

PATENT SPECIFICATION

(11)

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- (21) Application No. 18213/76 (22) Filed 20 Jan. 1975
 (62) Divided out of No. 1 491 101
 (31) Convention Application No. 448 758 (32) Filed 6 March 1974 in
 (33) United States of America (US)
 (44) Complete Specification published 9 Nov. 1977
 (51) INT. CL.² F28C 3/08
 B01D 45/08
 (52) Index at acceptance
 F4K 12A1Y



(54) IMPROVEMENTS TO INJECTOR TYPE LIQUID COOLING APPARATUS

(71) We, BALTIMORE AIRCOIL COMPANY INC., a Corporation organized and existing under the laws of the State of Delaware, United States of America of Jessup, Maryland, United States of America, do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to an injector type liquid cooling apparatus. In such apparatus a liquid to be cooled is sprayed into a conduit to induce cooling air flow through the conduit along with the liquid. These devices are sometimes called injector type cooling towers.

More specifically, the invention is concerned with arrangements for achieving liquid-air separation toward the outlet end of the conduit.

According to the present invention there is provided an injector type liquid cooling apparatus including an air conduit open at both ends to the atmosphere, a plurality of liquid spray nozzles positioned near one end of the conduit and distributed across its cross-section, said nozzles being oriented to direct liquid spray toward the other end of said conduit, liquid-air separator means positioned in said conduit near its said other end, for intercepting liquid sprayed by said nozzles and for causing said liquid to flow downwardly along said liquid-air separator means, said liquid-air separator means including a plurality of strips distributed across the conduit cross-section and arranged side by side therein in a generally upright attitude, said strips being arranged in upper and lower banks, a liquid collection tray positioned along the bottom of each bank and means to direct liquid collected in the trays into a common sump positioned below said conduit.

The liquid-air separation means provides a high degree of separation of the sprayed liquid from the induced air without appreciable interference with air flow and permits a large amount of water to be accommodated in a limited region.

Injector type cooling towers in which the present invention may be used are shown and described in British Patent No. 1,346,253. As shown therein, water to be cooled is sprayed *via* one or a plurality of nozzles into a conduit open at both ends to the atmosphere. The spray ingests atmospheric air into the conduit in admixture with the water. The air cools the water by both sensible and evaporative heat transfer. The air and water are separated at the downstream end of the conduit by means of curved liquid-air separator strips which intercept the water droplets and increase their gravity component so that the water flows down along the strips to a recovery sump below them.

Prior art liquid-air separation means are shown in the abovementioned British Patent. These liquid-air separation means comprise a plurality of elongated up-standing strips arranged parallel to each other and distributed across the cross-section of the conduit to define a plurality of slot like passageways extending out from its discharge end. The strips have corrugations to cause lateral deflection of the sprayed liquid droplets so that the gravity component of their momentum is increased relative to their forward component, and the droplets therefore collect upon and flow down the strips while the air from the conduit continues to flow out between the strips. In order to increase the liquid handling capacity of the strips, the arrangements of the above identified Patent include the provision of tilted strips and the provision of two cooling conduits mounted one above the other, each with its

own spray means and each having its own liquid collection means.

As stated above, the invention involves arranging the strips of the liquid-air separator in upper and lower banks. This arrangement increases the capacity of the liquid-air separation means so that the spaces between the strips do not become so flooded with water that air flow between them becomes restricted. Liquid collection trays are arranged under each bank of strips, and water collected in the upper liquid collection trays can be directed down to a common water collection sump so that the water from the upper banks of strips does not flood the lower banks.

The invention will be more clearly understood from the following description which is given by way of example only with reference to the accompanying drawings, wherein:

Figure 1 is a side elevational view, taken in section and partially cut away, of an injector type water cooling system in which the present invention is embodied;

Figure 2 is a top plan view, partially cut away, of the water cooling system of Figure 1;

Figure 3 is a fragmentary perspective view of the nozzle and inlet air stabilizing strip arrangement forming a portion of the embodiment of Figs. 1 and 2;

Fig. 4 is an end view partially cut away, taken along line 4-4 of Fig. 1; and

Fig. 5 is an enlarged section view taken along line 5-5 of Fig. 1.

