

- [54] **COOLING TOWER**
- [75] Inventors: **Hiroo Shiraishi**, Fukuoka; **Hiroyoshi Kurohara**, Chikushi; **Shinjiro Tomita**, Fukuoka; **Senji Takenaka**; **Nobuo Yamada**, both of Yokohama; **Motoyoshi Hashitani**, Niiza, all of Japan
- [73] Assignees: **Japan Gasoline Co., Ltd.**; **Shin-Nihon Reiki Co., Ltd.**, both of Tokyo; **Aza-yunohara**; **Oaze-Futsuk-aichi**, both of Chikushino-shi, Fukuoka-ken., Japan

2,626,129	1/1953	Obert.....	239/193 X
2,895,566	7/1959	Coulter.....	55/257 X
3,113,102	12/1963	Schulze.....	210/150
3,214,348	10/1965	Lichtenstein.....	261/DIG. 11
3,290,025	12/1966	Engalitcheff, Jr.....	261/112 X
3,419,251	12/1968	Eckert.....	261/97 X
3,526,393	9/1970	Meek.....	261/112 X
3,599,877	8/1971	Goldschmied.....	239/566 X
3,722,227	3/1973	Esser et al.....	261/112 X
3,731,461	5/1973	Hamon.....	261/111 X

FOREIGN PATENTS OR APPLICATIONS

962,753	7/1964	Great Britain.....	165/174
1,215,187	12/1970	Great Britain.....	165/174

[22] Filed: Nov. 9, 1972

[21] Appl. No.: 305,126

Primary Examiner—Tim R. Miles

Assistant Examiner—Richard L. Chiesa

Attorney, Agent, or Firm—Woodhams, Blanchard and Flynn

[30] Foreign Application Priority Data

Mar. 6, 1972	Japan.....	47-22373
Mar. 22, 1972	Japan.....	47-28670

[52] U.S. Cl..... 55/257, 62/305, 239/566, 261/98, 261/DIG. 11

[51] Int. Cl..... B01f 3/04

[58] Field of Search 261/112, 111, 97, 98, DIG. 11; 55/257; 239/193, 566; 62/310, 305; 165/115, 117, 174

[56] References Cited

UNITED STATES PATENTS

2,616,670 11/1952 Van Der Molen..... 165/115

[57] ABSTRACT

A cooling tower comprising an outer casing provided with air inlets and an air outlet, net-like fillers disposed in said outer casing, a liquid distributor for sprinkling a fluid to be cooled onto the fillers, a basin for receiving the fluid which has been sprinkled from said liquid distributor and flowed downwardly along said fillers, a suction blower mounted to direct air to said fillers disposed in the outer casing, and an eliminator provided to prevent splash liquids formed in the outer casing from dispersing outside the outer casing.

