July 5, 1966 J. C. NIEMANN 3,259,177

LIQUID COOLER AND CONTROL THEREFOR

Filed June 25, 1963 3 Sheets-Sheet 1

FIG. 1

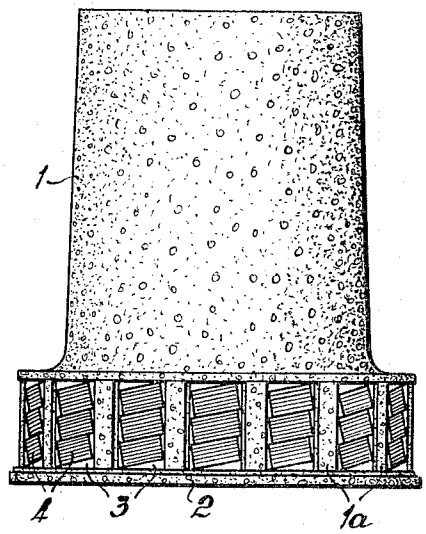
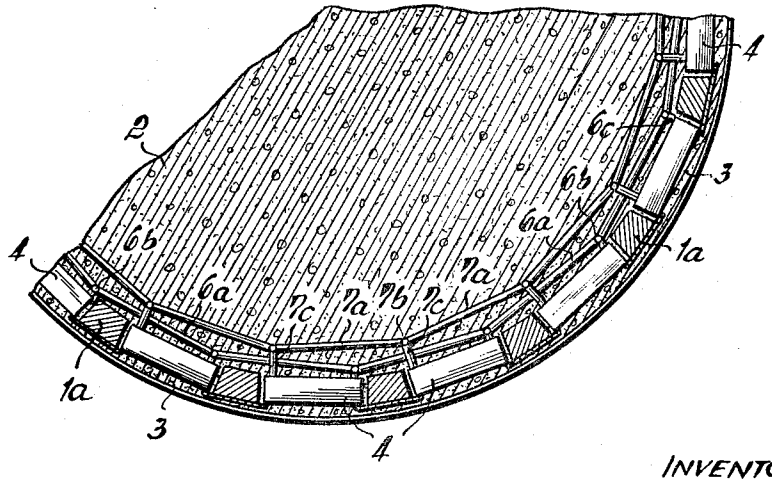


FIG. 3



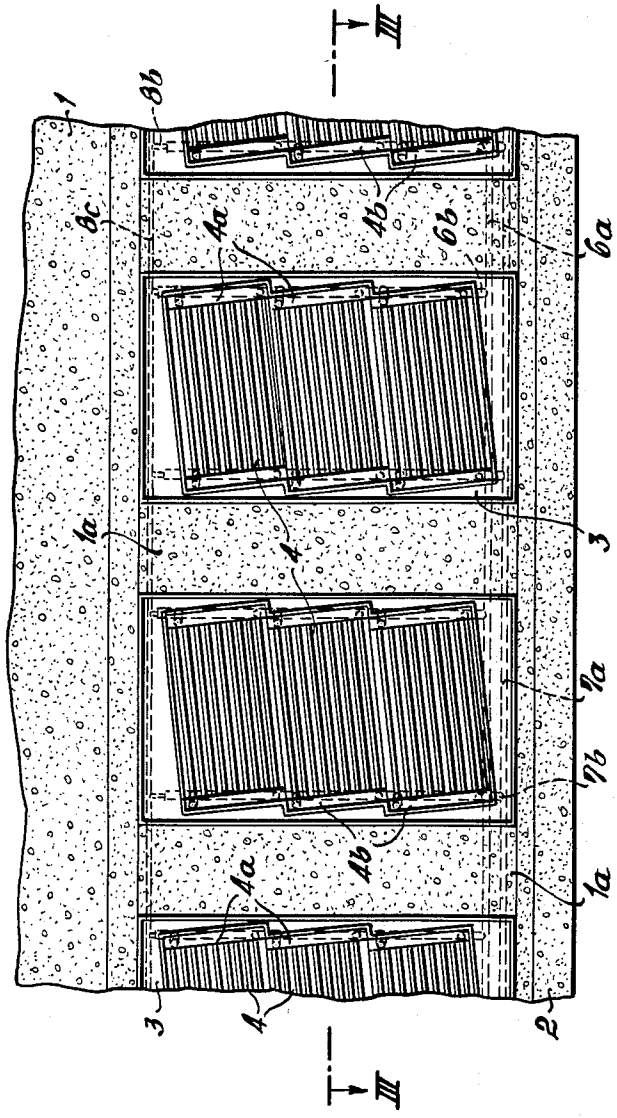
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FIG. 2



