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HEAT EXCHANGE SYSTEM

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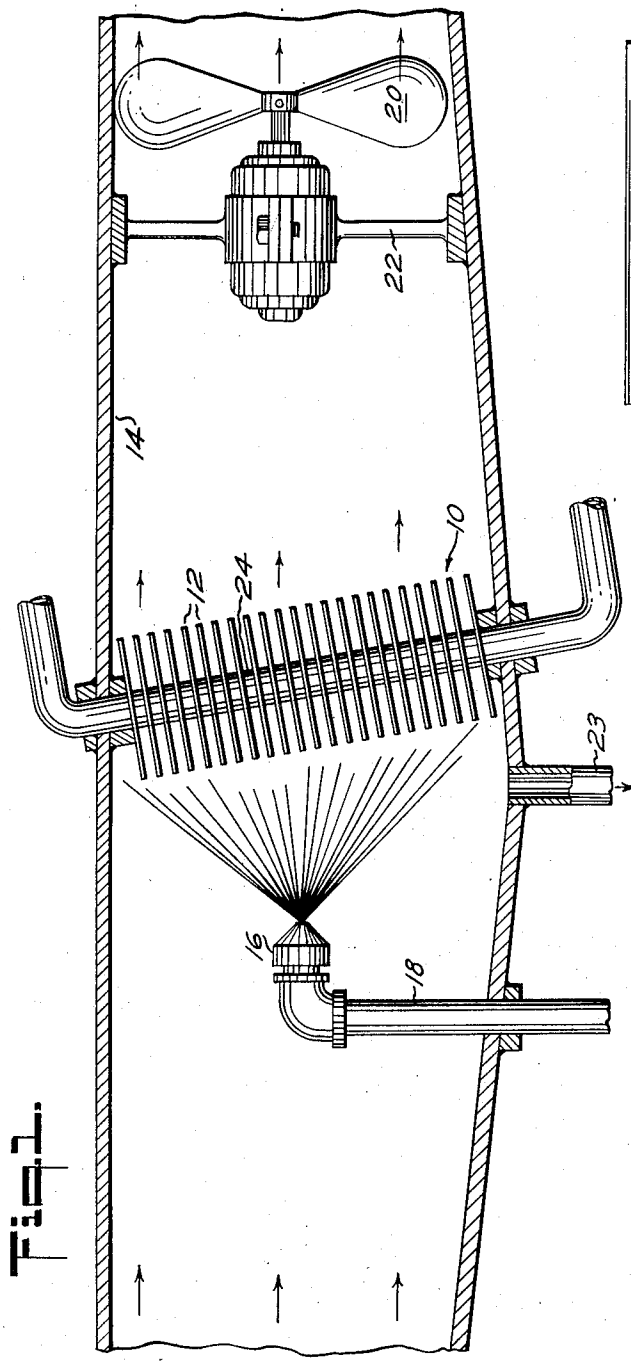


Fig. 1

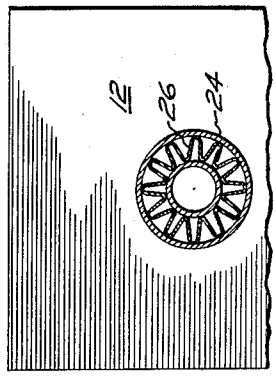


Fig. 3

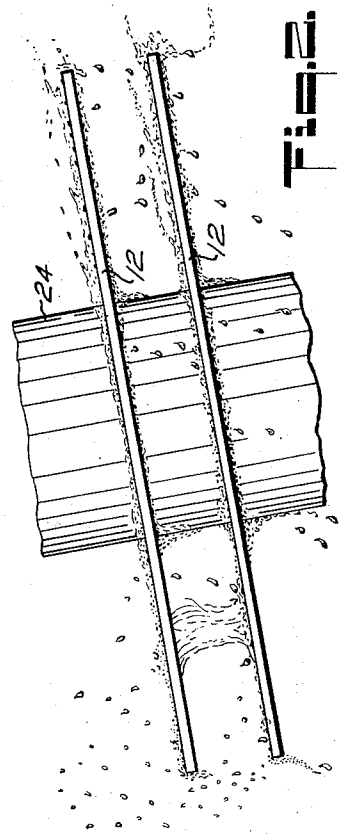


Fig. 2

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HEAT EXCHANGE SYSTEM

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The present invention is in the field of heat exchange and relates in particular to cooling systems for dissipating heat to an evaporating liquid. An important application of the invention is in the construction and operation of evaporative condensers of the type commonly employed in refrigeration and air conditioning systems.