5 Claims, 17 Drawing Figures

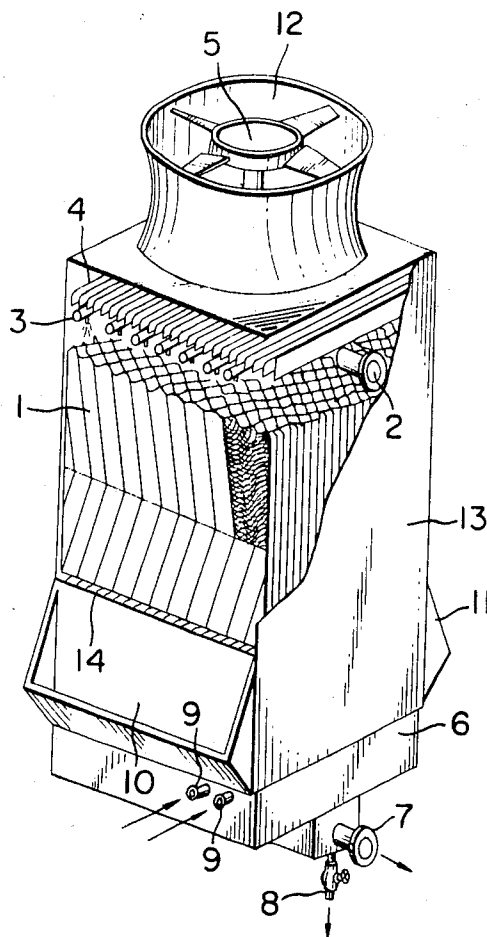


FIG. 1

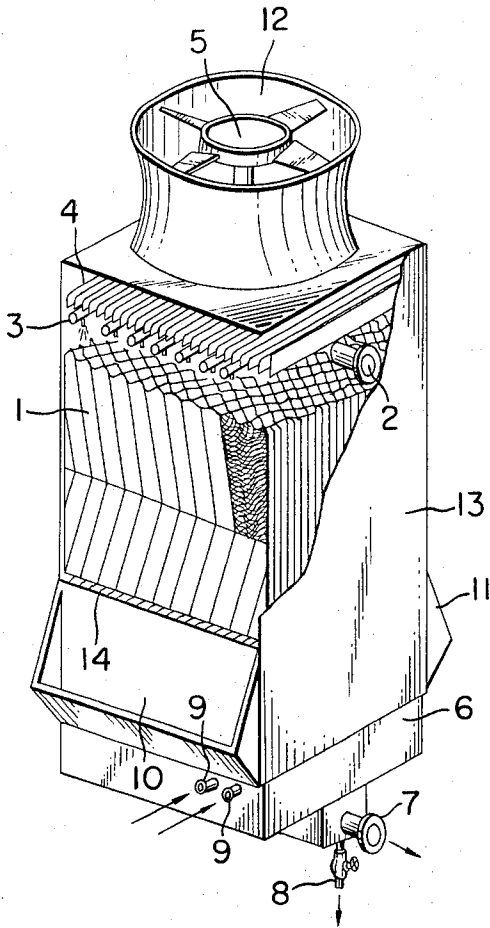


FIG. 2

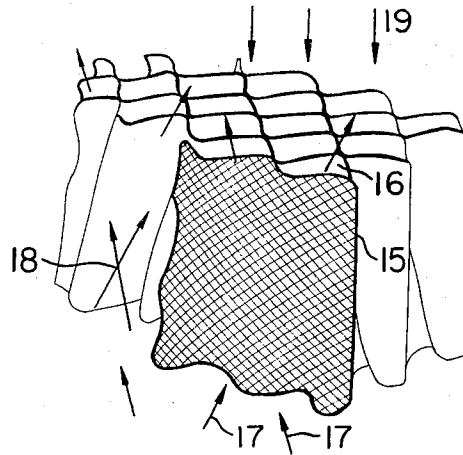


FIG. 3

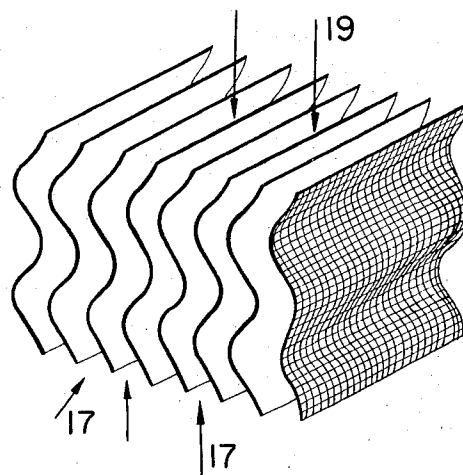


FIG. 4

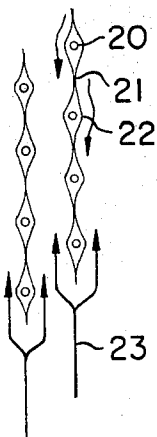


FIG. 5

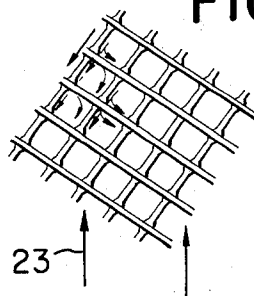


FIG. 6

PRIOR ART

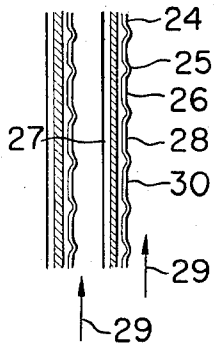


FIG. 7

PRIOR ART

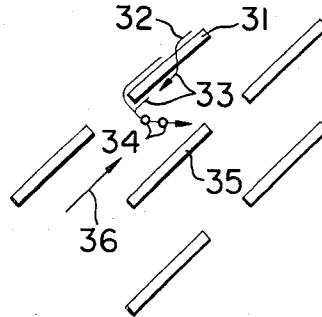


FIG. 9

PRIOR ART

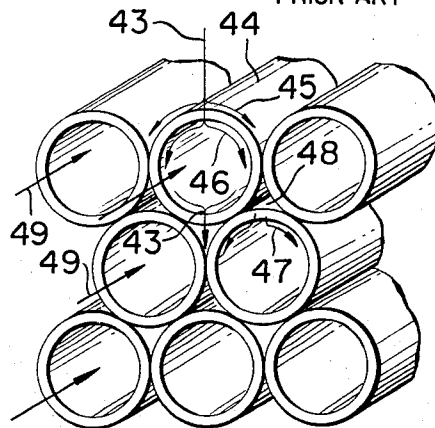


FIG. 8

PRIOR ART

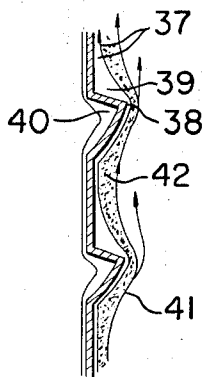


FIG. 10

PRIOR ART

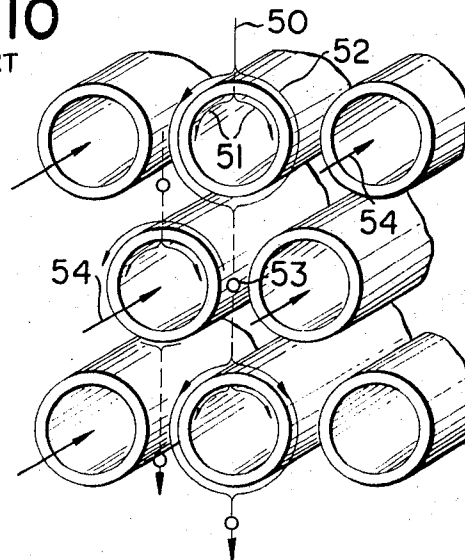


FIG. 11