INVENTOR

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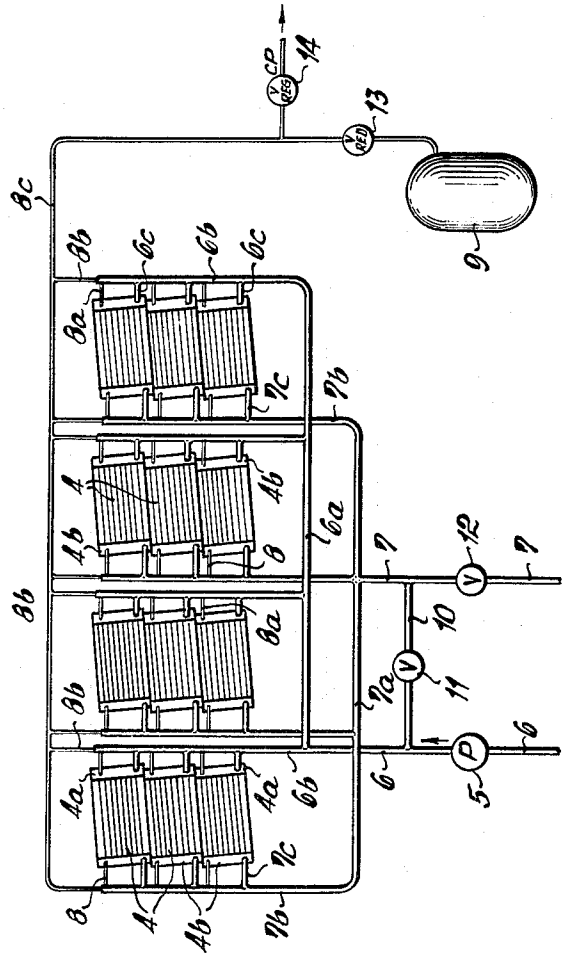
by Michael S. Striker

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LIQUID COOLER AND CONTROL THEREFOR

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FIG. 4



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3,259,177

LIQUID COOLER AND CONTROL THEREFOR

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14 Claims. (Cl. 165—34)

The present invention relates to air-conditioned surface coolers for liquids. More specifically, the invention relates to surface coolers whose current of cooling air is produced by natural chimney draft. Still more specifically, the invention concerns such surface coolers in which heat exchange elements are located in openings provided in the wall of a chimney-like tower open at the top, such openings being circumferentially distributed about the wall adjacent the lower periphery thereof.

Surface coolers of this type can serve to cool any kind of liquid media in large industrial plants. In large steam power plants, where the cooling water used for directly precipitating the waste steam must be continuously recirculated, such coolers can also be used to cool the water during the recirculation thereof.

The cooling range of the media to be cooled is generally defined by upper and lower limits which must not be exceeded. Heretofore it has been difficult to regulate the cooling devices that the discharge temperature of the medium to be cooled remained within these limits, such difficulty being based on the fact that the cooling capacity of the device is dependent upon the ambient temperatures which in turn are subject to frequent fluctuation. Of course, in surface coolers with forced air circulation, that is coolers employing fans, it is relatively simple to regulate the rate of heat exchange by varying the speed of the fan or even switching the fan off altogether.

