conduits 103 containing a working fluid (e.g., water, Freon or another refrigerant), some of which exists as a vapor V and some of which exists as a liquid L, as illustrated in Figs. 3 and 4. Each of the conduits 103 includes an evaporator section 105 extending laterally from an open end 107 of the conduit and a condenser section 109 extending laterally from another open end 111 of the conduit. Each of the conduits also includes a liquid return section 113 for flow of liquid L condensed in the condenser section 109 to the evaporator section 105.

[0029] As illustrated in the drawings, the liquid return section 113 for each conduit 103 is connected to the evaporator section 105 at a position away from the open end 107 of the evaporator section. For example, the liquid return section 113 is suitably connected to the evaporator section 105 at an end of the evaporator section opposite the open end 107. The liquid return section 113 is also connected to the condenser section 109 at a position away from the open end 111 of the condenser section (e.g., at an end of the condenser section opposite the open end 111 of the condenser section) so the evaporator section 105 and condenser section of each conduit 103 are in fluid communication with one another through the respective liquid return section. The liquid return section 113 of at least one conduit 103 is distinct from the liquid return section of another of the conduits. As illustrated, for example, each conduit 103 has its own liquid return section 113, meaning the liquid return section for each conduit is distinct from the liquid return sections of all the other conduits.

[0030] The evaporator sections 105, condenser sections 109, and liquid return sections 113 are each suitably substantially straight sections of the respective conduit 103, although this is not required to practice the invention. The sections 105, 109, 113 can be connected to one another using a 90 degree elbow connector or other suitable connector. The conduits 103 could also be formed by bending a single segment of pipe to produce the various sections 105, 109, 113 of the conduit. The evaporator sections 105 of the conduits 103 suitably have a horizontal orientation. At least a portion of the condenser section 109 for each conduit 103 is at an elevation higher than the elevation of the evaporator section 105 of the respective conduit 103. For example, as illustrated in Fig. 2, the open end 111 of the condenser section 109 is suitably at an elevation above the elevation of the open end 107 of the evaporator section 105 for each of the conduits 103. The condenser sections 109 are inclined downward from their open ends 111 so gravity assists flow of liquid L condensed in the condenser section toward the liquid return section 113. The liquid return sections 113 can suitably have an orientation inclined downward from the condenser sections 109 to the evaporator sections 105. In the illustrated embodiment, however, the liquid return sections 113 are substantially horizontal. Further, the degree of inclination in any of the various parts of the conduit 103 is suitably relatively slight (e.g., about 1 percent slope). Moreover, conduits that do not have any slope are within the broad scope of the invention.

[0031] Although the embodiment illustrated in the drawings has a configuration in which gravity drives or assists flow of condensed liquid L through the heat pipe 101 to the evaporator sections 105, condensed liquid can be returned to the evaporator portion of a heat pipe without any gravity assistance and/or against gravity using various internal wicking features and/or pumps known to those skilled in the art without departing from the scope of the invention.

[0032] As illustrated in Figs. 1-5, the conduits 103 are suitably generally U-shaped and have a substantially horizontal orientation. In particular, the difference in elevation between the highest part of the conduit 103 (e.g., at openings 111 in the illustrated embodiment) and the lowest part of the conduit (e.g., evaporator section 105 and/or at the openings 107) is suitably no more than about 10 percent of the overall length of the conduit, meaning the conduit has a substantially horizontal orientation. The conduits 103 are arranged so they are spaced vertically from one another, as illustrated in Fig. 1. For example, the conduits 103 are suitably stacked generally one on top of the other so they each have an identical U-shaped footprint when viewed from the top, as illustrated in Fig. 5. The conduits 103 may lie directly on top of one another so the top of one conduit is in contact with the bottom of another conduit within the broad scope of the invention. In the illustrated embodiment, however, the conduits 103 are retained in spaced relation from one another and fins extend vertically between the conduits. Referring to Fig. 1, one set of fins 121 is connected to the evaporator sections 105 of the conduits 103 to facilitate absorption of heat from the environment. Another set of fins 123 is connected to the condenser sections 109 of the conduit to facilitate release of heat to the environment. The fins 121, 123 are suitably large thin metal plates that extend continuously between the conduits 103 such that the conduits are embedded in the fins. The sets of fins 121, 123 extend continuously along substantially the entire length of the evaporator sections 105 and condenser sections 109. Only some of the fins 121, 123 are shown in Fig. 1 to show the conduits better. The liquid return sections 113 are substantially free of fins to limit heat transfer between the working fluid in the liquid return sections and the environment.

[0033] The heat pipe 101 is suitably configured so the evaporator sections 105 are positioned on one side of a space 131 for receiving a cooling coil 135 (Fig. 5) and the condenser sections are positioned on the opposite side of the space. In Fig. 5, the heat pipe 101 is illustrated in combination with a cooling coil 135 (broadly a

"cooling system"). The cooling coil 135 is conventional except for the heat pipes 101 and need not be described or illustrated in detail. Those skilled in the art will recognize the cooling coil 135 is suitably part of a conventional air conditioning system (not shown). The evaporator sections 105 of the heat pipe 101 collectively form an array of evaporator sections disposed in the path of air incoming to the evaporator of the cooling system for pre-cooling air before it arrives at the evaporator. The condenser sections 109 of the heat pipe 101 collectively form an array of condenser sections disposed in the air path downstream of the evaporator of the cooling system for re-heating overly cooled air to a temperature that is suitable for the occupants of a building cooled by the cooling system.

