

A DISTRICT COOLING SYSTEM

Field of the Invention

- 5 The invention relates to a district cooling system arranged to utilize spent chilled water to provide outdoor cooling.

Background

- 10 Maintaining thermal comfort for building occupants is a primary goal for the design of HVAC systems. In defining “thermal comfort” the ASHRAE Standard 55, specifies the combination of indoor thermal environmental factors and personal factors that produce thermal environmental conditions acceptable to a majority of occupants within a space. Conditions falling outside the limits set out by the standard are considered not
15 conforming to “comfort” air-conditioning. For instance, air-conditioning for certain industry process will have air conditions outside the ASHRAE standard 55 and hence it is considered “process” air-conditioning.

- District cooling system is an outsourcing alternative to on-site chilled water production
20 for air conditioning. Reference to the ASHRAE Standard 55, applies equally to environmental conditions for occupants provided by a district cooling system. District cooling is well suited for commercial districts with high cooling load density. It raises the energy efficiency related to air conditioning more effectively, whilst still

conforming the requirements of international standards, such as the ASHRAE Standard 55..

In a district cooling system, cooling energy is conveyed using water as medium which is called chilled water. Chilled water supply of about 4.5°C is piped from chiller plants through a chilled water supply pipe to buildings within the district. The air-conditioning system in each building uses supply chilled water to remove heat load generated within in order to meet the requirements of thermal comfort for occupants within the buildings. The heat load is carried away by chilled water return pipes back to the plant for processing before sending back to the buildings through chilled water supply pipes. Accordingly, the interface between the supply pipe and the return pipe is defined as being when the end users for whom the system has been designed, have been serviced.

In order for the chiller plant to work at an optimum efficiency, the optimum chilled water return temperature is about 13°C. However, the actual return temperature is usually lower than the optimum return chilled water temperature eg 12 to 12.5°C.

Summary of Invention

In a first aspect, the invention provides a district cooling system comprising: a chilled water supply pipe for conveying cooling energy from a water chilling station to plurality of end users; a chilled water return pipe for conveying the heat load from end users to the chilling station; a branch application comprising a branch supply pipe and a branch

return pipe both connected to the chilled water return pipe; said branch application further including a heat exchanger, said heat exchanger arranged to receive water from the branch supply pipe and exit water to the branch return pipe; wherein the heat exchanger is arranged to provide spot cooling for outdoor.

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In a second aspect, the invention provides a two stage cooling system, comprising a fan coil cooling unit, and; an evaporative cooling unit; wherein said cooling system is arranged to deliver ambient air to the fan coil cooling unit, and subsequently deliver cooled air to the evaporative cooling unit.

10 In a third aspect, the invention provides a method for cooling, the method comprising the steps of: receiving chilled water from a chilled water return pipe in a district cooling system; supplying the chilled water to a heat exchanger, and; returning the supplied chilled water to the chilled water return pipe in the district cooling system; wherein the heat exchanger is arranged to cool air at an unconfined area.

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In a fourth aspect, the invention provides a method for cooling air, the method comprising the steps of: directing ambient air across a fan cooled coil, said coils having water flowing through said coils; and consequently producing fan coil cooled air;

directing the fan coil cooled air through an evaporative cooling system; and

20 consequently producing cooled air.

Accordingly, the invention provides a branch application from the chilled water return pipe. A district cooling system provides chilled water to a range of end users, with water supplied by the supply pipe. Following delivery of the chilled water to the designated end users, the chilled water is returned through the return pipe. It is the return pipe that
5 provides chilled water to the branch application.

In one embodiment, the branch application may be retrofit, and so added after the installation and commissioning of the district cooling system.

The outdoor cooling application is characterized as providing cooled without meeting
10 all the conditions necessary to comply with ASHRAE standard 55 which is essentially meant for indoor comfort air-conditioning purpose. The outdoor cooling is to provide spot cooling in areas where there are no physical confines like walls, roofs etc like indoor space would have. Because of this lack of physical confine, certain air-conditioning process parameter like relative humidity is difficult to be maintained
15 meaningfully. As a result, it is not meaningful to consider relative humidity and such parameter in an outdoor cooling context.

The cooling device used to provide outdoor spot cooling requires very low flow.
20 Aggregate of these cooling devices to provide spot cooling for an outdoor event typically is less than 1% of the total district cooling system chilled water flow. Using return chilled water from district cooling system has the advantage of providing outdoor spot cooling at no additional energy cost to the district cooling plant.

The branch application may have an interface, such as a distribution point, to facilitate connection between a licensed operator and the branch application. The interface may be arranged to connect the heat exchanger, and so connecting to the branch supply and
5 branch return pipes. Alternatively, the distribution point may be beyond the heat exchanger, and so provide an interface to connect the air supply to the licensed operator.

The heat exchanger may be arranged to provide air to an outdoor cooling unit, to distribute the cooled air to vents within the desired location.

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Brief Description of Drawings

It will be convenient to further describe the present invention with respect to the accompanying drawings that illustrate possible arrangements of the invention. Other
15 arrangements of the invention are possible and consequently, the particularity of the accompanying drawings is not to be understood as superseding the generality of the preceding description of the invention.

Figure 1 is a schematic view of a district cooling system according to one embodiment
20 of the present invention;

Figure 2 is a schematic view of a district cooling system according to a further embodiment of the present invention;

Figure 3A is a schematic view of a one stage heat exchanger according to one embodiment of the present invention;

- 5 Figure 3B is a schematic view of a two-stage heat exchanger according to one embodiment of the present invention, and;

Figure 4 is a psychrometric chart plotting the resultant variation in temperature and humidity based upon the two-stage heat exchanger of Figure 3B.

