(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 592 936 B1

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention
of the grant of the patent:
30.05.2007 Bulletin 2007/22

(21) Application number: **04708825.7**

(22) Date of filing: **06.02.2004**

(51) Int Cl.:
F28D 5/02 *(2006.01)*

(86) International application number:
PCT/GB2004/000459

(87) International publication number:
WO 2004/072569 (26.08.2004 Gazette 2004/35)

(54) COOLING SYSTEM

KÜHLSYSTEM

SYSTEME DE REFROIDISSEMENT

(84) Designated Contracting States:
BE DE ES FR GB IT

(30) Priority: **12.02.2003 GB 0303195**

(43) Date of publication of application:
09.11.2005 Bulletin 2005/45

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Printed by Jouve, 75001 PARIS (FR)

Description

[0001] This invention relates to cooling systems, more particularly to those including a closed circuit evaporative heat exchanger of the forced draught configuration.

[0002] Closed circuit evaporative heat exchangers are used in a variety of industrial settings to provide cooling or condensing of refrigerants. Very broadly, cooling is provided by means of a cooling fluid which draws heat from the area to be cooled and transports it to a heat exchanger where the fluid is cooled again. In the case of a refrigerant condensing system, as part of a refrigeration process, refrigerant vapour enters the heat exchanger where it is condensed and leaves the heat exchanger as liquid. In both cases air is blown over the heat exchanger coils to remove heat from the liquid or vapour. The cooling process is enhanced by spraying water onto the coils so that a proportion of the water is evaporated by the air flow.

[0003] In such systems the majority of the water sprayed onto the heat exchanger coils in the air distribution plenum does not evaporate but drains off into a sump at the bottom of the air distribution plenum. From there it is pumped through a strainer back to the spray nozzles to be recycled. Typically evaporative heat exchanger products are designed to use parts which are common to both closed circuit and open cooling towers. The sump in conventional closed circuit towers is therefore of a sufficiently large capacity to be able to be used in an open tower as well as a closed circuit configuration.

[0004] As mentioned above, the cooling provided by the heat exchanger is enhanced by spraying water onto the coils of the heat exchanger. However, such enhanced cooling is not always necessary. For example, during the winter months sufficient cooling may be achieved without the evaporative effect of the water, i.e. so called "dry operation" is possible.

[0005] However, dry operation requires the sump to be drained as the water therein would otherwise freeze and cause damage to the system as a result of the forced flow of cold air over it. This is problematic since the processes of draining and replenishing the sump are time consuming - typically taking several hours. Furthermore it is usually necessary to shut off the cooling system during at least some of the draining or replenishment period, in order to prepare the sump for dry or wet operation respectively by securing make-up valve floats, level controls etc. It is not therefore considered practically or economically feasible to drain and replenish the sump every day. This means that dry operation can only be carried out for a short proportion of each year where even during the daytime, temperatures are predictably low enough that "wet" operation will not be required. It will be appreciated that the potential savings of water and energy required to operate the water pump and any sump heaters are seriously curtailed as a result.

[0006] It is also known in some closed circuit evaporative heat exchanger systems to provide a sump located remotely from the air distribution plenum. Most of the unevaporated water is either drained or pumped continuously to the remote sump during wet operation, and is then pumped from the remote sump back to be sprayed onto the heat exchanger coils again. The advantage of such a remote sump is that it is not necessary to drain the whole body of water from a sump in the air distribution plenum in order to achieve dry operation since only a small amount of water remains in the air distribution plenum and this can be drained relatively quickly. Water in the remote sump is not subjected to the cold airflow in the air distribution plenum and so may be prevented from freezing by suitable heaters.

[0007] There are several disadvantages to a remote sump however. Firstly, additional space is required to accommodate it, which is generally expensive. Secondly, more powerful pumps are required to account for the additional static height through which the water must be pumped. Thirdly, the overall number of components required and the cost of installation is also increased. Together these factors can more than outweigh any cost saving in being able to operate the system more efficiently with respect to water consumption and spray pump energy. It may be however that a remote sump is necessary to allow dry operation and prevent over-cooling in some circumstances.

[0008] Another problem with conventional closed circuit evaporative heat exchanger arrangements is that it is necessary to halt operation of the system in order to carry out routine maintenance such as inspection, functional testing, cleaning etc. of the parts inside the air distribution plenum. This is a particular problem for conventional systems without a remote sump since equipment in the sump and water make-up system will also be affected. Such regular interruption of the running of the system is obviously disruptive and expensive.