The injector type cooling tower of Figs. 1 and 2 comprises a conduit 10 formed of sheet material and having a generally rectangular cross section of substantially uniform dimensions throughout its length. The conduit 10 has an air inlet end 12 and an air outlet end 14 both open to the atmosphere. Between these two ends, the conduit 10 is made up of a top wall 16, a bottom plate 18, a bottom wall 37 and side walls 20.

A plurality of water supply manifolds 22 extend parallel to each other horizontally across the conduit interior near the air inlet end 12. Water to be cooled is pumped by external means (not shown) to these manifolds. A plurality of spray nozzles 24 are provided at spaced apart locations on each of the manifolds 22 and these spray nozzles are aimed to project sprays of water 25 into the conduit 10 toward its air outlet 14.

Turning now to Fig. 3, it will be seen that the water sprays 25 from the nozzles 24 are of generally flat, fan shaped configuration. That is, the sprays diverge much more extensively in the vertical direction than in the horizontal direction. As pointed out in previously mentioned

British Patent No. 1 346 253 this serves to maximize cooling and air entrainment. The nozzles of each manifold are aligned with corresponding nozzles in the other manifolds.

At the air inlet end 12 of the conduit 10, as shown in Figs. 1 and 2, there are provided a plurality of closely spaced vertical air flow stabilizing strips 26 distributed across the conduit cross section just upstream of the water supply manifolds 22. These inlet air stabilizing strips are of thin sheet material and they are positioned to lie in planes which are essentially parallel to the planes of the sprays from the nozzles 24. The strips 26 are each formed with at least one corrugation 26a and these corrugations are aligned with each other so that the strips are spaced apart with minimal overlap of these corrugations 26a.

Also as shown in Figs. 1 and 2, there are provided a plurality of spaced apart liquid-air separator strips 28 near the air outlet end of the conduit 10. These separator strips also are of sheet material and they are positioned to lie in vertical planes distributed across the conduit cross section.

An upper water collection shelf 30 extends horizontally across the conduit 10 in the region of the liquid-air separator strips 28. As shown in Fig. 1 this shelf divides the separator strips into upper and lower banks 28a and 28b. The shelf 30 is provided around its edge with short upstanding walls 32 so as to form a shallow tray. As shown in Figs. 1, 2 and 4, bypass openings 34 are provided in the bottom of the tray to allow water collected therein to pour down to a lower water collection shelf 36 just under the lower bank 28b of liquid-air separator strips.

The lower water collection shelf 36 is supported a short distance above the bottom wall 37 of the conduit by vertical walls 38 and 40. A sump 42 is formed in the bottom of the conduit 10. The lower extent of the sump is defined by the bottom wall 37 and the lower water collection shelf 36, and the upper extent is defined by the level of the water contained therein.

The wall 40 extends up higher than the shelf 36 and serves to prevent water from flowing forwardly out of the sump 42. As shown by the phantom line L, the water level in the sump 42 is normally maintained slightly above the level of the shelf 36. An overflow outlet 43, near the other end of the unit prevents this water level from rising too high.

A plurality of curved turning vanes 44 extend horizontally across the conduit 10 downstream of the liquid-air separator strips 28. These turning vanes are curved

upwardly from the horizontal; and they serve to deflect moisture laden air exiting from the conduit 10 up and away from the conduit so that it cannot be recirculated back into the inlet end 12. It will be appreciated that these turning vanes are open to the atmosphere and that no special protective structures such as baffles are used.

