

[54] **LIQUID COOLING SYSTEM,
APPARATUS AND METHOD**
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[58] Field of Search**261/90-92; 210/219, 242; 239/22, 23, 219-221, 223, 224**

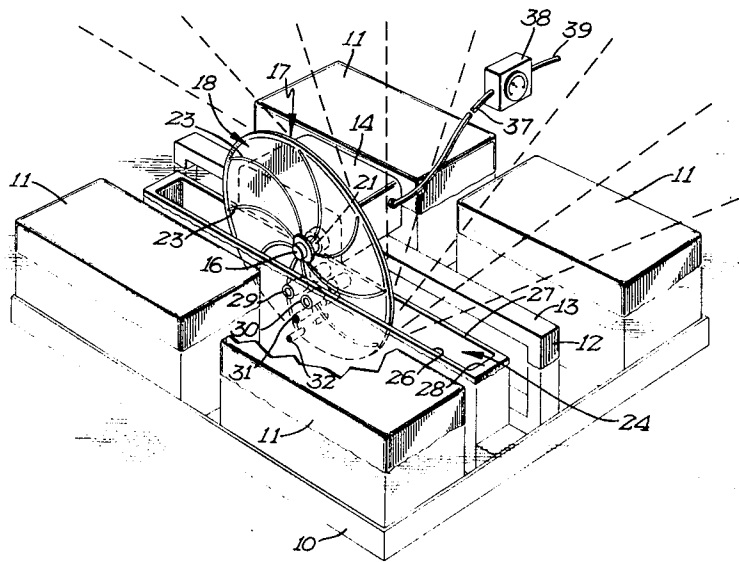
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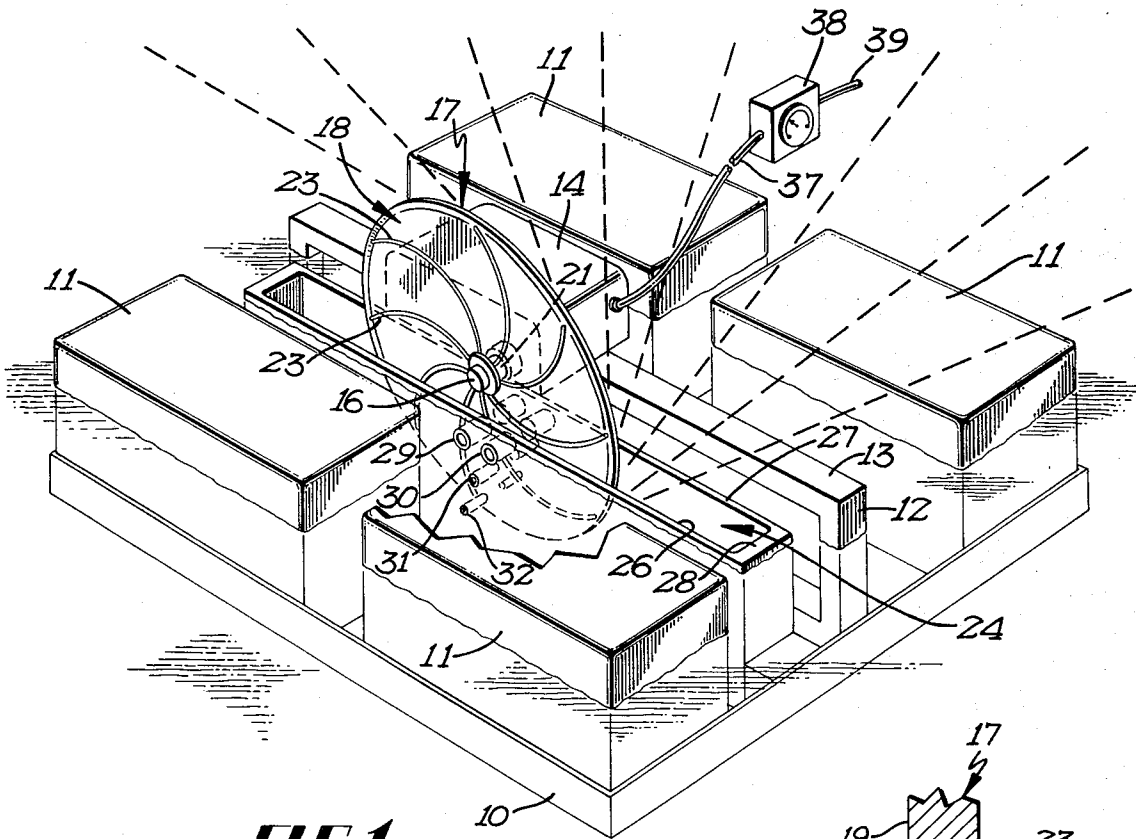
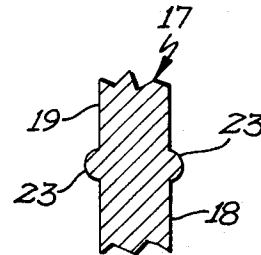
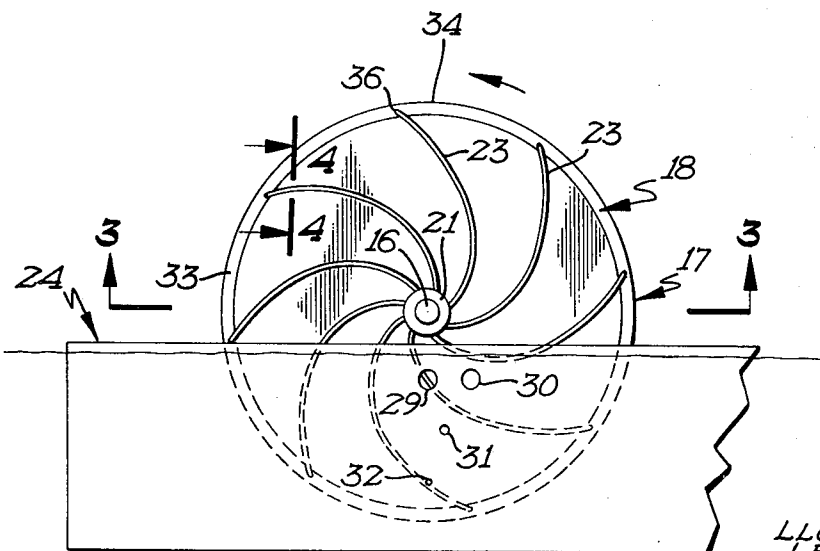
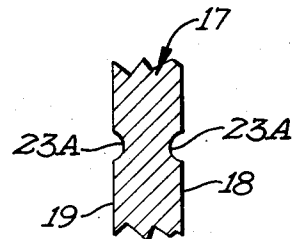
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[57] **ABSTRACT**
A method is disclosed for cooling liquid at high volume rate by projecting fine drops of liquid throughout the area above the surface of a reservoir of limited size, so that the unevaporated portions of such drops fall back into the reservoir and the drops normally remain close enough to the surface to minimize drift losses. Apparatus for projecting such liquid includes a rotatable member having a surface generally perpendicular to its axis of rotation. The axis is oriented so that the surface is at an angle to the horizontal, and liquid is fed to specific limited areas of the surface from which fine drops will be projected upwardly in response of the member. Such apparatus is shown in connection with a cooling system for practicing the above method, and in which liquid effluent from an operating plant is fed to such liquid projecting and spraying apparatus at one area of a reservoir, is transferred by such spraying to another area of the reservoir and is cooled during such transfer by evaporation exposure to the atmosphere above the reservoir. The system includes means defining and separating the two reservoir areas to facilitate high volume rates of spray transfer and to prevent normal liquid flow from one area to the other except by means of such spray transfer.

