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[54] HEAT EXCHANGE METHODS AND APPARATUS
4 Claims, 1 Drawing Fig.

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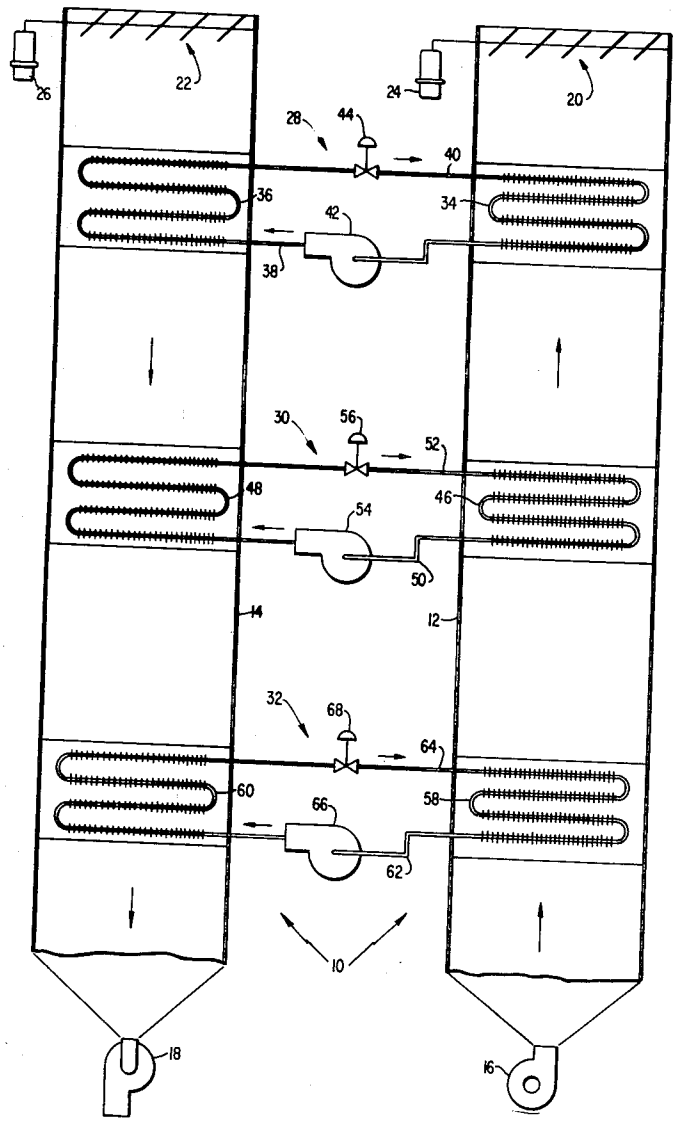
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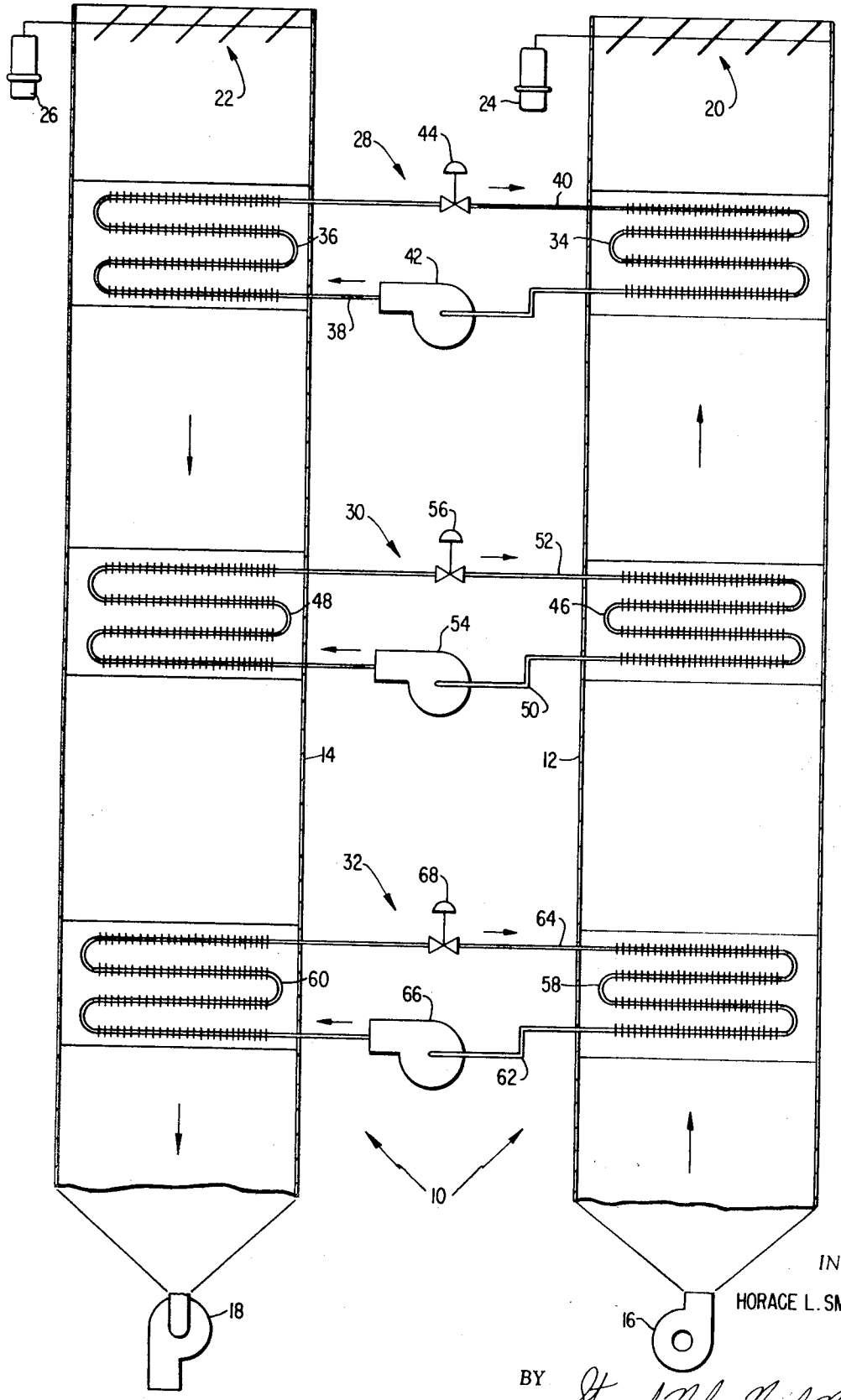
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ABSTRACT: Heat exchange apparatus and methods in which liquids having different phase change characteristics absorb heat from a relatively hot gas at one location and give up the heat to a relatively cool gas at a second location.