In general a cooling system brings a fluid to be cooled into thermal contact with a coolant fluid of lower temperature to which heat is transferred. This invention is primarily concerned with systems in which heat is transferred to the coolant fluid through fins and its object is to improve the efficiency of heat transfer so that a smaller and less expensive heat exchanger may be used for a given job, and so that less power is required to bring the fluids into thermal contact.

In systems of this invention the fluid to be cooled is brought into thermal contact with a film of liquid over which is passed a stream of gas, by flowing the fluid to be cooled through a conduit of thermally conductive material while maintaining the liquid film on fins in thermal contact with the conduit. The conduit is desirably provided with a large internal area, preferably by means of longitudinal internal fins mounted in the annular region between the conduit and an internal concentric tube. Cooling is provided by spraying or otherwise supplying the fins with an evaporative liquid, generally water, while a stream of air or other gas is flowed past them.

A significant improvement has been found to result if the fins are inclined from the horizontal, and the gas stream is flowed past them, with the lower edges of the fins upstream from the upper edges, at a velocity substantially counteracting gravitational flow of the liquid across the fins. This greatly increases the amount of liquid contained on the fins and also maintains this liquid in a rippling and agitated condition, with the result of increasing substantially the rate of heat transfer.

The velocity of the gas stream and the inclination of the fins are of course interrelated, and it has also been found that the angle of the fins to the direction of the gas stream should not be so great that the aerodynamic action of the fins interferes with the gas flow along their surfaces. Best operation results if the gas stream is flowed substantially parallel to the fins with its velocity controlled to prevent substantially the downward free flow of the liquid across the fin surfaces. This condition may be seen to exist when the liquid on the fins is in a rippling and agitated condition and flows off them from both the upper and lower edges.

A representative and preferred embodiment of this invention is described in detail below, reference being made to the drawings in which:

Fig. 1 is a cross-sctional side elevation showing a cooling system embodying this invention.

Fig. 2 is an edge view of a fin illustrating the behavior of the liquid film under preferred conditions.

Fig. 3 is a cross-sectional end view showing the preferred construction of the conduit for the liquid to be cooled.

In the illustrated embodiment a heat exchanger **10** having several external spaced parallel fins **12** is mounted in a generally horizontal air duct **14** with the fins **12** inclined from the horizontal at an angle to the axis of the duct. A spray head **16** is mounted on a pipe **18** in the duct to direct a spray of water against the fins and a fan **20** is mounted on brackets **22** within the duct to create an air stream through the duct in the direction such that the lower edges of the fins **12** are upstream from the upper edges, as indicated by the arrows. Water draining from the fins is collected and removed by sloping the bottom of the duct **14** downwardly to a drain conduit **23**.

The heat exchanger **10** (as best shown by Fig. 2) conveniently consists of a conduit **24** for the fluid to be cooled, to the outside walls of which are mounted the fins **12**. The inside of the conduit **24** is provided with longitudinal fins **26** mounted between and in thermal contact with the inner wall of conduit **24** and the outer wall of an inner concentric tube **28**. The internal fins **26** are conveniently formed by curving a corrugated sheet of conductive material to occupy the annular space between the conduit **24** and tube **28**, with the corrugations extending between them. This construction is conveniently provided by loosely assembling the corrugated sheet defining fins **26** between the conduit **24** and tube **28**, then expanding the tube, as by drawing a mandrel through it, to press the ridges of the corrugations into tight contact with the enclosing walls, as disclosed in greater detail in United States Patent No. 2,611,587. The fluid to be cooled may be passed through both the conduit **24** and tube **28**, although it is preferable to dispense with the center tube **28** as a conduit for fluid, since somewhat greater efficiencies may thus be obtained.

In operation, the fluid to be cooled, for instance compressed refrigerant gas, is flowed through the conduit **24**, while water is sprayed from the spray head **16** onto the fins and an air stream past the fins is circulated by the fan **20** at a velocity to restrain the free downward gravitational flow of water from the fins and to maintain the water as a rippling and agitated film flowing from both edges of the fins, as shown in Fig. 3.