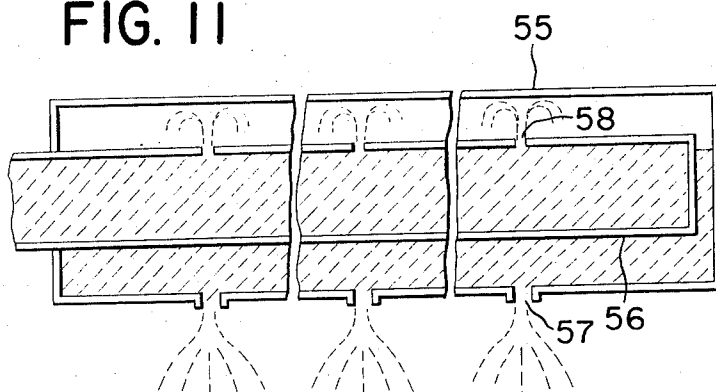


FIG. 12

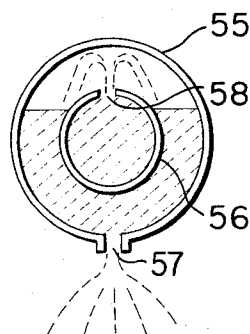


FIG. 13

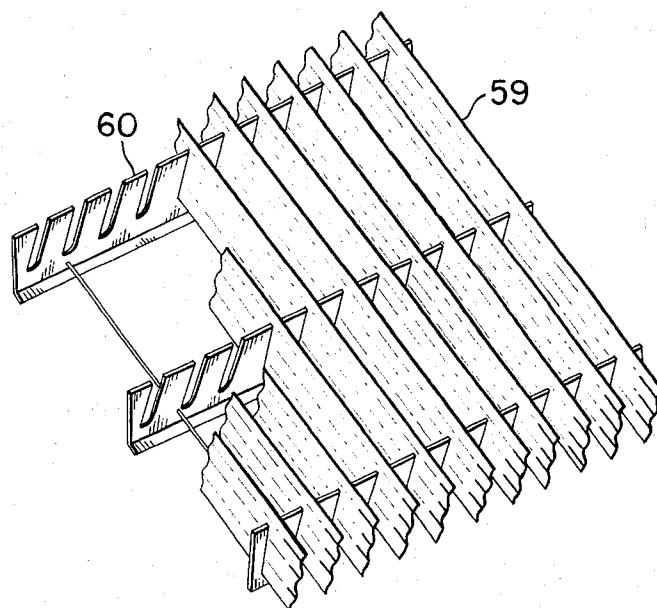


FIG. 14

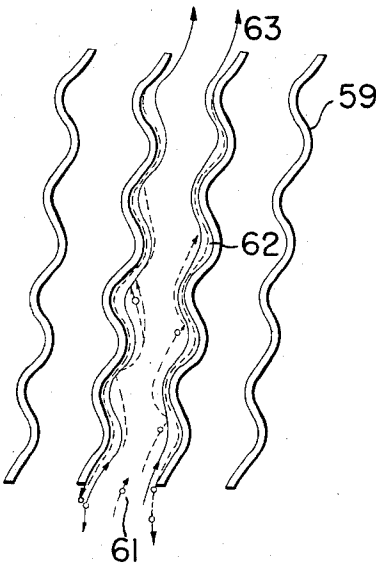


FIG. 15

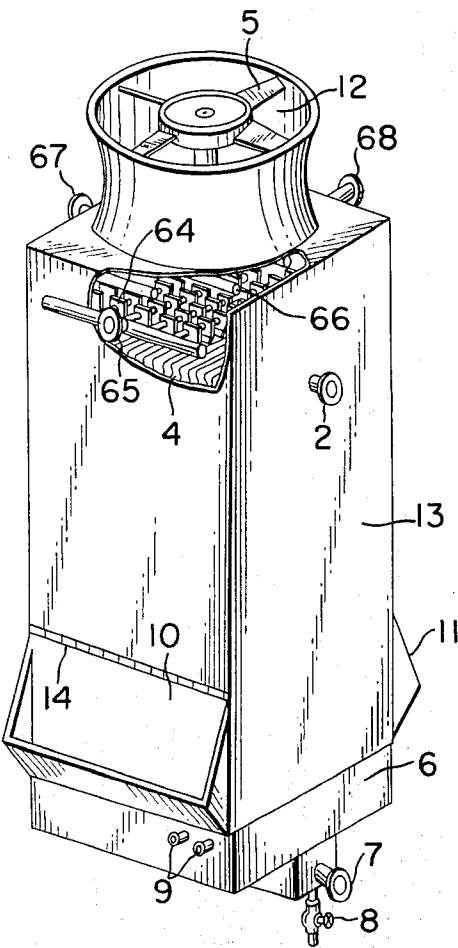


FIG. 16

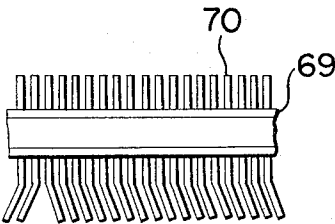
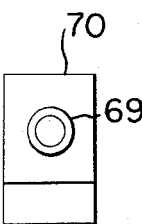


FIG. 17



COOLING TOWER

CROSS-REFERENCE TO RELATED APPLICATION

This application is related to our copending application U.S. Ser. No. 305,127, filed Nov. 9, 1972.

BACKGROUND OF THE INVENTION

a. Field of the Invention

This invention relates to improvements in a cooling tower for cooling a fluid, such as a process fluid.