On the other hand, and although this expedient cannot be employed in the case of surface coolers which depend on natural chimney draft and do not have forced air circulation, i.e., the type of coolers to which this invention is directed, means for varying the rate of heat exchange are known in such installations also. For example, it is known to vary the cross-section of the passage for the cooling air within the cooling elements by means of louvers. This, however, entails considerable expenditures in view of the fact that cooling towers employing such constructions often have a height of 80 meters and more, with a base diameter in excess of 60 meters, the heat exchange elements being distributed around the base of the cooling tower and extending to a height of 15 meters or more.

Another attempt at varying the heat exchange rate of plants employing natural chimney draft consists in selectively varying the number of heat exchange elements past which the medium to be cooled is circulated. However, the number of heat exchange elements which can be thus added to or subtracted from the cooling process must be quite large in order to be effective; if only a few elements are involved the variation in the heat exchange rate is too slight to be of any significance. If, on the other hand, provisions are made for switching sufficiently large numbers of elements, the plant becomes exceedingly complicated and expensive. Moreover, provision must be made for evacuating those elements which are switched off at any given time in order to prevent frost damage since there is always the danger that the medium to be cooled might freeze. Besides entailing additional expenses, the evacuation controls are so complicated that it is practically impossible to assure rapid adjustment of the heat exchange rate.

To overcome the difficulties mentioned above, it has

been proposed to provide the cooling tower with openings whose free cross-sectional areas could be varied so as to regulate the admission of additional air which must not, however, act upon the heat exchange elements. This suggestion has the advantage that only the cross-sectional area of the openings for the additional air need be varied, and the openings provided for this purpose can consequently be kept much smaller than the cross-sectional area of the heat exchange elements themselves would be.

The invention, although based on this underlying consideration, goes still further and provides for varying the size of the effective heat exchange surface area by adjusting the height of the liquid level within the heat exchange elements.

Having in mind the need for controlling the heat exchange capacity in dependence upon the ambient temperature, or upon the discharge temperature of the medium to be cooled, and through the intermediary of varying the size of the effective heat exchange surface, the invention proposes to vary the height of the liquid level within the heat exchange elements and to thereby adapt the size of the effective heat exchange surface to the cooling requirements prevailing at a given time. Contrary to the known solutions discussed before, where such adaptation can be achieved only by providing complicated control devices at great cost, the invention achieves the desired effect in a simple and efficient manner by regulating the level of the liquid columns in the feed and discharge conduits. As a rule, only a single regulating device—such as a slide valve in the main return flow conduit—is necessary for this purpose; such a device can easily be controlled automatically by means of thermostats in dependence upon the ambient temperature or upon the discharge temperature of the medium to be cooled.

In accordance with a further aspect of the invention the means for regulating the height of the liquid level within the heat exchange elements, or of the liquid columns in the feed and discharge conduits, may also be the adjustable distributor of a turbine, or an adjustable pump connected in the main feed conduit. If necessary these devices can be combined with a slide valve and disposed in the main return flow conduit; in the latter case it is preferable to additionally provide a by-pass conduit which directly connects the main feed conduit with the main return flow conduit and which may be closed by means of another slide valve so as to permit—depending on the ambient temperature—a portion of the medium to be cooled to be shunted from the main feed conduit directly into the main return flow conduit while simultaneously reducing the height of the liquid column in the cooler, so as to mix in this manner that portion which has been shunted aside—and which has not been cooled—with the cooled portion of the medium to be treated.

The invention can be carried into practice very simply by feeding the liquid to be cooled to the heat exchange elements from a distributing conduit arranged below the elements and through at least substantially vertical feed conduits laterally connected with the heat exchange elements and connected in parallel with the distributing conduit. The liquid is then discharged from the heat exchange elements from the side opposite that at which it is fed thereinto through at least substantially vertical discharge conduits which are also connected in parallel to a collecting conduit provided below the heat exchange elements. The means for influencing the level of the liquid at any given time are preferably so constructed that they regulate the height of the liquid columns in the feed conduits on the admission side of the heat exchange elements while correspondingly varying the flow head of the liquid to be cooled within the heat exchange elements,

but maintain unchanged the height of the liquid columns in the discharge conduit on the discharge side of the heat exchange elements—or vice versa.