[0009] US-3 784 171 discloses an evaporative heat exchange apparatus having a V-section sump and two sets of blowers.

[0010] It is an object of the present invention to provide an evaporative heat exchanger in which the problems set out above are at least partially alleviated.

[0011] The present invention provides a closed circuit evaporative heat exchanger as claimed in claim 1.

[0012] Thus it will be seen by those skilled in the art a sump is still provided within the main air distribution plenum, but the sump is not used to collect the unevaporated water but instead a collection surface drains into the sump. This means that the sump may be at least partially thermally isolated from the main part of the plenum. This makes it possible to prevent the water therein from freezing when ambient air temperatures are below freezing point, whereas this is not viable with the conventional sump arrangement which is exposed to the airflow in the plenum. Such arrangements have the advantage of substantial flexibility in that they are able to be swapped between wet and dry operation rapidly and as often as required, but without the disadvantages of providing a remotely located sump.

[0013] The sump is arranged such that water therein is prevented from freezing during cold weather operation. This can be achieved by ensuring a sufficient degree of thermal isolation and providing heating means, preferably thermostatically controlled. This allows varying environmental temperatures to be accounted for as well.

[0014] The drain interface between the collection surface and the sump is arranged to form a liquid lock between the two so that an uneven air pressure may be maintained between them. The benefit of this feature is that the sump may then be maintained at substantially atmospheric pressure, whilst the main part of the plenum is at an elevated pressure resulting from the forced airflow. The physical isolation of the interior of the sump from the interior of the main air distribution plenum also avoids contact with the water sprays. These two factors allow at least the sump to be accessed for maintenance even when the system is in operation with the associated fans running. It will be appreciated that this capability gives a significant advantage over prior art systems which have to be taken out of operation for even routine maintenance.

[0015] The amount of water used in the spray cycling system via the sump may, as in the prior art, be of a volume similar to that associated with a sump used in an open tower cooling system. However, the Applicants have appreciated that since, in accordance with invention, a new form of sump is contemplated, the minor benefit of commonality between sump modules is forfeited, but that this means that volume restriction imposed by using a common sump need no longer apply and that in fact additional benefit may be achieved by using less water.

[0016] Thus, in preferred embodiments, the evaporative water spray system is arranged to operate with just sufficient water for wet operation. In one exemplary embodiment the system operates with approximately 90 litres of water per square metre of coil area. This contrasts with a conventional system in which a volume of approximately 240 L/m^2 is used (which is consistent with use of a standard sized sump).

[0017] Not only does the use of a significantly reduced volume of water save water, but it also means that the sump may be smaller than would otherwise be the case, less powerful heaters are required to prevent it from freezing, and less chemical water treatment is required, all of which help to reduce costs.

[0018] The preferred embodiment of the invention set out above is understood to involve using the minimum water volume needed for the evaporation process. In practice this minimum quantity is dependent upon the capacity of the water distribution system including pipework, the proportion of the water which is falling through the air distribution plenum at any one time and the minimum quantity of water required by the pumping system to operate properly. This is to be contrasted with the prior art in which significantly larger volumes than the minimum for wet operation are used and indeed in which consideration has not previously been given to this minimum required quantity.

[0019] It will be appreciated that in practice in accordance with the invention, means will be provided for replenishing water lost through evaporation. Any means well known in the art may be used such as a float-operated valve, electronic sensor, optical sensor etc. Such water replenishment may have some inherent hysteresis such that the actual volume of the water in the system at any one time may cycle between a predetermined maximum and minimum.

[0020] A preferred embodiment of the present invention will now be described, by way of example only, with reference to the accompanying drawings in which:

> Figure 1 is a cut-away view of a conventional closed circuit evaporative heat exchanger shown for the purposes of reference only; and
>
> Figures 2a and 2b are cut-away side and end views respectively of a closed circuit evaporative heat exchanger in accordance with the invention.