In general, a cooling tower comprises an outer casing provided with air inlets and an air outlet, fillers disposed in said outer casing, a liquid distributor for sprinkling a fluid to be cooled on to the fillers, a basin for receiving the fluid which has been sprinkled from said liquid distributor and flowed downwardly along said fillers, a fan mounted to direct air to said fillers disposed in said outer casing, and an eliminator provided to prevent splash liquids formed in said outer casing from dispersing outside the outer casing. In short, cooling towers are devices which can accomplish the cooling of a fluid efficiently by utilizing effectively the evaporative latent heat of the fluid itself.

b. Description of the Prior Art

Fillers varying in configuration and properties are used in cooling towers of this type. Especially, fillers comprising a water-permeable plane plate 24 or wavy plate having small projections 25 on the surface of the plate 24, such as illustrated in FIG. 6, are widely used. In case fillers of this type are employed, as is seen from FIG. 6, a fluid (hereinafter referred to as "water" because in many cases the fluid is water) which flows downwardly forms flowing films 26 and 27 on both the front and back surfaces of the plane or wavy plate 24, and a part 28 of the film flowing on one side permeates through the plate 24 and joins the film flowing on the other side. In such a state, these films move downwardly in parallel to the air flow 29.

In fillers of this type, since projections 25 are provided only on one surface, the mingling of water in the film 27 is insufficient on the side where no projections are provided, and the flow rate is higher on this side. The most characteristic feature of fillers of this type resides its water permeability, but since the flow rate of the film 26 on the front surface is lower than that of the film 27 on the back surface, permeating water 28 is allowed to permeate in the direction to the film 27 from the film 26, resulting in an increase of the flow amount of the film 27 on the back surface. Accordingly, it is impossible to attain sufficient mixing of the layer 30 of saturated air comprising a portion of the air flow 29 with the remainder of the fresh air, and the effect of heat transfer between air and water is further reduced. Moreover, since fillers of this type are composed of water-permeable porous plane plates 24 or wavy plates, in some environments, dust and the like contained in air are carried by the water into the pores of the plate and clog same. Thus, and the water permeability, the characteristic feature of these fillers, is greatly reduced. These are defects of the conventional fillers of this type.

Fillers composed of water-permeable plane plates disposed in an inclined manner, such as illustrated in FIG. 7, are also used. In fillers of this type, a flowing film 32 is formed on the upper surface of the inclined plane plate 31, and a part of the film 32 permeates to

the inside of the inclined plane plate 31 to form a flowing film 33. These films 32 and 33 fall down onto a plane plate 35 in the form of drops 34 (which are caused to move in an almost horizontal direction by the action of the air flow). Thus, fillers of this type are characterized in that the release of the heat from the water can be accomplished effectively by allowing water to flow in the above manner in the form of flowing films and drops.

Like the fillers illustrated in FIG. 6, the water-permeable fillers of this type are defective in that the pores can be clogged with dust or the like contained in air and their water permeability is reduced or lost, with the result that formation of the flowing films cannot substantially be expected and the effect of increasing the surface area of water by forming the film is reduced, whereby the merit or advantage gained by providing a water-permeating plane plate in an inclined manner is reduced almost in half.

The fillers of this type are also characterized in that the heat transfer effect by flowing films and drops can be attained effectively by changing the form of the flow of water alternately from flowing films 32 and 33 to drops 34. Namely, as many fine drops as possible are dispersed in the air flow and the time for contact between such water drops and air is maintained for a long time, to thereby accomplish the heat transfer effectively. However, since at the time when films 32 and 33 are changed into drops 34, these water drops 34 have a great particle size and they are caused to move in the horizontal direction by the air flow 36, the change of these water drops into fine splashes on the inclined plane plate cannot be expected, and good results are not obtained with respect to the effect of transfer of heat from water to air, even though the residence time of water in air is long.

For the foregoing reasons, conventional fillers characterized by the water-permeable property, such as illustrated in FIGS. 6 and 7, cannot be said to exhibit as good a heat transfer effect in comparison with fillers of this invention which will be detailed hereinafter.

Furthermore, there are used fillers composed of a non-water-permeable plane plate having concavo-convex projections thereon, such as shown in FIG. 8.

In fillers of this type, projections 38 are provided for mixing the flowing film 37 and lowering the rate of downward flow of the film 37. However, the thickness of the film 37 abruptly increases upstream of the projection 38 or in the concave portion of the back surface (see portions 39 and 40), and therefore, the increase of the surface area of water for evaporation is inhibited. Further, the direction of flow 41 of air is changed by the projections 38 and a layer 42 of saturated air is formed and an increase of the pressure drop of air occurs. For the above-mentioned reasons the heat transfer between air and water cannot be conducted completely effectively.

Still further, as illustrated in FIGS. 9 and 10, porous net-like cylinders which are used as packing in deaerators are sometimes used as fillers in cooling tower.

Fillers of this type take the form of a porous net-like cylinder composed of segments of a net molded to have a cylindrical form or like form, and these cylindrical segments are aligned in the lateral or longitudinal direction as illustrated in FIG. 9 or spaced from each other by a certain distance as illustrated in FIG. 10.

In fillers of this type (in the case of the arrangement shown in FIG. 9), when water 43 flows down on the cylindrical segment 44, a part of the water flows in the form of a film 45 along the outer surface of the cylindrical segment 44 downwardly in the peripheral direction and the other part of the water flows along the inner surface of the cylindrical segment 44 in the form of a film 46 downwardly in the peripheral direction. These films 45 and 46 flow on the outer and inner surfaces of such segments successively while following a locus such as designated as 47.

In the filler assembly composed of segments arranged in the above manner, a reduction of the rate of falling of water may be accomplished effectively but the films 45 and 46 form water film walls or drops of a large size in the cross section of the air flow direction such, as designated by numeral 48, and such walls or drops inhibit the flow of air and the heat transfer effect is extremely reduced on the outer surface of the cylindrical segment. As a result, the object of using a porous plate, i.e., the object of conducting the heat transfer effectively on both surfaces of the plate, is not attained.