The heat exchange elements themselves may be of any desired design and suitable constructions are well known in the art. In selecting the type of element to be used it must merely be remembered that the elements must permit the liquid-to-be-cooled to flow from intake to outlet in a substantially horizontal plane and without reversing its path so as to form a free upper liquid-surface. For this purpose the elements must be provided at their ends which are opposite in the direction of flow with connections for the feed and discharge conduit. Such connections may, for example, be in the form of chambers. The heat exchange elements may thus, for example, be constructed in a known manner as plate type heat exchangers, or they may be tubular heat exchangers in which the cooling air is guided through tubes which extend transversely in the element housing, the liquid to be cooled flowing around the outside of the tubes within the housing. In a particularly advantageous construction the heat exchange elements are of the tubular type and employ nests of tubes which are preferably provided with external ribs and which are connected to substantially vertical distributing and collecting chambers, the liquid to be cooled flowing through these tubes and the cooling air passing over the outside thereof.

Preferably heat exchange elements of this type are arranged in several rows and in groups, one above the other, at least the lower ends of the collecting and distributing chambers associated with the respective elements being connected in parallel to feed and discharge conduits which serve respective groups of the elements. In this arrangement the neighboring groups of superposed heat exchange elements can be connected on alternate sides to common feed and discharge conduits which communicate with the lower ends of the respective collecting and distributing chamber.

To permit ventilating and exhausting of the heat exchange elements the upper ends of the distributing and collecting chambers can be connected to venting conduits. This can be achieved in a simple manner by connecting the upper ends of the distributing and collecting chambers, and through these the feed and discharge conduits, to common connecting conduits whose cross-sectional dimension may be smaller than that of the feed and discharge conduits.

Although venting and exhausting of the heat exchange elements can be achieved by having the connecting conduits communicate with the atmosphere it is preferable to close off from the atmosphere that portion of the cooling system and of the conduits which is not filled with cooling liquid, and to fill this portion with air or, still better, an inert gas which inhibits corrosion. If necessary, this air or gas may be under a pressure exceeding that of the ambient atmosphere. In this case the connecting conduits—and thereby the feed and discharge conduits—are connected with a gas reservoir provided with means for regulating the gas pressure. The level of the liquid columns in the feed and discharge conduits can then be simply and advantageously controlled by varying the gas pressure. If this control is to be automatic and to depend on fluctuations in the ambient temperature it is merely necessary to let the pressure-regulating device, for example a regulating valve, be controlled by thermostats responsive to ambient temperature.

If the heat exchange elements employed are of the type using nests of tubes connected at their respective ends to the distributing and collecting chambers, respectively, it is advisable to incline each element relative to its horizontal plane and in the direction of flow at an angle corresponding at a maximum to the loss of flow pressure occurring in the elements at the smallest quantity of flow obtained per tube. The elements of adjacent groups of superposed heat exchange elements are respectively inclined relative to one another in opposite directions and may be connected to common feed and discharge conduits.

The novel features which are considered as characteristic for the invention are set forth in particular in the appended claims. The invention itself, however, both as to its construction and its method of operation, together with additional objects and advantages thereof, will be best understood from the following description of specific embodiments when read in connection with the accompanying drawings, in which

FIG. 1 is a side-elevational view of a cooling tower incorporating the present invention;

FIG. 2, in a partial elevational view, shows a detail of FIG. 1 on a larger scale;

FIG. 3 is a cross-section taken on the line III—III of FIG. 2;

FIG. 4 is a circuit diagram showing the inventive heat exchange elements and the conduits associated therewith;

FIG. 1 shows an air-conditioned surface cooler **1** in the form of a chimney-like cooling tower open at the top, composed of concrete or ferro-concrete, and having a bedplate **2** as well as a tower wall **1***a* in which openings **3** accommodating heat exchange elements **4** are provided adjacent the lower periphery. It will be understood that the openings **3** are circumferentially spaced about the wall **1***a*.