[0034] The conduits 103 are suitably made of relatively long narrow tubing. For example, the conduits 103 are suitably made of tubing no larger than 1 inch tubing, more suitably no larger than 5/8 inch tubing, more suitably no larger than 1/2 inch tubing and can in some cases be made of tubing no larger than 3/8 inch tubing. As illustrated in Fig. 5, the evaporator sections 105 and condenser sections 109 are generally parallel to one another and spaced from one another by a distance D1 that is at least about 2 feet, more suitably at least about 4 feet, still more suitably in the range of about 4 to about 10 feet, and still more suitably in the range of about 6 to about 8 feet. The length L1 of the liquid return sections 113 of the conduits is suitably about equal to the distance D1. The evaporator and condenser sections 105, 109 are suitably about equal in length. Each of the evaporator and condenser sections 105, 109 has a length L2 suitably in the range of about 25 to about 150 inches, more suitably in the range of about 50 to about 125 inches, and still more suitably in the range of about 75 to about 100 inches, with each of the foregoing lengths being suitable when the conduits are made from 1/2 inch tubing. If larger tubing is used, the lengths can be increased even more without experiencing a significant loss in efficiency.

[0035] The overall length of the flow path through the conduits 103 from the condenser opening 111, through the condenser section 109, liquid return section 113, and evaporator section 105 to the evaporator opening 107 is suitably in the range of about 50 inches to about 300 inches, more suitably in the range of about 60 to about 250 inches, more suitably in the range of about 100 to about 250 inches, more suitably in the range of about 125 to about 225 inches, and still more suitably in the range of about 150 to about 200 inches, with each of the foregoing lengths being suitable when the conduits are made from 1/2 inch tubing. Those skilled in the art will

recognize the lengths described above for the conduits and the various parts thereof are fairly long flow paths for a heat pipe made of ½ inch tubing. Again, if larger tubing is used, the lengths can be increased even more without experiencing a significant loss in efficiency. For example, when the tubing is 5/8 inch diameter tubing, the overall length of the flow path through the conduits 103 from the condenser opening, through the condenser section 109, liquid return section 113, and evaporator section 105 to the evaporator opening 107 is suitably in the range of about 100 inches to about 500 inches, more suitably in the range of about 200 inches to about 500 inches, and still more suitably in the range of about 200 inches to about 400 inches. As another example, when the tubing is 3/8 inch diameter tubing, the overall length of the flow path through the conduits is suitably in the range of about 12 inches to about 200 inches, more suitably in the range of about 12 inches to about 100 inches, and still more suitably in the range of about 12 inches to about 60 inches, and still more suitably in the range of about 24 inches to about 60 inches. As still another example, when the tubing is in the range of about 5/16 to 7mm diameter tubing, the overall length of the flow path through the conduits is suitably in the range of about 12 inches to about 50 inches. It costs substantially more to make heat pipes using larger diameter tubing than it does with smaller diameter tubing, so it is desirable to use the smallest diameter tubing that does not result in an unacceptably inefficient heat pipe. But the improvements described herein can also improve the efficiency for heat pipes in which the dimensions for the lengths and diameters of the conduits vary from those listed above within the scope of the invention.

[0036] The heat pipe 101 also has a common vapor manifold 151 in fluid communication with the open ends 107, 111 of each of said plurality of conduits 103 and extending between the open ends of the conduits so vapors V produced in the evaporator sections 105 can flow from the open ends 107 of the evaporator sections 105 through the common vapor manifold to open ends 111 of the condenser sections 109 without flowing through the conduits. Because the vapor V can return to the condenser sections 109 without flowing through the conduit, there is much less resistance to flow of liquid from the condenser sections to the evaporator sections 105 because counterflow of vapor and liquid L in the conduits 103 is greatly reduced or eliminated. The common vapor manifold can have many different configurations within the broad scope of the invention. As illustrated, the common vapor manifold 151 is an inverted U-shaped conduit having a generally upright evaporator leg 153, a

generally upright condenser leg 155, and a generally horizontal vapor passage 157 connecting the legs to one another so they are in fluid communication with one another through the vapor passage. The evaporator leg 153 and the condenser leg 155 are suitably substantially straight (e.g., vertical) sections of tubing. The vapor passage 157 is also a substantially straight section of tubing having the same diameter as the legs 153, 155. Although the legs and vapor passage of the manifold are straight in the illustrated embodiment, other configurations are possible within the broad scope of the invention. The vapor passage 157 can be connected to the legs 153, 155 of the vapor manifold 151 using a 90 degree elbow connection or other suitably connecting means. Similarly, a single piece of tubing can be bent into an inverted U-shape to form the common vapor manifold 151 within the scope of the invention.

[0037] The tubing for the common vapor manifold 151 suitably has a diameter that is larger than the diameter of the conduits 103, as in the illustrated embodiment. In one embodiment, the conduits 103 can be made from 0.5 inch or 3/8 inch copper tubing while the common vapor manifold 151 is made from larger diameter 5/8 inch or 0.5 inch copper tubing, respectively. However, the cross sectional flow area of the vapor manifold 151 can be much larger than described above or be the same or smaller than the cross sectional flow area a conduit 103 within the scope of the invention. It is also understood the conduits 103 and manifold 151 are not required to have any particular cross sectional shape within the broad scope of the invention.

[0038] The open ends 107 of the evaporator sections 105 open into the evaporator leg 153 of the manifold 151. The open ends 111 of the condenser sections 109 open into the condenser leg 155 of the manifold 151. In the illustrated embodiment, the evaporator leg 153 of the common vapor manifold 151 extends to a position that is higher in elevation than the highest of the open ends 107 of the evaporator sections 105. For example, the manifold 151 suitably extends a distance H1 (Fig. 3) above the highest of the open ends 107 of the evaporator sections 105. Likewise, the condenser leg 155 leg of the common vapor manifold 151 extends to a position that is higher in elevation than the highest of the open ends 111 of the condenser sections 109. The vapor passage 157 connects to the evaporator leg 153 at an elevation above the highest of the open ends 107 of the evaporator sections 105 and connects to the condenser leg 155 at an elevation above the highest of the open ends 111 of the condenser sections 109. The vapor passage 157 of the illustrated

embodiment is also at an elevation that is higher than the highest of the generally horizontal conduits 103. An opening 137 (Fig. 1) for receiving the cooling coil 135 as it slides relative to the heat pipe 101 into the space 131 is formed between the legs 153, 155 and under the vapor passage 157 of the vapor manifold. Like the liquid return sections 113 of the conduits 103, the common vapor manifold 151 is suitably substantially free of fins to limit heat transfer between the heat pipe 101 and the environment except at the evaporator and condenser sections 105, 109.