21 Claims, 12 Drawing Figures





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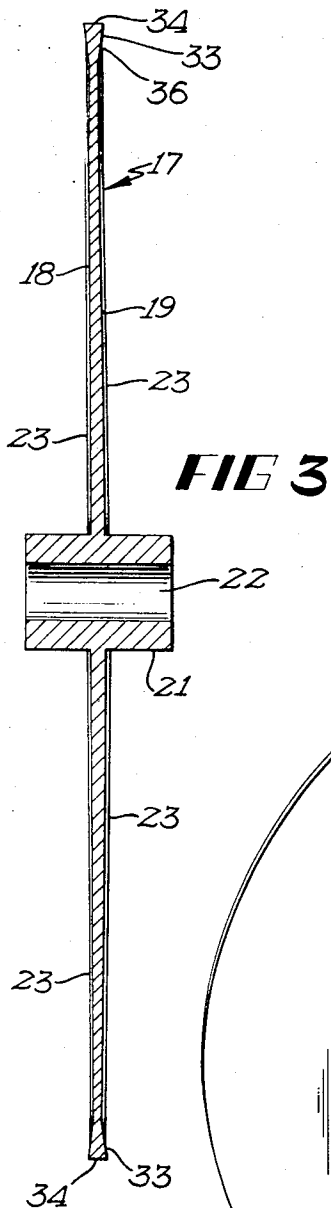


FIG 3

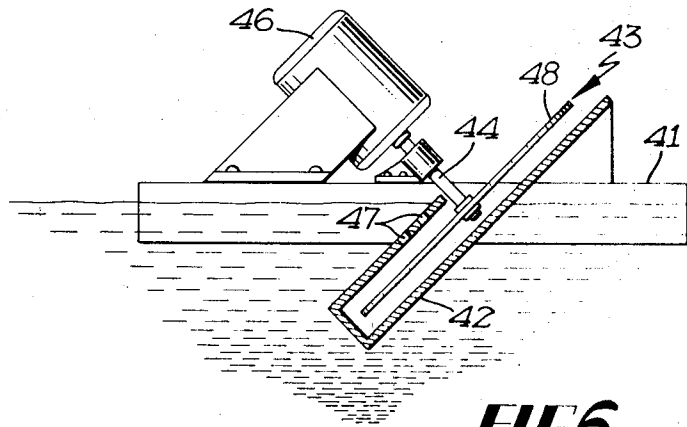


FIG 6

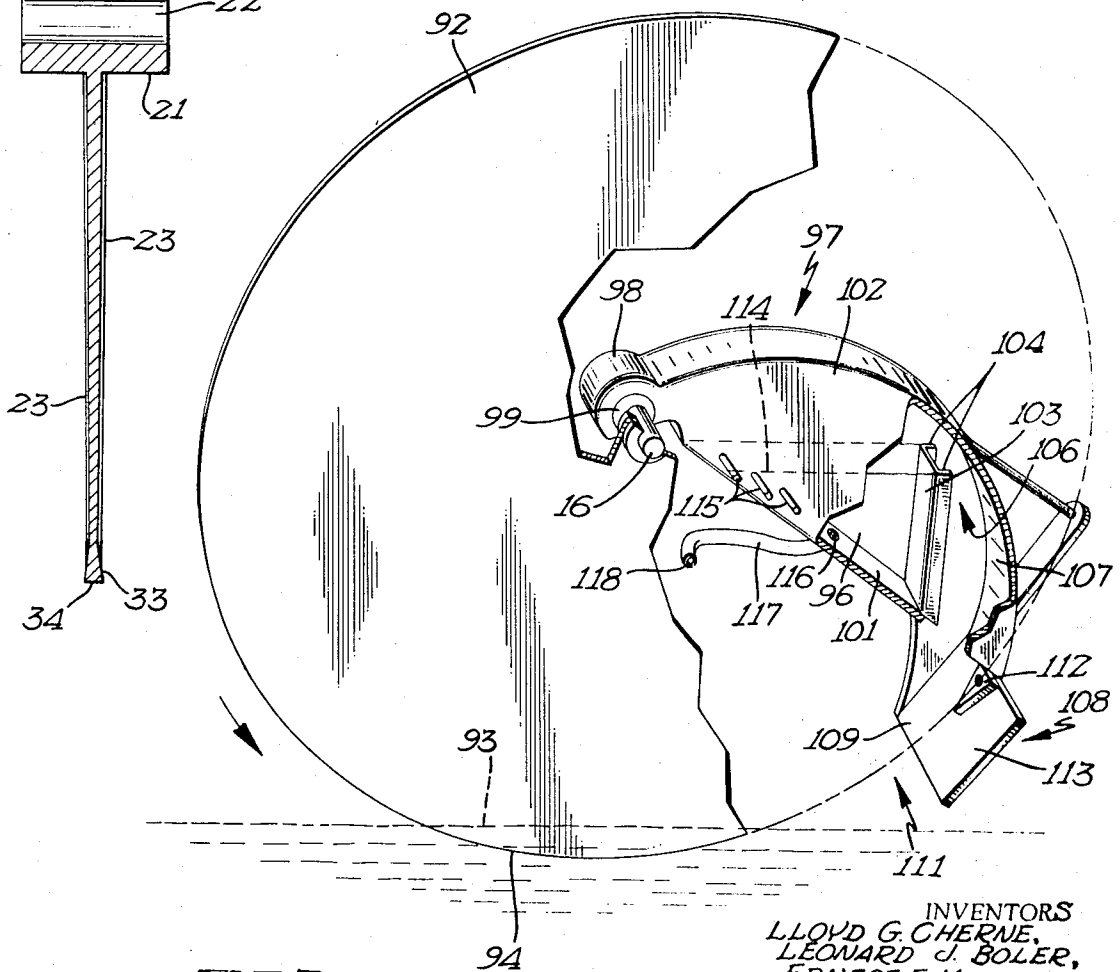


FIG 7

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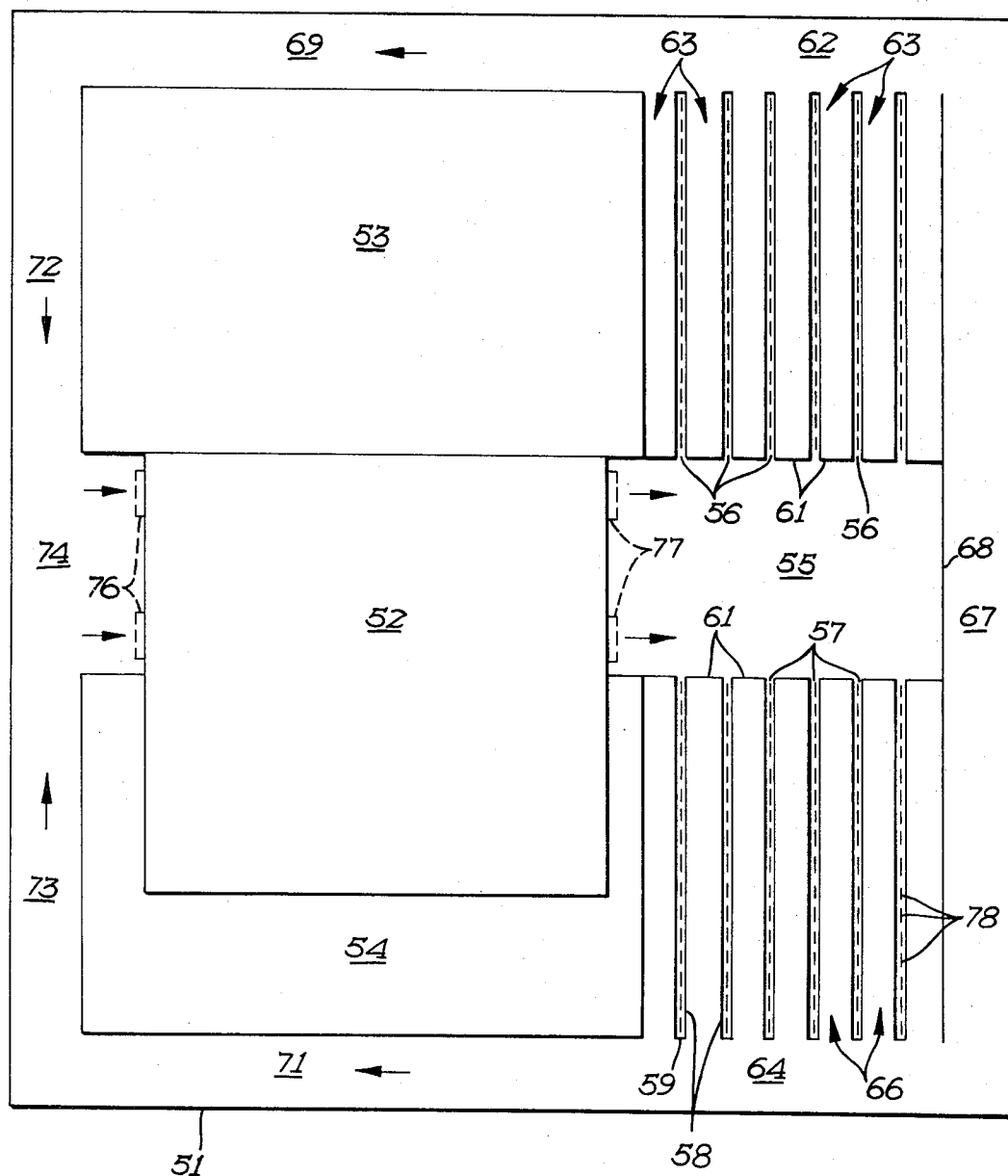