As can be seen from FIG. 2 each of the openings **3** houses a stack consisting of three superposed elements **4**. In turn, each of the heat exchange elements **4** consists of a plurality of rows of ribbed tubes which are inclined to the horizontal plane of the bedplate **2** and which communicate with their respective ends with a common elongated distributing chamber **4***a* and a collecting chamber **4***b*. In the example shown the chambers **4***a* and **4***b* are arranged normal to the tubes; the chambers are therefore inclined to the vertical plane of the tower **1** at the same angle at which the tubes are inclined to the horizontal plane of the bedplate **2**. It will be understood that it is of course also possible to dispose the chambers **4***a*, **4***b* normal or substantially normal to the horizontal plane of bedplate **2**, as long as at least the tubes of the elements **4** are slightly inclined to this plane. The reason for this inclination is the need for maintaining a constant flow pressure in the system. Naturally, if the liquid-flow in the system is reduced, then the flow pressure will ordinarily drop. Declining the tubes in the direction of flow will overcome this pressure drop by augmenting flow-pressure with the pressure resulting from gravity feed.

As most clearly seen in the circuit diagram of FIG. 4 feeding of the liquid to be cooled is affected by means of a pump **5** disposed downwardly of the heat exchange elements **4**. Pump **5** feeds the liquid to be cooled through a main feed conduit **6** and a distributing conduit **6***a* which is arranged below the respective stacks of heat exchange elements **4** and from which respective substantially vertical feed conduits **6***b* branch off to communicate with the stacks of elements **4**, so that the latter are thereby connected in parallel to the distributing conduit **6***a*. The individual elements **4** of each stack are connected with the nearly vertical feed conduits **6***b* by means of connecting conduits **6***c* which respectively communicate with the lower ends of the distributing chambers **4***a*. In view of the inclination of the tubes in each element **4**, the connecting conduits **6***c* communicate with the distributing chambers **4***a* on a level which is higher than the level at which respective connecting discharge conduits **7***c* communicate with the lower ends of the collecting chambers **4***b* at the other ends of the tubes of the element **4**. In turn, the connecting discharge conduits **7***c* communicate with substantially vertical discharge conduits **7***b* which are associated with the individual groups of superposed heat exchange elements **4**. The vertical discharge conduits **7***b* are connected in parallel to a common collecting conduit **7***a* located below the stacks of elements **4** and connected to a main collecting or return flow conduit **7**.

There are also provided connecting conduits 8, 8*a* which respectively communicate with the upper ends of the chambers 4*a*, 4*b* and with the conduits 6*c*, 7*c*; in turn, the connecting conduits 8, 8*a* communicate via conduit sections 8*b* with a common conduit 8*c* so that the entire system is connected with a reservoir 9 containing an inert gas.

To regulate the level of the liquid columns in the feed and discharge conduits 6*c*, 7*c*, the inert-gas reservoir 9 is connected to a compressor (not shown) which maintains the pressure in the inert-gas reservoir 9 at a level necessary to compensate for at least a considerable portion of the discharge pressure of the pump 5. The gas flow is controlled via a pressure-reducing valve 13 connected in the conduit 8*c*. Thus, that portion of the system which does not contain liquid can be filled with gas and thereby the level of the liquid columns in the feed and distribution conduits can be regulated. Intermediate the pressure-reducing valve 13 and the cooling system there is further arranged an adjustable pressure relief valve 14 which serves to relieve the excess pressure of the inert gas in the cooling system when the liquid level is to be raised for the purpose of increasing the effective heat exchange surface. Although both of the valves 13, 14 can be manually regulated it is preferable to control them automatically by means of thermostats responsive to the ambient temperature or to the discharge temperature of the medium to be cooled in the region of the main return flow conduit 7, respectively.