[0039] When the cooling coil 135 is on, air flows into the cooling coil and is cooled. Meanwhile, the evaporator sections 105 of the heat pipe 101 are exposed to the relatively warm air flowing into the cooling coil 135, represented in Fig. 5 by arrows A. Heat from the warm inlet air is absorbed by the fins 121 and evaporator sections 105. This process cools the air before it reaches the cooling coil 135. The absorbed heat causes liquid phase working fluid L to evaporate in the evaporator sections 105. Vapors V produced in the evaporator sections 105 flow into the evaporator leg 153 of the vapor manifold 151 through the openings 107, up to the vapor passage 157, across the vapor passage to the condenser leg 155, down into the condenser leg 155, and then into the condenser sections 109 through the openings 111. Because the air was pre-cooled by the evaporator sections 105 before reaching the cooling coil 135, the cooling coil can cool the air down to a temperature significantly below the temperature to which it would be cooled if there were no heat pipe present, but with little or no additional energy consumption. Because the air is cooled by the cooling coil 135 to this lower temperature, significantly more water vapor is condensed and removed from the air flowing through the cooling coil.

[0040] As this is occurring, the condenser sections 109 are exposed to the cold outlet air stream from the cooling coil 135, represented by arrows B in Fig. 5. As the cold air outlet stream flows through the fins 123, it absorbs heat released from the condenser sections 109 of the heat pipe 101 through condensation of the working fluid in the condenser sections. The interaction of the cold air from the cooling coil 135 and the condenser sections 109 warms the air to a comfortable temperature and produces condensation of the working fluid in the condenser sections of the heat pipe 101. The liquid L condensed in the condenser sections flows from the condenser sections 109 to the evaporator sections 105 through the respective liquid transfer sections 113. The air warmed by the condenser sections 109 has lower relative humidity than it would

without the heat pipe 101. Moreover, the heat pipe dehumidifies the air with little or no additional energy consumption.

[0041] Because the common vapor manifold 151 allows vapors evaporated in the evaporator sections to flow to the condenser sections through the vapor manifold, there is less resistance to flow of liquid L through the conduits 103 to the evaporator sections 105 and there is less resistance to flow of vapor V to the condenser sections 109 because of the relative absence of counter flowing vapor and liquid in any section of the heat pipe 101. This increases the speed at which vapor V and liquid L flows through the heat pipe 101 and thereby allows the heat pipe 101 to perform efficiently even when the overall length of the conduits 103 is relatively long and the inner diameter of the conduits is relatively small (e.g., as described above). Moreover, the heat pipe 101 can perform efficiently with a relatively low charge of working fluid. For example, the charge of working fluid can suitably be in the range of about 15 percent to about 60 percent, more suitably in the range of about 15 percent to about 45 percent, more suitably in the range of about 15 percent to about 30 percent, and still more suitably in the range of about 20 percent to about 30 percent. In other examples, the interior surface of the tubing has grooves (which those skilled in the art will recognize aids flow of liquid through the tubing by capillary action) and the charge of working fluid can suitably be in the range of about 20 percent to about 50 percent, more suitably in the range of about 20 percent to about 45 percent, more suitably in the range of about 25 percent to about 40 percent, and still more suitably in the range of about 25 to 35 percent. Grooved tubing typically works better with a slightly larger charge of working fluid compared to tubing that is smooth on the inside. As further examples, the charge of working fluid is suitably less than about 40 percent, still more suitably less than about 35 percent, and still more suitably no more than about 30 percent. As those skilled in the art know, the amount of charge is the weight of working fluid (liquid + vapor) in the system expressed as a percentage of the weight of liquid phase working fluid that would completely fill the interior volume of the heat pipe. It is understood that larger charges than those specified above may be used within the broad scope of the invention. Accordingly, the performance of the heat pipe 101 can be equivalent to conventional heat pipe having significantly more expensive larger diameter tubing for the conduits and requiring a higher volume of working fluid. It is understood the improvements described herein can also improve

efficiency of the heat pipes with the charge of working fluid varies from the amounts described above without departing from the scope of the invention.

[0042] As illustrated in Fig. 1, the system 101 can include a valve 161 installed in the common vapor manifold 151 for selectively reducing flow of vapor through the common vapor manifold. The valve 161 is suitably moveable (e.g., manually or via an electronic control system, not shown) between first and second operating positions such that there is relatively less resistance to flow of vapor through the common vapor manifold 151 in the first position (e.g., a fully open position) and relatively more resistance to flow of vapor through the common vapor manifold in the second position (e.g., a fully closed position). Thus, the valve provides the ability to adjust the efficiency of the system from a higher heat transfer efficiency for better dehumidification to a lower heat transfer efficiency. It may be desirable to operate in a lower heat transfer efficiency mode when the air flowing into the system is already relatively dry and less dehumidification is desired. The valve 161 is optional. Although the valve illustrated in Fig. 1 is a manually operated ball valve, it is understood it will often be desirable to use an electronically controlled valve so the valve can be operated from a remote position (e.g., by a processor). If desired the valve 161 can be positionable at one or more additional operating positions intermediate the first and second positions (e.g., an infinite number of positions between a fully closed position and a fully open position) to provide greater control over the amount of fluid flowing through the common vapor manifold 151.

[0043] Figure 6 illustrates another embodiment of a heat pipe system, generally designated 101'. This system 101' includes multiple heat pipes 101 nested together so they work in tandem. In Fig. 6, there are two heat pipes 101 in the system 101' and each of the two heat pipes is exactly the same as the heat pipe 101 in Fig. 1 except one of the heat pipes is slightly smaller than the other so it can nest inside the other. It is understood there could be more than two heat pipes nested together without departing from the scope of the invention. The system 101' operates in a manner that is substantially the same as the system 101 in Fig. 1, except the system 101' has a greater capacity to transfer heat because of the multiple heat pipes 101 working in tandem.