[0021] Turning firstly to Figure 1, a prior art closed circuit evaporative heat exchanger may be seen. A sealed heat exchanger coil A through which coolant liquid passes is provided in an air distribution plenum B. A fan system C driven by a motor D is provided at one end of the plenum B. At the top of plenum B is a series of nozzles E which are arranged to spray water over the heat exchanger coil A. A sump F is provided at the bottom of the plenum B with a capacity of 240 litres per square metre of coil area and a pump G is provided to pump water up from the sump F to the spray nozzles E. A water replenishment system H using a float valve ensures that a minimum quantity of water in the sump is maintained. '

[0022] In operation coolant liquid or refrigerant vapour is fed to the heat exchanger coil A where heat is extracted from it to cool or condense it before it is returned, as is well known in the art. The fan C forces a rapid flow of air over the heat exchanger coil A in the air distribution plenum B to extracting heat from the coolant fluid or vapour. Evaporative cooling is provided by the water spray system which draws water from the sump F using the pump G. Some of the water sprayed from the nozzles E will evaporate. The remainder of the water is collected in the sump F from where it is recycled back up to the spray nozzles E. Water lost through evaporation is replaced by the water replenishment system H.

[0023] In order to obtain access to the sump F to carry out inspection and maintenance it is necessary to shut down the system and switch the fan C off, thereby limiting the frequency with which this can be carried out in practice. Furthermore, if the environmental temperature is such that the additional cooling effect of the water spray system is no longer required, all of the water must be drained from the sump F in order to prevent it freezing due to the cooling effect of the forced cold air flow. This is so time consuming that it can only be carried out when the operator is confident that the temperature will not rise sufficiently again to require wet operation for a considerable time (i.e. over a period of more than a day).

[0024] An embodiment of the present invention may now be seen in Figures 2a and 2b. As in the apparatus described with reference to Figure 1, the closed circuit evaporative heat exchanger comprises a heat exchanger coil 2 disposed in an air distribution plenum 4 and conveying a coolant fluid or refrigerant to and from an area to be cooled (not shown) via pipe couplings 6. At one end of the air distribution plenum 4 is a fan 8 driven by a motor 10 via a belt 12. The blades of the fan 8 are housed within a casing 14 and thus are not visible in Figure 2a.

[0025] Unlike the system shown in Figure 1, there is no open sump at the bottom of the air distribution plenum 4. Instead the sump 16 is defined in the lower part of one end of the air distribution plenum 4 by a sloping baffle wall 18. In this embodiment the sump has a capacity of ninety litres per square metre of coil area, but this is purely exemplary and this figure is dependent e.g. upon the coil length. The baffle wall 18 depends downwardly from the rear end wall 20 of the plenum 4. It terminates so as to leave a gap between its end and the base of the sump 16. The baffle wall 18 extends between the two opposed side walls of the plenum 4 - in other words perpendicular to the plane of Fig. 2a or left to right in Fig. 2b.

[0026] The area of the lower part of the air distribution plenum 4 not taken up by the sump 16 is formed as a sloping base 22. The base 22 slopes towards the baffle wall 18, but stops just short of its so as to leave a small gap 24 running from one side wall of the plenum 4 to the other. The base also extends between the two side walls so that the gap 24 runs along the width of the plenum 4. The baffle wall 18 and the base 22 each form collection surfaces onto which water falling from the heat exchanger coils 2 will land.

[0027] Within the sump 16 there is a float-operated valve 26 connected to an inlet spout 28 for maintaining a minimum level of water in the sump 16. This level of water is set to be the minimum amount required for wet operation of the heat exchanger (taking into account the capacity of the pipes etc. in the rest of the system). At the base of the sump 16 is a strainer 30 through which water from the sump may be drawn by a pump 32 and pumped up a vertical pipe 34 on the outside of the rear end 20 of the plenum, where it re-enters the plenum 4 to feed a water distribution pipe 36.

[0028] A series of nozzles 38 is spaced along the water distribution pipe 36 so that water is forced out in a conical spray over the heat exchanger coils 2 under the pressure imparted by the pump 32. One such nozzle 38 may be seen more clearly in the scrap detail view above it. Above the water distribution pipe 36 is a series of drift eliminators 40, one of which is also shown more clearly in a scrap detail view. These separate water droplets entrained in the airstream leaving the heat exchanger and prevent those droplets being lost from the system.

[0029] Finally, a pair of access doors 42 are provided in the lower part of the end wall 20 of the plenum to allow external access to the interior of the sump 16.

[0030] Operation of the apparatus will now be described. As in the prior art system the fan 8 forces air to flow over the heat exchanger coils 2 to extract heat from the coolant fluid therein. When additional cooling is required the pump 32 is operated to draw water from the sump 16 through the strainer 30 and force it through the nozzles 38 so as to form a fine spray over the heat exchanger coils. A significant cooling effect is achieved by evaporation of some of the water. The unevaporated water falls down towards the bottom of the air distribution plenum 4 and onto the collection surfaces formed by either the baffle wall 18 or the sloping base 22. Water falling onto these parts does not remain there but drains into the small gap 24 between them.