Upon observation of the device in operation it will also be observed that the combination of gravity and the countercurrent of air produces, in addition to an agitated repelling of the water, a transient plugging of the space between adjacent fins. The water plugs dance back and forth at random between the fins, moving not only back and forth but also laterally with respect to the direction of air flow. The water plugs do not appear to be permanent but are blown out after a few seconds. It is not known whether this intermittent plugging and unplugging of the passages between adjacent fins contributes to the efficiency of heat exchange, although it does appear that maximum efficiency is obtained when the velocity of the air and the inclination of the fins is so adjusted that the phenomena of intermittent plugging is observed.

In a typical embodiment such conditions exist with an air stream flowing horizontally at a velocity of 1000 feet per minute against fins inclined from the horizontal by between about 5 and 15 degrees. However, as pointed out above both the inclination of the fins and the velocity of the air along their surfaces may be varied complementarily to establish the desired conditions in the liquid film on the fins, as may be detected by observation of the behavior of the film of liquid.

Although this invention has been described in detail with reference to a preferred embodiment it is contemplated that modifications will readily occur to those skilled

in the art, and that such modifications may be made without departing from the scope of the invention.

Having thus disclosed our invention and described in detail a preferred embodiment thereof, we claim and desire to secure by Letters Patent:

1. A heat exchange system comprising conduit means in thermal contact with fins, said fins being inclined about 4 to 15 degrees from the horizontal, means for supplying a liquid to said fins, and means for passing a substantially horizontally directed stream of gas past said fins from the lower edges to the upper edges at a velocity along the surface of the fins substantially counteracting gravitational flow of the liquid across said fins and maintaining the liquid thereon in a layer.

2. The method of cooling a fluid in a conduit and in thermal contact with a fin exteriorly of the conduit and inclined about 4 to 15 degrees from the horizontal, comprising supplying a water film upon said fin, and passing a substantially horizontally directed stream of gas past said fin from the lower edge to the upper edge at a velocity along the water film surface substantially counteracting gravitational flow of the film on said fin.

3. A heat exchange system comprising conduit means in thermal contact with fins, said fins being inclined upwardly from the horizontal substantially from the front to the rear edges thereof, means for supplying a liquid to said fins in an amount to cover same with a solid film of the liquid, and means for passing a stream of gas past said fins from the front edges to the rear edges at a velocity along the surface of the fins substantially overcoming the free downward gravitational flow of the liquid upon said fins.

4. A heat exchange system comprising conduit means in thermal contact with fins, said fins being inclined upwardly from the horizontal substantially from the front to the rear edges, spray means for covering the fins with a solid layer of liquid, and means for passing a substantially horizontally directed stream of gas past said fins from the front edges to the rear edges at a velocity along the surface of the fins substantially overcoming gravitational flow of the liquid across said fins and thereby provide a continuously flowing layer of liquid on said fins.

5. The method of cooling a fluid in a conduit comprising passing said fluid in the conduit in thermal contact with

a fin inclined from the horizontal, supplying evaporative liquid upon said fin in an amount to completely cover same and flow freely on the fin, and passing a stream of gas across said fin from the lower edge to the upper edge at a velocity along the surface of the liquid on the fin substantially restraining the free gravitational flow of the liquid upon the fin and to maintain the water as a rippling and agitated film flowing from both the upper and lower edges thereof.

6. In an evaporative condenser for cooling liquids, conduit means in thermal contact with fins, said fins being inclined from the horizontal and spaced from each other for the flow of air therebetween, means directing liquid upon the fins from adjacent the lower edge thereof in an amount to completely cover same and flow thereupon, and means for moving a stream of air between said fins from the lower to the upper edges thereof at a velocity substantially overcoming the free gravitational flow of the liquid on the fins.

7. The method of cooling a fluid in a conduit comprising passing said fluid in the conduit in thermal contact with a fin inclined from the horizontal, continuously supplying an evaporative liquid upon said fin in an amount sufficient to cause said liquid to normally gravitationally flow towards the lower edge of said fin, and at the same time passing a stream of gas across said fin from the lower to the upper edge thereof at a velocity sufficient to substantially overcome the gravitational flow of liquid whereby liquid will flow over both the upper and lower edges of the fin, the amount of liquid supplied being sufficient to have substantially the entire upper surface of said fin continuously covered with liquid notwithstanding evaporation of said liquid and the overflowing thereof from the fin edges.

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