[0044] Figure 7 illustrates another embodiment of a heat pipe system, generally designated 101". This heat pipe is substantially identical to the heat pipe 101 illustrated in Fig. 1, except as noted. The heat pipe 101" has a common vapor rail 151"

having a vapor passage 157" configured to extend from the top of the evaporator leg 153 to the top of the condenser leg 155 along a path that matches the U-shaped contour of the conduits 103. Accordingly, a portion of the common vapor manifold 151" is on the same side of the heat pipe 101" as at least one (e.g., all) of the liquid return sections 113 of the conduits 103. As illustrated in Fig. 7, the vapor passage 157" extends from the top of the evaporator leg 153 along and above the evaporator section 105, liquid return section 113, and condenser section 109 of the uppermost conduit. The vapor passage 157" is configured so it wraps around the same side of the cooling coil 135 as the conduits. This allows the heat pipe 157" to be installed around the cooling coil 135 without requiring the vapor rail 151", and in particular the vapor passage 157" thereof, to be passed over the top of the cooling coil. This can be desirable, for example, when the cooling coil 135 is already installed and obstructions would prevent or make it difficult to move the vapor passage 157 for the embodiment illustrated in Fig. 1 over the top of the cooling coil to wrap the conduits 103 around the sides of the cooling coil during installation of the heat pipe. The heat pipe 101" illustrated in Fig. 7 can also be nested with one or more similar heat pipes in a manner analogous to the nesting illustrated in Fig. 6.

[0045] Another embodiment of a heat pipe, generally designated 101'", is illustrated in Fig. 8. This heat pipe 101'" is substantially identical to the heat pipe 101 illustrated in Fig. 1 except as noted. The conduits 103'" of this heat pipe 101'" have evaporator sections 105'" and condenser sections 109'" that double back on themselves so the open ends 107'", 111'" are at the same end of the system as the liquid return sections 113 of the conduits. The overall shape of the conduits 103'" is that of a horizontal U, with the doubled back evaporator and condenser sections 105'", 109'" forming the sides of the U and the liquid return sections 113'" forming the bottom of the U. The overall length of the conduits 103'" is suitably the same as the lengths of the conduits 103 described above. However, doubling back of the evaporator sections 105'" and condenser sections 109 requires the working fluid to flow double the length of the cooling coil to flow through the condenser section and through the evaporator section. Accordingly, the heat pipe 101'" in Fig. 8 is particularly suitable for small and medium sized cooling coils. The common vapor manifold 151'" is substantially similar to the vapor manifold 151 described above, but it is at the same end of the heat pipe 101'" as the liquid return sections 113 of the conduits 103". Accordingly, similar

to the embodiment illustrated in Fig. 7, there is no need to pass the common vapor rail 151 over the top of the cooling coil 135 during installation.

[0046] The evaporator sections 105 and condenser sections 109 are suitably horizontal (e.g., perfectly horizontal or substantially free of any incline), as illustrated. Each evaporator section 105 is suitably doubled back in such a way that the end 107 of the evaporator section is spaced inward from the end of the liquid return section 113 connected to the evaporator section. Each condenser section 109 is suitably doubled back in such a way that the end 111 is spaced outward from the end of the liquid return section that is connected to the condenser section. Accordingly, when the heat pipe 101 is installed for use with cooling coil 135, each evaporator section 105 includes a first portion 105a adjacent the opening 107 and a second portion 105b remote from the opening 107 and upstream of the first portion in the cooling coil intake stream. Likewise, each condenser section 109 includes a first portion 109a adjacent the opening 111 and a second portion 109b remote from the opening 111 that is upstream of the first portion in the flow out of the cooling coil. The evaporator leg 153 of the common vapor manifold 151 is positioned inside the portions 105b of the evaporator sections 105 that are remote from the open ends 107. The condenser leg 155 of the common vapor manifold 151 is positioned outside the portions 109b of the condenser sections 109 that are remote from the open ends 111. When the heat pipe 101 is in use, this arrangement causes temperature gradients to form in the conduits 103 that pump the working fluid through the heat pipe 101. In particular, evaporator portion 105b will be warmer than portion 105a and condenser portion 109a will be warmer than portion 109b. The thermal gradients pump working liquid L from the warmer portion toward the cooler portion.

[0047] Another embodiment of a heat pipe, generally designated 201, is illustrated in Fig. 9. Except as noted, this heat pipe 201 is substantially identical in construction to the heat pipe 101 described above. The heat pipe includes a common vapor manifold 251 that is analogous to the manifold 151 describe above. However, the conduits 203 of this heat pipe 201 are substantially straight all the way from one end 107 to the other 111 instead of U-shaped. Consequently, the ends 107, 111 of the conduits 203 are spaced much farther from one another and the vapor manifold 251 has a much longer vapor passage 257 than is the case for the heat pipe 101. The entire vapor manifold 251, including the evaporator leg 253, condenser leg 255, and vapor

passage 257, and the conduits 203 are oriented on a common plane. In this embodiment, the evaporator sections 205 are in-line with the condenser sections 209. The heat pipe 201 includes a first set of fins 221 on the evaporator sections 205 and a second set of fins 223 on the condenser sections 209. Only some of the fins 221, 223 are shown in Fig. 6. The liquid return section 213 is a short segment of the conduit 203 that is substantially free of fins positioned between the evaporator and condenser sections 205, 209. As illustrated, the conduits 203 and vapor passage 257 are substantially horizontal in orientation. It is noted however the conduits 203 could be inclined slightly downward from the condenser sections to the evaporator sections to provide gravity assistance for liquid flow from the condenser sections toward the evaporator sections within the scope of the invention.