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HEAT EXCHANGE METHODS AND APPARATUS

This invention relates to heat exchange and, more particularly, to novel, improved methods and apparatus for transferring heat from one gas to another.

One primary object of the invention resides in the provision of methods and apparatus as described in the preceding paragraph.

Many devices for transferring heat from one gas to a second gas at a lower temperature have heretofore been proposed. Such heat exchangers are either of the recuperative or regenerative type.

In a recuperative-type heat exchanger, two fluids are separated by a heat transfer surface, one fluid flowing continuously on one side of the surface and the other fluid on the opposite side. When tubes are used, one fluid flows inside the tubes and the other outside. In a plate-type recuperative heater, the two fluid streams flow in alternate passages formed by the plates.

In a regenerative-type heat exchanger, the heat exchange member is alternately heated by one fluid and cooled by a second fluid. A typical regenerative heat exchanger includes a regenerator rotatably mounted in a housing divided into separate compartments through which hot and cool gases flow. As it rotates, the regenerator absorbs heat from the hot gas in one compartment and gives the heat up to the cooler gas in the other compartment.

Another well-known regenerative heat exchanger is the checkerwork type. In this type of heat exchanger, hot and cool gases are alternately circulated through refractory checkerwork to transfer heat from the hot gases to the checkerwork and from the checkerwork to the cooler gas.

In both the recuperative and regenerative types of heat exchangers as heretofore constructed, both the hot and cold gases must be brought to a single location. This rules out the possibility of heat recovery in many cases such as in drying operations. In such applications very large volumes of air are employed, and the makeup air may be supplied from a location widely separated from that at which the exhaust air is discharged.[1]([1]In a typical paper machine the location at which air is exhausted from the machine would be 100 feet or more from the point at which cool, ambient, makeup air is introduced into the system.) To bring the two fluid streams to a single location would require such large and extensive ducting and such blower capacity as to be economically unfeasible in many cases.

Another important and primary object of the present invention is the provision of novel, improved methods and apparatus which make it feasible to transfer heat from a relatively hot gas at one location to a cooler gas at a second location which may be considerably removed from the first location.

In the practice of the present invention, two or more liquids having different phase change characteristics[2]([2]The term "different phase change characteristics" will be used herein to identify liquids having different freezing points or different boiling or degradation points or both.) are circulated through convective heat exchangers over which a relatively hot gas flows to transfer heat from the gas to the liquid. The heated liquids then flow to a second location where they again circulate through convective heat exchangers. At this location a relatively cooler gas is circulated over the heat exchangers, absorbing heat from the liquids flowing through them.

One major advantage of this novel arrangement is that it makes it feasible to extract heat from a hot gas at one location and transfer it to a cooler gas at a second location.

Also, in a typical application of the present invention such as that just discussed, moisture-laden air may be discharged from the dryer section of a paper machine at a 500° F. temperature while makeup air may enter the system at a temperature of 0° F. during wintertime operation. I have found that significant benefits are obtained by employing at least two and sometimes even three heat exchange liquids to transfer heat from the hotter gas to the cooler gas in such circumstances.

One of these liquids will preferably be water because of the inexpensiveness, low viscosity, and high sensible heat capacity of this liquid. However, water by itself is not suitable over the typical wide temperature range discussed above. At the low end of the range water may freeze. In the upper part of the range, it will exist only in the vapor phase except at pressures so high as to make the use of this medium impractical.

I have now found that the physical limitations of water as a heat transfer medium for the purposes described above can be negated by employing a combination of heat transfer liquids having different phase change characteristics to transfer heat from the hotter to the cooler gas. A high boiling point liquid is utilized where the temperatures are above the practical limits of water, and a liquid having a low freezing point and low viscosity at low temperatures is employed where the temperatures are too low for the use of water to be practical.

In short, the present invention has the advantage that heat can be efficiently transferred from a very high temperature gas to one at very low temperatures.

Another advantage of the present invention is that it is capable of producing significant cost savings. Heat recovery is efficient, and little power is required to circulate the heat transfer liquids.

Primary objects of the present invention have been identified above. From the foregoing it will be apparent that other important but more specific objects of the invention reside in the provision of methods and apparatus for transferring heat from one gas to another:

1. which make such heat transfer practical even when the two gases are at widely separated locations;

2. which make such heat transfer feasible even though there may be a wide difference in temperature between the two gases;

3. which are efficient and economical to operate and therefore capable of providing significant cost savings.

Other objects and features and further advantages of the present invention will become apparent from the appended claims and as the ensuing detailed description and discussion proceeds in conjunction with the accompanying drawing in which the single FIGURE is a schematic illustration of heat exchange apparatus in accord with the principles of the present invention.

Referring now to the drawing, this depicts in generally diagrammatic form apparatus **10** in accord with the present invention for transferring heat from a hot gas flowing through a duct **12** to a cooler gas flowing through a duct **14**. The hotter and cooler gases are circulated through ducts **12** and **14** in opposite directions by blowers **16** and **18**. Dampers **20** and **22** may be adjusted to regulate the rate of flow through ducts **12** and **14** by actuating motors **24** and **26**.

