The present invention involves an evaporative cooling fan including air cooling and vapor removal heat exchangers using string heat exchanger fabricated with string-screen-fill packs, which are formed of a multiplicity of string-screen-fill with string screens on both sides. The air cooling heat exchanger cools hot air by contacting with cold water and vapor removal heat exchanger condenses vapor by contacting with cold water. Using such cooling or condensing function of the string heat exchanger, vapor removable and non-removable evaporative cooling fans are invented in the present invention. The vapor non-removable cooling fan is preferred to be operated in environmentally open area and the vapor removable cooling fan is operated in any places. Both evaporative cooling fans have an advantage to be operated in the high humid area. In the present invention, the fabrication methods of vapor removable and non-removable evaporative cooling fans are described.
Notes: L1 to L7 represent locations of room air in a typical dry cleaning shop when an EVACDW cooling fan is operated.

PSYCHROMETRIC CHART

Notes:
45°C - CS: cooling of air due to cold water
CS: starting point of condensing
CS → 40: condensing
45°C → ES: evaporative cooling
ES: stop point of evaporative cooling
EVAPORATIVE COOLING FAN USING STRING-SCREEN-FILLS AS HEAT EXCHANGER AND FABRICATION THEREOF

CROSS-REFERENCE TO RELATED APPLICATION

REFERENCES CITED

U.S. Patent Documents


Foreign Patent Documents

KR 100516391 Sep. 14, 2005 Park
KR 100516392 Sep. 14, 2005 Park

Other Publications

[0012] STAR COOLING TOWERS, Countedlow and Crossflow Film Fills,

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

[0015] Not Applicable.

REFERENCE TO SEQUENCE LISTING, A TABLE, OR A COMPUTER PROGRAM LISTING

CPMPACT DISC APPENDIX

[0016] Not Applicable.
which retains lower temperature than dew point temperature of vapor in humid air, since the vapor is condensed into dew by contacting with objects sustaining lower temperature than dew point temperature of vapor. At the same time the vapor is condensed into dew, the cooled and humid air passing through the evaporative heat exchanger (EVAHX) is cooled by dissipating some heat retained in cooled and humid air to the DEWHX through the convection and condensation mechanism of water contacting with the cooled and humid air. Hence, the cooled and humid air passing through EVAHX can reduce its moist content to a comfort level by vapor condensing process of DEWHX.

To cool and condense hot humid air and to compensate the disadvantages of the current evaporative cooler and machine shop big fan described above, the EVA cooling fan and EVADEW cooling fan are invented by the inventor of the present invention using plate type string-screen-fills (SSF), which is applied to U.S. patent by the present inventor (U.S. patent application Ser. No. 13/053,382). The EVA and EVADEW cooling fans are schematically drawn in FIGS. 1 and 2, respectively. The FIG. 1 shows that the EVA cooling fan consists of EVAHX, fan blower, and water circulation pump and FIG. 2 shows that the EVADEW cooling fan consists of EVAHX, DEWHX, fan blower, and water circulation pump. The EVAHX and DEWHX are string heat exchangers invented by the present inventor to eliminate the disadvantages the PVC film fills pack of the current cooling towers (U.S. patent application Ser. No. 13/053,382). The string heat exchanger is fabricated by assembling several SSFs. The SSF is in a rectangular frame whose thickness is in the range of 1 to 5 cm with vertical-string-screens (VSS) on both sides of the SSF. The specification method of the SSF is described in detail in the U.S. patent application (U.S. application Ser. No. 13/053,382).

The water cooling functions and advantages of the rectangular SSF pack previously invented by the present inventor are briefly described in this section. When the water to be cooled is sprayed on the top perforated plate of the rectangular SSF pack, the sprayed water spreads over the top perforated plate and is uniformly imbibed down through holes by the surface tension of strings suspending from the holes on the top and bottom plates of the SSF pack, and then flowing down on the surface of strings. The water flowing down on the surface of strings becomes circumferential thin film water on the circular surface of string, which can make a contacting area between water and cooling air maximized and also make the water as thin as possible. Such conditions of water flowing down on the surface of strings are significant advantages of strings to provide high water cooling efficiency of water. And another significant advantage of string is that the flowing down of water on the surface of strings does not create any conditions of forming scales and fouling on strings, which means no formation of the scales and fouling in the SSF pack, resulting in no-reduction of the flowing rate of cooling air and the serve life of SSF pack.

For cooling of the hot ambient air containing high vapor concentration (hot and humid air), the condensation cooling process dominates and so the EVADEW cooling fan is preferred. To eliminate vapor in the high humid air, the DEWHX in the EVADEW cooling fan initially operates by supplying cold water as described. When the hot and high humid air is passing over the surface of water flowing down on the strings in the DEWHX, the vapor in the air condenses into water by changing itself into water molecules on the water surface whose temperature is lower than the dew point of incoming hot and humid air. Hence, the amount of vapor retained in the air gets lower and the temperature of the water increases due to dissipating of the heat (latent heat) retained in vapor to the bulk water. In this case, the temperature of air decreases and the concentration of vapor in air decreases until the vapor in the air reaches the saturation state (evaporation rate of water molecules and condensation rate of vapor are equalized) because condensation rate of vapor is much greater than reversing rate to air of vapor due to the dominant condensation of vapor. Such net transferring of vapor to air usually takes place in the high humid air. To accelerate the cooling of hot humid air to reach the comfort level of vapor and temperature (a comfort zone in summer is defined as temperature is between 73 and 80°F and relative humidity is between 20 and 78%) of the air, the operation of DEWHX pauses and then the EVAHX initiates the evaporation process of water by circulation of tap water when the concentration of vapor reaches a moderate low level (vapor concentration is still high). As the concentration of vapor in the air is low enough for evaporation to take place under moderate level of
temperature of air, the evaporation process occurs. Owing to the evaporation process of water, the temperature of the air gets lower and the vapor in the air slightly increases. After temperature and vapor reaches a moderate level (still higher than comfort zone level), the DEWHX initiates again for both of them to be operating to decrease temperature and vapor concentration to reach the comfort zone of air. When the comfort zone level is reached, the flow rates of tap water and cold water are controlled to keep the room conditions in comfort level. Likewise, while such cooling process of hot and high humid air is carry out in a room or closed area, the room air is cooled by alternatively operating the EVA and EVADEW cooling fan. The tap water, directly used for cooling temperature of air in the EVAHX, is circulated through the tap water reservoir tank, while the cold water for condensing vapor is supplied into the DEWHX, which is provided by passing through an ice tank from faucet. The colder than its dew point the water used for condensing vapor is, the faster and more the vapor condenses. To maintain such condensation of vapor, the coldness of cold water should be kept steadily lower than dew point temperature. To do this, the new cold water should be continuously introduced to pass once through the DEWHX instead of its circulation, which means the once used cold water is discarded out of the EVADEW cooling fan.

