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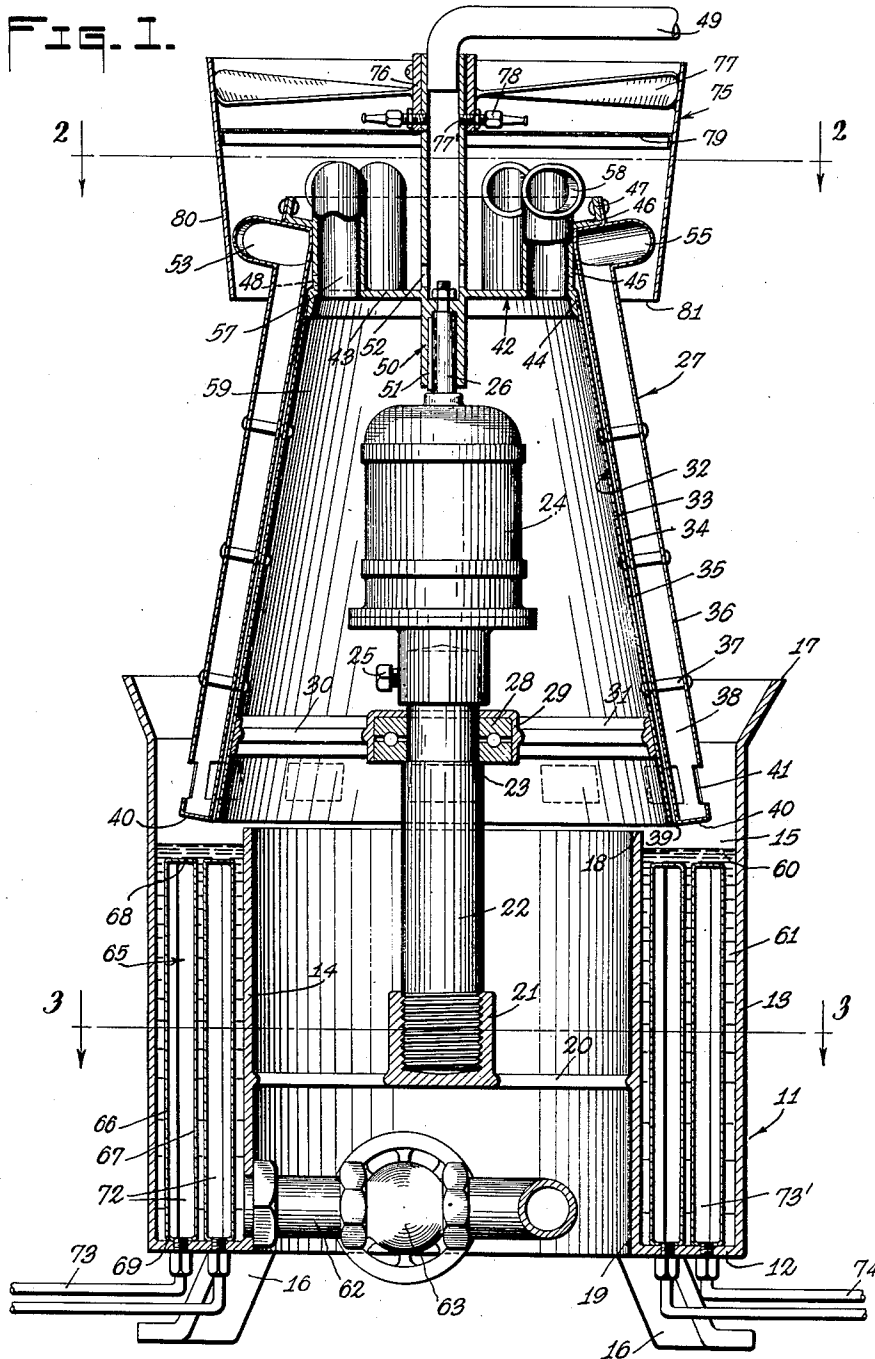
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2,092,249

COOLER FOR LIQUIDS AND GASES

Filed April 25, 1934

3 Sheets-Sheet 1



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FIG. 2.