FIG 8

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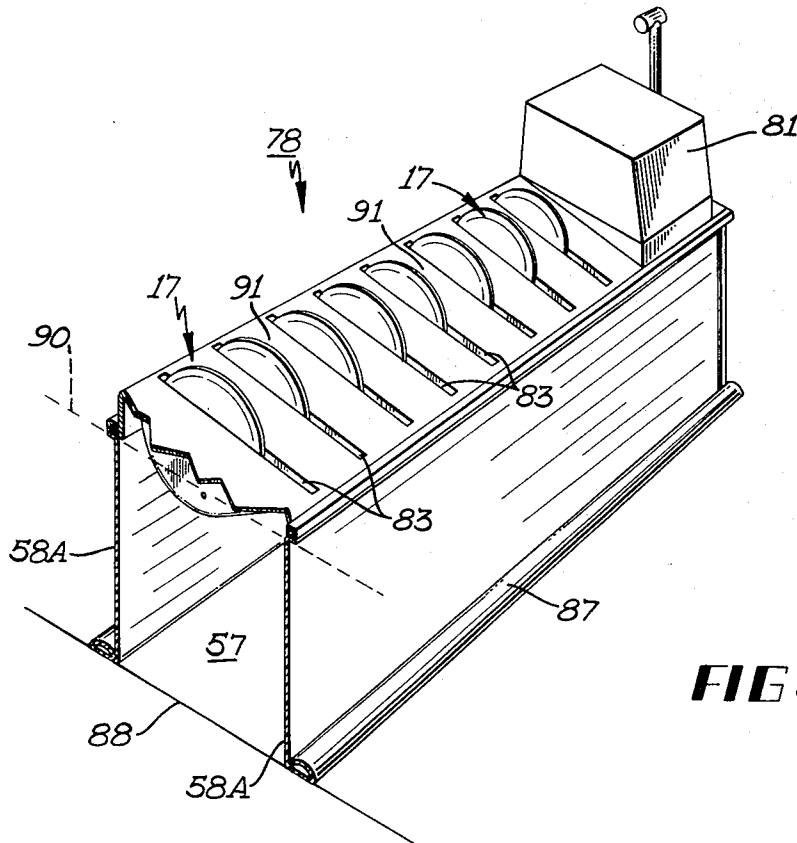


FIG 9

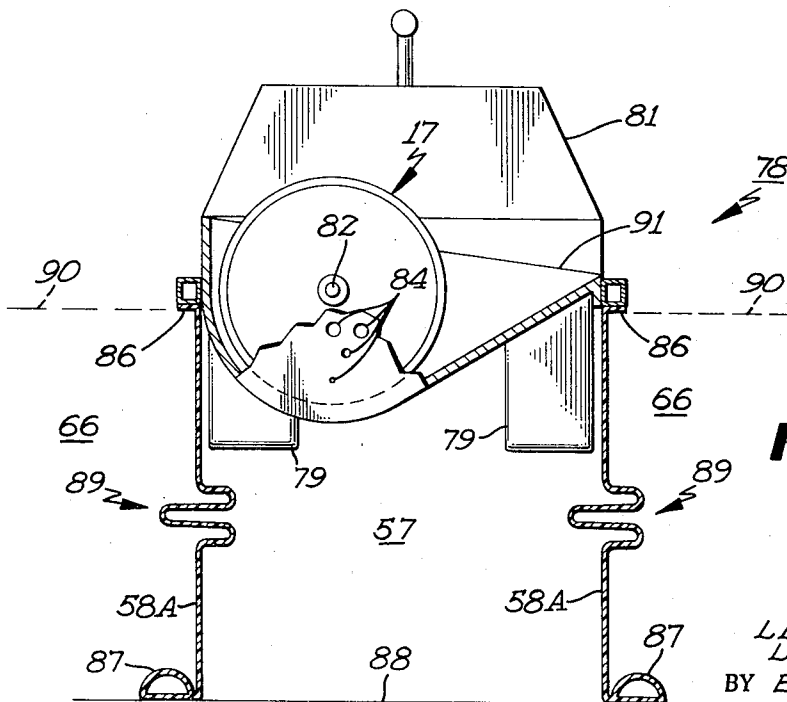
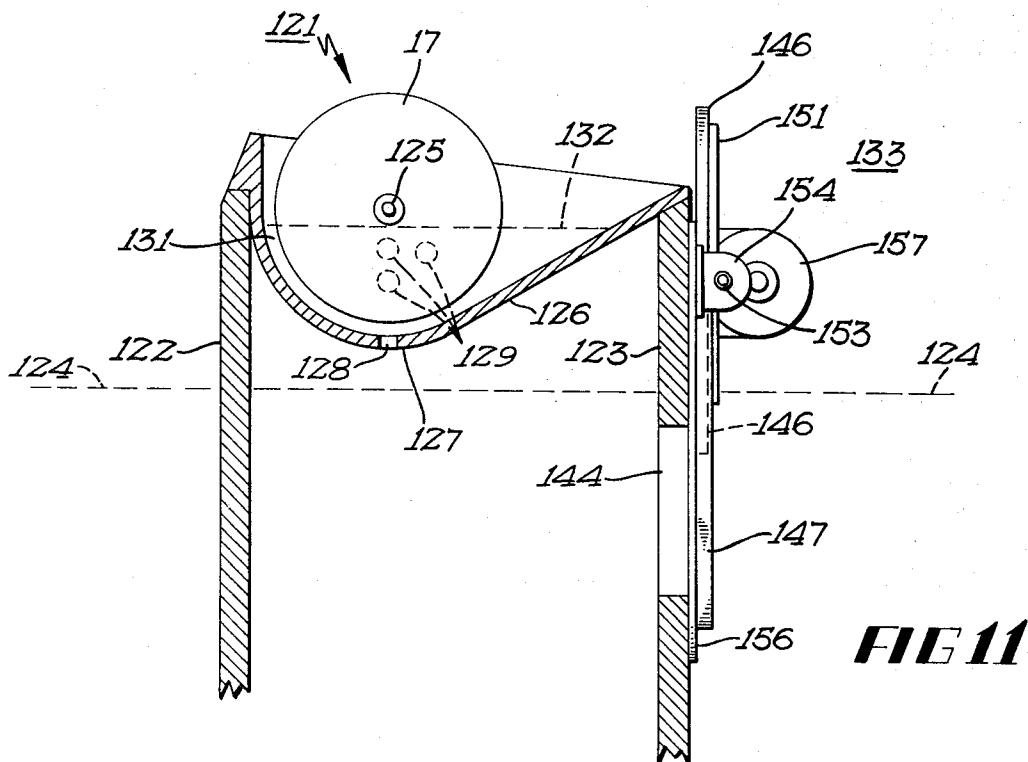