[0027] To save water due to rejecting it to the environments, the flow rate of cold water is controlled lower than 1.5 gallon/hour per square foot (cited from reference of the American Society of Mechanical Engineers) of cross section of the DEWHX. The water of 1.5 gallon per hour of cold water is uniformly sprayed on the entire top perforated plate of the DEWHX and imbibed through the entire holes by surface tension of wet strings threaded over the holes and then flows down the strings by wetting the entire surface of strings contacted by air passing transversely through strings. The total amount of water being necessary to completely wet all surfaces of strings is a quantity of water being capable to form thin water film on the surface of strings whose temperature of cold water warms up close to the dew point of cold water at the bottom of strings. The cooling of air is achieved by evaporation of water and convection of heat at the interface between air and water as described. However, when the vapor condenses onto the surface of cold water, a net warming occurs on that surface of the water, because the vapor forms water molecules by absorbing latent heat in the air due to its condensation process when it has interacted on the cold surface of water and then a larger amount of water molecules bringing heat in themselves are absorbed into water, compared with inverted amount of vapor re-evaporated from the surface of water. Correspondingly, the ambient air surrounding the interface of air and water gets cool.

[0028] The purpose of the present invention is a fabrication of the evaporative cooling fans, including EVAHX and DEWHX, using the plate type SSFs eliminating the disadvantages exhibited in the machine shop big fan and in the current evaporative coolers.

SUMMARY OF THE INVENTION

[0029] The EVA and EVADEW cooling fans of the present invention are schematically illustrated in FIGS. 1 and 2. The EVA cooling fan is used in open spaces or large confined facilities, while the EVADEW cooling fans are preferred in closed spaces. They use rectangular column shape string-heat-exchangers which are made with one or more of rectangular plate type string-screen-fill packs. The string-screen-fills heat exchangers are formed of a multiplicity of rectangular plate type string-screen-fills with string screens on both sides. The string-heat-exchanger imbibes water sprayed on its top perforated plate into its holes and then flows down on the surface of the strings vertically suspending over the holes of the top and bottom perforated plates. During its flowing down on the surface of the strings, the water cools the hot air or condenses vapor retained in air through the evaporation and convection heat transfer mechanisms of water driven by contacting with hot and/or moist air traveling in a direction transverse to the descent of the water on the surface of strings by forced draft of fan blower attached on the opposite side of the entrance of air. Using such cooling or condensing function of the string-heat-exchanger, the EVA cooling fan cools the hot air by EVAHX heat exchanger and blows cool air out of the cooling fan. The EVADEW cooling fan is a cooling fan with a DEWHX heat exchanger placed between an EVAHX heat exchanger and a fan blower to remove vapor retained in the cooled air as shown in FIG. 2. The cool air blowing out of the EVA cooling fan retains moist produced by the evaporation process of EVAHX heat exchanger, which is a main reason why the EVA cooling fan is operated in the open spaces. On the contrary, why the EVADEW cooling fan is allowed in the closed spaces is that the cool air leaving the EVADEW cooling fan does not retain an unnecessary and excessive moist due to the DEWHX heat exchanger’s removal of the moist produced by the EVAHX heat exchanger.

[0030] The fabrication of the evaporative cooling fans is completed through four steps of fabrications: determination of fabrication factors, the fabrication of SSFs and SSF packs, installation of the SSF packs into the evaporative cooling fans, and performance test of the evaporative cooling fans. The determination of fabrication factors of SSF and SSF pack requires determination of a lot of factors such as string materials and type, hole size on the top and bottom perforated plate of the evaporative heat exchanger, interval between adjacent strings in the heat exchanger, specific number of strings per unit cross section area of SSF pack, variation of specific area of SSF pack depending on string diameter, water cooling effective length of string in heat exchanger, verification of flying away of water from strings, and calculation factor for computation of hole size from arbitrary string size, and cooling effect due to string type.

[0031] The fabrication of SSFs and SSF packs includes fabrication of SSF frame having attachment tabs and semicircular holes on frame, winding a long string over the SSF frame, and assembly of a plurality of SSFs into SSF pack. One or more SSF packs are installed into the location of the evaporative heat exchanger and vapor condenser in the evaporative cooling fans and then finally the performance of the evaporative cooling fans is tested. The determination of fabrication factors of the SSF and SSF pack and the fabrication of SSF and SSF pack are described in detail in the previous invention of String-Thick-Plates Pack for Use in Cooling Tower (U.S. application Ser. No. 13/053,382) invented by inventor of the present invention. The installation of SSF packs in the evaporative cooling fans and its performance test are described here in the present invention and also the fabrication of the SSF and SSF packs is briefly described.

[0032] The fabrication of SSF and SSF packs is fabricated by assembling a plurality of the SSFs invented by the present inventor. One unit of SSF is a rectangular shape
string screen plate with two vertical-string-screens (VSS) on its both sides, which are apart in 1 cm, other dimensions are possible, and strings are wound over the top and bottom frames in the longitudinal direction as shown in FIG. 3. As shown in FIG. 3, the VSS is comprised of several strings vertically suspended from over the top and bottom frames separated sufficiently apart from each other as shown in FIG. 3. Several SSFs are assembled in a SSF pack which is installed in the EVAHX. Therefore, one unit of SSF pack is a standard fill medium for fabricating of basic standard SSF packs, 15(W)×30(H)×10(D) and 15(W)×60(H)×10(D) cm as shown in FIGS. 4A and 4B, respectively, necessary to fabricate SSF packs to be used for EVAHX of evaporative cooling fans.

[0033] The SSF is fabricated by winding a single long string over the top and bottom frames of the SSF rectangular frame as shown in FIG. 3. In an exemplary case of using string of 2.5 mm in diameter, the small and large standard frames have 16 semicircular holes of 6 mm in diameter on each of their both sides. Their intervals between the centers of the adjacent semi-circular holes are 10 mm, other intervals are possible. The SSF is fabricated by tightly winding a long single string of 2.5 mm in diameter by 8 turns passing through the every other semicircular holes separated by 20 mm, on the sides of the top and bottom frames shown in FIG. 3. Hence, the string loaded SSF is fabricated as shown in FIGS. 3, which is pre-standard SSF with one half (8 strings loaded holes) of total number of strings on the VSS on each side and thickness of 10 mm. When 10 units of pre-standard SSF’s are assembled together, a standard SSF’s pack in dimension of 15(W)×30(H)×10(D) cm and 15(W)×60(H)×10(D) cm are produced by completing VSS including 16 strings on both sides of the SSF.