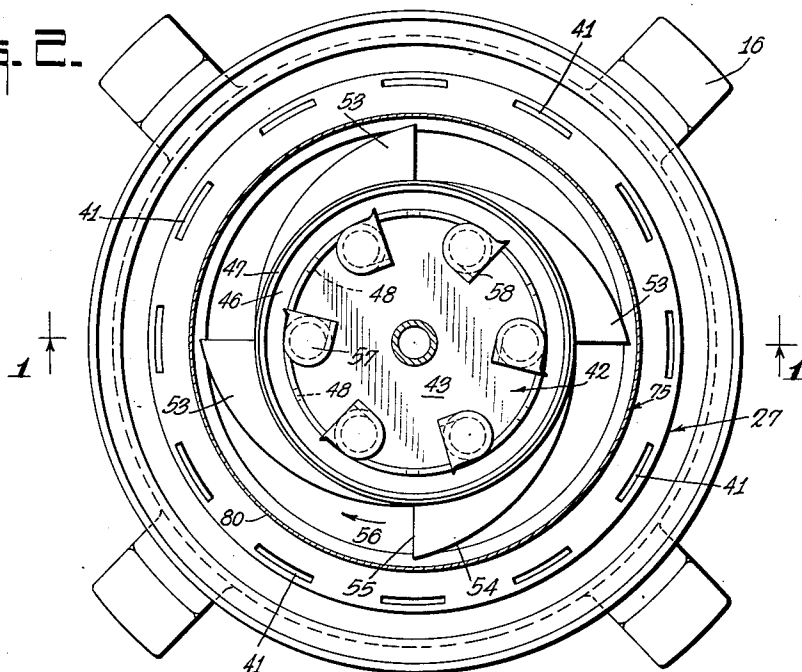
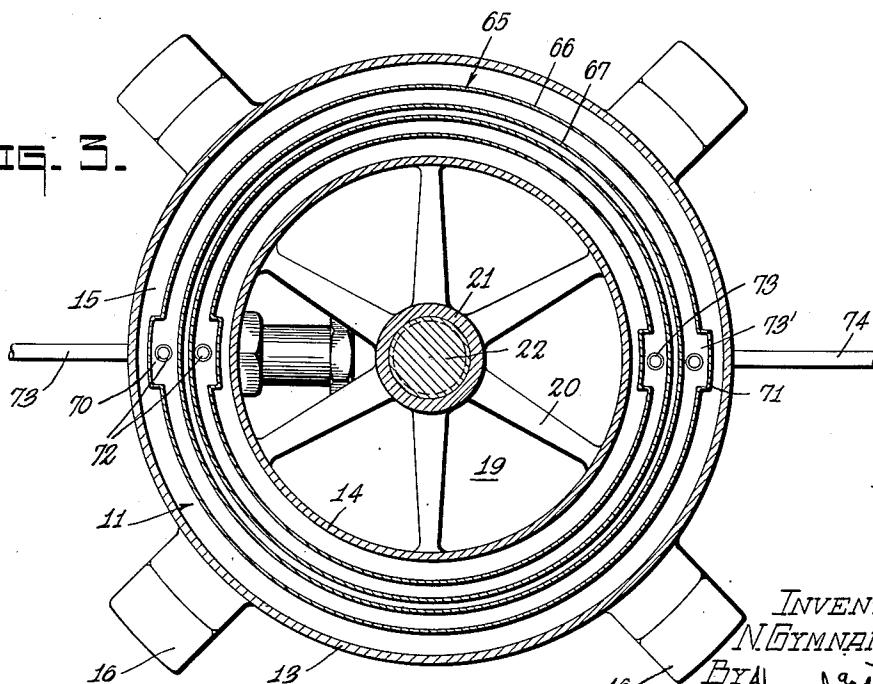


FIG. 3.