Heat exchange apparatus **10** includes three independent closed circulation systems **28**, **30** and **32** for heat exchange liquids of different phase change characteristics.

Circulation system **28** has a finned tube type heat exchanger **34** in duct **12** and a similar heat exchanger **36** in duct **14**. Conduits **38** and **40** connect the two heat exchangers to complete the closed circulation system. A pump **42** interposed in conduit **38** circulates a heat exchange liquid through closed circulation system **28**, and a valve **44** is interposed in conduit **40** to regulate the rate of flow through the system.

Circulation systems **30** and **32** are similar to the system **28** just described. In circulation system **30**, the heat exchangers are identified by reference characters **46** and **48**, the conduits by reference characters **50** and **52**, and the pump and flow-controlling valve by reference characters **54** and **56**, respectively. And in system **32**, the heat exchangers are identified by reference characters **58** and **60**, the conduits by reference characters **62** and **64**, the pump by reference character **66**, and the flow-controlling valve by reference character **68**.

The three circulation systems **28**, **30**, and **32** are filled with heat transfer liquids having different phase change characteristics. Water is preferably employed in system **30** because of its low cost and ready availability and because of its low viscosity and high sensible heat capacity.

In typical applications of the present invention the temperatures of the gases flowing over heat exchanger **36** may drop to or below the freezing temperature of water. Accordingly, in such applications, system **28** is filled with a liquid having a lower freezing point than water, low viscosity at low temperatures, and a high sensible heat capacity. Satisfactory heat transfer liquids for this system include conventional permanent antifreezes, aqueous solutions of lithium chloride and other salts, etc.

The liquid flowing through circulation system **32** may be heated to temperatures far above 212° F. in typical applications of the present invention. Accordingly, it would be necessary to pressurize system **32** to keep the water in liquid form in such cases. As temperatures increase, this becomes increasingly impractical and uneconomical, especially where the two gas ducts are widely separated. Therefore, system **32** is preferably filled with a heat transfer fluid which will remain liquid at temperatures of at least several hundred degrees Fahrenheit[3] without pressurization. Suitable heat transfer liquids include Aroctor 1248 (a chlorinated biphenyl) and Isopropyl Santowax (a polyphenyl alkyl which are produced by Monsanto Chemical Co., and XF1–014 (an aryl oryloxy silone manufactured by Dow Chemical Company). Aroclor 1248 liquid may be heated to temperatures on the order of 550°–570° F. without boiling and without exceeding a permissive rate of decomposition of slightly less than 0.001 percent per hour of operation. Since a buildup of decomposition products of approximately 20 percent can be tolerated before pumping costs become excessive, the same liquid may be used for 3 years or more without replacement.

[3] Such liquids, including those described hereinafter, are also only practical for use over a limited, relatively high temperature range (they could not be used in system 30 in a typical application, for example) as they are solids or highly viscous at lower temperatures.

If the medium is to be heated to higher temperatures, Isopropyl Santowax or XF1–014 may be employed. Isopropyl Santowax liquid can safely be heated to temperatures of about 700° F. At 700° F., this liquid has substantially the same rate of decomposition that Aroclor 1248 has at 550° F. XFl-014 can be used at temperatures up to about 800° F. At 700° F. XF1–014 has substantially the same rate of decomposition as Isopropyl Santowax at the same temperature.

For applications where temperatures higher than those obtainable by the heat transfer liquids described above may be advantageously utilized, eutectic mixtures of organic salts such as HTS may be employed as the heat transfer medium. Heat transfer media of this type are described in detail in my U.S. Pat. No. 3,258,204 issued June 28, 1966, to which reference may be made if deemed necessary.

As mentioned above, the gases are circulated in opposite directions through ducts **12** and **14**. This keeps the temperature changes of the heat transfer liquids in each of the heat exchangers and the temperature changes in the gases as they flow over the heat exchangers at practical and economical levels. Also, this arrangement produces maximum operating efficiences.