[0048] One embodiment of system 271 including a plurality of the heat pipes 201 is illustrated in Figs. 10 and 11. The system 271 is suitable for transporting heat between two different and parallel ducts in a ventilation system and includes a frame 273 (Fig. 11) and a plurality of the heat pipes 201 supported by the frame. The heat pipes 201 are arranged relative to one another so an array 275 of evaporator sections 205 is formed on one side of the system and an array 281 of condenser sections 209 is formed on the other side of the system. As illustrated in Fig. 10, for example, the heat pipes 201 are arranged so the conduits 203 of the plurality of heat pipes are parallel to one another. Further, the evaporator sections 205 of the heat pipes 201 are in side-by-side relation to one another in the evaporator array 275 and the condenser sections 209 are also in side-by-side relation to one another in the condenser array 281. The fins 221 in the evaporator array 275 (Fig. 11) are spaced from the fins 223 in the condenser array 209 by a gap 225 aligned with the liquid return sections 213 of the conduits 203. The fins 221, 223 suitably extend continuously between adjacent heat pipes 201, as illustrated in Fig. 11.

[0049] The system 271 can be installed in the duct system 291 of an HVAC (not shown) as illustrated schematically in Fig. 12. The side having the evaporator array 275 is installed in an inlet duct 293 conveying exterior air toward the HVAC. The side having the condenser array 281 is installed in an adjacent duct 295. Air in the ducts 293, 295 flows in opposite directions as indicated by arrows A and B. During the summer, the system 271 transfers heat from relatively warm air being taken into the HVAC system from outside the building through one of the ducts 293 to relatively cooler stale air from inside the building that is being exhausted to outside

the building by the HVAC system through the other duct 295. This saves energy by pre-cooling the intake air before it reaches the cooling coil using the already cooled stale air being exhausted by the HVAC.

[0050] In winter, the system 271 can be operated in heat recovery mode by reversing the direction of heat transfer through the heat pipes 201. For example, the stale air from inside is now being vented to the exterior through the duct 295 is now relatively warmer while colder fresh air from the exterior of the building is conveyed to the HVAC through the adjacent duct 293. Because of the reversal of the direction of the temperature gradient between the sides of the system 271, what was the evaporator array 275 in the summer now functions as a condenser array and what was the condenser array 281 in the summer now functions as an evaporator array. The warm exhaust air flowing through the exhaust duct 295 evaporates the working fluid in the evaporator array 281 while the colder air in the inlet duct 293 condenses the working fluid in the condenser array 275. The heat captured from the warmer exhaust air by evaporation of the working fluid is transferred to the other side of the heat pipe system 271 where it pre-heats the colder inlet air before it arrives at the HVAC. Consequently, significantly less energy is required to heat the colder incoming air than would be required without the heat pipe system 271.

[0051] Significantly, no tilting mechanism is required to reverse flow of the liquid phase working fluid through the heat pipe system 271. This is contrary to some prior art heat pipe based heat recovery modules in which a complicated tilting system and more costly flexible ducts are needed to adjust the inclination of the conduits and use gravity to overcome resistance to flow of the liquid phase working fluid associated with counterflowing vapors in the conduits. Instead, whenever the condenser array 275 is in a relatively warmer environment and the evaporator array 281 is in a relatively cooler environment, the flow of the working fluid through the system 271 automatically reverses and the condenser sections function as evaporator sections while the evaporator sections functions as condenser sections. This is because the common vapor manifold 251 sufficiently reduces resistance to flow of liquid phase working fluid in the conduits 203 that natural liquid pumping forces produced by the thermal gradient are sufficient to produce flow of liquid between the condenser array 275 and evaporator array without requiring any gravitationally induced flow in the conduits. Accordingly, the conduits 203 can remain in the same horizontal orientation for operation in summer and winter.

[0052] Another embodiment of a heat pipe, generally designated 301, is illustrated in Fig. 13. The heat pipe includes first and second sets of conduits 303a, 303b. Each conduit 303 in the first and second sets 303a, 303b extends between opposite open ends and is spaced vertically from the other conduits in the same set. The conduits suitably have the lengths and diameters specified above for the conduits 103 of the heat pipe 101 in Fig. 1. The conduits 303 are suitably all substantially straight, although this is not required to practice the invention. The conduits 303 of the first set 303a are in generally side-by-side relation with the conduits of the second set 303b and are spaced laterally from the conduits of the second set by a gap 305. The heat pipe 301 includes two vapor manifolds 311', 311" each of which includes a pair of legs 315, 317 and a vapor passage 321 extending between and in fluid communication with the legs. The legs and vapor passages of the first manifold are designated with a single prime (') after the reference number while the legs and vapor passage of the second manifold are designated with a double prime (") after the reference number.

[0053] The first leg 315' of the first manifold 311' is at one end of the conduits 303 of the first set 303a while the second leg 317' of the first manifold is at the opposite end of the conduits of the second set 303b. The vapor passage 321' extends across the gap 305 and between the legs 315', 317'. The vapor passage 321' is in fluid communication with the legs 315', 317' and allows vapor to flow through the manifold 311' between the end of the conduits 303 of the first set 303a and the ends of the conduits of the second set 303b on the opposite side of the heat pipe 301 without flowing through any of the conduits of the first or second sets. The second vapor manifold 311" is substantially identical to the first 311' except that its legs 315", 317" are connected to the ends of the conduits 303 opposite the ends to which the legs 315', 317' of the first manifold 311' are connected. The vapor passages 321', 321" of the manifolds 311', 311" are suitably substantially straight and criss-cross one another as they extend over the top of the gap 305.

[0054] The heat pipe 301 is suitable for use in a heat transfer system used to transfer heat between two different ducts of a ventilation system. Although the heat pipe 301 can be the only heat pipe in the ventilation system within the scope of the invention, it is possible to combine the heat pipe 301 with various other heat pipes to create a set of heat pipes that work together in the ventilation system. For example, Fig 14 is a top plan view of a set of heat pipes that can be supported by the frame 273

of the heat transfer system illustrated in Fig. 11 instead of the six heat pipes 201 in that embodiment. There are four heat pipes in Fig. 14. The first heat pipe 301 is the heat pipe illustrated in Fig. 13. The second heat pipe 401 is substantially similar to the heat pipe 301 illustrated in Fig. 13 except that it is dimensioned to nest with the first heat pipe 301. As illustrated in Fig. 14, the conduits of the second heat pipe 401 are positioned in the gap 305 between the first and second sets 303a, 303b of conduits for the first heat pipe 301. The third and fourth heat pipes 201 in Fig. 14 are each substantially identical to the heat pipe 201 illustrated in Fig. 9 and described above. The conduits for the third and fourth heat pipes are each positioned in the gap between the conduits of the first and second set for the second heat pipe 401. It is understood that another heat pipe similar to the heat pipe 301 could be nested within the second heat pipe 401 instead of or in addition to the third and fourth heat pipes 201 in Fig. 14.