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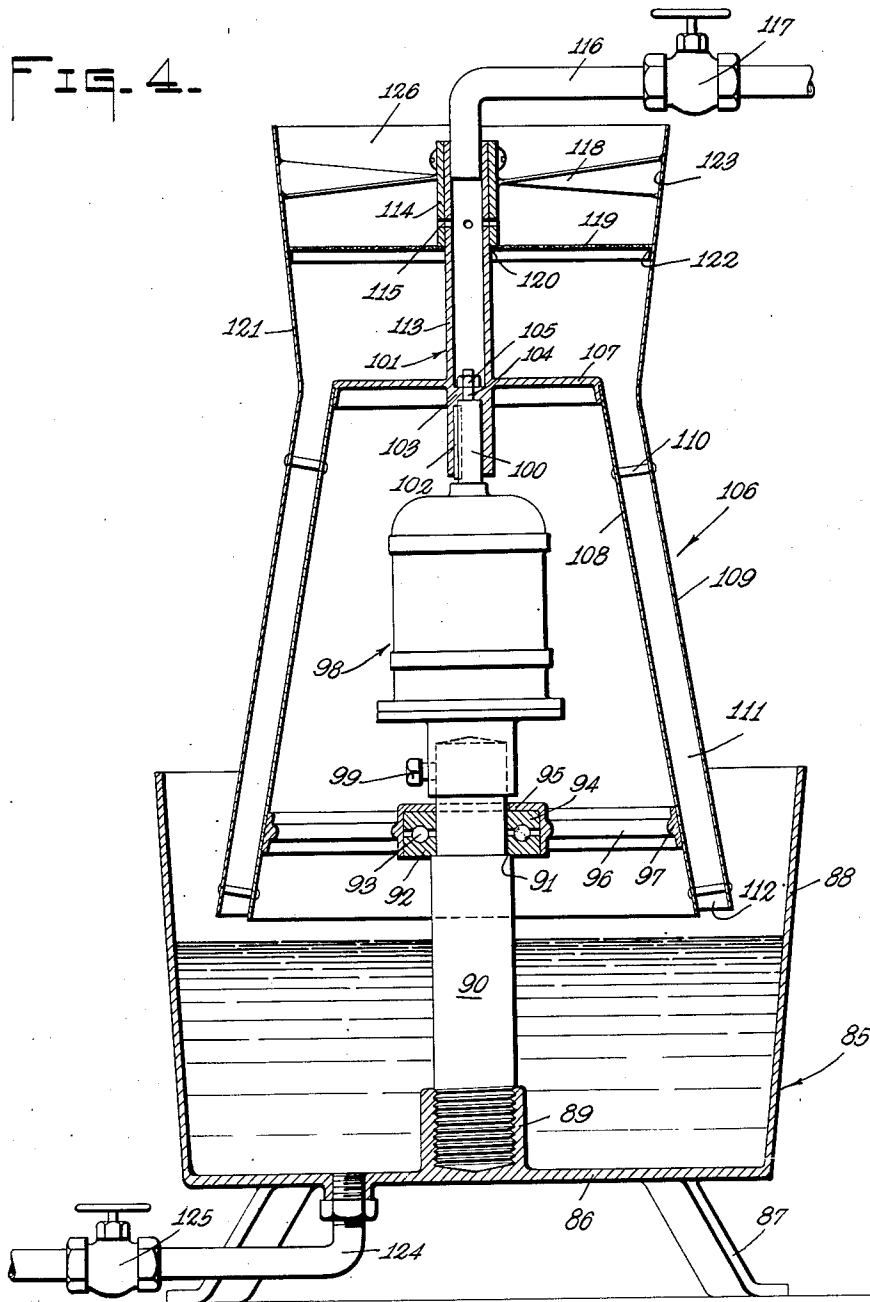
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FIG. 4.



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UNITED STATES PATENT OFFICE

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COOLER FOR LIQUIDS AND GASES

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Application April 25, 1934, Serial No. 722,307

21 Claims. (Cl. 261—112)

An object and feature of my invention is the construction of a cooler and method of cooling both liquids and gases in which the liquid or gases are passed through one element of a rotating cooler device in a thin film. Further, the cooler device is rotated so that the thin film flows in a downward direction by centrifugal action, thus, although the film may be very thin in cross section it forms an annular body forming a frustrum of a cone with the large or discharge end at the bottom. Therefore, the gases or liquids being cooled, due to the outward throw by centrifugal action, flow downwardly and are discharged at the bottom of the cooling element.

The cooling element is made in the form of a hollow frustrum of a cone and on the outside has an outer annular chamber also forming a frustrum of a cone through which air is driven, this air being caught at the top by scoops or buckets and forced downwardly through the outer air chamber. In addition, a series of rotating air intakes at the top force a stream of air downwardly inside of the cone-shaped cooler chamber. The walls which confine the liquid or gases to be cooled are quite thin so that a large surface is exposed on both the outside and the inside of the liquid or gas chamber to the cooling action of the air currents.

A further detailed feature of my invention comprises mounting the cooler unit with the assembly of the cone-shaped liquid or gas chamber and the outside cooling air chamber on a single central column or post which post also supports an electric motor for driving the assembly of units on a vertical axis.

Another and further feature of my invention as it relates to a liquid cooler is collecting the cooled liquid from the rotary centrifugal cooler in an annular liquid receptacle. In this liquid receptacle there are hollow ring-shaped structures immersed in the liquid and thus subjected to a cooling action, and liquids or gases which could not be cooled by contact with the air are chilled by the transference of heat between the hollow rings and the cool liquid in which they are immersed. A continuous flow is maintained through the hollow cooling rings which are in the form of annular hollow chambers and may be nested together in the annular liquid receptacle. There is also a continuous flow of the cooling liquid which is chilled by the centrifugal cooling unit.

Another object and feature of my invention is the provision of an air humidifier which moistens the air used on the inside and on the outside of

the rotary liquid cooler. This humidifier preferably uses a screen on which water is sprayed and a fan blows the air and water through the screen to the rotary cooler. The screen and fan are preferably located above the rotor cooler and attached to the liquid reservoir supplying the cooler. The fan and screen rotate with the rotary liquid cooler.