[0034] The SSF used for fabrication of DEWHX is fabricated by reducing the string spacing of adjacent strings by half of the string interval of SSF used in EVAHX with other dimensions same. The DEWHX requires small amount of water, compared with amount of water used in EVAHX, to condense water on the surface of strings, and in turn the thickness of water flowing down on the surface of strings is thinner. Hence, the string spacing can be reduced, since there is no problem for wet strings to be stuck together due to thick water flowing down on the surface of strings. Reduction of the string spacing increase chances of contacting of vapor and water, and therefore thickness of SSF pack can be reduce by the same reduction rate of the string spacing. Thus, the thickness of the SSF used for DEWHX is reduced by half of that used for EVAHX: dimensions of the thinner SSF for DEWHX are 15(W)×30(H)×5(D) cm and 15(W)×60(H)×5(D) cm.

[0035] <String Materials and String Type> The string used in the present invention is a polyester string, other materials are possible, which has excellent physical and chemical properties like high melting temperature, high resistance to most chemicals, high tenacity for stretching and shrinking, and high durability so that the polyester string is suitable for fabrication of SSF. The polyester strings used in the present invention are spiral corrugated non-hairy and hairy polyester strings, other string types are possible. The hairy and spiral corrugate on string effect the cooling of hot air to be cooled by 5% lower than plain string. Therefore, when the hairy and corrugate string is used to the evaporative cooling fan, the cooling effect of the evaporative cooling fan can be increased by 5% more.

[0036] <Determination of Thickness of SSF Pack> To determine the thickness of SSF pack able to effectively cool and condense the hot moist air using SSF with thickness of 10 mm, several thicknesses of the SSF pack, 5, 10, and 15 cm, were tested. As results of testing, the effective thickness of the SSF pack fabricated with strings of 2.5 mm in diameter is determined to be 10 cm, wherein the air is cooled down to 30% of the inlet air temperature and the moisture is removed by 35%.

[0037] <Fabrication and Installation of EVAHX and DEWHX> EVAHX and DEWHX are fabricated in an exactly same way and configuration, but thickness of the DEWHX is thinner than that of the EVAHX. The EVAHX is fabricated using standard SSF packs shown in FIGS. 4A and 4B. The small and medium size EVAHXs are made by assembling small and medium standard SSF packs shown in FIGS. 4A and 4B side by side as shown in FIGS. 5A and 5B, respectively. Large EVAHX is constructed by piling small SSF packs shown in FIG. 4A on the top of the large SSF packs shown in FIG. 4B. The EVAHX is installed in a heat exchanging zone of EVA cooling fan as shown in FIG. 1 and both of EVAHX and DEWHX are installed in a condensing zone of EVADEW cooling fan as shown in FIG. 2.

[0038] <Advantages of Present Invention> Major advantage of the EVADEW cooling fan and EVA cooling fan of the present invention is the ability to substantially reduce the moisture content in the cooled air by more than 30% of those of the current evaporative coolers and to be continuously used in the machine shop without any problems of moisture accumulation in the machine shop, respectively.

[0039] Another major advantage of the EVADEW cooling fan and EVA cooling fan of the present invention is the ability to cool a room enough as low as an air conditioner cools it without using of cooling agent and compressor, which reduces a large amount of electric consumption by 30% of that of the air conditioner.

[0040] Minor advantage of the present invention is the ability to be in service life of more than 25 years since the polyester strings and aluminum used in the present invention has excellent physical and chemical properties like high melting temperature, high resistance to most chemicals, high tenacity for stretching and shrinking, and high durability.

[0041] And further advantage of the SSF packs of the present invention within the cooling towers is that the materials of the SSF’s pack, polyester strings, aluminum or aluminum alloy, polypropylene, are non-hazardous and suitable for safe and disposal at the end of service life.

BRIEF DESCRIPTION OF THE DRAWINGS

[0042] FIG. 1 is a schematic picture of side view EVA cooling fan. FIG. 2 is a schematic picture of side view EVADEW cooling fan. FIG. 3 is a schematic picture of SSF. FIG. 4A is a schematic picture of unit standard SSF’s pack of 15(W)×30(H)×10(D) cm. FIG. 4B is a schematic picture of unit standard SSF packs of 15(W)×60(H)×10(D) cm. FIG. 5A illustrates a schematic picture of piling 2 standard SSF’s packs of 15(W)×30(H)×10(D) cm to form an evaporative heat exchanging or vapor condensing pad of 30(W)×30(H)×10(D) cm. FIG. 5B illustrates a schematic picture of piling 4 standard SSF’s packs of 15(W)×60(H)×10(D) cm to form an evaporative heat exchanging or vapor condensing pad of 60(W)×60(H)×10(D) cm. FIG. 5C illustrates the schematic picture of piling each 6 SSF’s packs of 15(W)×30(H)×10(D) cm and 15(W)×60(H)×10(D) cm to form an evaporative heat exchanging or vapor condensing pad of 90(W)×90(H)×10(D) cm. FIG. 6 shows psychrometric chart including 4 cooling
cycles for cooling of 4 room air initial conditions such as 95°F and 75% RH, 95°F and 40% RH, 95°F and 18% RH, and 95°F and 15% RH. FIG. 7 shows psychrometric chart zones of room air initial conditions for EVA and EVADEH cooling fan to cool room air into Comfort Zone. FIG. 8 shows schematic flow diagram of room air and heat/vapor generated from cloth steam press machine in a typical dry cleaning shop due to operation of EVA and EVADEH cooling fans. FIG. 9 shows psychrometric chart showing operation of EVADEH cooling fan in a dry cleaning shop.

**[0043]** Description of Number in the Drawings

1 machine shop cooling fan, 2 new cold water or circulated water supply, 3 water sprayer, 4 air filter, 5 string, 6 water level controller, 7 water discard outlet port, 8 water reservoir, 9 water inlet port to water circulation pump, 10 water circulation pump, 11 solenoid valve, 12 tap water inlet port, 13 axial fan blower, 14 air flow direction, 15 ice tank water cooler, 16 top perforated plate of heat exchanger, 17 EVAHX, 18 bottom perforated plate of heat exchanger, 19 DEWHX, 20 EVADEH cooling fan, 21 circulated water inlet pipe to EVAHX, 22 circulated water supply, 23 used cold water transport pipe, 24 single unit of SSF, 25 top frame of SSF frame, 26 pathway of cooling air, 27 bottom frame of SSF frame, 28 side frame of SSF, 29 unit standard SSF's pack of 15(W)x30(H)x10(D) cm, 30 discharge of cool air, 31 top perforated plate of SSF, 32 entrance of hot air, 33 guiding wall to control direction of traveling of hot air, 34 bottom perforated plate of SSF, 35 bottom standard SSF's pack of 15(W)x33 60(H)x10(D) cm, 36 evaporative or condensing heat exchanger pad of 30(W)x30(H)x10(D) cm, 37 evaporative or condensing heat exchanger pad of 60(W)x60(H)x10(D) cm, 38 evaporative or condensing heat exchanger pad of 90(W)x90(H)x10(D) cm, 39 heat and vapor generator, 40 flow direction of heat and vapor, 41 duct ventilation hood, 42 room air flow, and 43 insulated duct.

**DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT**

**[0044]** Designing of EVA and EVADEH Cooling Fans

The components of the EVA cooling fan 1 are EVAHX 17, axial fan blower 13, water circulation pump 10, water sprayer 3, ice water cooler 15, tap water solenoid valve 11, water reservoir 8, and water tank water level controller 6. The EVAHX 17 and axial fan blower 13 are horizontally installed by positioning of the EVAHX 17 behind the axial fan blower 13 as shown in FIG. 1. The water reservoir 8 is located at the bottom of EVAHX 17 and the water sprayer 3 is at the top of EVAHX 17. The water circulation pump 10 is on the floor of the EVA cooling fan 1 and connected to the water sprayer 3 and the water reservoir 8. The tap water solenoid valve 11 is attached on tap water inlet port 12 and controls supplying of tap water. The reservoir water level controller 6 checks water level in the water reservoir 8 and connected to the tap water solenoid valve 11. The fan blower 13 is designed to change direction of blowing of air. The design of the EVADEH cooling fan 20 is almost same with that of the EVA cooling fan 1 except addition of the DEWHX 19 between fan blower 13 and EVAHX 17 and transferring spent water passed the DEWHX 19 through the used cold water transport pipe 23 to the water reservoir 8 at the bottom of EVAHX 17.

**[0045]** Fabrication and Installation of EVAHX in EVA Cooling Fan

The size of the EVAHX 17 is determined, whose cooling active size is equal and greater than the diameter of fan blower 13. Then, the EVAHX 17 is fabricated as shown in FIGS. 5A, 5B, or 5C by assembling two or more standard rectangular columnar SSF Packs of 15(W)x30(H)x10(D) cm 29 shown in FIG. 5A or 15(W)x60(H)x10(D) cm 35 shown in FIG. 5B or by combining of both of them depending on the diameter of fan blower 13. As an application example, the fan blower 13 of 30 cm in diameter needs EVAHX 17 which has a square area of 30x30 cm, fabricated by joining together of two standard SSF packs of 15(W)x30(H)x10(D) cm 29 as shown in FIG. 5A and the EVAHX 17 to form fan blower 13 of 60 cm in diameter is fabricated by assembling 4 units of 15(W)x60(H)x10(D) cm 35 by side as shown in FIG. 5B. For the fabrication of the larger EVAHX 17 than these, several SSF's packs of 15(W)x30(H)x10(D) cm 29 and 15(W)x60(H)x10(D) cm 35 joint together to form a square as shown in FIG. 5C. Installation of the EVAHX 17 is accomplished by inserting into the heat exchanging zone of the EVA cooling fan 1 or attaching on the rear side of the fan blower 13.

**[0046]** Fabrication and Installation of DEWHX in EVADEH Cooling Fan

In the same way as in the EVA cooling fan 1, the DEWHX 19 is fabricated by assembling side by side or combining thinner SSF's packs 29, 35 depending on the fan blower size and then inserted between fan blower 13 and EVAHX 17 as shown in FIG. 2. Hence, the fan blower 13, DEWHX 19, and EVAHX 17 are installed in their consecutive order in the EVADEH cooling fan 20.

**[0047]** Operation of EVA Cooling Fan

Tap water is directly supplied under the control of the solenoid valve 11 to the top perforated plate 16 of the EVAHX 17 of the EVA cooling fan 1 through the water inlet port 12 and then the water is sprayed on the top perforated plate 16 of the EVAHX 17. The sprayed water is imbibed by the strings 5 into the holes on the perforated plate 16 and then flows down on the surface of the strings 5 suspended from between top and bottom perforated plates 16, 18 of the EVAHX 17. The water reached to the bottom perforated plates 18 of the EVAHX 17 flows out of the EVAHX 17 through the holes on the bottom perforated plate 18 and then is collected in the water reservoir tank 8. The water in the water reservoir tank 8 is circulated by the water circulation pump 10 to the water sprayer 3 on the top of the EVAHX 17 and then flows down through the EVAHX 17. The hot air comes into the EVA cooling fan 1 through the air filter 4 on the entrance of the hot air by the forced draught of the fan blower 13, which is on the opposite side of the entrance of the hot air. The hot air 14 travels transversely through the strings 5 vertically suspended from between the top and bottom perforated plates 16, 18 and then flows out of the EVA cooling fan 1 through the fan blower 13 as shown in FIG. 1. While the hot air 14 travels through the strings 5, the hot air 14 contacts with cold water flowing down on the surface of the strings 5 and cools by dissipating some heat retained in the hot air 14 to the cold water through the evaporation and convection mechanism of water.

**[0048]** Operation of EVADEH Cooling Fan

The EVAHX 17 of the EVADEH cooling fan 20 operates in the same way as that of the EVA cooling fan 1 operates except for no-supplying of the tap water. Tap water is supplied after passing an ice tank water cooler 15 under the control of the solenoid valve 11 to the top of the DEWHX 19 of the EVADEH cooling fan 20 through the water inlet port 12 and then the cold water is sprayed on the top perforated plate 16 of the DEWHX 19. The supplied cold water flows down on the surfaces of strings 5 built in the DEWHX 19 to the bottom of the DEWHX 19 and then is transferred through the used cold.
water transferring pipe 23 to the water reservoir 8 located at the bottom of the EVAHX 17. The transferred used cold water mixes with a warm water previouslyreserved in the water reservoir 8. The mixed water is circulated to the top of the EVAHX 17 by the water circulation pump 10 and flows down on the strings 5 built in the EVAHX 17. Likewise, simultaneously supplying water to the DEWHX 19 and EVAHX 17, the cold water and warm water are respectively flowing down on the surface of the strings 5 built-in the DEWHX 19 and EVAHX 17 at the same time. During the flowing down of water on the surface of the strings 5 in the both heat exchanger 17, 19, the hot moist air 14 comes into the EVADEW cooling fan 20 and discharges out of the EVADEW cooling fan 20 through the fan blower 13 on the opposite side of the entrance of the hot moist air 14 after traveling transversely through the strings 5 of the 2 heat exchangers, EVAHX 17 and DEWHX 19, which are consecutively built in the EVADEW cooling fan 20. The hot moist air coming into the EVADEW cooling fan 20 cools by the same way as described in the EVA cooling 1.