In some cases only two heat exchange liquids are required. For, example, in some applications of the invention the lowest temperature reached by a heat exchange liquid may be well above the freezing point of water. In this case the low temperature system is unnecessary. Such conditions may occur, for example, where the hot gas has a high moisture content and is cooled below the dewpoint of the gas as sensible heat is extracted from it. In this case large quantities of latent heat may be made available for transfer to the water in an intermediate temperature system.

And, in other cases, the inlet temperature of the gas in duct **14** may not be low enough to require the use of a liquid having a lower freezing point.

In other applications the operating condition may be such that use of the high boiling point liquid can be eliminated.

The foregoing and similar modifications of the invention are fully intended to be covered in the appended claims to the extent they are not expressly excluded therefrom.

The invention may be embodied in other specific forms without departing from the spirit or essential characteristics thereof. The present embodiments are therefore to be considered in all respects as illustrative and not restrictive, the scope of the invention being indicated by the appended claims rather than by the foregoing description, and all changes which come within the meaning and range of equivalency of the claims are therefore intended to be embraced therein.

What is claimed and desired to be secured by Letters Patent is:

1. Gas to liquid to gas heat exchange apparatus comprising; a first flow means for a heated gas; a second flow means for a cooler gas, said second flow means being independent of and separated from the first flow means; means for transferring heat from a gas in the first flow means to a gas in the second flow means which includes at least two flow circuits for fluid heat exchange media, each such circuit comprising a heat exchanger in the first flow means, a heat exchanger in the second flow means, conduit means extending between the first and second flow means and connecting the two heat exchangers into a closed circulation system, and pump means for circulating a heat exchange medium through the closed circulation system; a first heat exchange liquid in a first of said flow circuits; a second heat exchange liquid having a boiling or degradation point above that of the first heat exchange liquid in a second of said circuits; means for circulating the heated gas first to that heat exchanger of the second flow circuit in the first flow means and then to that heat exchanger of the first flow circuit in said first flow means; means for circulating the cooler gas first to that heat exchanger of the first flow circuit in said second flow means and then to that heat exchanger of the second flow circuit in said second flow means; means for independently controlling the rate of flow of the heat exchange liquid through each of the flow circuits; and means for independently controlling the flow of the gas through first and second flow means.

2. The heat exchange apparatus of claim **1**, wherein the freezing point of the heat exchange liquid in one of said flow circuits is lower than the freezing point of the heat exchange liquid in the other of said flow circuits.

3. The heat exchange apparatus of claim **1**, wherein one of said heat exchange liquids is water

4. Gas to liquid to gas heat exchange apparatus comprising; a first flow means for a heated gas and a second flow means for a cooler gas, said second flow means being independent of and separated from the first flow means and each of said flow means having an inlet and an outlet; means for transferring heat from a gas in the first flow means to a gas in the second flow means which includes three flow circuits for fluid heat exchange media, each such circuit comprising a heat exchanger in the first flow means, a heat exchanger in the second flow means, conduit means extending between the first and second flow means and connecting the two heat exchangers into a closed circulation system, and pump means for circulating a heat exchange medium through the closed circulation system; water in one of said flow circuits; a second heat exchange liquid having a boiling or degradation point in excess of 212° F. in a second one of said circuits; and a third heat exchange liquid having a freezing point below 32° F. in the third of said circuits; the heat exchangers through which the second heat exchange liquid flows being nearest the inlet of the first flow means and nearest the outlet of the second flow means; the heat exchangers through which the third heat exchange fluid flows being nearest the outlet of the first flow means and nearest the inlet of the second flow means; and the heat exchangers through which the water flows being between the other two heat exchangers in both of said flow means; means for independently controlling the rate of flow of the heat exchange liquid through each of the flow circuits; and means for independently controlling the flow of the gas through the first and second flow means.

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