[0055] As illustrated schematically in Fig. 15, a heat transfer system 571 including the frame 273 described above supports the four heat pipes 301, 401, 201, 201 illustrated in the Fig. 14 so the conduits extend from a position within the first duct 293 to a position within the second duct 295 different from the first duct in a manner similar to what is illustrated in Fig. 12. However, in contrast to the embodiment illustrated in Fig. 12, the airflow A, B in the ducts 293, 295 is in the same direction instead of in opposite directions. Many HVAC systems use a parallel flow arrangement through adjacent ducts instead of counterflow and the system illustrated in Fig. 15 can provide significant advantages when there is parallel flow. When the heat transfer system 571 is used in parallel flow situations as illustrated in Fig. 15, the heat pipes operate more efficiency because vapors are exchanged between the first and second sets of conduits 303 for heat pipe 301 and heat pipe 401.

[0056] Without exchange of working fluid between the upstream and downstream heat pipes in a parallel flow situation, as illustrated in Fig. 15, the evaporator and condenser sections of the heat pipe on the upstream side would be exposed to a relatively large temperature difference. Each heat pipe farther downstream would be exposed to a smaller temperature difference because the of heat already transferred between the two air streams by the one or more heat pipes farther upstream before the air arrives at the downstream heat pipe. Further, the heat pipes on the downstream end of the system may operate inefficiently because of the smaller temperature difference.

[0057] On the other hand, in the heat pipes 301, 401 in the system 571 illustrated in Fig. 14 and 15 vapor flows through the manifolds 351 from the warmer end of the system in each duct 293, 295 to the cooler end of the system in the opposite duct. This helps establish and maintain temperature driven pumping forces that circulate the working fluid through the heat pipe. It also helps ensure that each of the heat pipes 301, 401, 201, 201 is exposed to a temperature difference that supports efficient operation of the heat pipe.

[0058] Figure 14A is a top plan view of another set of heat pipes that can be supported by the frame 273 of the heat transfer system illustrated in Fig. 8 instead of the six heat pipes 201 in that embodiment. There are three heat pipes in Fig. 14A. The first heat pipe 301 is the heat pipe illustrated in Fig. 13. The second and third heat pipes 401, 501 are substantially similar to the heat pipe 301 illustrated in Fig. 13 except the second heat pipe 401 is dimensioned to nest with the first heat pipe 301 and the third heat pipe 501 is dimensioned to nest within the second heat pipe. The heat pipes illustrated in Fig. 14A operate in a similar manner to those illustrated in Fig. 14 except the vapor manifolds of the third heat pipe 501 also allow vapor exchange to occur which can further augment efficiency of a heat transfer system using the heat pipes 301, 401, 501.

[0059] It is also noted that any of the vapor manifolds described for any of the embodiments described herein can optionally include a valve similar to the valve 161 illustrated Fig. 1 and described above to reduce the capacity of the heat pipes. Again, the valves can be electronically actuated valves (e.g., solenoid valves) to facilitate control of the valve by a processor, although the valve in Fig. 1 is illustrated as a manually operated ball valve.

[0060] When introducing elements of the ring binder mechanisms herein, the articles “a”, “an”, “the” and “said” are intended to mean that there are one or more of the elements. The terms “comprising”, “including” and “having” and variations thereof are intended to be inclusive and mean that there may be additional elements other than the listed elements. Moreover, the use of “forward” and “rearward” and variations of these terms, or the use of other directional and orientation terms, is made for convenience, but does not require any particular orientation of the components.

[0061] As various changes could be made in the above without departing from the scope of the invention, it is intended that all matter contained in the above

description and shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

CLAIMS

What is claimed is:

1. A heat pipe comprising:

a plurality of conduits, each conduit including an evaporator section extending laterally from a first open end of the respective conduit, a condenser section extending laterally from a second open end of the respective conduit, and a liquid return section, the liquid return section for each conduit being connected to the evaporator section at a position away from the first open end and connected to the condenser section at a position away from the second open end so the evaporator and condenser section are in fluid communication with one another through the liquid return section for flow of liquid condensed in the condenser section to the evaporator section, the liquid return section of at least one conduit being distinct from the liquid return section of another of the conduits; and

a common vapor manifold in fluid communication with and extending between the first and second open ends of each of said plurality of conduits so vapors produced in the evaporator sections can flow from the first open ends through the common vapor manifold to the second open ends without flowing through the conduits.

2. A heat pipe as set forth in claim 1 wherein the vapor manifold comprises first and second legs, the first open ends of said plurality of conduits opening into the first leg and the second open ends of said plurality of conduits opening into the second leg, the manifold further comprising a vapor passage connecting the first and second legs to one another for flow of vapors evaporated in the evaporator sections to the condenser sections through the common vapor manifold.

3. A heat pipe as set forth in claim 3 wherein said plurality of conduits are arranged so they are spaced apart vertically from one another, the first leg of the common vapor manifold extends to a position that is higher in elevation than the highest of the first open ends, and the second leg of the common vapor manifold

- 5 extends to a position that is higher in elevation than the highest of the second open ends.

4. A heat pipe as set forth in claim 3 wherein the vapor passage connects to the first leg of the common vapor manifold at an elevation above the highest of the first open ends and the vapor passage connects to the second leg at an elevation above the highest of the second open ends.