FIG 10

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LIQUID COOLING SYSTEM, APPARATUS AND METHOD

BACKGROUND OF THE INVENTION

In connection with electric power generating plants, either of the conventional fossil fuel types or the atomic energy type, high volume flow rates of liquid are needed for cooling purposes. It has been customary in many cases to obtain such cooling liquid from a nearby stream, lake or other natural waters. In some cases, such liquid is utilized on a "once through" basis, and is then returned to the natural source after such use. Since the liquid is used for cooling, its temperature at the point of discharge from such a plant is higher than the temperature of the original source. If the higher temperature liquid is then discharged back into the original natural source, such as a river or stream, there is a possibility, depending on the particular climate, the nature of the stream and other factors, that the higher temperature discharge will have an adverse effect. This possibility is popularly referred to as "thermal pollution." Where such liquid has been used in the cooling condensers of an atomic reactor, there has been the further fear that the discharged liquid might conceivably have a radiation level which would be objectionable or unsafe from a public health standpoint. To avoid this latter factor, proposals have been made for recirculating the liquid rather than utilizing it on a "once through" basis. Such recirculation requires substantial cooling. Various installations have been provided with extremely large and expensive cooling towers which introduce a substantial cost factor in the generation of electric power, whether they are used for cooling of effluent for complete recirculation, or whether they are used to reduce the temperature of the cooling liquid to a point where it can be restored to the original natural source without undesirably raising the temperature of such source.

In an effort to avoid some of the disadvantages of tall cooling towers, such as the power requirements to pump large quantities of liquid to the top of a 500 foot tower, for example, or the loss of moisture by "drift," with possible inconvenience or adverse effect as moisture or ice is dropped on surrounding areas, or the problems of supporting large and expensive pieces of equipment on a small area at the base of such tower, other proposals have been made for the utilization of large cooling ponds into which the heated liquid effluent from such a plant is discharged and left to cool. The land area, however, which would be required for effective cooling of the required quantities of water for a generating plant of substantial capacity makes this approach impractical.

SUMMARY OF THE INVENTION

The present invention provides a system, method and apparatus for the cooling of such liquid effluents at a relatively high volume rate of flow, without the necessity of using large and high cooling towers or extremely large area lagoons or reservoirs. From a method standpoint, the invention includes the spraying of fine drops of liquid to be cooled so that such drops are exposed to the atmosphere above the surface of a liquid reservoir. The liquid to be cooled is fed into one area of such a reservoir, the cooled liquid is removed from another area of the reservoir, and the liquid is transferred from

the first such area to the second area substantially entirely by the spraying step. The preferred method for carrying out the spraying step involves the centrifugal projection of the fine drops of the liquid upwardly from the surface of such a reservoir.

A complete system or plant installation according to the invention thus includes a power plant or other processing plant which utilizes liquid for cooling purposes, in combination with an adjacent or surrounding liquid reservoir of limited area. Cool water is drawn from one area of the reservoir into the plant, and the same liquid, which increases in temperature as a result of its use for cooling within the plant, is then discharged into another area of the reservoir. The reservoir area which receives the heated effluent is effectively separated by suitable barriers from the other portion of the reservoir which holds the cooled liquid. The barriers are so arranged that the heated effluent is sprayed upwardly, promptly after it reaches the reservoir area into which it is discharged, so that the thermal efficiency of evaporative cooling will be increased by virtue of the greater difference in vapor pressure between a higher temperature liquid and the surrounding atmosphere than would be the case if the temperature of the liquid were first lowered to any extent. In summary, then, the spraying step is applied to the hot liquid as soon after the liquid reaches the reservoir as is feasible, without permitting the liquid to spread out through the reservoir and dissipate any substantial portion of its heat content before the spraying operation takes place.

From an apparatus standpoint the invention includes a rotatable spray member which has a liquid distributing surface substantially perpendicular to the axis of rotation of the spray member. The spray member is oriented so that such spray surface is at an angle to the horizontal. In the preferred form of apparatus this spray surface is vertical and may be provided by a circular disk or plate lying in a vertical plane, rotatable about a horizontal axis, and thus providing two parallel, vertical, liquid distributing surfaces on a single plate. A plurality of such plates may be mounted on a single shaft and driven by a single power source.

Liquid is fed to only a limited area of such a liquid distributing surface, and preferably to the area immediately below the axis of rotation, so that a majority of the liquid is fed to the general area of the surface which lies below such axis but not more than half way from the axis down to the outer circumference or periphery of the spray surface.

The spraying action of such apparatus is facilitated by the provision of spiral guides on the spray surface, either in the form of recessed channels or projecting ribs. Such guide portions extend in a spiral curve outwardly from points near the axis of rotation and curve smoothly to points at the outer periphery which are generally located forwardly, in the direction of rotation, from the inner point of origin of each guide. A preferred formula for establishing the spiral pattern for such guides is given later in this specification.

The apparatus includes means for adjusting such factors as the speed of rotation of the spray surface, as a means of controlling the desired size of drops for optimum evaporative cooling, and the relative vertical head or pressure at which fluid is fed to the spray surface, in order to help control the volume rate at which

liquid is sprayed by such apparatus. The preferred drop size is not more than 0.5 centimeters in diameter. The drops are preferably projected for limited exposure to the atmosphere for a period of not more than 3 seconds, while the drops are not more than substantially 25 feet above the surface at which they are to be collected.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings which form a part of this application, and in which like numbers indicate like parts,

FIG. 1 is a perspective view of a liquid cooling apparatus according to the present invention;

FIG. 2 is a partial side elevation view of the device of FIG. 1;

FIG. 3 is a partial sectional view on the line 3—3 of FIG. 2 showing details of the rotatable spray member construction;

FIG. 4 is a partial sectional view on the line 4—4 of FIG. 2;

FIG. 5 is a view similar to FIG. 4 of a modified embodiment;

FIG. 6 is an end elevational view, partly in section, of a modified form of the apparatus of FIGS. 1 to 4;

FIG. 7 is a partial perspective view of another embodiment of the invention;

FIG. 8 is a plan view of a power plant and accompanying liquid cooling installation according to the invention;

FIG. 9 is an enlarged perspective view of a portion of a reservoir area similar to that of FIG. 8 showing details and arrangement of a spray apparatus unit and modified barrier wall members therein;

FIG. 10 is a partial sectional view on the line 10—10 of FIG. 9, but with the parts shown at a lower water level;

FIG. 11 is a view similar to FIG. 10 of another barrier wall modification; and

FIG. 12 is a partial side elevation of the device of FIG. 11.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

A preferred embodiment of the liquid cooling apparatus unit according to the present invention is shown in FIGS. 1 through 4. This apparatus includes a base member 10 which is provided with a plurality of bouyant floats 11 adapted to support the apparatus at the surface of a body of liquid to be cooled. The supporting frame includes centrally located members 12 and 13 which provide support for a motor housing or power unit 14 at a level which will keep the motor unit above the liquid on which the unit floats. Power unit 14 has a power output shaft 16 which in this case is mounted with its axis horizontal and parallel to the liquid level in the supporting reservoir. Mounted on this power shaft 16 is a rotatable spray member 17 which has a liquid distributing spray surface 18 perpendicular to the axis of shaft 16. Spray member 17 and surface 18 accordingly rotate around axis 16.