Another object and feature of my invention is the combination of a liquid cooler with an air humidifier in which the water to be cooled is blown through a screen to distribute the water in intimate contact with the air and this water and air is then passed downwardly over a centrifugal cooler having a rotatable inner skirt formed as a frustrum of a cone and an outer shell spaced therefrom forming an annular space through which the water with the air is driven, both the water and the air being subject to centrifugal action and being brought into intimate contact.

A characteristic feature of my invention is that while, for instance, water or other liquid being cooled flows downwardly while confined in a cone-shaped passage of larger diameter at the bottom and in which the structure forming the passage is rapidly rotated, the centrifugal force or action on the liquid causes this to whirl or rotate with the conical passage structure. In addition due to the component of the centrifugal force, there is developed a positive downward flow, the centrifugal force acting on the cone-shaped structure, the apex of which is uppermost. In addition a certain amount of air enters the annular cone-shaped space for the liquid and hence performs a function by cooling the liquid in direct contact. The downward component due to the centrifugal action of the liquid operates with the force of gravity to develop a positive downward flow of the liquid, even when it is maintained in a very thin film and thus the cooler has a large capacity as to the quantity of liquid which may be cooled.

My invention is illustrated in the accompanying drawings, in which:

Fig. 1 is a vertical section taken on the line 1—1 of Fig. 2 in the direction of the arrows, the supporting column and motor being shown in elevation.

Fig. 2 is a plan taken on the line 2—2 of Fig. 1 in the direction of the arrows.

Fig. 3 is a horizontal section on the line 3—3 of Fig. 1 in the direction of the arrows.

Fig. 4 is a vertical section through a further

modification in which the air and water is forced through the centrifugal cooler.

In my invention I employ a substantially cool liquid receptacle 11 which is illustrated as having a base or floor 12, an outer wall 13, and an inner wall 14, thus forming an annular receptacle 15. The receptacle is indicated as being mounted on legs 16. The upper edge of the outer wall 17 extends above the upper edge 18 of the inner wall. There is thus a large central vertical opening 19 inside of the inner wall 14 to accommodate a downward flow of cooling air, as hereinunder described. A spider structure 20 is constructed inside of the inner wall 14 and attached thereto and this has an internally threaded socket 21. In this socket there is mounted a column 22, the column being threaded at its lower end, having a shoulder 23. At the top of the column an electric motor 24 is secured in place, being attached by a set screw 25. The rotary shaft 26 of motor 24 extends above the upper end of the motor and is in vertical alignment with the column.

A rotary air cooled device designated by the assembly numeral 27 is constructed as follows:

An anti-friction bearing 28 is mounted on the column 22, one of the races engaging the shoulder 23. An inverted cup 29 engages the upper race and has a spider 30 formed integral therewith. This spider has a ring 31 at its outer periphery. A cone-shaped cooler structure 32 is formed with an inner wall or skirt 33, an outer parallel wall or skirt 34, leaving a narrow, annular space 35. The outer cone-shaped wall 36 is parallel to the walls 33 and 34, these walls being held together and properly spaced by a series of rivets 37. This leaves an annular space 38 for the downward flow of air. There is an annular opening 39 at the lower end of the walls 33 and 34 forming a discharge from the cooling space 35. A closure ring 40 connects the lower edge of the wall 34 and the outer wall 36. This outer wall is provided with a plurality of openings or windows 41 for the outward flow of air.

A reservoir construction designated by the assembly numeral 42 is mounted at the top of the air cooled device 27. This reservoir has a base 43 with a flange 44 secured to the upper edge of the inner wall 33. An outer cylindrical wall 45 extends upwardly from the base. It is provided with an outwardly flared section 46 and a flange 47 secured to the upper edge of the outer wall or shell 36. A series of perforations 48 allow water or other liquid which is discharged into the reservoir by the feed pipe 49 to flow outwardly into the narrow space 35 between the walls 33 and 34 and thus flow downwardly.

It will be apparent that as the thin film of water flows outwardly over the base 43 and through the perforations 48 that a certain amount of air will be carried into the cone-shaped annular space between the inner wall 33 and the outer wall 34, thus having a cooling action.

The cone-shaped air cooled device is rotated by means of a sleeve 50 which has a socket 51 keyed to the motor shaft 26. The shaft and sleeve are attached by means of a bolt and nut. The sleeve has an upper portion which extends through the base 43 of the liquid reservoir: This upper portion of the sleeve has perforations 52 for the flow of water which is fed by the water pipe 49' discharging in the upper end of the sleeve.