The filler assembly shown in FIG. 10 overcomes the defects of the filler assembly shown in FIG. 9. In this case, water 50 falls in the form of films 51 and 52 on the inner and outer surfaces of the cylindrical segments downwardly in the peripheral direction, and the water falls down onto the next lower cylindrical segment in the form of drops 53. As in the case of the inclined plane plate shown in FIG. 7, however, at the time when the film is changed into drops, water is collected on the lowermost end portion of the cylindrical segment and falls in the form of drops of a large size or discontinuous plate-like films. Further, since these drops or discontinuous films fall in parallel to the air flow 54 on one line, the effective contact between air and water is not entirely attained throughout the total section of the air flow, and hence, the transfer of the heat from water to air is not sufficiently effective. Moreover, in case filler assemblies composed of such cylindrical segments are packed as fillers into a certain vessel, a great number of supporting members or spacers must be provided to support these segments respectively. Thus, these supporting members or spacers reduce greatly the flow of air, resulting in an increase of the pressure drop. Further, an increase in the manufacturing cost of the fillers and increase of expenses for construction of the cooling tower are inevitably brought about.

For the foregoing reasons, in the filler assembly composed of the above-mentioned cylindrical segments, the evaporation surface area of water formed per unit volume of water is as low as, or is less than, in the conventional fillers illustrated in FIGS. 6, 7 and 8, and the effect of the heat transfer between air and water is not good.

SUMMARY OF THE INVENTION

This invention relates to an evaporative cooling tower which comprises an outer casing provided with air inlets and an air outlet, net-like fillers of a wavy configuration provided in the outer casing, a liquid distributor of a double-tube structure mounted to sprinkle a fluid to be cooled, a basin for receiving the fluid which has been sprinkled from said liquid distributor and flowed along said fillers, a suction blower mounted to direct air to the fillers provided in the outer casing, and an eliminator of a wavy plate-like configuration dis-

posed for preventing splash liquids formed in the outer casing from dispersing outside the outer casing.

This invention also relates to an evaporative cooling tower of the above structure wherein the fluid to be sprinkled from the liquid distributor is sea water and a dry heat exchanger is provided at the air outlet to remove fine droplet splashes of sea water leaking out of the eliminator, especially salt components contained therein.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view illustrating an embodiment of the cooling tower of this invention.

FIG. 2 is a view showing a filler of this invention composed of net segments of an inclined wavy configuration.

FIG. 3 is a view illustrating a filler of this invention composed of net segments of a horizontal wavy configuration.

FIGS. 4 and 5 are partially enlarged, sectional views illustrating the behaviors of water and air passing through the filler of this invention.

FIG. 6 is a view illustrating the behaviors of water and air passing through a conventional filler of a water-permeable plane plate or wavy plate.

FIG. 7 is a view illustrating the behaviors of water and air passing through a conventional filler of a water-permeable plane plate which is installed in an inclined position.

FIG. 8 is a view illustrating the behaviors of water and air passing through a conventional filler of a non-water-permeable plane plate provided with concavo-convex projections formed thereon.

FIGS. 9 and 10 are views illustrating the behaviors of water and air observed when net-like cylinders conventionally used as packing are employed as fillers of the cooling tower of this invention.

FIGS. 11 and 12 are sectional views illustrating the liquid distributor of this invention having a double-tube structure.

FIG. 13 is a view illustrating a part of the eliminator of a wavy plate-like form according to this invention.

FIG. 14 is a view illustrating a part of a vane plate of the eliminator.

FIG. 15 is a perspective view illustrating a modified cooling tower according to the invention.

FIG. 16 is a sectional view of one of the tubes used in the dry heat exchanger employed in the embodiment of FIG. 15.

FIG. 17 is an end view of the structure shown in FIG. 16.

DETAILED DESCRIPTION OF THE INVENTION:

A primary object of this invention is to provide fillers for a cooling tower which can completely overcome the above-mentioned defects of conventional fillers customarily used for cooling towers, such as the water-permeable fillers shown in FIGS. 6 and 7, non-water-permeable fillers shown in FIG. 8 and the fillers of net cylinders shown in FIGS. 9 and 10 and which can attain effective cooling with high efficiency by utilizing the advantageous features of these conventional fillers sufficiently.

This invention relates to a cooling tower comprising a plurality of water-permeable fillers disposed therein to conduct an effective gas-liquid contact, character-

ized in that net or screen-like plates of a wavy configuration are used as filler segments.

Accordingly, this invention provides a cooling tower which comprises an outer casing 13 provided with air inlets 10, 11 and an air outlet 12, fillers 1 of wavy porous net-like plates disposed in the outer casing 13, a liquid inlet 2 and, a liquid distributor 3 for sprinkling a fluid to be cooled onto the fillers, a basin 6 for receiving the fluid which has been sprinkled from said liquid distributor 3 and flowed downwardly along said fillers, a discharge conduit 7 for discharging the cooled liquid, a waste outlet 8, a suction blower 5 disposed to direct air to the fillers 1 provided in the outer casing, and an eliminator 4 mounted to prevent splash liquids formed in the outer casing from dispersing outside the outer casing. A support 14 is provided for the fillers and inlets 9, 9 for liquid are provided.

In accordance with one feature of this invention, there is provided a cooling tower of the above structure wherein a cylindrical liquid distributor having a double-tube structure, sectional views of which are shown in FIGS. 11 and 12, is provided as the liquid distributor.