As shown in FIGS. 3 and 4, spray member 17 in this embodiment actually has two liquid distributing spray surfaces 18 and 19 which are essentially parallel to each other on opposite faces of member 17. The spray member includes a suitable hub portion 21 with an

axial opening 22 adapted to fit the power shaft 16 and be keyed to it in known manner.

According to a further feature of the invention, the spray surfaces 18 and 19 include appropriate guide portions which are illustrated in FIGS. 1 to 4 in the form of slightly projecting ribs 23 which extend outwardly from the hub portion 21 to the outer circumference of the spray member. As shown in FIG. 2, these guide portions curve forwardly with respect to the direction of rotation of member 17 (indicated by the arrow in FIG. 2). In this embodiment the outer ends of these guide members stop just short of the outer periphery of the spray member as illustrated in FIG. 3. Here the outer circumferential edge of the member 17 has a somewhat outwardly flared or tapered region 33, so that the periphery or outer edge 34 of the member 17 is somewhat wider in an axial direction than the inner portions of the spray member 17, and even wider than the total thickness through the guide members 23 and the spray member. The point 36 at the outer end of each spiral guide member 23 is spaced inwardly from the rim 34. The invention contemplates the feeding of liquid to limited areas of the spray surfaces 18 and 19 at predetermined locations such that the liquid will be carried by the rotating spray surface and urged outwardly by centrifugal action, guided by ribs 23 until the liquid is sprayed in fine drops from the outer periphery of member 17. Just before such drops are projected centrifugally from the member 17, the beveled areas 33 tend to divert the direct radial path of the liquid to assist in spreading out the area in which the sprayed droplets are projected.

As shown particularly in FIGS. 1 and 2, the apparatus includes means to control the area or areas at which liquid is fed to the rotating spray surface. In this embodiment, spray member 17 is rotated with its lower portion in a troughlike section 24 defined by spaced parallel sidewalls 26 and 27 and a bottom wall 28 connected therebetween. This trough 24 is separated by such wall members from the body of liquid in which the apparatus is floated and these walls extend upwardly above the liquid level so that the manner in which water is introduced to the trough can be controlled.

For this purpose the invention contemplates the provision of feeding means illustrated as conduits or passageways in the respective side walls 26 and 27. These conduits are so located as to deliver most of the desired volume of water to the limited area of the spray surface which lies below the axis of rotation of the surface, but not more than substantially halfway down to the lower edge of the spray surface. Thus, as shown in FIG. 2, there are a plurality of major inlet openings 29 and 30 which deliver most of the liquid into this area. One or more smaller feed openings 31 and 32 may also be provided at a somewhat lower level to insure the desired distribution of liquid to this limited lower area of the spray surface in such a way that liquid will be sprayed somewhat uniformly throughout the area vertically above the spray member, as such liquid is fed upwardly and outwardly along the guide members 23 during rotation of the surfaces 18 and 19.

This apparatus provides a means for controlling the degree of atomization or particle size obtained as such liquid is projected centrifugally into the atmosphere. The particle size is controlled in this instance by adjust-

ment of the speed of rotation of the spray surface. The means for accomplishing such adjustment is illustrated in FIG. 1 as a variable rheostat 38 connected into the electric supply lines 37 and 39 which provide current for an electric motor in the power unit 14.

We have found that operation of a spray surface or rotor of the type described in FIGS. 1 to 4 will project fine particles or drops of liquid upwardly into the region extending to 25 feet above the surface of the liquid in the reservoir, the height of projection and the particle size being controllable to provide for limited exposure of the drops to the atmosphere for evaporative cooling during a time period in the range of generally not more than 3 seconds. For optimum cooling, the drop size is preferably no greater than 0.5 centimeters in diameter. As a practical matter some of the drops may be larger than this, but most of them should generally be within this specified size range.

Centrifugal projection of drops of liquid in this manner provides the possibility of cooling of the liquid by as much as 20° to 25° through evaporative cooling of the drops, i.e. through evaporation of a certain percentage of the liquid included in each drop.

The spiral path of the guide members 23 is designed to facilitate the desired drop pattern or path of flow of liquid as such liquid flows centrifugally outwardly on the liquid distributing spray surface during rotation of the spray member. The desired centrifugal atomization and projection of a fine spray has been achieved by designing the spiral guide members, so they curve outwardly and forwardly in the direction of rotation along a path substantially determined by the equation

$$r = k\theta,$$

in which r is the radius in inches outwardly from the axis of rotation, θ is the angle in radians ahead of the point of origin of the spiral at said axis, and k is a constant in the range from 7 to 12 inclusive, preferably 10.

In one recommended embodiment according to FIGS. 1 to 4, a circular spray member having a diameter of 30 inches was designed with spiral guide ribs having a width of 0.100 inches and projecting outwardly substantially 0.050 inches from the surfaces 18 and 19. The number of such guides should be high enough to space them close together, and in this case was chosen to provide an angular or circumferential separation of approximately 10° between each rib. The spiral path was determined by the above formula, with k equal to 10.

Member 17, including such ribs, may be formed as a single or unitary member of strong plastic material, such as that currently sold under the trademark "Nylon." Other materials may also be used. With molded plastic materials it may be desirable to provide a non-circular hub opening 22 to fit a non-circular shaft portion 16.

Various relative arrangements, numbers and sizes of the feed openings may also be used. In the arrangement shown in FIGS. 1 and 2, one recommended set of openings includes feed openings of 1 inch diameter at 29 and 30, ½ inch diameter at 31, and ¼ inch diameter at 32.

Proper selection or adjustment of the various factors discussed will help provide the desired centrifugal atomization and projection of a sufficiently fine spray

to achieve the desired degree of evaporative cooling. With a 30 inch diameter circular spray surface, for example, excellent atomization was achieved at a rotary speed of the order of 450 r.p.m. (revolutions per minute). With a smaller circular spray surface diameter, a higher rotary speed is recommended, e.g. in the range of 500 r.p.m. for a 24 inch diameter spray surface.

As shown in FIG. 5 the spray surfaces 18 and 19 of the rotatable spray member 17 may be provided with spiral guide portions of modified construction. Here the guides are formed as recessed channels 23A with curved inner or bottom cross sections as illustrated, in place of the projecting ribs 23 of FIGS. 1 to 4. In some cases, a suitable degree of centrifugal atomization and projection of fine drops may also be achieved with a smooth rotary spray surface which includes no spiral guide members such as the ribs 23 or channels 23A. Preferably, however, and particularly where a greater volume rate and height of spray projection are desired, such spiral guides will be utilized.

Another modified form of spray apparatus according to the invention is shown in FIG. 6, in which a float member 41 supports a trough 42 at an angle of substantially 45° to the horizontal. Spray member 43 is mounted for rotation on shaft 44 driven by a motor 46. Liquid is fed into the trough through openings 47 in the limited area of the upper surface 48 of spray member 43 which lies below the axis of shaft 44, but preferably not more than half way down to the lower edge of the spray surface 48. In this case the spray surface 48 extends generally in a plane which has a horizontal component, as well as a vertical component. The angular arrangement facilitates the downward feeding of the liquid through openings 47 onto the upper surface 48 of this plate and provides for projection of the liquid with a greater horizontal component which tends to direct the spray away from the cooling unit, rather than at least partly in a plane directly above it.