At the upper end of the annular air passage 38 there are a plurality of air scoops 53. These scoops are flared outwardly as indicated at 54

and each have an enlarged opening 55 so that when the reservoir with the structure depending therefrom rotate in the direction of the arrow 56, this being illustrated in a clockwise direction, air is forced into the scoops 53 and downwardly through the annular passage 38 and discharged outwardly through the lower openings 41.

An air flow through the inside is obtained by means of air pipes 57 which extend upwardly through the base 43 of the water reservoir and have intake funnels 58 at their upper ends extending above the water reservoir. These funnels are directed with their open ends facing in the direction of rotation of the rotor and thus catch the air and force this downwardly through the pipes 57 and through the interior space 59 inside of the inner wall structure 33, the air flowing downwardly over the motor 24, the column 22 passing through the spokes of the spider 30 being discharged at the lower portion of the rotor. A certain amount of this air will flow downwardly through the cylindrical passage 19 in the inside of the liquid receptacle 11 although some of this air will strike the surface 60 of the cooled liquid 61 in the liquid receptacle.

The manner of operation and function of the liquid cooler so far described is as follows:

The liquid feed into the reservoir 42 enters the narrow cone-shaped, annular space 35 between the walls 33 and 34 and the outside shell wall 36; the liquid is forced outwardly by centrifugal action which develops a suction action on the liquid in the reservoir. This liquid is discharged at the open lower end 38 of the passage 35 into the liquid receptacle 11. The liquid level in this receptacle is maintained substantially constant by having a delivery pipe 62 connected to the bottom of this receptacle, the pipe being shown as attached to the inner wall 14 and having a control valve 63 which may regulate the discharge of the cooled liquid, the rate of discharge being constant so as to maintain a constant liquid level, such as 60, in the liquid receptacle.

A large volume of air is caught by the scoops 53 and forced downwardly through the air passage 38 between the wall 34 and the shell wall 36. This air contacts with a large area of the wall 34 and develops a heat transfer action between the downwardly flowing air and the downwardly flowing liquid in the narrow space 35. The air from the annular passage 38 has a free discharge through the openings 41 and thus a large volume of air may be utilized for cooling the outside surface of the thin, cone-shaped ring of liquid.

A cooling action is also obtained on the inside wall 33 by the air which is caught by the funnels 58 and forced downwardly through the pipes 57 and through the inner space 59 surrounding the electric motor and the column 22. This air develops a swirl in its downward movement and thus a large volume of air is brought into contact with the wall 33 and forms a heat transfer agent between the thin cone of liquid in the liquid passage 35 and the air on the inside of the wall. Some of this air, as above described, strikes the surface 60 of the liquid and is discharged upwardly over the rim 17 of the outer wall 13 of the liquid receptacle, the main bulk of air, however, crossing downwardly through the open space 19 inside of the liquid receptacle.

The cooler for liquids or gases which cannot be cooled in contact with the air is by the employment of a stack of hollow cooling rings 65. These each have annular outer and inner sur-

faces 66 and 67 with tops and bottoms 68 and 69 and are in the form of hollow rings inserted in the liquid receptacle 11 between the annular outside wall 13 and the inside wall 14 and immersed in the cold liquid 61. Each of these has an enlarged inlet section 70 and a smaller outlet section 71. At the inlet section of each ring there is a vertical inlet pipe 72 connected through the base 69 of the ring and the base 12 of the liquid receptacle with an inlet pipe 73. The vertical pipe has a series of perforations for distributing the liquid or gas the full height of the hollow ring. At the outlet enlargement 71 there is also a vertical pipe 73' with perforations connecting through the base of the ring and the base of the receptacle with the draw-off pipe 74. The liquids or gases to be cooled in the hollow rings are thus forced through the perforations in the inlet pipe and flow in both directions around each hollow ring and the cold liquid is drawn off through the vertical perforated pipe 73 and the draw-off pipes 74. In this manner the liquid, such as water, may be cooled in the rotary cooler and used to cool the gases or liquids in the hollow annular rings.

The cooling action of the air in the shell 36 is caused partly by the expansion of this air as it is caught by the scoops 53 and then subjected to the centrifugal action of the rapidly rotating shell. As the air descends in the shell it is forced outwardly by the centrifugal force and on account of the air having a free discharge at the bottom of the shell the air becomes expanded and, hence, functions to extract heat from the liquid in the narrow chamber 35 between the inner and outer walls 33 and 34. In addition, the air entering in the center through the pipes 57 is given a swirling motion as these pipes are rotating. In addition, the friction of the air against the inside wall 33 continues this swirling action and forces the air outwardly due to centrifugal action, developing an expansion of the air toward the bottom of the rotor compared with its density at the intake through the pipes 57. This causes a cooling action on the inside wall 33 and extracts heat from the liquid in the narrow space 35.