The afore-described regulating means can be replaced by, or supplemented through, a slide valve 12 disposed in the return flow conduit 7. By throttling the return flow of liquid in the conduit 7 the slide valve 12 affects the level of the liquid columns in the feed and discharge conduits. Valve 12 may be operated by suitable electromagnetic, electro-pneumatic, or electro-hydraulic devices which are preferably automatically controlled through thermostats responsive to the ambient temperature or to the discharge temperature of the medium to be cooled, respectively. As shown in FIG. 4 a by-pass conduit 10 is additionally provided if the valve 12 is incorporated in the system. Such a by-pass conduit directly connects the main feed conduit 6 with the main return flow conduit 7 and has in turn connected to it another slide valve 11. This arrangement is particularly advantageous for operation of the system in the winter time, i.e., in the case of low ambient temperatures, since it is thus possible to shunt a portion of the medium to be cooled from the main feed conduit 6 directly into the main return flow conduit 7, rather than letting it pass through the cooling tower 1, thus permitting the liquid in the cooling tower 1 to be maintained at a low level whereby the size of the effective exchange surface is kept small irrespective of the volume of the liquid to be cooled. This largely prevents undesirable undercooling.

It has already been pointed out earlier that in cases where the effective heat exchange surface area is changed by varying the liquid level in the heat exchanger, it is necessary not only to stop circulation of liquid in that heat exchange-element portion whose surface area is currently not required, but to positively evacuate the liquid from such portions. In accordance with the present invention this is a simple matter since the heat-exchange elements are all interconnected so that a reduction in the height of the liquid columns in the feed or discharge conduits brings with it a corresponding variation in the level of the liquid in the heat exchange element. By suitably varying the height of the liquid columns in the feed or discharge conduits the portion or portions of the heat exchange elements whose heat exchange surface is not required can therefore be readily and positively emptied of the medium to be cooled. This, in conjunction with the aforementioned automatic control of the system through the various regulating devices, prevents freezing of the heat exchange elements in case of very low ambient temperatures; additional measures, requiring for example, the attention of the operator, are not necessary.

The invention may be embodied in other specific forms without departing from the spirit or essential characteristics thereof. The present embodiment is therefore to be considered in all respects as illustrative and not restrictive, the scope of the invention being indicated by the appended claims rather than by the foregoing description and all changes which come within the meaning and range of equivalency of the claims are therefore intended to be embraced therein.

I claim:

1. An air conditioned surface cooler for liquids comprising, in combination, a chimney-like tower open at the top and having a lower peripheral wall portion formed with openings therethrough; a plurality of heat exchange elements respectively located in said openings so that cooling air will be drawn over said heat exchange elements by the draft produced by the chimney-like tower, said heat exchange elements each including a substantially vertical distributing chamber, a substantially vertical collecting chamber transversely spaced therefrom, and a plurality of heat exchanger pipes connecting said chamber with one another; means, including an inflow conduit and a return flow conduit, for feeding liquid to be cooled into said heat exchange elements each including a substantially vertical from; and control means co-operating with said heat exchange elements for varying the height of the liquid level therein to thereby regulate the size of the effective heat exchange surface area.

2. An air conditioned surface cooler for liquids comprising, in combination, a chimney-like tower open at the top and having a lower peripheral wall portion formed with openings therethrough; a plurality of heat exchange elements respectively located in said openings so that cooling air will be drawn over said heat exchange elements by the draft produced by the chimney-like tower, said heat exchange elements each including a substantially vertical distributing chamber, a substantially vertical collecting chamber transversely spaced therefrom, and a plurality of heat exchanger pipes connecting said chamber with one another; means, including an inflow conduit and a return flow conduit, for feeding liquid to be cooled into said heat exchange elements and for discharging cooled liquid therefrom; and control means cooperating with said heat exchange elements for varying the height of the liquid level therein to thereby regulate the size of the effective heat exchange surface area, said control means including pump means connected to said inflow conduit and regulating means operatively connected to said heat exchange element for admitting thereto a gaseous medium at a pressure higher than the pressure created in said heat exchange element by said pump means so as to thereby fill up part of said elements with said medium and thus depress the level of liquid in said elements.