10 The air flow stabilizing strips 26 are supported at their lower ends by means of brackets 46 and 47 located just above a strainer cover 48. The forwardmost bracket 46 is integral with the bottom plate 18. 15 The downstream ends of the strainer cover 48 and the bottom plate 18 are connected to slanted guide brackets 52 which hold a strainer 54. The manner in which this strainer arrangement operates to provide improved water straining is described in our copending application No. 2306/75 (Serial No. 1 490 394). As can be seen in Fig. 1, the sump 42 extends under the conduit 10 and through the strainer 54 to an inlet end support wall 56. A water outlet port 58 is provided in one of the conduit side walls 20 just under the strainer cover 48. This outlet port 58 is connected to external conduit means (not shown) to convey the cooled water to various utilization means. As will be seen more fully hereinafter, the strainer cover 48 serves to direct water which flows down the strips 26 forwardly and in front of the strainer 54 so that it will flow through the strainer before exiting from the device. A tapered liquid flow control plate 59 extends across the sump 42 between the strainer 54 and the water outlet port 58. This plate extends from the bottom of the strainer cover 48 to a level close to the bottom wall 37 near the outlet port 58; and it tapers up to progressively higher levels toward the opposite side of the device. This restricts the flow of water to a greater extent in the region of the outlet port 58 and thereby serves to maintain an even flow of water through the strainer 54 in all regions thereof. An access door 61 is provided formed in one of the side walls of the device to permit entry into the interior of the device for repair and cleaning of various components and for replacement of the strainer 54.

A curved lower air inlet lip 60 extends across the conduit air inlet end 12 along the lower ends of the air flow stabilizing strips 26. This curved lip serves to maintain a smooth eddy free flow of air into the lower regions of the conduit.

60 An upper support channel 62 maintains the upper ends of the air flow stabilizing strips 26 in position. Just downstream of the channel 62 there is provided an upper air inlet slot 64 which extends across the 65 top of the conduit 10 to a location slightly

downstream of the water supply manifolds 22. The top wall 16 of the conduit is curved up and back to form an upper air inlet lip 66 along the downstream edge of the slot 64. This slot and lip arrangement serves to improve and increase inlet air flow and to prevent ice formation as will be explained more fully hereinafter.

In operation of the system, water to be cooled is pumped into the water supply manifolds 22 and is sprayed out through the nozzles 24 into the conduit 10. These sprays, as pointed out above, are of generally flat, fan shaped configuration lying in parallel vertical planes. The sprays from the different nozzles intersect with each other downstream of the nozzles and the outermost sprays contact the conduit walls in the same region so that there is formed a pressure seal across the conduit cross section. The momentum of the sprays causes air to be drawn in between the air flow stabilizing strips 26 and through the upper air inlet slot 64. This air is thoroughly mixed with and is carried along by the sprays as they pass through the conduit. At the downstream end of the conduit the air and water are separated as the water impinges upon and flows down along the surface of the strips 28 while the air continues to flow out between them.

The amount of water sprayed through the nozzle is varied by changing the pressure in the manifolds 22. The amount of water sprayed through the nozzles is also varied by changing the size of the nozzle orifices. The amount of variation which can be accepted for the particular nozzle arrangement is limited by the ability of the liquid-air separator means to provide effective operation with minimal liquid loss due to overflowing. Under conditions of operation where the liquid-air separator strip means become overflowed, it is advantageous to use two or more banks of liquid-air separator strip means each having its own water collection shelf and bypass opening towards the lower sump as described later.

As the air and water move together through the conduit, the air absorbs heat from the water through latent heat transfer. Also, where the ambient dry bulb temperature is low enough, a cooperative sensible heat transfer also takes place. In such case, because of the physical contact between the air and water, the air is heated to a higher dry bulb temperature which enables the air to hold more moisture before becoming saturated. Thus, an increased portion of the sprayed water can evaporate into the air so that the water becomes further cooled. As will be explained more fully hereinafter, the construction and arrangement of the conduit 10 is such as

to obtain a substantial volume rate of air flow while maintaining a high relative velocity between the cooling air and the sprayed water, with corresponding high heat transfer between the two. Also, near the outlet end a high relative velocity is obtained by virtue of the cross flow relationship of the horizontally moving air and the downwardly flowing water on the liquid-air separator strips 28.

It will be appreciated that all of the water which impinges upon the upper bank of strips 28a flows down only to the upper water collection shelf 30. This water passes through the bypass openings 34 toward the lower water collection shelf 36 so that it bypasses the lower bank of liquid-air separator strips. Thus, the only water which flows down the lower bank of separator strips is that which is actually intercepted by them. It will also be appreciated that with this arrangement neither the upper nor the lower bank of liquid-air separator strips will become excessively flooded with water which otherwise would impair their ability to prevent the sprayed water from being carried out along with the exhaust air.