In addition to the above described cooling arrangements, I make provision for an additional cooling in hot dry weather by means of the air humidifier designated by the assembly numeral 75. This employs a collar 76 which may be attached to the upper end of the sleeve 50 and has a plurality of radial fan blades 77. The sleeve has a plurality of perforations 77' which may normally be closed by plugs if the humidifier is not to be used, but if it is used, discharge nozzles 78 are aligned with these perforations for removing the plugs. These nozzles are adjustable to give a horizontal water spray which discharges on a wire mesh screen 79. This screen is secured at its inner edge 80 to the lower edge of the collar 76 and which is attached at its outer edge to a downwardly tapered flat ring 80 which is secured to the outer end of the fan blades. This ring has its lower edge 81 extending below the scoops 53 preferably being as close to these as is possible.

The manner of operation and functioning of the air humidifier is as follows:

The water flowing in through the pipe 52' is sprayed horizontally by the adjustable spray nozzles 78 and spreads over the screen 79. The rotating fan blades which rotate with the sleeve drive the air downwardly through the wire mesh

and thus carry a water mist. This mist is caught by the scoops and funnels and carried through the shell and through the interior part of the rotating cooler. This action cools the air so that it makes a better cooling medium and moreover, a certain amount of the water is deposited on the inside and outside walls 33 and 34 by the liquid cooler, and when evaporating due to the current of air, extracts heat from the liquid undergoing the cooling operation. A certain amount of water may be caught at the upper end of the liquid receptacle and drop therein but this water will be chilled and hence aid in the cooling effect on the liquid in the annular coolers immersed in the liquid receptacle.

In the construction of Fig. 4, I utilize a water receptacle 85 which is illustrated as having a base or floor 86 supported on the legs 87 and a side wall 88, the receptacle being preferably formed circular. On the base there is a threaded socket structure 89 in which is supported a column 90, the column being threaded at the bottom into the socket. The column has a shoulder 91 on which rests a lower race 92 of an anti-friction bearing 93. The outer race 94 supports an inverted cup-shaped hub 95 from which radiate spokes 96 to a ring 97. The hub, ring, and spokes form a spider construction.

On the outer end of the column an electric motor 98 is mounted, the fixed housing of the motor being clamped by set screw 99. The rotor of the motor has a rotatable shaft 100 extending upwardly in axial alignment with the column 90. A sleeve 101 has its lower end 102 keyed to the motor shaft 100. This sleeve is provided with a transverse partition 103 through which extends a bolt end 104 of the motor shaft and the sleeve.

The rotated cooler has a head 107 preferably formed integral with the sleeve, and depending from this head there is an inner skirt-like wall 108 which forms a frustum of a cone. The lower portion of this skirt is secured to the ring 97. Thus the skirt of the rotor is rotated by the motor shaft and held in a concentric position as to the column 90 by the hub 95 and the anti-friction bearings 93.

Secured in spaced relation to the skirt 108 there is a shell 109 attached to the skirt by rivets 110, or the like, thus leaving an annular cooling space 111 which forms a frustum of a cone and is open at its lower end 112. The lower end of the cooler extends a considerable distance below the top of the wall 88 of the water receptacle 85. The sleeve has an upward extension 113 to which is secured a collar 114 to rotate with the sleeve. The sleeve and collar are provided with a series of apertures 115 for the outward flow of water from the sleeve, this water being supplied by an inlet water pipe 116 having a control valve 117. Secured to the collar there are a series of fan blades, 118 and below these blades there is a water screen 119 preferably formed of wire mesh fabric secured at its inner edge 120 to the lower part of the collar 114. Preferably formed integral with and extending above the shell 109 there is a casing 121. The outer periphery of the screen is secured to this casing at 122 and the blades are also secured to the casing 123. Thus the casing is rotated with the blades and the screen. The bottom of the water receptacle is provided with an outlet pipe 124 having a control valve 125. The upper end of the casing thus has a large opening 126 for the in and down flow of air.