[0031] As may be appreciated from Figure 2a the level of water in the sump is such that the gap 24 is at least partially filled with water. This forms a water lock between the air distribution plenum 4 and the sump 16. This water lock allows a differential air pressure to be maintained between the main part of the plenum 4 and the sump 16 so that access to the sump 16 may be obtained, e.g. for inspection and maintenance, whilst the main fan 8 is still running and the system is operational.

[0032] During dry operation, the pump 32 is shut off and the remaining water drains through the gap 24 into the sump 16. Within sump 16 the water is no longer in direct contact with the air stream generated by the fan 12. It will be appreciated therefore that since no water remains in the main part of the air distribution plenum 4, i.e. in contact with the cold air flow, the likelihood of it being frozen is significantly reduced.

[0033] Although not shown in Figure 2a, thermostatically controlled heaters are provided to maintain the temperature of the water in the sump 16 above freezing. However, since the sump 16 is relatively small compared to the distribution plenum 4, and is separated from the cold air stream by the baffle wall 18, the power required for such heaters is relatively low.

[0034] It will furthermore be appreciated that the quantity of water in the sump 16 is significantly less than in the sump F in Figure 1. Not only does this give savings on the amount of water required to fill the equipment, but also the cost of chemical treatment needed and the amount of heat required to prevent it from freezing.

[0035] The embodiment described above gives the overall advantage that it is fully flexible in that it can be operated in either wet or dry mode as required and moreover can be switched very quickly between these modes.

Example

[0036] A prototype apparatus similar to that described above with reference to Figs. 2a and 2b was constructed and tested. The sump water volume of the test apparatus was 860 litres and the fan gave an airflow of 27 cubic metres per second over the heat exchanger coils. However, a normal atmospheric pressure was maintained in the sump interior by virtue of the water lock.

[0037] When the pump of the evaporative cooling system was switched off and the ambient temperature reduced to -10° C, the sump and water lock remained completely free of ice with a heat input from the sump heater of a modest 4 KW.

Claims

1. A closed circuit evaporative heat exchanger comprising:

an air distribution plenum (4);
means for spraying water into said plenum (4);
a collection surface (18, 22) for collecting unevaporated water sprayed into said plenum, said collection surface (18, 22) being arranged to drain into a sump (16) within said plenum (4), substantially without water remaining on the collection surface; and
a drain interface (24) between the collection surface (18, 22) and the sump (16), said interface being arranged to form a liquid lock between the plenum (4) and the sump (16) so that an uneven air pressure may be maintained between them **characterised in that** the sump is arranged such that water therein is not exposed to a forced airflow.

2. A heat exchanger as claimed in claim 1 wherein said means for spraying water is arranged to operate with just sufficient water for said wet operation of the heat exchanger.

3. A heat exchanger as claimed in claim 2 arranged to operate with approximately 90 litres of water per square metre of coil area.

Patentansprüche

1. Verdunstungswärmetauscher mit geschlossenem Kreislauf, umfassend:

eine Luftverteilerkammer (4);
ein Mittel zum Sprühen von Wasser in die Kammer (4);
eine Auffangfläche (18, 22) zum Auffangen von nicht verdunstetem, in die Kammer gesprühtem Wasser, wobei die Auffangfläche (18, 22) dazu ausgebildet ist, in einen Sumpf (16) in der Kammer (4) abzuleiten, im Wesentlichen ohne dass Wasser auf der Auffangfläche verbleibt; und
eine Ableitungsschnittstelle (24) zwischen der Auffangfläche (18, 22) und dem Sumpf (16), wobei die Schnittstelle dazu ausgebildet ist, eine Flüssigkeitssperre zwischen der Kammer (4) und dem Sumpf (16) zu bilden, sodass ein ungleicher , Luftdruck dazwischen beibehalten werden kann;

dadurch gekennzeichnet, dass der Sumpf derart ausgebildet ist, dass das Wasser darin keinem erzwungenen Luftfluss ausgesetzt ist.

2. Wärmetauscher nach Anspruch 1, wobei das Mittel zum Sprühen von Wasser dazu ausgebildet ist, mit einer gerade ausreichenden Wassermenge für den Nassbetrieb des Wärmetauschers betrieben zu werden.