The cooled water which has flowed down the upper and lower banks of liquid-air separator strips 28 and onto the lower water collection shelf 36 passes over the edge of the shelf in the sump 42. This water then flows back along the sump and through the strainer 54 where it is cleaned of any solid particles which may have been entrained during contact with the atmospheric air drawn into the system. After passing through the strainer, the cooled water passes out of the device via the water outlet port 58.

The air flow stabilizing control strips 26 positioned upstream of the nozzles 24 serve to maintain a smooth eddy free flow of air aligned with the direction of nozzle spray so that when the air encounters the nozzle sprays it has no velocity components which detract from the pumping action of the sprays. Furthermore, this flow direction control is maintained irrespective of ambient wind direction. Thus, if any cross wind components are present, they will be eliminated by the strips 26 before the ambient air contacts the nozzle sprays. As shown, the strips 26 are arranged in planes parallel to the planes of the flat sprays from the nozzles. It will be appreciated that the sprays would be most seriously affected by cross wind components against the planes of the sprays. Thus, with the present arrangement, i.e., with the strips 26 lying in planes parallel to the planes of the flat sprays, the maximum resistance to cross wind effects is presented in the plane of maximum sensitivity of the sprays.

It occasionally happens that a strong wind is blowing either directly or nearly directly in a line from the air outlet end to the air inlet end of the device. In such case it may happen, for example, when the system is operating at low capacity and the water sprays are not of maximum intensity, that the air pumping action of the sprays is insufficient to overcome the back force of the wind. In such case, if the device were not provided with the corrugated inlet air stabilizing strips, such back flow of air would carry some of the sprayed water out through the air inlet end of the device. This disadvantage is overcome in the present invention because of the presence of the corrugations 26a in the air flow stabilizing strips 26. These corrugations cause the strips to serve as mist eliminators so that the back blown water droplets catch on them and flow down between the strip support brackets 46 and 47 and onto the strainer cover 48. This water then flows over the downstream edge of the strainer cover 48 and into the sump 42. From there it passes through the strainer 54 and out through the water outlet port 58.

It will be noted that the sprays from the uppermost and lowermost rows of nozzles impinge quite sharply against the top wall 16 and the bottom plate 18 respectively. It has been found that if the air flow in these regions is not eddy free, a mass of recirculating air will be trapped just upstream of the impingement locations. Besides interfering with and reducing normal air flow these eddies carry water droplets which can freeze and build up a coating of ice on the adjacent structure in sub-freezing ambients. The present invention overcomes this problem by virtue of the curved inlet lips 60 and 66 and the upper air inlet slot 64. Since the system is immersed in the very air which is to be driven through it, the air tends to enter the conduit 10, especially at the edges thereof, from all directions. Thus, at the immediate edges of the air inlet end of the conduit, some of the incoming air undergoes a sharp change in direction. This is illustrated in Fig. 1 at the lower edge by the arrow A, and at the upper edge by the arrow B. It is this sharp turn of incoming air which could establish eddies in these regions. Now in the case of the lower edge of the conduit, because of the presence of the vertical inlet end support wall 56, the incoming air undergoes a 90° maximum direction change as illustrated by the arrow A. It has been found that the curved inlet lip 60 along the lower edge of the inlet end will serve to prevent eddies from taking place. In the case of the upper edge however, the incoming air may undergo a 180°

maximum change of direction as illustrated by the arrow B. This produces a severe tendency toward eddy formation which is more difficult to overcome than in the case of the lower edge. It has been found, however, that even this condition can be eliminated by the provision of the slot 64 downstream of the air flow stabilizing strips 26, along with the curved inlet lip along the downstream edge of the slot. Besides overcoming the tendency toward eddy formation, the slot 64 permits a substantially larger quantity of air to be injected into the system by the water sprays than would otherwise be possible. Accordingly, the slot 64 also assists in increasing the cooling capacity of the system.

As shown in Fig. 5 the separator strips 28 are each formed with corrugations 29. The number of corrugations, and the corresponding width of each strip, vary depending on the amount of liquid that flows down them. Thus, where the large amounts of liquid are to be separated, strips having a large number of corrugations and a corresponding width may be provided.