The manner of operation and functioning of the cooler of Fig. 4 is as follows:

Manifestly, as the motor is operated and its shaft 100 rotated, the cone-shaped cooling unit 106 is rotated as is also the casing 121 and the fan blades 118. The water discharged from the perforations 115 spreads over the screen 119 and is forcibly driven through this screen by the air current from the fan 118. Any water that is discharged on the closed head 107 flows outwardly by centrifugal action and downwardly through the annular passage or space 111 between the apron 108 and the shell 109. The air blown downwardly by the fans is also driven through this space. On account of the rapid rotation of the rotor most of the water is driven outwardly by centrifugal action against the inside of the shell 109. It also flows downwardly by gravity. The air is also forced outwardly by centrifugal action and downwardly by the air pressure due to the fan 118. This brings the air in intimate contact with the water, evaporating a considerable amount of the water and thus cooling the water which is not evaporated. This water with the air is discharged through the lower end 112 of the water cooler, the water being collected in the water receptacle 85 and the air, after a reverse flow, discharging over the top of the wall 88. The flow of the moist or humidified air spreads outward laterally so that relatively dry air is taken in through the air intake 126.

As there is a downward and circular flow of air in the cone-shaped rotating liquid space of Figs. 1 and 4, this action facilitates the cooling of the liquid, which liquid develops a rotating motion due to the centrifugal action of the rotary cooling structure and hence develops an intimate direct contact of the liquid and air.

Various changes may be made in the details of construction without departing from the spirit or scope of the invention as claimed.

I claim:

1. A cooler having a vertical shaft, a water reservoir mounted on top of said shaft, means to rotate the shaft and the reservoir, a hollow cone-shaped rotor secured to the reservoir and having inside and outside walls spaced in close proximity, inlets from the reservoir to said space, the rotor being outwardly flared downwardly, a liquid receptacle to receive the cooled liquid discharged downwardly and outwardly, and means to blow air over the inside and outside surface of the rotor.

2. A cooler as claimed in claim 1, the means to blow air downwardly on the outside of the rotor comprising an outer shell on the rotor, and scoops at the top of the shell to drive air through the shell from the top to the bottom.

3. A cooler having a vertical column, an electric motor mounted thereon, a vertical shaft driven by the motor, a water reservoir secured to the upper end of the shaft, a hollow cone-shaped rotor secured to the reservoir and having parallel, cone-shaped inner and outer walls slightly spaced apart, a liquid connection between the reservoir and the upper end of the hollow rotor, the lower end of the rotor being open, and a water receptacle to receive water discharged from the lower end of the rotor.

4. A cooler as claimed in claim 3, a shell secured to the outside of the rotor and forming a cone-shaped annular space, air scoops at the top of the shell to blow air through said space, said shell having air outlets at the bottom.

5. A cooler as claimed in claim 3, pipes extend-

ing upwardly through the reservoir and having funnels positioned to blow air downwardly through the hollow rotor past the motor and said column.

6. A cooler having a liquid receptacle, a column supported thereby, a motor on the column having a vertical rotary shaft, a liquid reservoir secured to the shaft, a cone-shaped hollow rotor extending downwardly from the reservoir and having inside and outside walls spaced a small distance apart, the reservoir having inlets to said space, there being a discharge opening at the bottom of the rotor from said space, and means to flow air by the action of the rotor and the rotating reservoir into contact with the inside and outside surfaces of the rotor.

7. A cooler as claimed in claim 6, the means to flow the air comprising a shell secured to the outside of the rotor having discharge openings at the bottom and scoops at the top to blow air through the space between the shell and the rotor, and pipes extending upwardly through the reservoir and having funnels to blow air downwardly around the motor and column and in contact with the inside surface of the rotor.

8. A cooler as claimed in claim 6, said liquid receptacle being annular with an opening through the center, the means to flow the air driving a portion of the air in contact with the inside surface of the rotor and through the opening of the liquid receptacle.

9. A cooler as claimed in claim 6, said liquid receptacle located below the discharge end of the rotor, a hollow ring-like cooling structure in the liquid receptacle and having a vertical inlet pipe with discharge openings at one side, and a vertical outlet pipe with discharge outlets at the diametrically opposite side.

10. A cooler as claimed in claim 6, said annular liquid receptacle being annular and having vertical inside and outside walls positioned below the rotor forming a support for the column, and a hollow cooling chamber in the water receptacle, said chamber having vertical inside and outside walls parallel to the walls of the liquid receptacle and having a vertical inlet pipe on one side with inlet openings and a vertical outlet pipe on the opposite side with outlet openings.

11. A liquid cooler comprising in combination, a rotary cooling element having a skirt forming a frustum of a cone with the large end down, a closure head at the top, a shell structure positioned outside of the skirt and forming with the skirt an annular passage, means to rotate the skirt and the shell, means to discharge water downwardly above the said closure head, means to blow air to mix with the water and blow the water and air through the space between the shell and the skirt.