The cooled air passing through the EVAHX 17 continuously enters the DEWHX 19. In the DEWHX 19, some vapor retained in the moist cool air contacts with cold water (temperature of the water is lower than dew point temperature of vapor) flowing down on the surface of the strings 5 to condense and to be absorbed onto the water on the surface of the strings 5. After passing through the DEWHX 19, the air becomes cool and dry.

[0049] <Performance Test of Evaporative Cooling Fan by Psychrometric Chart> When air contacts with water, the transfer of heat and vapor take place through the air and water body and their interface. Their transfers are affected by combination of evaporation, convection, and infrared radiation, resulting in increasing or decreasing of enthalpy (latent heat and specific heat) and temperature (wet and dry bulb) and specific volume of air, concentration (relative and specific humidity) of vapor, and temperature of water. Such designing factors of the evaporative cooling fan should be calculated using empirical and theoretical equations relating to them. However, they can be simply obtained from psychrometric chart developed employing all relevant variables for water evaporative cooling mechanism. Accordingly, if two factors are known, others can be obtained from the psychrometric chart.

[0050] Exemplary operations of the EVA and EVADEW cooling fan 1, 20 for cooling hot room air retaining high, medium, and low humidity into comfort zone of 73-80°F. and 20-78% RH in summer using psychrometric chart are described as follows. First, the hot humid air retaining 95°F. and 75% relative humidity (0.027 lbs-moisture/lb-dry-air) is cooled by the cooling operation cycle one (CC1) of cooling fan as shown in FIG. 6. Starting Node a of 95°F. and 75% RH is marked on the chart as shown in FIG. 6. As the room air humidity is high, the condensation process of the humid air dominates and so the DEWHX 19 in the EVADEW cooling fan 20 is initiated to condense high concentrated vapor. Since the air retaining 95°F. and 75% relative humidity loses its heat (amount of vapor is not changed) onto the surface of cold water passing through the DEWHX 19, the temperature of the air at the surface of the cold water decreases and its relative humidity increases by following the left horizontal direction arrow B of CC1. When the air reaches its dew point temperature at Node C, the temperature and relative humidity of air reaches 86°F. and 100% (true saturation relative humidity of apparatus is slightly less than this), respectively. The saturated air keeps cooling on the surface of cold water and loses its heat to cold water, resulting in becoming lower temperature than the dew point temperature. Then the vapor more than saturated vapor being able to retain at the lower temperature of air condenses into water. Keeping going down of the temperature of saturated air due to continuously losing its heat to cold water, the vapor in the saturated air continuously condenses by following the saturation temperature line S, which takes place until the temperature of saturated air reaches the pre-set low temperature, 59°F., of cold water at Node D, in case of 100% cooling efficiency. Considering by-pass factor (BF) 10% of cooling fan, the air just passing the DEWHX 19 becomes 63°F. (=BT, Tp, T, 0.1(95-59)+59), referring to an article of “Air Conditioning Psychrometrics”) and 98% RH at Node D. Under the assumption of mixing of initial hot and humid air and the cooled air passing through the DEWHX 19, the final temperature and humidity of room air becomes 79°F. and 90% at Node X which are obtained by mixing rule referring to “http://www.hgsiemens.com and EngineeringToolBox.com.” The final temperature and relative humidity of the air at Node X is not in the comfort zone. Hence, to cool room air at Node D into the comfort zone, it must be heated by applying an electric heater. Consequently, the initial room air having hot and high relative humidity higher than 70% is not possible to be cooled into comfort zone using only EVADEW cooling fan 20 as shown by the cooling operation cycle CC1 in FIG. 6.

[0051] In case of the room air retaining medium and low humidity, the operation of EVADEW cooling fan 20 is preferred like cooling cycles of a b c d e f g, Cooling Operation Cycle 2 (CC2), and I II III IV f. Cooling Operation Cycle 3 (CC3), respectively, as shown in FIG. 6. When the EVADEW cooling fan 20 is operated in the room retaining medium and low humid hot air, both EVAHX 17 and DEWHX 19 are simultaneously operated and the air passes sequentially through the EVAHX 17 and DEWHX 19. Medium humidity cooling cycle of CC2 is initiated for the air to enter the evaporative heat exchanger, EVAHX. Starting Node a of 95°F. and 40% RH is marked on the chart as shown in FIG. 6. Through the evaporation process of EVAHX, the air retaining 95°F. and 40% RH loses its heat to the water and in turn some water is evaporated into the air on the surface of normal tap water passing through the EVAHX 17. As a result of evaporation process, the temperature of the air decreases and its relative humidity increases. Such an evaporation process takes place at the wet bulb temperature of the air on the surface of the normal tap water, which indicates left diagonal direction arrow b in CC2. After passing the EVAHX 17, the air enters the DEWHX 19 and starts to be cooled by contacting with cold water without evaporation of cold water. This starting point is marked at Node c. Until the air reaches the vapor saturation state marked by Node e in CC2, the cooling process of the DEWHX 19 is continued by following left horizontal direction arrow d in CC2. Such cooling cycle of air is continued until the saturation temperature of air at Node e is reached. Once the air entering the DEWHX 19 reaches the saturation temperature, the excess vapor is condensed into cold water in the DEWHX 19 and is discharged with cold water out of the EVADEW cooling fan 20. The cooling process of the DEWHX 19 after Node e is same as in the CC1 described above. The final temperature and relative humidity of the room obtained through the EVADEW cooling fan 20 become 77°F. and 60% RH, respectively, which are in the comfort zone.
Low humidity cooling cycle of I→II→III→IV→# (CC3) with the initial room condition of 95° F. and 15% RH marked at Node I in FIG. 6. is operated in the same way as in the CC2 and the final temperature and relative humidity of the room air are 76° F. and 33% RH, which also locates in the comfort zone. While the cooling cycles CC2 and CC3 are operated in the closed small spaces, open spaces or large confined facilities can use the EVA cooling fan I which is operated with EVAHX 17 only. In the open spaces or large closed facilities, the vapor retaining in the cooled air leaving the EVA cooling fan I is not accumulated and dissipates into the surrounding environment and therefore the moist in the cooled air is not necessary to be removed and persons working around in front of the EVA cooling fan can feel comfortable. Thus, the EVA cooling fan I is preferred in the open or large spaces. The exemplary operation of the EVA cooling fan I in the open or large closed spaces is given as cooling operation cycle of α→β→γ→δ (CC4) shown in FIG. 6, which has the initial operation condition of 95° F. and 18% RH. Since the relative humidity of the air is low, the evaporation process of the EVA cooling fan takes place to increase vapor concentration in the air and decrease the air temperature. As a result of this evaporation process, the air condition changes by following the diagonal directed arrow marked by β of wet bulb temperature line being able to reach the condition of the comfort zone marked at Node γ in the cooling operation cycle CC4 as shown in FIG. 6. To meet the condition of comfort zone marked at Node γ in CC4, the condition of the air leaving the EVA cooling fan I should get slightly higher relative humidity and cooler temperature marked at Node γ in CC4 than comfort zone in order to cover up. The loss of cooling effect due to the bypassing of air without contacting with cooling water. Then, the air leaving the EVA cooling fan I can reach the condition of the comfort zone marked at Node γ, 74° F. and 60% RH, in the CC4. The cooled air leaving the EVA cooling fan I dissipates into the open or large closed space without mixing with the warmer air in the space and therefore workers exposing the cooled air of 74° F. and 60% RH around in front of the cooling fan can feel comfortable. The operation of the EVA cooling fan I is simple like CC4 as shown in FIG. 6. Namely, the initial condition, 95° F. and 18% RH, of the air becomes 74° F. and 60% RH by the only evaporation process of the EVA cooling fan and therefore the final conditions of the EVA cooling fan I being able to reach the comfort zone are easily and simply controlled.