5. A heat pipe as set forth in claim 1 wherein said plurality of conduits are arranged so they are spaced apart vertically from one another and the common vapor manifold has an inverted U-Shape.

6. A heat pipe as set forth in any preceding claim wherein the evaporator sections have a horizontal orientation.

7. A heat pipe as set forth in any preceding claim wherein the condenser sections are inclined downward from the second open ends.

8. A heat pipe as set forth in any preceding claim wherein said plurality of conduits are made of tubing no larger in diameter than $\frac{1}{2}$ inch tubing.

9. A heat pipe as set forth in any preceding claim wherein the length of each of said plurality of conduits is in the range of about 100 to about 250 inches.

10. A heat pipe as set forth in any preceding claim wherein the second end of each of said plurality of conduits is at an elevation that is higher than an elevation of the first end of the respective conduit.

11. A heat pipe as set forth in any preceding claim wherein the conduits are U-Shaped and the evaporator sections have a horizontal orientation.

12. A heat pipe as set forth in one of claims 1-10 wherein the conduits are substantially straight.

13. A heat pipe system comprising a frame and a plurality of heat pipes as set forth in claim 12 supported by the frame, the heat pipes being arranged relative to one another so the evaporator sections of the heat pipe conduits are positioned to form an array of evaporator sections on a first side of the frame and the condenser sections of the heat pipe conduits are positioned to form an array of condenser sections on a second side of the frame opposite the first side of the frame.

14. A heat pipe system as set forth in claim 13 further comprising a plurality of fins in thermal communication with the heat pipe conduits, the fins including a first set of fins in the array of evaporator sections and a second set of fins in the array of condenser sections, the first and second sets of fins being spaced from one another.

15. A heat pipe system as set forth in any one of claims 13 and 14 installed in a duct system of an HVAC system, wherein the array of evaporator sections is in a first duct of the duct system and the array of condenser sections is in a second duct of the duct system, one of the first and second ducts leading to an inlet of the HVAC system and the other of the first and second ducts extending from an outlet of the HVAC system.

16. A heat pipe as set forth in any one of claims 1-12 further comprising fins connected to the conduits in the evaporator section to facilitate heat transfer and fins connected to the conduit in the condenser section to facilitate heat transfer, the liquid return section and common vapor manifold being free of fins.

17. A heat pipe as set forth in any preceding claim further comprising a working fluid contained in the conduits and common vapor manifold.

18. A heat pipe as set forth in claim 17 wherein the heat pipe contains no more than a 35% charge of the working fluid.

19. A heat pipe as set forth in any one of claims 1-11 and 16-18 in combination with a cooling coil, the evaporator sections of the conduits being

disposed in the path of air flowing into the cooling coil and the condenser sections of the conduits being disposed in the path of air downstream of the cooling coil.

20. A heat pipe as set forth in any one of claims 1-11 and 16-19 in combination with another substantially identical heat pipe nested within the heat pipe.

21. A heat pipe as set forth in any one of claims 1-4, 6-11, and 16-20 wherein the common vapor manifold has a U-shaped configuration and at least a portion of the common vapor manifold is on the same side of the heat pipe as at least one of the liquid return sections of the conduits.

22. A heat pipe as set forth in any one of claims 1-11 and 16-21 wherein the evaporator sections and condenser sections are configured so they are doubled back on themselves.

23. A heat pipe as set forth in claim 22 wherein the common vapor manifold has an inverted U-shape and is on the same side of the heat pipe as the liquid return sections of the conduits.

24. A heat pipe as set forth in claim 22 wherein the conduits have a horizontal U-shaped configuration and the common vapor manifold has an evaporator leg adjacent and connected to the evaporator sections, a condenser leg adjacent and connected to the condenser sections, and a vapor passage extending between the
5 evaporator leg and condenser leg, the evaporator leg being positioned inside a portion of the evaporator sections of the conduits and the condenser leg being positioned outside a portion of the condenser sections.

25. A heat pipe as set forth in any preceding claim further comprising a valve moveable between first and second operating positions, the valve producing relatively less resistance to flow of vapor through the common vapor manifold in the first position and relatively more resistance to flow of vapor through the common
5 vapor manifold in the second position.

26. A heat transfer system adapted for transferring heat between two different ducts in a ventilation system, the system comprising a heat pipe comprising, a plurality of conduits, each conduit including an evaporator section extending laterally from a first open end of the respective conduit, a condenser section extending laterally from a second open end of the respective conduit, and a liquid return section, the liquid return section for each conduit being connected to the evaporator section at a position away from the first open end and connected to the condenser section at a position away from the second open end so the evaporator and condenser section are in fluid communication with one another through the liquid return section for flow of liquid condensed in the condenser section to the evaporator section, the liquid return section of at least one conduit being distinct from the liquid return section of another of the conduits; and

a common vapor manifold in fluid communication with and extending between the first and second open ends of each of said plurality of conduits so vapors produced in the evaporator sections can flow from the first open ends through the common vapor manifold to the second open ends without flowing through the conduits.

27. A heat transfer system as set forth in claim 26 wherein the conduits are substantially straight.

28. A heat transfer system as set forth in any one of claims 26 and 27 wherein the heat pipe is a first heat pipe, the system further comprising at least one additional heat pipe, each additional heat pipe comprising: a plurality of conduits, each conduit including an evaporator section extending laterally from a first open end of the respective conduit, a condenser section extending laterally from a second open end of the respective conduit, and a liquid return section, the liquid return section for each conduit being connected to the evaporator section at a position away from the first open end and connected to the condenser section at a position away from the second open end so the evaporator and condenser section are in fluid communication with one another through the liquid return section for flow of liquid condensed in the condenser section to the evaporator section, the liquid return section of at least one conduit being distinct from the liquid return section of another of the conduits; and

a common vapor manifold in fluid communication with and extending
15 between the first and second open ends of each of said plurality of conduits so vapors produced in the evaporator sections can flow from the first open ends through the common vapor manifold to the second open ends without flowing through the conduits.