In both the apparatus of FIGS. 1 to 4 and the embodiment of FIG. 5, the feed openings or conduits permit the respective troughs 24 and 42 to fill with water up to the level of the surrounding liquid, when the spray member is at rest. As soon as operation of the spray member is started, however, the action of the rotating spray surface or surfaces will soon throw out excess liquid from the trough. During normal running thereafter, the amount of liquid fed to the spray surface will depend on the total cross sectional area and individual areas of the respective feed openings and their vertical location with respect to the surrounding surface level of the liquid. This vertical location determines the normal "head" or operating pressure at which liquid is fed through the various openings.

FIG. 7 discloses another modifications of the present invention which is particularly designed to make it possible to maintain the axis of rotation of the rotary spray surface at a higher level above the surface of the liquid to be sprayed. In the device of FIGS. 1 to 4, for example, the shaft 16 is relatively close to the surface of the body of liquid, in order that the liquid may be fed by gravity through the openings in the side of trough 24 to the desired limited area of the spray surface. With shaft 16 relatively close to the water level, it is either necessary to provide a water-tight recess for the motor

unit (when the unit is directly coupled to the shaft with the motor shaft as an extension of shaft 16), or it is necessary to mount the motor at a higher level and provide some sort of connection between the higher motor shaft and the lower spray member shaft 16.

The device of FIG. 7 is accordingly designed to permit location of a horizontal shaft such as shaft 16 at a greater distance above the liquid level to facilitate mounting of the driving motor above that liquid level. This embodiment includes a rotary spray member 92, which may be similar to any of the spray members previously described, but which is illustrated in this case as a flat thin circular metal plate member. Spray member 92 is fixed to shaft 16 for rotation therewith, and shaft is placed far enough above the level of the body of liquid (shown by dotted line 93) so that only the lowermost portion 94 of the circular peripheral edge of spray member 92 dips into the liquid during normal operation.

According to this feature of the invention, this peripheral edge 94 serves as a so called "pumping" portion of the spray member to project or pump desired quantities of the liquid to a higher level, where the liquid can be received in a supply reservoir 96 and thereafter fed by gravity to the desired limited area of the spray surface at one side of spray member 92. Such an auxiliary supply reservoir may take various forms and is illustrated in FIG. 7 as including a reservoir space 96 defined within a housing 97 which may be supported at one end 98 by the same part of the device which carries the bearing support 99 for shaft 16. Housing 97 includes a downwardly inclined bottom wall 101, spaced sidewalls 102, and a vertical inner partition 103 which is connected to sidewalls 102 by flanges 104. Thus the auxiliary liquid reservoir space 96 is defined by the sidewalls 102, bottom wall 101 and partition 103.

Partition 103 is spaced inwardly from the curved outer wall 107 of housing 97 to provide a passageway 106 through which liquid may be projected upwardly into the auxiliary reservoir 96. Liquid is guided through this passageway 106 not only by the curved outer wall 107, but also by a suitable deflecting plate 108. Plate 108 is mounted opposite the peripheral pumping edge 94 of the spray member 92 in position to intercept drops of liquid which are centrifugally projected by edge 94 upwardly into the space 111 above liquid surface 93. Plate 108 extends at 109 to one side of the plane of plate 92 and may also extend at 113 to the opposite side of that plane. A tapered or triangular deflector guide 112, with its pointed end facing downwardly and in the plane of plate 92, assists in deflecting the projected liquid to one side or the other of plate 92. It will be understood that a further reservoir such as reservoir 96 could be mounted on the near side of spray member 92 in order to receive liquid from the deflector plate area 113 and then supply it by gravity flow to the near side of plate 92 as a spraying surface.

The shape and location of reservoir 97 and its inner partition 103 are selected to provide a liquid level (shown at 114) within the reservoir which will be high enough to provide the desired feeding of such liquid by gravity to the specified limited areas of the spray member 92. Thus the reservoir housing 97 may have openings 115 in its sidewalls 102 at positions which will

direct liquid from the auxiliary reservoir 96 to the spray surface on the far side of plate 92. The feeding means may also include one or more openings 116 in the bottom wall 101, connected by tubular conduits 117 to a lower discharge opening 118 which also directs liquid from the auxiliary supply reservoir to the desired area of the spray surface.

The construction shown in FIG. 7 accordingly provides a single rotary member which has both a pumping portion at its peripheral edge (to elevate the desired quantities of liquid to a supply reservoir at a higher level) and also a spray surface at one or both sides of the rotary spray member 92. Thus liquid can be fed from such a supply reservoir to limited spray surface areas which are located below the axis of rotation of shaft 16, but well above the liquid level 93 of the main body of liquid.

FIG. 8 illustrates a complete system embodiment of the invention for a complete power plant or other processing installation in which large quantities of water are utilized for cooling within the plant, are discharged at a higher temperature than normal as hot water effluent, and must be cooled at a high volume rate for recirculation through the plant. The system is illustrated on a plant site outline at 51 and includes a plant building 52 in which the water is to be used for cooling, together with one or more underlying or adjacent pieces of land or other supplemental buildings 53 and 54.

According to the present invention a liquid reservoir of limited area is located immediately adjacent, and in this particular illustration substantially surrounding, the plant itself. This reservoir includes a first area 55 into which the hot water effluent from the plant is fed directly by appropriate conduits or other means 77. This first reservoir area 55 includes a suitable series of barriers or partitions which extend from the bottom of the reservoir to a point above the surface and essentially prevent or limit the lateral and normal gravity flow of the hot water effluent from the first area of the reservoir to the remaining areas. These barriers define, as part of the first area 55, a series of narrow channels 56 extending laterally toward one side of the plant site, and a similar series of oppositely directed channels 57 extending laterally toward the opposite side of the plant site. These narrow channels are defined by parallel barriers 58 and are closed at their outer ends by end partitions or barriers 59. Additional barrier portions 61 connect the inner ends of the channel barriers 58 to the respective side barriers of the adjacent channels, as shown.

Thus the system of barriers just described provides a second or cold water area of the reservoir which includes a portion 62 at one side of the installation from which projecting channels 63 of substantially greater width than channels 56 extend inwardly between the channels 56 to receive liquid sprayed from channels 56 in a manner described below. A similar cold water area 64 at the opposite side of the installation includes inwardly projecting receiving channels 66 of substantially greater width than the hot water channel areas 57, along which channels 66 extend.

The cold water area of the reservoir includes channels 69 and 71 extending from the areas 62 and 64 respectively along the sides of the plant and commu-

nicating with cross channels 72 and 73 which bring the cool water to an area 74 from which it may be removed through outlet means 76 and directed into plant 52 for a further cooling operation therein.

In the illustrated layout, the areas 62 and 64 are also connected to each other by a cross channel 67 at the hot water end of the plant. This channel 67 is fully separated from the hot water area 55 by additional barrier means 68.

According to the present invention the hot water in the first area of the reservoir is cooled by projecting it upwardly in fine drops of appropriate size in a direction and at a velocity providing for evaporative cooling of the drops within the region up to substantially 25 feet above the surface of the reservoir. The projected drops are free to fall under the influence of gravity and their direction of projection is such that most of them fall within the cold water receiving channels 63 and 66 which are located at each side of the narrow hot water channels 56 and 57 respectively, from which the drops have been originally projected upwardly. In the system shown in FIG. 8 these narrow channels 56 and 57 may be defined by rigid vertical walls 58 and may each contain a plurality of floating liquid cooling apparatus units 78, which may be of the types shown in any of the preceding figures.