The relationship between corrugation height and the spacing between adjacent ones of the strips 28 has been found to be important in obtaining maximum liquid-air separation with minimum resistance to fluid flow. Thus, in the preferred embodiment a very slight but positive overlap or nesting is sufficient to intercept every portion of the liquid spray while allowing maximum spacing for free flow of air. The extended surface of the multiple corrugated strips allows the liquid caught thereon to spread out thinly as it flows down the strips so that substantially all of the liquid becomes exposed to a cross flow of air for maximum cooling.

Reverting now to Figs. 1 and 3 it will be seen that the upper ends of the air flow stabilizing strips 26 are permanently affixed inside inner channels 70, with each channel 70 holding a group of strips. The channels 70 fit loosely but snugly inside the channel 62. Further, as can be seen in Fig. 1, an elongated flange member 72 extends horizontally along the inlet edges of the strips 26 in each group, and is permanently affixed to each strip in the group.

As seen, the flange member 72 is bent down to form a handle for lifting up on and pulling out each group of strips. The above described arrangement facilitates assembly and disassembly of the air flow stabilizing strips at the inlet end of the device. As can be seen, in assembly, the channels 70 do not extend to the top of the channel 62, but instead, a clearance C exists between the tops of the channels 70 and 62. Each group of strips 26 may be

removed as a unit simply by lifting up on its handle like flange member 72 to raise the strips so that their bottom edges clear the brackets 46 and 47. This upward movement is accommodated by the clearance C. The flange member 72 is then pulled outwardly to remove the lower ends of the group of strips, and the strips are then lowered to release their upper ends and their inner channel 70 from the channel 62. With this arrangement, ready access may be had to the manifolds 22 and the nozzles 24.

Reference is made under Section 9 to our British Patent Nos. 1,299,922 and 1,299,921. Reference is also made to our copending Application No. 2305/74 (Serial No. 1 491 101) in which we claim an injector type liquid cooling apparatus, including an air conduit open at both ends to the atmosphere, a plurality of liquid spray nozzles positioned near one end of the conduit and distributed across its cross-section, said nozzles being oriented to spray liquid towards the other end of said conduit, liquid-air separator means positioned in said conduit near its said other end for intercepting liquid sprayed by said nozzles and for causing said liquid to flow downwardly along said liquid-air separator means, a liquid collection sump positioned to collect liquid which flows down from the liquid-air separator means, and an air flow stabilizing means comprising a plurality of parallel strips distributed across said one end of said conduit upstream of said spray nozzles.

WHAT WE CLAIM IS:—

1. An injector type liquid cooling apparatus including an air conduit open at both ends to the atmosphere, a plurality of liquid spray nozzles positioned near one end of the conduit and distributed across its cross-section, said nozzles being oriented to direct liquid spray toward the other end of said conduit, liquid-air separator means positioned in said conduit near its said other end, for intercepting liquid sprayed by said nozzles and for causing said liquid to flow downwardly along said liquid-air separator means, said liquid-air separator means including a plurality of strips distributed across the conduit cross-section and arranged side by side therein in a generally upright attitude, said strips being arranged in upper and lower banks, a liquid collection tray positioned along the bottom of each bank and means to direct liquid collected in the trays into a common sump positioned below said conduit.

2. Apparatus according to claim 1, wherein the means to direct the liquid collected in the different trays comprises



maximum change of direction as illustrated by the arrow B. This produces a severe tendency toward eddy formation which is more difficult to overcome than in the case of the lower edge. It has been found, however, that even this condition can be eliminated by the provision of the slot 64 downstream of the air flow stabilizing strips 26, along with the curved inlet lip along the downstream edge of the slot. Besides overcoming the tendency toward eddy formation, the slot 64 permits a substantially larger quantity of air to be injected into the system by the water sprays than would otherwise be possible. Accordingly, the slot 64 also assists in increasing the cooling capacity of the system.