29. A heat transfer system as set forth in claim 28 wherein the heat pipes are arranged relative to one another to form an array of evaporator sections on one side of the system and an array of condenser sections on an opposite side of the system.

30. A heat transfer system as set forth in claim 29 further comprising a first set of fins on the evaporator sections and a second set of fins on the condenser sections.

31. A heat transfer system as set forth in any one of claims 26-30 further comprising a frame supporting the heat pipes and fins, the frame being configured to extend from a first ventilation duct into a second ventilation duct different from the first duct.

32. A heat transfer system as set forth in any one of claims 26-31 wherein when the evaporator sections of the heat pipes are in a relatively cooler environment and the condenser sections are in a relatively warmer environment, the evaporator sections can be operated as condenser sections and the condenser sections can be
5 operated as evaporator sections without requiring any tilting of the heat pipes to reverse the flow of the liquid in the conduits.

33. A heat transfer system as set forth in any one of claims 26-32 wherein said plurality of conduits are made of tubing no larger in diameter than ½ inch tubing.

34. A heat transfer system as set forth in any one of claims 26-33 wherein the length of each of said plurality of conduits is in the range of about 100 to about 250 inches.

35. A heat transfer system as set forth in any one of claims 26-34 wherein the heat pipe contains no more than a 35% charge of the working fluid.

36. A heat transfer system adapted for transferring heat between two different ducts in a ventilation system, the system comprising a heat pipe comprising, first and second sets of conduits, each set of conduits comprising a plurality of conduits extending between open ends and spaced vertically from one another, the
5 conduits of the first set being in generally side-by-side relation with the conduits of the second set and spaced laterally from the conduits of the second set,

a first vapor manifold comprising a leg at one end of the conduits of the first set, another leg at an opposite end of the conduits of the second set, and a vapor passage extending between and in fluid communication with the legs of the first
10 manifold, wherein the vapor passage extends between the first and second sets of conduits so vapor can flow between the ends of the conduits of the first set and the opposite ends of the conduits of the second set through the first vapor manifold without flowing through any conduits of said first and second set of conduits, and

a second vapor manifold comprising a leg at one end of the conduits of the
15 second set, another leg at an opposite end of the conduits of the first set, and a vapor passage extending between and in fluid communication with the legs of the second manifold, wherein the vapor passage extends between the first and second sets of conduits so vapor can flow between the ends of the conduits of the first set and the opposite ends of the conduits of the second set through the second vapor manifold
20 without flowing through any conduits of said first and second set of conduits.

37. A heat transfer system as set forth in claim 36 wherein the vapor passages of the first and second manifolds extend diagonally across a gap between the first and second sets of conduits and criss-cross one another.

38. A heat transfer system as set forth in any one of claims 36 and 37 wherein the conduits of the first and second sets of conduits are substantially straight.

39. A heat transfer system as set forth in any one of claims 36-38 wherein the vapor passages of the first and second manifolds extend across a top of a gap between the first and second sets of conduits.

40. A heat transfer system as set forth in any one of claims 36-39 wherein said plurality of conduits made of tubing having a diameter no larger than $\frac{1}{2}$ tubing.

41. A heat transfer system as set forth in any one of claims 36-40 wherein the length of each of said plurality of conduits is in the range of about 100 to about 250 inches.

42. A heat transfer system as set forth in any one of claims 36-41 wherein the heat pipe contains no more than a 35% charge of a phase changing working fluid.

43. A heat transfer system as set forth in claims 36-42 wherein the heat pipe is a first heat pipe, the system further comprising a second heat pipe comprising:
first and second sets of conduits, each set of conduits comprising a plurality of

5 conduits extending between open ends and spaced vertically from one another, the conduits of the first set being in generally side-by-side relation with the conduits of the second set and spaced laterally from the conduits of the second set by a gap,

a first vapor manifold comprising a leg at one end of the conduits of the first set, another leg at an opposite end of the conduits of the second set, and a vapor passage extending between and in fluid communication with the legs of the first manifold, wherein the vapor passage extends across the gap between the first and second sets of conduits so vapor can flow between the ends of the conduits of the first set and the opposite ends of the conduits of the second set through the first vapor manifold without flowing through any conduits of said first and second set of conduits, and

15 a second vapor manifold comprising a leg at one end of the conduits of the second set, another leg at an opposite end of the conduits of the first set, and a vapor passage extending between and in fluid communication with the legs of the second manifold, wherein the vapor passage extends across the gap between the first and second sets of conduits so vapor can flow between the ends of the conduits of the first set and the opposite ends of the conduits of the second set through the second vapor manifold without flowing through any conduits of said first and second set of conduits,

wherein the second heat pipe is nested within the first heat pipe so the first and second sets of conduits for the second heat pipe are positioned in the gap between the first and second sets of conduits for the first heat pipe.

44. A heat transfer system as set forth in claim 43 further comprising a third heat pipe, the third heat pipe comprising;
a plurality of conduits extending between opposite open ends; and
a vapor manifold in fluid communication with and extending between the first and second open ends of each of said plurality of conduits so vapors can flow between the first and second open ends of the conduits through the vapor manifold without flowing through the conduits,

wherein the conduits for the third heat pipe are positioned in the gap between the first and second sets of conduits for the second heat pipe.

45. A heat transfer system as set forth in claim 44 further comprising a fourth heat pipe, the fourth heat pipe comprising:
a plurality of conduits extending between opposite open ends; and
a vapor manifold in fluid communication with and extending between the first and second open ends of each of said plurality of conduits so vapors can flow between the first and second open ends of the conduits through the vapor manifold without flowing through the conduits,

wherein the conduits for the fourth heat pipe are positioned in the gap between the first and second sets of conduits for the second heat pipe.

46. A heat transfer system as set forth in any one of claims 36-45 wherein the heat pipe is supported by a frame mounted in a ventilation system so the conduits of the first and second set of conduits extend from a position within a first duct to a position within a second duct different from the first duct and the first set of conduits are upstream of the second set of conduits in each of the first and second ducts.