3. Wärmetauscher nach Anspruch 2, welcher dazu ausgebildet ist, mit ungefähr 90 Litem Wasser pro Quadratmeter Windungsbereich betrieben zu werden:

Revendications

1. Echangeur thermique à évaporation en circuit fermé, comportant :

un plénum de distribution d'air (4),
des moyens pour pulvériser de l'eau dans ledit plénum (4),
une surface de recueil (18, 22) pour recueillir de l'eau non évaporée pulvérisée dans ledit plénum, ladite surface de recueil (18, 22) étant prévue pour drainer dans un puisard (16) dans ledit plénum (4), sensiblement sans que de l'eau ne reste sur la surface de recueil, et
une interface de drainage (24) entre la surface de recueil (18, 22) et le puisard (16), ladite interface agencée pour former un verrou liquide entre le plénum (4) et le puisard (16), de sorte qu'une pression d'air irrégulière peut être maintenue entre les deux, **caractérisé en ce que** le puisard est agencé de telle sorte que de l'eau située dans celui-ci n'est pas exposée à un écoulement d'air forcé.

2. Echangeur thermique selon la revendication 1, dans lequel lesdits moyens pour pulvériser de l'eau sont agencés pour fonctionner avec juste suffisamment d'eau pour ledit fonctionnement à l'état humide de l'échangeur thermique.

3. Echangeur thermique selon la revendication 2, prévu pour fonctionner avec approximativement 90 litres d'eau par mètre carré d'aire de serpentin