Alternately, however, such units 78 may be constructed as illustrated in FIGS. 9 and 10. These alternate units provide an arrangement in which the floating spray units may also position and support the upper edges of flexible barrier wall members 58A to define the reservoir areas and channels described and shown in FIG. 8. Thus a typical unit 78 is shown with bouyant or floating supports 79 and carries a suitable power unit 81 such as an electric motor which may be controlled from a remote point. Power unit 81 drives a horizontal shaft 82 on which are mounted at least two or more disks 17 which provide a plurality of liquid distributing spray surfaces essentially similar to the surfaces on the spray member of FIGS. 1 to 4. These rotary water cooling disks 17 are located in separate troughs 83 which are similar in their function and operation to the trough 24 of FIG. 1. Just as in the device of FIGS. 1 through 4, the sidewalls of these troughs are provided with conduit means or openings 84 which permit the flow of hot liquid from the hot water channels such as 57 to the specified limited areas of the rotary spray surfaces. Thus the construction and operation of the spray members 17 of apparatus unit 78 is substantially similar to that of the liquid cooling apparatus of FIGS. 1 through 4, except that a single power unit in this case drives a plurality of spray members on a common shaft.

As further shown in FIGS. 9 and 10, the floating spray unit 78, or a series of such units extending along a desired channel 56 or 57 of FIG. 8, may be constructed to support the upper edges 86 of modified barrier wall members 58A made of flexible water impermeable material. The lower edges 87 of these wall members are designed to engage and be held down on the bottom 88 of the reservoir by suitable means, such as the addition of weights or sand (not shown) on or within the tubular sections shown at these lower edges.

At least a portion of each wall 58A is capable of flexing or folding, as shown at 89 in FIG. 10, to accom-

modate changes in reservoir liquid levels. Thus in FIG. 9, the liquid level indicated by line 90 is at its maximum height above reservoir bottom 88, and the wall members 58A are extended to their full vertical height. In FIG. 10, liquid level 90 is relatively lower, and the folding of the walls at 89 accommodates this difference in level, while maintaining the desired barrier to retain heated effluent within channels 56 or 57, until the liquid can be sprayed by units 78 to the adjacent channels of the second or cooled liquid area of the reservoir.

Spray apparatus units 78 include a further feature, as shown in FIGS. 9 and 10. Thus each unit has an upper spray catching surface 91 which essentially covers the top of the unit and the surface area of channels 56 and 57, except for troughs 83 and spray members 17. This spray catching surface is thus adapted to receive drops projected by members 17 which might otherwise fall back into the first reservoir area. Surface 91 is inclined, as particularly shown in FIG. 10, to provide means discharging the collected liquid laterally into the adjacent channel 66 of the second reservoir area.

As illustrated in FIG. 8, each of the channels 56 and 57 has a substantial number of spray units, the number and capacity of such units being selected to provide a spraying capacity adequate to transfer liquid by centrifugal projection from the first or hot water area of the reservoir to the second or cool water area of the reservoir at a volume rate equivalent to that at which the plant 52 requires cooling water. The barrier system described in connection with this layout effectively limits or prevents the transfer of hot liquid from the first area to the second area except by means of the centrifugal upward projection of the liquid in a manner designed to insure evaporative cooling while such drops are moving freely through the atmosphere under the combined effects of their initial projection velocities and the downward acceleration of gravity.

An additional feature of the system shown in FIG. 8 is that the barriers may be so designed (e.g. by extending rigidly above the maximum reservoir levels) as to permit the liquid to seek different levels in the respective hot water and cold water areas of the reservoir. Thus if hot water is discharged into the first area 55 at a greater volume rate than the spray units can transfer from the hot water channels to the adjacent cold water channels, the level in area 55 and the hot water channels may gradually go up until such time as the rate of hot water discharge into area 55 is reduced, or the overall feed rate of the spray units is increased to transfer a higher volume rate of water into the cool areas. The higher water level in the hot water areas can also be utilized for automatic control of the number of spray units 78 which are energized, or of the volume rate of transfer by the individual spray units, or a combination of such factors.

A preferred modification of the system shown in FIG. 8 is illustrated in FIGS. 11 and 12. In the device of FIG. 11 (which is a view similar to FIG. 10) the barrier wall members 122 and 123 which separate the respective first and second areas of the reservoir are of essentially rigid construction and extend from the bottom of the reservoir upwardly to a point well above the expected maximum water level 124 in the second area of the reservoir, i.e. the area containing the cooled liquid. These barrier wall members may accordingly provide

at least a portion of the supporting means for the spray unit 121. As in the device of FIG. 10, spray unit 121 includes a plurality of individual rotary spray members 17 which are driven for rotation in one direction around the axis of a horizontal supporting or drive shaft 125. Each spray member 17 is supported within a suitable trough or casing which has a bottom wall 126. According to a feature of this preferred modification of the invention this bottom wall 126 is provided substantially at its lowest point 127 with a limited opening 128, for a purpose described below. Feed openings 129 in the sidewall 131 of the casing or trough for each spray member 17 are located and adapted to permit gravity flow of liquid to the desired limited areas of the rotary spray member 17, whenever the water level in this first area of the reservoir is high enough so that feed openings 129 are submerged. Such a normal water level as shown at 132, and this normal water level in the first area of the reservoir is substantially higher than the maximum water level shown at 124 in the second area of the reservoir.

The construction just described is such that the spray units 121 are supported at a level in this first area of the reservoir which is high enough to maintain all portions of the spray members at a level somewhat above the maximum water level 124 in the adjacent second area of the reservoir. In effect, the combination of the rigid barrier wall members 122 and 123, and the particular feeding means for the liquid to be cooled, maintain a substantially higher water level at 132 in the first area of the reservoir during normal operation of the system. This preferred embodiment, moreover, includes means for selectively lowering the water level in the first area of the reservoir so that either one of two objectives can be accomplished. First of all, a limited lowering of the water level 132 decreases the vertical "head" at which liquid is fed by feed openings 129 to the rotary spray members 17. If the level 132 is lowered far enough, some portion of openings 129 may even be above the liquid level and thus be ineffective to feed liquid to members 17. Thus the total volume of liquid which is centrifugally atomized and projected by member 17 can be reduced.

Secondly, and as a further possible objective, the liquid level 132 in the first area of the reservoir may be selectively lowered all the way down to at least the maximum water level 124 shown in the second area of the reservoir. In such a case, any liquid remaining within the spray units 121 above the bottom trough walls 126 would readily drain through bottom openings 128. Thus all portions of spray units 121 would be drained, and the spray units 121 would be entirely out of effective operation. Such an arrangement might be desirable during periods of shut-down, particularly if there were any risk that climatic conditions might cause freezing of liquid within the units 121 while the plant was shut down and the liquid had an opportunity to cool by normal environmental conditions to a temperature below the freezing point.

In this case the means for selectively lowering the water level is illustrated as adjustable valve means in the barrier wall 123. This wall is accordingly provided with a suitable opening 144 at a level below the water level 124, and preferably lower than the lowest expected operating level in either area of the reservoir.

Valve opening 144 is closed by vertically movable and adjustable valve plate 146. This valve plate 146 can be adjusted vertically within guides 147 and 148. In its lowermost position, the plate 146 will project downwardly below the lower edge 149 of opening 144 and completely close the opening. In that case the operating water level 132 in the first area of the reservoir between barrier walls 122 and 123 will be determined as desired by the level at which liquid effluent is fed into this first reservoir area by the feeding means.

To provide for selective opening of the valve mechanism, vertical racks 151 are provided on valve plate 146. These racks are engaged and driven by pinions 152 on a control shaft 153 supported in bearings 154. These bearings are carried by a suitable valve frame or body member 156 secured to barrier wall 123. An electric motor 157, or other suitable power source may be energized to move the valve selectively between a fully closed position and any one or more desired partially or fully opened positions. During normal plant operation, for example, if only a limited degree of cooling of the liquid effluent between barrier walls 122 and 123 is required, valve member 146 may be partially opened to permit some limited direct flow of effluent from the first area to the second area of the reservoir, without requiring all of such liquid to be transferred by the spraying action of units 121. In most cases, however, as previously noted in this specification, the valve member 146 would be kept fully closed in order to achieve maximum evaporative cooling, by permitting liquid to be transferred from the first area to the second area of the reservoir only by the spraying action of rotary members 17.