This cylindrical liquid distributor 3 has a double-tube structure consisting of an outer tube 55, both ends of which are closed, and a liquid feed tube 56 inserted through one end of the outer tube 55, one end of said liquid feed tube 56 being closed. Liquid openings 57 are provided at suitable intervals along the lower side of said outer tube 55, and liquid overflow openings 58 are provided along the upper side of the liquid feed tube 56. When a conventional cylindrical liquid distributor (single-tube structure) is employed, a uniform pressure distribution of the liquid introduced in the tube cannot be obtained along the entire length of such a tube. More specifically, the pressure of the liquid differs between the inlet end of the tube and the opposite end of the tube. Therefore, the amount of the liquid sprayed on the unit area of the cooling zone is not uniform, and hence, it is impossible to obtain an efficient contact between the liquid and air on the filler surface. In contrast, when the liquid distributor 3 of a double-tube structure is provided according to this invention, the liquid overflowing from the openings 58 is transferred to the outer tube 55 and sprayed from the openings 57 of the outer tube. Thus, the spraying can be accomplished under substantially uniform pressure along the entire length of the tube 55. As a result, the coolant liquid is uniformly distributed and sprayed.

In accordance with another feature of this invention, there is provided a cooling tower of the above-mentioned structure, wherein a wavy plate-like eliminator 4, details of which are illustrated in FIGS. 13 and 14, is provided for preventing splash liquids formed in the outer casing from dispersing outside the outer casing. This eliminator 4 includes wavy vane plates 59 disposed at suitable intervals, and supported on supporting members 60. Liquid droplets 61, present in the air stream, which flows in the direction of arrow 63 impinge violently against the surfaces of the wavy plate-like vane plates 59, and flow downwardly thereon while forming a liquid film 62. In the case of an ordinary zig-zag eliminator, the thus formed liquid film tends to split off liquid droplets again therefrom, and these droplets are discharged outside the outer casing. In such case, the resistance to passage of air is increased, resulting in an increase of the pressure drop. Therefore, it is necessary to increase the operation power.

In this embodiment of the cooling tower of this invention provided with the above eliminator, the amount of the liquid discharged outside the casing is extremely lowered, for instance, to less than 0.02% of the total amount of the circulated liquid, and the pressure drop of the air flow is also reduced to an extremely low level.

In accordance with a still further feature of this invention, there is provided a cooling tower of the above-mentioned structure, wherein sea water is used as the liquid and a dry heat exchanger is provided at the air outlet to remove fine droplet splashes of sea water leaking out of the eliminator, especially salt components contained therein.

Since the principle of removal of splash liquids by the eliminator resides in the utilization of the flow of air passing through the apparatus, it is difficult to remove completely fine droplet splashes of sea water. Further, if it is intended to remove completely splashes of sea water by the action of the eliminator, the pressure drop of air is increased and a great power is necessary for operating the suction blower sufficiently, which results in economical disadvantages.

In case an ordinary eliminator is used, more than 0.02% of circulated sea water is allowed to disperse outside the outer casing by failure to remove it by an action of the eliminator.

Even when the eliminator of this invention is used, it is difficult to attain complete prevention of dispersion of fine droplet splashes of sea water outside the outer casing, and a very small quantity of sea water is discharged outside the outer casing. The thus-splashed sea water discharged outside the outer casing together with waste air influences harmfully the environments of not only the factory but also neighbouring private houses, and there is a fear of causing a pollution problem.

The above defects can be completely overcome by the provision of a dry heat exchanger of this invention such as illustrated in FIGS. 15, 16 and 17. Namely, fine droplet splashes of sea water that cannot be completely removed by the eliminator 4 can be completely eliminated by the action of this dry heat exchanger without substantial increase of the power for the suction blower. An example of the dry heat exchanger to be used in this invention is illustrated in FIG. 15, and one of the heat-exchange tubes employed therein is illustrated in FIGS. 16 and 17. The dry heat exchanger has a structure including a plurality of tube 69 each having fins 70 bonded to the periphery of the tube 69. As the heat source to be introduced into the tubes in this dry heat exchanger, various high temperature fluids may be used, and it is also possible to utilize the high temperature of the incoming fluid to be cooled. In this case, the fluid to be cooled is introduced from an inlet 65 and discharged from an outlet 68, and then introduced into the cooling tower from the inlet of the pipe 2 for feeding a fluid to be cooled. The thus introduced fluid to be cooled is sprinkled from the liquid distributor, as described above, and is cooled while it flows downwardly along the surface of the fillers.

Removal of scales of salt components (composed mainly of NaCl) thus deposited on the surfaces of these finned tubes is accomplished in the following manner.

At regular intervals, for instance, every 1 to 2 days, the suction blower 5 is stopped for a short time, and sea water is fed in through inlet 67 and is sprayed on the fins of the tube of the dry heat exchanger of the from the liquid distributor 66 for supplying sea water,

whereby the scales are dissolved in the thus-sprayed sea water. Then, the sea water containing scales dissolved therein is collected in the liquid-collecting basin 6 and discharged from the waste opening 8.

Other objects and features of this invention will be apparent from the detailed description given hereinbelow.

FIG. 1 is a perspective view illustrating one embodiment of the cooling tower of this invention. This cooling tower is a cooling tower of the counter-flow type. The invention will now be described by reference to an example relating to a cooling tower of the counter-flow type, but needless to say, this invention can be applied to any conventional cooling towers, as long as the application does not deviate from the essence of this invention.