<Psychrometric Chart Zones of Initial Room Conditions Able to Be Cooled into Comfort Zone> The comfort zone is a range of temperature and humidity conditions of air which people can feel comfortable within. Their ranges in summer are 73-80° F. and 20-78% RH, respectively, which are marked as a shaded area in the psychrometric chart shown in FIGS. 6 and 7. From the performance tests of EVA and EVADEW cooling fans 1, 20 using psychrometric chart as shown in FIG. 6, it is understood that a large range of temperature and humidity shown in psychrometric chart can be converted into the comfort zone by using the EVA and EVADEW cooling fans 1, 20 and cold water retaining dew point temperatures of 41 to 59° F. Hence, based on the psychrometric chart on which the cooling cycles of the EVA and EVADEW cooling fans 1, 20 are drawn as shown in FIG. 6, the psychrometric chart zones of the initial conditions of room air which EVA and EVADEW cooling fans 1, 20 cool into the comfort zone are drawn in FIG. 7. FIG. 7 shows five zones of initial condition such as ZONE 1 to 5 as shown in FIG. 7. ZONE 1 can be cooled into the comfort zone using EVADEW cooling fan 20 (only DEWHX 19 is operated in this zone) assisted with an electric heater. When the initial room air in this zone is cooled using the DEWHX 19, the air leaving the EVADEW cooling fan 20 is cooler and higher in humidity than the comfort zone as Node D (63° F. and 97% RH) shown in the cooling operation cycle of CC1 shown in FIG. 6 and reaches a final room condition of 79° F. and 90% RH marked at X after mixing with the initial condition 95° F. and 78% RH of the room. This final room air condition is much higher than the range of the comfort zone as shown in the CC1. Therefore, the cool humid air leaving the EVADEW cooling fan 20 needs to be heated in order to get into the comfort zone right after leaving the EVADEW cooling fan 20. Thus, the initial conditions of the room in ZONE 1 cannot be cooled into the comfort zone using EVA or EVADEW cooling fans 1, 20. Namely, ZONE 1 is excluded for cooling capabilities into the comfort zone of EVA and EVADEW cooling fans 1, 20. Such initial room conditions in ZONE 1 unable to be cooled into the comfort zone by the cooling operation cycle of CC1 are located in the psychrometric chart above an extended straight line YZ of the line Xb between a dew point 10° F. marked at X and an upper corner b of the comfort zone. ZONE 2, 3, and 4 can be cooled into the comfort zone by using EVADEW cooling fan 20 (both EVAHX 17 and DEWHX 19 in the EVADEW cooling fan 20 are operated). The initial room conditions are in medium and low humidity of 10-60% RH and high temperature of higher than 85° F. so that the EVAHX 17 first starts operating to cool the hot humid air, resulting in increasing of humidity in the air and then the DEWHX 19 is operated to remove the excess moist in the air by condensing process as described in the cooling operation cycle of CC2 and CC3 shown in FIG. 6. To condense the excess moist, DEWHX 19 requires a cold water of 41-59° F. lower than dew point temperatures of the initial room air. Hence, as shown in FIG. 7, the initial condition boundaries of each ZONE 2, 3, and 4 are determined depending on the dew point temperature of 41, 50, and 59° F, respectively, and their determination methods of the initial room condition zones are same. Hence, as one example of their determination, the initial room conditions in ZONE 3 are determined as follows. As shown in FIG. 7, the pre-set dew point of the EVADEW cooling fan is marked at X on the chart and then straight lines passing the boundary corners a, b, and d of the comfort zone from the dew point X are drawn. On the extended lines of aA, bB, cC, and dD, A, B, C, and D are respectively marked at the same distances from the boundary corners a, b, c, and d with lengths of aA, bB, cC, and dD and then the set points A, B, C, and D are connected to create ZONE 3 for the psychrometric chart boundaries of the initial conditions of room air as shown in FIG. 7. Likewise, ZONE 2 and 4 are determined. There is one exception for drawing the initial condition boundary of ZONE 4 related to the dew point 59° F. marked at X. In this case, the line connecting dew point of 59° F. and boundary of the comfort zone cannot be lower than wet bulb temperature line of 59° F., dark solid line XF, since the evaporation process of water takes place along the wet bulb temperature line higher than or equal to the dew point 59° F. Thus, the lower part, shaded area below line EF in ZONE 4, of the initial condition boundary of ZONE 4 below that wet bulb temperature line of 59° F. is cut out as shown in FIG. 7. The initial room air conditions located in ZONE 5 shown in FIG. 7 are simply and directly cooled into the comfort zone by the
cooling operation cycles CC4 of EVA cooling fan 1 as shown in FIG. 6 and also a part of the ZONE 5, lower than 30% RH and higher than 90° F. shown in FIG. 7, are cooled by EVADEW cooling fan 20 as described above. Hence, the initial room conditions able to be cooled by only EVA cooling fan 1 are located in a sub-zone, adeGEF, in ZONE 5, which is equal to subtraction of some initial conditions included in the lower part of ZONE 3 and 4 from ZONE 5. In other word, the initial room conditions in the sub-zone, adeGEF, in ZONE 5 cannot be cooled into the comfort zone by the EVADEW cooling fan 20. Eventually, all initial air conditions except the conditions in the range of 80-90° F, 1.5-50% RH and higher than 75° F, and 60% RH (roughly drawn from sub-zone adeGEF in ZONE 5 and ZONE 1) can be cooled by EVADEW cooling fan 20 in small closed rooms. Namely, The initial air conditions in closed small rooms higher than 90° F. and lower than 60% RH can be cooled by EVADEW cooling fan 20. On the contrary, the EVA cooling fan 1 can be applied to cool the hot dry initial air conditions in the entire ZONE 5 down to cool air for workers working in front of the fan in the open or large spaces to feel cool enough.