3. An air conditioned surface cooler for liquids comprising, in combination, a chimney-like tower open at the top and having a lower peripheral wall portion formed with openings therethrough; a plurality of heat exchange elements respectively located in said openings so that cooling air will be drawn over said heat exchange elements by the draft produced by the chimney-like tower, said heat exchange elements each including a substantially vertical distributing chamber, a substantially vertical collecting chamber transversely spaced therefrom, and a plurality of heat exchanger pipes connecting said chamber with one another and sloping downwardly from said distributing chamber toward said collecting chamber at a predetermined angle calculated to maintain constant flow pressure in said pipes despite variation in the flow rate of said liquid; means, including an inflow conduit and a return flow conduit, for feeding liquid to be cooled into said heat exchange elements and for discharging cooled liquid therefrom; and control means co-operating with said heat ex-

change elements for varying the height of the liquid level therein to thereby regulate the size of the effective heat exchange surface area.

4. An air conditioned surface cooler for liquids comprising, in combination, a chimney-like tower open at the top and having a lower peripheral wall portion formed with openings therethrough; a plurality of heat-exchange elements respectively located in said openings so that cooling air will be drawn over said heat-exchange elements by the draft produced by the chimney-like tower; means, including an inflow conduit and a return flow conduit, for feeding liquid to be cooled into said heat-exchange elements and for discharging cooled liquid therefrom; and control means cooperating with said heat-exchange elements for varying the height of the liquid level therein to thereby regulate the size of the effective heat exchange surface area, said control means including regulating means for admitting a gaseous medium under pressure to said heat-exchange elements so as to thereby fill part of said elements with said medium and thus depress the level of liquid in said elements.

5. A cooler according to claim 1, further including venting conduit means connected to the upper ends of the respective distributing and collecting chambers and open to the atmosphere.

6. An air conditioned surface cooler for liquids, as defined in claim 5, further comprising connecting conduit means connecting said inflow conduit and said return flow conduit with respective uses of a plurality of said members, and wherein said venturing conduit means are of a smaller diameter than the diameter of said connecting conduit means.

7. A cooler according to claim 1, further comprising a pressurized gas reservoir operatively connected to said cooler, and wherein the cooling system and its pipe conduits are sealed off from the ambient atmosphere and any space not filled with the liquid to be cooled is filled with a gas supplied from said gas reservoir.

8. A cooler according to claim 7, wherein the gas is air.

9. A cooler according to claim 7, wherein the gas is an inert gas.

10. A cooler according to claim 7, further comprising means provided for regulating the pressure of gas in said system whereby the level of liquid in the system may be selectively varied in dependence upon the prevailing gas pressure.

11. A cooler according to claim 1, further comprising by-pass conduit means interconnecting said inflow and return-flow conduits and being connected with said inflow conduit beyond the pump in the direction of flow of the liquid to be cooled, said by-pass conduit means comprising valve means selectively operable for opening and closing said by-pass conduit means whereby a portion of the liquid to be cooled may be shunted into said return-flow conduit without being cooled.

12. A cooler according to claim 1, wherein said regulating means for varying the height of the liquid level within the cooler includes a slide valve introduced in the main return flow conduit and thermostatic means for automatically controlling said slide valve in dependence upon the ambient temperature and the discharge temperature of the liquid to be cooled.

13. A cooler according to claim 1, wherein said heat exchange elements comprise nests of tubes connected at their respective ends to said distributing and collecting chambers, said heat exchange elements being inclined to the horizontal in the direction of flow of the liquid and to an extent corresponding at the most to the loss of flow pressure within the elements occurring in the case of the smallest quantity of flow per tube.

14. A cooler according to claim 13, wherein the groups of superposed heat exchange elements directly adjacent to each other are alternately inclined to each other in opposite directions, and each is connected to common feed and discharge conduits.

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