The fluid to be cooled, which has been heated in some other heat exchange system, such as process fluid, is fed through a feed pipe 2 and sprinkled from the liquid distributor 3 of a double-tube structure. At the same time, air is sucked from air inlets 10 and 11 by means of the suction blower 5. Thus, the heat exchange is mainly effected on the surfaces of fillers 1 provided inside the cooling tower, and a cooled process fluid is obtained.

As illustrated in FIG. 2, net or screen-like plates 1 of an inclined wavy configuration are disposed on the filler rack 14 so that the crests of waves of the every two adjoining filler segments, for instance, segments 15 and 16, are inclined to touch each other and a space for passage of the air flow is formed in the vertical direction.

When sea water is used as the liquid, in this invention a dry heat exchanger such as illustrated in FIGS. 15, 16 and 17 is provided according to need so as to remove fine droplet splashes of sea water leaking out of the eliminator, especially salt components contained therein.

The operation of the cooling tower of this invention will now be detailed.

Air is fed into the outer casing from air inlets 10 and 11 by actuating the suction blower 5 and discharged from the air outlet 12. As is illustrated in FIGS. 2 and 3, air passes through spaces formed between fillers. A process fluid (high temperature water) is introduced as a fluid to be cooled from the inlet 2 and sprinkled from openings of the liquid distributor 3 having a double-tube structure. The process fluid sprinkled from this liquid distributor is allowed to flow downwardly on the surface of the fillers in the form of a film flow, and in this state it is gradually cooled. The cooled process fluid is finally withdrawn from the outlet 7 and fed to some other heat exchanging system.

In case the fluid to be cooled is sea water, in general, sea water is introduced from an inlet 65 into the dry heat exchanger 64 in order to utilize the heat contained in sea water effectively. This sea water is then passed through the tube of the dry heat exchanger 64 and flowed out from a discharge opening 68, which is generally connected to the inlet 2 of a pipe 2 for feeding the fluid to be cooled to the cooling tower. Then, the sea water is cooled in the above-mentioned manner. In order to remove scales of salts (composed mainly of NaCl) deposited on the surfaces of the tubes and fins of the dry heat exchanger 64, at suitable intervals, for instance, every 1 to 2 days, the suction blower is stopped for a short time and sea water is sprayed on the

dry heat exchanger from the liquid distributor 66 for supplying sea water, whereby scales are dissolved in the thus sprayed sea water, following which the sea water containing scales dissolved therein is collected in the basin 6 and discharged from the waste opening 8.

In the embodiment illustrated in FIG. 1, a net plate 1 of an inclined wavy configuration shown in FIG. 2 is employed, but of course, it is also possible to employ a filler of a net plate of a horizontal wavy configuration such as illustrated in FIG. 3.

The effects attained by providing these net plate fillers of this invention in the cooling tower will now be described more specifically.

The net plate 1 of an inclined wavy configuration used in the embodiment of FIG. 1 permeates water therethrough regardless of whether it flows on the front or back surface. Therefore, as illustrated in FIG. 2, if the wave is inclined so that it is longitudinal to the direction of falling of the water, the portion of the trough on one side thereof is simultaneously the crest of the wave on the opposite surface of the mesh line, and thus, both the crest and trough are present on the same mesh line. Accordingly, there does not occur the defect observed when a water-permeable or non-water-permeable plate is arranged to form an inclined wave such as shown in FIG. 2, namely the defect that water is collected on the trough portion of the wave to form a so-called water passage and the heat transfer effect is reduced.

Further, the net plates of inclined wavy configuration are packed so that the packing directions of every two adjoining segments are offset to each other. Therefore, as illustrated in FIG. 2, the air flow 17 undergoes a mild mingling action at the crest portion of one segment 16, and parts 18 of the air flow rise while being contacted and mingled with each other. Thus, either the temperature of the humidity can be maintained at the same level throughout the air flow. In such state, the air flow has contact with water as the fluid to be cooled. Therefore, the effect of the heat transfer from water to air is very good.

Further, this net plate filler of an inclined wavy configuration has the following structural advantages: (1) no water drops are formed in the section of the air flow, (2) no supporting member or spacer is necessary for supporting the filler, (3) concavo-convex projections need not be provided on the filler, (4) it is sufficient if about one bend of the inclined wave is formed on the filler, (5) the inclination angle can be made smaller than as in the conventional fillers, etc. Because of these structural characteristics, in the case of the filler of this invention, the pressure drop in the air flow can be greatly minimized as compared with conventional fillers such as shown in FIGS. 7, 8, 9 and 10.

Also a net plate molded to have a horizontal wave such as shown in FIG. 3 gives an excellent heat-transferring effect.

The filler of this type is inferior to the net plate of an inclined wavy configuration shown in the embodiment of FIG. 1 with respect to the action of contact and mingling in the air flow, but it is advantageous in that the rate of falling of water is low and the pressure drop of air is small.

In the case of the filler of this type, because of the small pressure drop, the flow rate of air can be increased and a layer of saturated air formed in the vicinity of the film flow is disturbed by the contact between

air and the linear flow of water or by the mingling action of the air flow per se, with the result that the evaporative heat transfer can be accomplished effectively.