[0054] <Application of EVADEW Cooling Fan to Dry Cleaning Shop> Room air in a dry cleaning shop usually is hot and humid, since heat and steam generated from operation of a steam press 39 is accumulated in the interior of the cleaning shops. In summer, the extent of getting hot and humid in the shop is much severer. In a typical dry cleaning shop, a cloth steam press 39 is placed near to the wall or corner of the shop to maximize an efficiency of working and usage of space and windows or doors are keeping open to control the accumulation of moist in the shop. To effectively circulate shop air, the EVADEW cooling fan 20 is placed near the opposite wall across shop from the steam press 39 and to prevent directly dissipating of heat and moist from the steam press 39 to interior space, a duct 43 is installed between the steam press 39 and the EVADEW cooling fan 20 and its duct ventilation hood 41 is suspending from ceiling above the steam press 39 as shown in FIG. 8. In addition to that FIG. 8 illustrates the installation configuration of the EVADEW cooling fan 20, steam press 39, and duct in the cleaning shop as described above. FIG. 8 shows a flowing pattern of room air and locations of several different qualitative room air to be formed due to mixing hot moist and dry cool air by convection and radiation of heat from the steam press 39, which are L1 to L7 as shown in FIG. 8. L1 is a location of extremely hot moist air retaining high temperature and high concentrated vapor generated from the steam press 39. L2 is a location of hot moist air of extremely hot moist air and much warmer room air at location L7 than average conditional room air at location L6, and L3 shows a location of hot moist air transferred through the duct 43 up to the entrance of the EVADEW cooling fan 20. L4 is a location inside the EVADEW cooling fan 20 where the hot moist air becomes cool and low moist air producing due to condensing process of cold water in the EVADEW cooling fan 20. L5 is the location of cool and low moist air leaving EVADEW cooling fan 20 and entering room and L6 indicates the location of average conditional room air by convectional mixture of cool and low moist air at location L5 and much warmer room air at location L7. L7 is the location of much warmer room air which the average conditional room air is changed into due to exposing to heat radiation heat from the steam press 39 and extremely hot moist air. The duct ventilation hood 41 is used for collecting a mixture of much warmer room air and extremely hot moist air generated from the steam press 39. The duct 43 is insulated to prevent condensing of moist in the mixed air on the wall of the duct 43 and the duct hood 41 is fabricated as large as possible to suck all heat and vapor 40 generated. Solid arrows 40 indicate flowing of hot and humid air and dot arrows 42 flowing of room air.

[0055] The operation of the EVADEW cooling fan 20 is initiated supplying tap water and cold water to the top perforated plates of the EVAHX 17 and DEWHX 19 built in the EVADEW cooling fan 20, respectively. Next, the air circulation fan puts into operation and then the room air is circulated through the duct hood 41, duct 43, EVADEW cooling fan 20, and room space. The room air passing through entire room space re-enters the duct hood 41 and circulates through the same route. Such circulation of the room air continues until the operation of the EVADEW cooling fan 20 is stopped. During the circulation of the room air, the tap water and cold water supplied to the top perforated plates have been imbibed into the holes on the top perforated plates and flown down on the surface of strings built in the EVAHX 17 and DEWHX 19, respectively, and the room air is transversely traveling through the strings in the EVAHX 17 and DEWHX 19 built in EVADEW cooling fan 20 and discharges into the room space. While the water and room air are crossly flowing each other in the EVAHX 17 and DEWHX 19, the room air contacts with water on the surfaces of the strings to be cooled and dry or humid (controlled by pre-setting of relative humidity to meet the conditions of the comfort zone). During the operation of the EVADEW cooling fan 20, the hot humid air at location L2 shown in FIG. 8 sucking into the duct hood 41 is produced by mixing extremely hot and humid air at location L1 generated from the steam press 39 and warmer room air at location L7. The hot humid air at location L2 is transferred to location L3, the air entrance of the EVADEW cooling fan 20 through the duct 43 from location L2. The hot humid air at location L3 enters the EVADEW cooling fan 20 and sequentially passes through the EVAHX 17 and DEWHX 19 in the EVADEW cooling fan 20 and then to be discharged into the room space. The cool and low humid air at location L5 leaving the EVADEW cooling fan 20 enters the room space. The cool and low humid air at location L5 entering the room space is mixed with much warmer room air at location L7 to become an average conditional room air at location L6 by convection process. The much warmer air at location L7 imbibles into the duct hood 41 with extremely hot and humid air at location L1 generated from the steam press 39. While such a cooling cycle is repeated, the hot and humid air at location L2 becomes cool and low humid air and in turn the cooling and condensing process of the DEWHX 19 is getting slow. At this point, the evaporation process of the EVAHX 17 dominates to cool the cool and low humid air due to low concentration of vapor in the cool and low humid air. Accordingly, the cool and low humid air gets cooler and concentration of vapor increases. When the concentration of vapor is high enough for the operation of the DEWHX 19, the DEWHX 19 dominates to cooling process again. Likewise, the alternative operation of the DEWHX 19 and EVAHX 17 cools the extremely hot and humid air at location L1 in the dry cleaning shop.