According to the foregoing specification, the nature and background of this invention have been set forth, and some of the ways of practising the invention have been described, with emphasis on the preferred embodiments presently contemplated as the best mode carrying out such invention.

What is claimed is:

1. A system for treating hot liquid effluent at a predetermined high volume rate of flow, said treating system comprising a liquid reservoir having its upper surface exposed to the atmosphere, means for feeding said hot effluent to a first area of the reservoir outlet means for removing cooled effluent from a second area of the reservoir barrier means separating said first and second reservoir areas, and spraying means in said one area for spraying fine drops of the liquid effluent freely into the atmosphere above said reservoir in a direction, velocity and drop size providing evaporative cooling of the liquid by exposure of the drops to said atmosphere and also providing for projection of falling drops into the second area of the reservoir, said spraying means including a plurality of rotatable spray members having vertical spray surfaces and supported at the surface of said reservoir in said first area for rotation on a horizontal axis, and means for rotating said spray members and centrifugally projecting said drops upwardly from the surface of the reservoir.

2. A system according to claim 1 in which said spraying means comprises a plurality of spray apparatus units, means supporting said spray apparatus units at the surface of the liquid in said one area of the reservoir, and each spray apparatus unit having a plurality of

said rotatable spray members each provided with at least one liquid distributing spray surface, means supporting the spray members of each unit for rotation on an individual unit axis intersecting and perpendicular to the spray surfaces of that unit, with said spray surfaces, extending partly beneath the surface of the liquid in said one area, and means for feeding liquid from said one area of the reservoir to a limited area of each spray surface below the point of intersection of its axis and said spray surface.

3. A system according to claim 2 in which said means supporting said spray apparatus units comprises float means, and said system having barrier wall members preventing the free flow of effluent from said one area to said second area except for projection by said spraying means, said barrier wall member having upper edges supported by said spray apparatus units, lower edges engaging the bottom of said reservoir, and intermediate flexible portions providing a variable vertical height for said barrier wall members for different liquid levels in the reservoir.

4. A system according to claim 2 in which at least one spray unit has an upper spray catching surface for receiving drops projected by said spray members which fall back above said one area of the reservoir, said spray catching surface including means discharging into the second area of the reservoir the drops which fall back onto the spray catching surface.

5. A system according to claim 2 having barrier wall members which extend rigidly above the maximum water level in the second reservoir area and provide at least a portion of the means supporting the spray apparatus units, said spray units being supported at a level in said one area of the reservoir such that all portions of the spray members are higher than the maximum water level in the second reservoir area, said feeding means and barrier wall members normally maintaining a higher water level in said one reservoir area than in the second area, and said system having means for selectively lowering the water level in said one area to a level at which each spray member is entirely above and out of contact with the liquid level in said one area.

6. A system according to claim 5 in which the means for selectively lowering the water level in said one area comprises adjustable valve means in at least one barrier wall member.

7. A system for treating hot liquid effluent at a predetermined high volume rate of flow, said treating system comprising a liquid reservoir, spraying means in one area of said reservoir for projecting fine drops of the liquid effluent freely into the atmosphere above said reservoir in a direction velocity and drop size providing evaporative cooling by exposure of the drops to said atmosphere while the drops are above the reservoir and free to fall into it, feeding means for feeding said hot effluent to the spraying means at said volume rate, outlet means for removing effluent from the reservoir, and barrier means normally preventing the free flow of hot effluent to said outlet means except through said feeding means and spraying means.

8. A system according to claim 7 in which said feeding means feeds said hot effluent directly to said one area of the reservoir, said outlet means removes cold effluent from a second area of the reservoir, said spraying means provides for projection of falling drops into

the second area of the reservoir, and said preventing means includes barrier wall members in said reservoir preventing the free flow of effluent from said one area to said second area except for projection by said spraying means.

9. A system according to claim 8 in which said barrier wall members permit the liquid effluent to assume different levels in said respective reservoir areas.

10. A system according to claim 5 in combination with an operating plant, in which said feeding means is connected to receive the hot liquid effluent from said plant, and said outlet means is connected to recirculate the cooled effluent to said plant.

11. A system according to claim 9 in which said barrier wall members define a plurality of elongated, spaced, parallel, channels for said one area of the reservoir and a plurality of intermediate, elongated, spaced, parallel, channels for the second area of said reservoir, said wall members providing a barrier extending vertically throughout the reservoir and thereby preventing movement of liquid from the one area to the second area except by spraying of said liquid over said wall members.

12. Liquid cooling apparatus for upward projection of fine drops of liquid comprising a spray member having at least one liquid distributing spray surface, means supporting the spray member for rotation on an axis intersecting and perpendicular to said spray surface, with said spray surface extending at an angle to the horizontal, driving means for rotating said spray member in one direction around said axis, and means for feeding liquid to said spray surface, in which said means for feeding liquid directs the liquid to a limited area of said spray surface below the point of intersection of said axis and said spray surface, and in which said supporting means maintains the spray member at a predetermined relative vertical height with respect to the normal surface level of a body of liquid from which the apparatus is adapted to project said drops, said spray member having said limited area of its spray surface lower than said normal surface level, said apparatus including a trough having walls defining a separate space extending above and below said normal surface level and within which trough said spray member may rotate, and said means for feeding liquid including a passageway communicating with the body of liquid and directing such liquid against said limited area of said spray surface.

13. Liquid cooling apparatus according to claim 12 having means for variable adjustment of the speed of rotation of said spray surface.

14. Liquid cooling apparatus according to claim 12 in which said spray surface is a circular plane surface having a plurality of spiral guide portions thereon extending radially outwardly from inner points located near said axis, said guide portions curving forwardly in the direction of rotation along a path determined by the equation

$$r = k\theta,$$

in which r is the radius in inches from said axis, θ is the angle in radians ahead of the point of origin of the spiral at said axis, and k is a constant in the range from 7 to 12 inclusive.

15. Liquid cooling apparatus for upward projection of fine drops of liquid comprising a spray member having at least one liquid distributing spray surface, means supporting the spray member for rotation on an axis intersecting and perpendicular to said spray surface, with said spray surface extending at an angle to the horizontal, driving means for rotating said spray member in one direction around said axis, and means for feeding liquid to said spray surface, in which said means for feeding liquid directs the liquid to a limited area of said spray surface below the point of intersection of said axis and said spray surface, and in which said apparatus includes a floatable support member for maintaining the spray member at a predetermined relative vertical height with respect to a liquid surface on which the support member and apparatus are adapted to float, said spray member having said limited area of its spray surface lower than the level of liquid on which the apparatus is adapted to float, said apparatus including a trough having walls defining a separate space extending above and below the liquid level and within which said spray member may rotate, and said means for feeding liquid including a passageway communicating with the liquid on which the apparatus is adapted to float and directing such liquid against said limited area of the

spray surface.

16. Liquid cooling apparatus according to claim 15 in which said spray member is a circular plate with two parallel spray surfaces, and in which said axis is horizontal and said spray surfaces are vertical.

17. Liquid cooling apparatus according to claim 16 having a plurality of said spray members supported for rotation on said axis and operatively connected for simultaneous rotation by said driving means.

18. Liquid cooling apparatus according to claim 15 in which said spray member surface has a plurality of guides radiating from said point of intersection of said axis and said surface.

19. Liquid cooling apparatus according to claim 18 in which said guides include ribs projecting from said surface.

20. Liquid cooling apparatus according to claim 18 in which said guides include recessed channels in said surface.

21. Liquid colling apparatus according to claim 18 in which said guides extend along a spiral pattern, which extends outwardly from said point of intersection and forwardly in the direction of rotation.

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