In fillers of this invention such as shown in FIGS. 2 and 3, the net plate has a property that water is allowed to pass through the spaces of meshes completely, as illustrated in partially enlarged views of FIGS. 4 and 5. Accordingly, the film flow 21 is converted to a linear flow 22 by the mesh line 20 of the net, and forms of linear flow and film flow appear alternately and the mingling of the flow and the branching of the flow are caused to occur along the mesh line of the net, whereby the rate of falling of water is greatly reduced and the surface area for evaporation is greatly increased. While such effective state is maintained along the net plate of a wavy configuration, the air flow 23 has a contact with the linear flow or film flow of water with the layer of saturated air being disturbed by the form change of water from the linear flow to the film flow or from the film flow to the linear flow. Thus, a very effective heat transfer is accomplished.

Results of tests in which the fillers of this invention molded to have a wavy configuration are compared with several conventional fillers with respect to the falling rate of water are shown in Table 1 given below.

Table 1

Sample No.	Kind of Filler	Falling Rate of Water	Remarks
1	non-permeable wavy plate composed of vinyl chloride resin	1.10 m/sec	comparison
2	water-permeable wavy plate	0.75 m/sec	example of filler of FIG. 6 arranged to have wavy form
3	non-permeating plate having concavo-convex projections	0.702 m/sec	example of filler of FIG. 8
4	water-passing net plate (mesh size = 2 mm × 2 mm)	0.623 m/sec	example of filler of this invention
5	water-passing net plate (mesh size = 3 mm × 4 mm)	0.522 m/sec	example of filler of this invention

As is seen from the results shown in Table 1, when the wavy net plate is used as the filler of the cooling tower, the falling rate of water is very low as compared with the cases where the conventional fillers are used. Therefore, the filler of this invention can give a good efficiency of gas-liquid contact and ensures a long contact time, with the result that the heat transfer efficiency is very high as compared with the case of the conventional fillers.

As detailed hereinabove, when fillers composed of a net plate having a wavy configuration are used according to this invention, formation of walls of water drops or water films is inhibited without inviting an increase of the pressure drop in the air flow, and the use of supporting members or spacers is not required, and if provision of such members is necessary, the number of them can be greatly reduced.

Furthermore, the provision of specific concavo-convex projections on the filler is not required at all. Therefore, formation of drifts of air and water can be prevented, and it is possible to reduce the falling rate of water and maintain the contact between water and air for a long time.

Moreover, the surface area of water for evaporation can easily be increased, and linear and film flows of water suitable for obtaining a good heat transfer effect can be formed and the mingling and branching of these flows can always be accomplished. As a result, without formation of a layer of saturated air, the heat transfer can be conducted very effectively with high efficiency between water and air. Thus, a cooling tower of a very high cooling efficiency is provided according to this invention.

What we claim is:

1. A cooling tower comprising a casing having side wall means with air inlet opening means for atmospheric air near the lower end thereof, said casing having outlet opening means at its upper end for discharging heated air; a basin disposed below said casing for receiving cooled liquid therefrom; an air-moving impeller associated with said outlet opening means for drawing air into said casing through said inlet opening means and discharging the air through said outlet opening means; gas-liquid contact means comprising a plurality of generally upright porous sheet-like screens each having an undulating configuration, said screens being arranged in association with each other to define upright passages for flow of upwardly rising air which air is adapted to contact liquid flowing downwardly on the screens; a plurality of liquid distributors mounted inside said casing between the upper ends of said screens and said outlet opening means, said liquid distributors being arranged in a generally horizontal array for distributing liquid substantially uniformly onto the upper ends of said screens, each liquid distributor comprising an elongated outer tube which is closed at both its axial ends and which has a series of axially spaced openings of essentially the same size along its lower side for discharging liquid substantially vertically downwardly onto the upper ends of the screens, an elongated inner tube fixed to and projecting through one axial end of said outer tube and extending axially therein substantially to the other axial end of said outer tube, said inner tube being radially spaced from the interior wall of said outer tube to define therewith an annular zone for holding a quantity of the liquid, the axial end of said inner tube disposed within said outer tube being closed and the other axial end of said inner tube being connected to a source of the liquid, the portion of said inner tube located within said outer tube having a series of axially spaced openings along its upper side, so that liquid supplied to said inner tube overflows therefrom upwardly through said openings in said inner tube and then flows downwardly in said annular zone and accumulates to a substantial depth therein and the liquid flows downwardly through the openings in said outer tube under substantially uniform pressure along the entire length of said outer tube and onto the upper ends of said screens; and eliminator means mounted in said casing above said liquid distributors for minimizing the flow of splash liquid through said outlet opening means.

2. A cooling tower as set forth in claim 1, wherein the screens are disposed in an inclined manner with adjacent screens being oppositely inclined so that the crest portion of each screen crosses the trough portion of the adjacent screen and there are formed passageways for the passage of the air flow between such portions.

3. A cooling tower as set forth in claim 1, wherein the screens are disposed so that the screens are arranged in

11

parallel to each other and the crests and troughs of each pair of adjacent screens confront and are spaced from each other with a continuous passageway being formed between each pair of screens.

4. A cooling tower as set forth in claim 1, including a dry heat exchanger mounted in said casing between the upper end of said eliminator and said outlet opening means, said dry heat exchanger comprising a plurality of externally-finned tubes mounted in a horizontal array and disposed in the path of the air flow; and a de-

12

vice for feeding liquid mounted in said casing above said dry heat exchanger and arranged for spraying liquid onto the fins to dissolve solids adhering thereon.

5. A cooling tower as set forth in claim 1, wherein said eliminator includes spaced-apart undulating vane plates disposed at an angle to the air flow for preventing splash liquids formed in the outer casing from dispersing outside the outer casing.

* * * * *

15

20

25

30

35

40

45

50

55

60

65