As shown in Fig. 5 the separator strips 28 are each formed with corrugations 29. The number of corrugations, and the corresponding width of each strip, vary depending on the amount of liquid that flows down them. Thus, where the large amounts of liquid are to be separated, strips having a large number of corrugations and a corresponding width may be provided.

The relationship between corrugation height and the spacing between adjacent ones of the strips 28 has been found to be important in obtaining maximum liquid-air separation with minimum resistance to fluid flow. Thus, in the preferred embodiment a very slight but positive overlap or nesting is sufficient to intercept every portion of the liquid spray while allowing maximum spacing for free flow of air. The extended surface of the multiple corrugated strips allows the liquid caught thereon to spread out thinly as it flows down the strips so that substantially all of the liquid becomes exposed to a cross flow of air for maximum cooling.

Reverting now to Figs. 1 and 3 it will be seen that the upper ends of the air flow stabilizing strips 26 are permanently affixed inside inner channels 70, with each channel 70 holding a group of strips. The channels 70 fit loosely but snugly inside the channel 62. Further, as can be seen in Fig. 1, an elongated flange member 72 extends horizontally along the inlet edges of the strips 26 in each group, and is permanently affixed to each strip in the group.

As seen, the flange member 72 is bent down to form a handle for lifting up on and pulling out each group of strips. The above described arrangement facilitates assembly and disassembly of the air flow stabilizing strips at the inlet end of the device. As can be seen, in assembly, the channels 70 do not extend to the top of the channel 62, but instead, a clearance C exists between the tops of the channels 70 and 62. Each group of strips 26 may be

removed as a unit simply by lifting up on its handle like flange member 72 to raise the strips so that their bottom edges clear the brackets 46 and 47. This upward movement is accommodated by the clearance C. The flange member 72 is then pulled outwardly to remove the lower ends of the group of strips, and the strips are then lowered to release their upper ends and their inner channel 70 from the channel 62. With this arrangement, ready access may be had to the manifolds 22 and the nozzles 24.

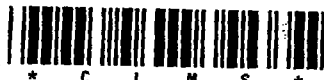
Reference is made under Section 9 to our British Patent Nos. 1,299,922 and 1,299,921. Reference is also made to our copending Application No. 2305/74 (Serial No. 1 491 101) in which we claim an injector type liquid cooling apparatus, including an air conduit open at both ends to the atmosphere, a plurality of liquid spray nozzles positioned near one end of the conduit and distributed across its cross-section, said nozzles being oriented to spray liquid towards the other end of said conduit, liquid-air separator means positioned in said conduit near its said other end for intercepting liquid sprayed by said nozzles and for causing said liquid to flow downwardly along said liquid-air separator means, a liquid collection sump positioned to collect liquid which flows down from the liquid-air separator means, and an air flow stabilizing means comprising a plurality of parallel strips distributed across said one end of said conduit upstream of said spray nozzles.

WHAT WE CLAIM IS:—

1. An injector type liquid cooling apparatus including an air conduit open at both ends to the atmosphere, a plurality of liquid spray nozzles positioned near one end of the conduit and distributed across its cross-section, said nozzles being oriented to direct liquid spray toward the other end of said conduit, liquid-air separator means positioned in said conduit near its said other end, for intercepting liquid sprayed by said nozzles and for causing said liquid to flow downwardly along said liquid-air separator means, said liquid-air separator means including a plurality of strips distributed across the conduit cross-section and arranged side by side therein in a generally upright attitude, said strips being arranged in upper and lower banks, a liquid collection tray positioned along the bottom of each bank and means to direct liquid collected in the trays into a common sump positioned below said conduit.

2. Apparatus according to claim 1, wherein the means to direct the liquid collected in the different trays comprises

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bypass openings formed in the upper tray or trays.

3. Apparatus according to claim 1 or 2, wherein each tray comprises a generally horizontally extending shelf with up-
5 standing walls about its periphery.

4. Apparatus according to claim 1, 2 or 3, wherein each bank of strips extends down into its respective tray.

5. Apparatus according to any preceding claim, wherein said strips are cor-
rugated.

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Printed for Her Majesty's Stationery Office by The Tweeddale Press Ltd., Berwick-upon-Tweed, 1977.
Published at the Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies
may be obtained.