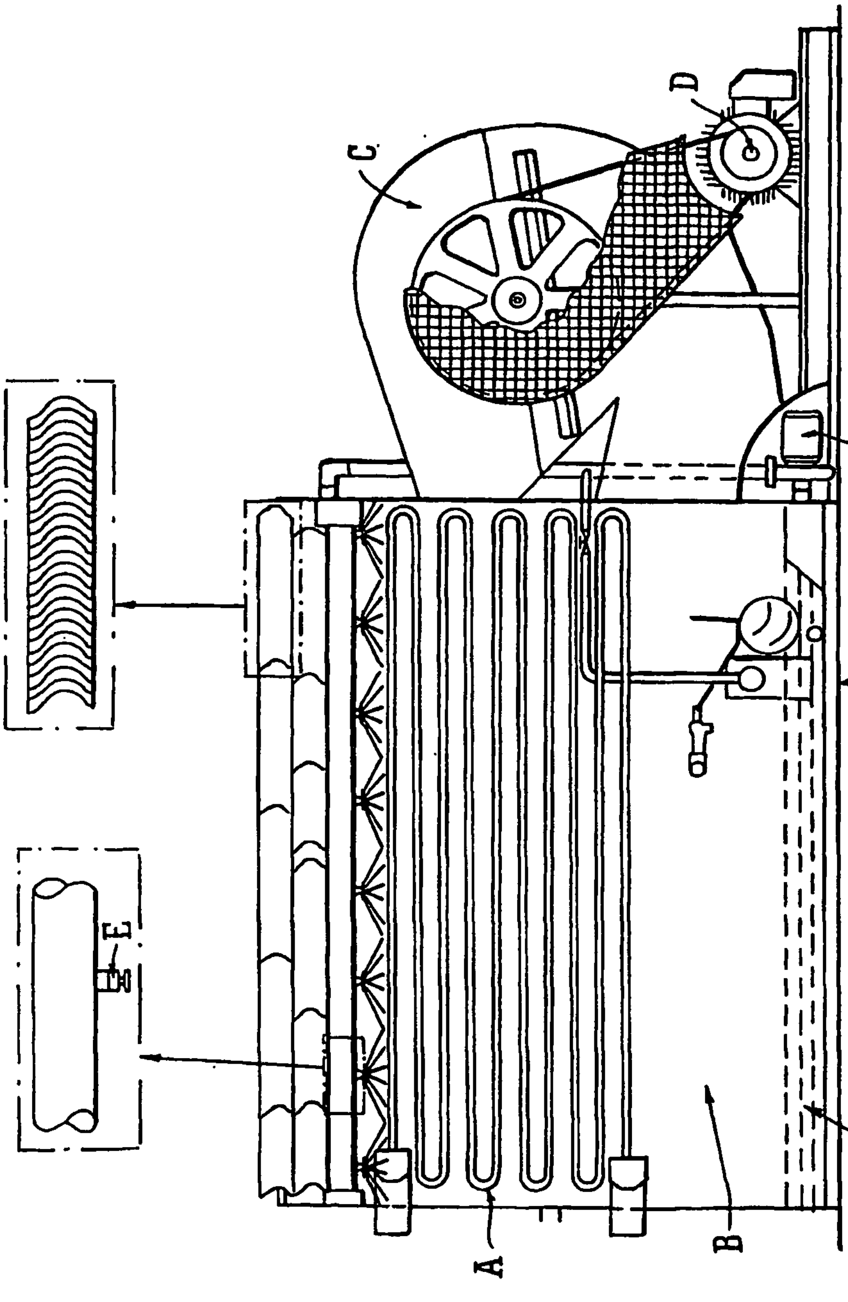

FIG. 1

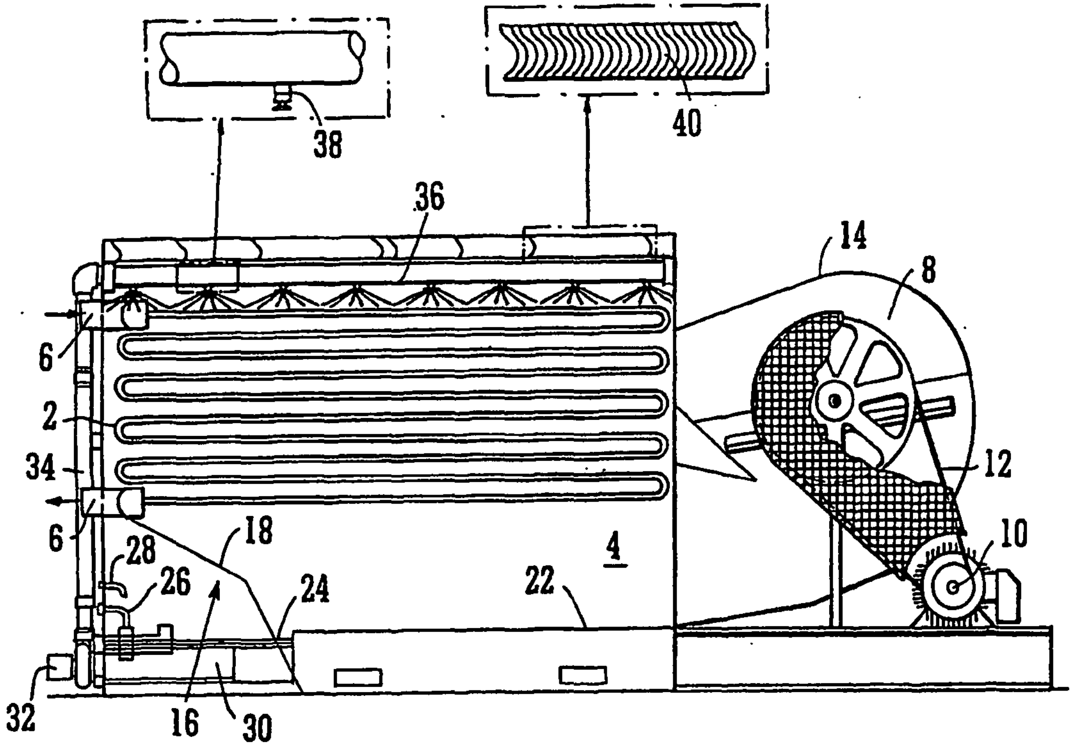

FIG. 2A

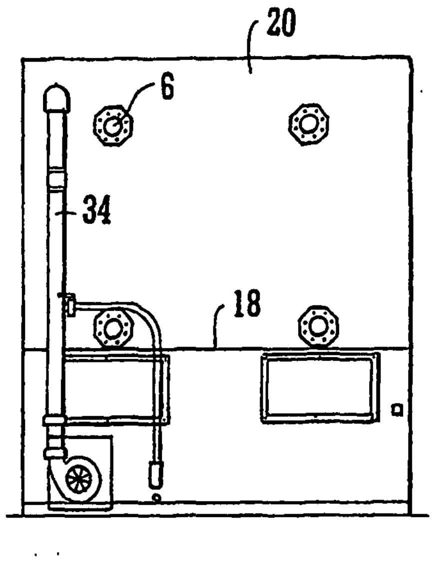

FIG. 2B