12. A water cooler having a liquid reservoir at the top, means to rotate the reservoir on a vertical axis, a cone-shaped cooler rotor having inside and outside walls spaced a slight distance apart and with the small end attached to the reservoir, there being liquid passages from the reservoir to said space, there being a discharge at the lower and wide end of the rotor at the bottom whereby liquid descends through the cooling space by gravity and centrifugal force developed, a shell secured in spaced relation to the outside wall of the rotor and having scoops at the top for intake air and openings at the bottom for the discharge of air, the air inside the shell being acted upon by centrifugal force developed by the rotation of the rotor and shell.

13. A water cooler as claimed in claim 12, an air humidifier positioned above and secured to the reservoir to rotate therewith, having a wire screen, means to spray water over the screen and means to blow air downwardly through the screen, the downwardly blown air being caught by the scoops.

14. A cooler having a cone-shaped hollow rotor with thin inside and outside walls positioned close together and having the base downwardly, means to flow a liquid downwardly through the hollow rotor under the action of gravity and centrifugal force, and means to flow air over both the inside of the inside and the outside of the outside wall of the rotor.

15. A cooler comprising a rotor having a hollow cone-shaped structure with thin inside and outside walls close together to form a thin annular space, means to flow liquid downwardly in said space, said rotor rotating on a vertical axis, an inlet at the small end of the rotor at the top and an outlet for liquid at the bottom, whereby the liquid flows downwardly by gravity and centrifugal action, and means to blow air in contact with the inside of the inside and the outside of the outer wall of the rotor.

16. A cooler having a rotor with thin inner and outer non-porous cone-shaped walls spaced apart, said walls being concentric to the axis of the rotor, such axis being vertical, the space between the walls thus being conical and having the small end uppermost, such space being in a radial measurement much smaller than the diameter across the outer wall, there being an annular opening to the said space at the top to air and having an unobstructed opening at the bottom connecting directly to the atmosphere, means to rotate the rotor, means to supply a liquid to the top of the rotor, whereby liquid and air may flow downwardly in the said space, the rotation of the rotor being adapted to cause a rotational swirl of the liquid and thereby develop a centrifugal action, the downward component of the centrifugal force developed by pressure on the cone-shaped outer wall being adapted with the force of gravity to develop a positive downward flow of the liquid and discharge of liquid and air together from the bottom of the space, the air and the liquid being brought into intimate contact in the downward flow through the said space.

17. A cooler as claimed in claim 16, the said rotor having an opening, whereby the inside of the inner wall is exposed to air.

18. A cooler as claimed in claim 16, the said rotor having an opening for admission of air into contact with the inside of the inner wall and being mounted whereby in its rotation the outer wall is brought in contact with air on its outside to thereby effect a heat transference from the

said space through both the inner and outer walls.

19. A cooler comprising in combination a rotary cooling element having a non-porous skirt forming a frustum of a cone with the large end down, a non-porous shell structure positioned outside of the skirt and forming with the skirt an annular passage, said passage having an unobstructed opening at the bottom and at the top connecting directly to atmosphere, means to rotate the skirt and the shell, means to flow liquid and air downwardly through the said space, whereby the liquid and air develops a rotational flow relative to the axis of the rotary cooling element, the air and water being discharged together at the bottom opening.

20. A cooler having a cone-shaped rotor with a hollow inside wall and an outside wall spaced apart, the inside wall being exposed on the inside and the outside wall on the outside to circulating air, the walls thereby forming a cone-shaped annular space, there being an annular opening at the top for entrance of liquid and a substantially annular space at the bottom for discharging a liquid downwardly, the base of the cone-shaped structure being lowermost, means to flow a liquid downwardly through the said space during rotation of the rotor whereby the liquid develops a circular motion and a centrifugal action to bring the liquid in intimate and changing contact with the inside and outside walls, the downward component of the centrifugal action being operative with the force of gravity to cause a downward circulation of the liquid and its discharge at the bottom.

21. A cooler having a rotor with inner and outer cone-shaped walls spaced apart forming an annular passage, the base of the cone structure being lowermost, there being a substantially annular opening between the walls at the top of the said passage for unobstructed entrance of air and liquid, there being a substantially annular unobstructed opening at the bottom of said passage for the discharge of air and liquid, the liquid at the discharge being adapted to drop by gravity into a receptacle and the air being adapted to discharge to atmosphere, the opening at the upper end of the said passage being exposed for entrance of air, means to supply a liquid to the top of the said passage, means to rotate the rotor whereby a rotational swirl is developed in the liquid in the said passage and thereby develops a centrifugal action in the liquid, the downward component of the centrifugal force operating on the cone-shaped outer wall being adapted to develop a positive downward flow of the liquid, the downward flow of the liquid being adapted to draw air downwardly through the annular passage and discharge the liquid with the air at the opening at the bottom.

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