[0056] Using the psychrometric chart, the cooling process of extremely hot and humid air generated from the steam press 39 in a typical dry cleaning shop is explained as shown in FIG. 9. The starting room air condition at Node L2 (Node numbers used in FIG. 9 are location numbers used in FIG. 8 and the air conditions of Node numbers represent the same...
meanings of the location number) is determined by mixing of extremely hot moist air at Node L1 and much warmer room air at Node L7 by applying a mixing rule given in the references of “hgs.siemens.com and EngineeringToolBox.com.” So, the room air at Node L2 is still a hot moist air. As the hot moist air at Node L2 has high humidity and the condensation cooling process dominates in high concentration of moist in air, the DEWHX 19 heat exchanger in the EVADEW cooling fan 20 works by following a condensation cooling cycle of L2→CS→L1.4→L1.5→L1.6→L1.7 shown in FIG. 9. Therefore, while the hot moist air at Node L2 is passing through two heat exchangers in the EVADEW cooling fan 20, the EBAHX 17 heat exchanger rarely works and the DEWHX 19 heat exchanger cools the hot humid air to become cool by its condensation cooling process. Such condensation cooling process continues until the temperature of the cool moist air reaches a saturation temperature at Node CS, which indicates a cooling process of Node L2→Node CS (Condensing Starting point). Generally, most evaporative cooling apparatuses have cooling efficiencies slightly less than 100%, since they have bypass factors that some air passes through cooling media without contacting them. Thus, as an actual saturation point of the DEWHX 19 (BT=62°C) is slightly lower than 100%, Node CS is a little way off the saturation point (90% relative humidity) as shown in FIG. 9. Once the temperature of the cool moist air has reached the saturation temperature (90% relative humidity), an excess moist that cool moist air cannot hold in itself due to lower temperature of the cool moist air than its saturation temperature, starts to be condensed at Node CS. This condensation cooling process is continued until the dew point temperature of the cool moist air meets the pre-set dew point temperature (Tp) (41°F, 50, and 59°F are used in the present invention) of the EVADEW cooling fan 20, which indicates Node CS→Node L4, cooling and condensing process being taken place in the EVADEW cooling fan 20. Node L4 shown in FIG. 9 is found as follows. Pre-set dew point temperature of the EVADEW cooling fan is marked at Node Tp of 50°F on saturation temperature curve as shown in FIG. 9 and then it is connected to the average conditional room air at Node L2. Node L4 is marked at the point that the line connecting the pre-set dew point 50°F and Node L2 intersects with vertical line at 54°F. \( ( = \beta F(Tp, Tm) + Tp = 0.1(90 - 50) + 50) \). The hot moist air leaving the EVADEW cooling fan 20 is cool and low moist air at Node L5, which is entering the room space. The cool and low moist air at location L5 is circulated through the room space by convection and mixed with much warmer room air at Node L7 to achieve a final average conditional room air at Node L6. While these cooling and condensing processes continue, new cold water is continuously supplied and used cold water is discarded. Hence, the pre-set dew point temperature is not changed and the concentration of moist in the room air continuously decreases and in turn the condensation cooling process is getting slow. Eventually, the relative humidity of the cool moist air, Node L2, reaches much lower relative humidity at Node L2 than Node L2. At this new low concentration of moist in the room air, the evaporative process dominates the cooling cycle, which is indicated as a new cooling cycle of L2→ES→CS→L1.4→L1.5→L1.6→L1.7. In this new cooling cycle, the cooling process of L2→ES is evaporative process and the rest processes of the new cooling cycle are same with previous ones. While the evaporative process of L2→ES is underway, relative humidity of the room air increases and the evaporative process slows. Conversely, the condensation process is getting active and finally dominates the cooling cycle, which comes back to previous cooling cycle starting with a lower relative humidity at Node L2. Alternatively changing the cooling cycle from condensation to evaporation and vice versa, the EVADEW cooling fan 20 cools the dry cleaning shop with removing the moist generated from the steam press 39.

While the present invention has been described as having an exemplary design, this invention may be further modified within the concept and scope of this disclosure. This application is therefore intended to cover any variations, uses, or adaptations of the invention using its general principles. Further, this application is intended to cover such departures from the present disclosure as come within known or customary practice in the art to which this invention relates.

What is claimed is:

1. An EVA cooling fan, comprising:
   a fan blower, evaporative heat exchanger, water circulation pump, water tank, and water sprayer as components of said EVA cooling fan, wherein said fan blower and said evaporative heat exchanger are horizontally installed by attaching said evaporative heat exchanger at the rear side of said fan blower, wherein said water tank and said water sprayer are at the bottom and top of said evaporative heat exchanger, respectively, and wherein said water circulation pump is located on the floor of said EVA cooling fan;

2. Evaporative heat exchanger as claimed in 1, comprising:
   a multiplicity of plate type string-screen-fills, each having a pair of vertical-string-screens on both sides of said plate type string-screen-fill, each of said vertical-string-screen having vertical strings separated sufficiently apart from each other, wherein said vertical strings passing through and over semi-circular holes on the frame of said plate type string-screen-fill;
   attachment tabs on said string-screen-fill frame, each of said attachment tabs located on side surfaces of said plate type string-screen-fill frame for joining said plate type string-screen-fills together side by side, whereby said attachment tabs are joined by aligning said attachment tabs with and inserting into the counterpart tabs of said plate type string-screen-fill to be joined by pressing;
   attachment tabs on said string-screen-fill frame, each of said attachment tabs locating on top and bottom surface of said plate type string-screen-fill frame for piling said plate type string-screen-fills, whereby said attachment tabs are joined by aligning said attachment tabs with and inserting into the counterpart tabs of said plate type string-screen-fill to be joined by pressing;

3. An EVADEW cooling fan, comprising:
   Said evaporative heat exchanger, condensing heat exchanger, said fan blower, said circulation pump, water tank, circulated water sprayer, and tap water sprayer as components of said EVADEW cooling fan, wherein said fan blower, said condensing heat exchanger, and said evaporative heat exchanger are horizontally installed in their consecutive order as described above, wherein said water tank and said circulated water sprayer are at the bottom and top of said evaporative heat exchanger, respectively, and wherein said tap water sprayer and said water circulation pump are at the top of said condensing heat exchanger and on the floor of said EVADEW cooling fan;
4. Condensing heat exchanger as claimed in 3, comprising:
a multiplicity of plate type string-screen-fills, each having
a pair of vertical-string-screens on both sides of said
plate type string-screen-fill, each of said vertical-string-
screen having 2 times number of vertical strings of said
evaporative heat exchanger separated apart from each
other, wherein said vertical strings passing through and
over semi-circular holes on the frame of said plate type
string-screen-fill;
attachment tabs on said string-screen-fill frame, each of
said attachment tabs locating on side surfaces of said
string-screen-fill frame for joining said plate type string-
screen-fills together side by side, whereby said attach-
ment tabs are joined by aligning said attachment tabs
with and inserting into the counterpart tabs of said plate
type string-screen-fill to be joined by pressing;
attachment tabs on said string-screen-fill frame, each of
said attachment tabs locating on top and bottom surface
of said plate type string-screen-fill frame for piling said
plate type string-screen-fills, whereby said attachment
tabs are joined by aligning said attachment tabs with and
inserting into the counterpart tabs of said plate type
string-screen-fill to be joined by pressing.