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Detailed Description

- It will be understood that reference to the ASHRAE Standard 55 is a means of communicating environmental conditions in terms of occupant “comfort” as would be understood by the skilled person. Therefore, rather than the term “comfort” being an arbitrary measure, we use this to define well establish requirements for building design, and more particularly design of cooling systems. The psychrometric chart of Figure 4 is provided, as a specific tool used in the industry, and ASHRAE Standard 55, to communicate this information.

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Figure 1 shows a district cooling system 5 having a chilled water supply pipe 10 and a chilled water return pipe 15. The system 5 is arranged to convey cooling energy to service a district 20 having an array of end users 25, each end user requiring the district

cooling system to provide thermal comfort levels for each of the occupants, such as in office buildings, conference spaces or hotels. To this end, each user 25 includes a collection of air handling units 30 which receive the chilled water 50, 40 which are used in the AHU's before returning 35, 45 the supply to the chilled water return pipe 15 so as to convey the heat load to the chilling station. The water supply temperature and return temperature will vary according to design considerations but, for instance, the chilled water supply may optimally be provided at 4.5°C and for a design return temperature of 13°C.

10 Using return chilled water for outdoor spot cooling may help to address 2 scenarios in district cooling system operation. Firstly, if the chilled water return temperature is meeting or slightly above design, outdoor cooling can be provided without affecting the district cooling system energy performance due to the economies of scale. Secondly, if the chilled water return temperature is below design, outdoor cooling will help to utilize

15 the unutilized cooling energy by the buildings within the district.

One embodiment of the outdoor spot cooling implementation is show in Figure 1. Cold energy may be better utilized by providing ancillary branches 55 such as adding a heat exchanger 60 to a pipe loop 65, 70 coupled to the return chilled water pipe 15. To this

20 end, the branch pipe 65 diverts a portion of the return chilled water to a heat exchanger 60 which may then deliver a portion of the excess cold energy for a separate application 75. In this embodiment, delivery of the cold energy is via a distribution point 72, which acts as an interface for “plugging” 74 the separate application into the branch

application 55. The separate application 75 may be for a licensed user seeking to establish a temporary event and so seeking cooled air as relief for their patrons. To this end, the licensed user plugs 74, say, air ducts into a permanently placed distribution point 72, with the branch application providing cooled air to the distribution point.

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The branch 55 may only draw a small proportion of the total chilled water flow and so allowing for a plurality of such branch applications which may variously be applied for cooling public spaces or other permanent or temporary application. By way of example, in a district cooling system, the return chilled water flow may be $12,000 \text{ m}^3/\text{h}$ whereby a
10 branch application may only require a flow of $120 \text{ m}^3/\text{h}$. Consequently, the impact on the return chilled water temperature may be small. It follows that even a small departure from the design return water temperature may provide an opportunity for several of such branch applications.

15 Figure 2 shows one such application 80 whereby the heat exchanger 60 delivers cooled air to outdoor cooling units (OCU). Such outdoor cooling units may be conveniently located for dedicated occasional use, including outdoor events whereby large numbers of people attending festivals, outdoor exhibitions and the like, can receive respite for what is essentially outdoor air conditioning. Therefore, a district cooling system
20 according to the present invention not only replaces discrete air conditioning systems but by using potentially unutilized cold energy from below design temperature return chilled water, branch applications 55 such as OCUs have the opportunity to enhance

patron comfort in circumstances which are otherwise difficult or energy intensive to provide.

The present invention provides several advantages for outdoor use. Firstly, being for
5 outdoor use, there is no requirement for meeting the indoor thermal comfort levels. Temperature provided at a few degrees less than ambient temperature, then provides relief to outdoor users. To this end, the reduction in temperature may be in the range 1°C to 5°C or 1°C to 10°C or 5°C to 10°C.

10 In a further embodiment, the branch application 55 may be permanent and thus located underground possibly in dedicated service conduits. Alternatively, such branches 55 may be temporary and installed tapping into the return chilled water pipe as required.

In a still further embodiment, the branch 55 may be semi-permanent with the
15 application 80, in this case outdoor cooling units, being a temporary addition. To this end the application 80 may be located above ground so as to be readily install and decommissioned when required. Such an application may be for outdoor cooling for an event that temporarily appropriates a built environment and thus may be required to be decommissioned so as to return the built environment to its former condition. An
20 example of this may be an annual parade or outdoor exhibition. Further, a motor racing event providing for a large audience on a street circuit may utilize such a temporary application to enhance the comfort of such an audience.

To this end, the interface between the branch 55 and application 80 may be readily available for installation and decommissioning, for instance, a distribution box installed in the built environment may be effective, so as to receive the temporary application as required, but not be intrusive following decommissioning.

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Given that such a branch application may require less than 1% of the flow of a return chilled water pipe for a district cooling system, such a flow may be within an error measurement of a flow meter for the return chilled water pipe. This demonstrates the minimal impact such branch applications may have on a district cooling system whilst
10 improving the overall efficiency of the system when using such applications.

Such a system may also be a “pay as you use” system ideally for pop-up restaurants, temporary market places, VIP marquees, or other premium service offered permanently, semi-permanently, or on a temporary basis. In this arrangement, the present invention
15 may be embodied as the branch application, including a heat exchanger to deliver cooled air, and termination at an interface. Such an interface may be in a purpose-built event space to allow for licensed users to establish temporary infrastructure which may be adapted to engage the interface, and so providing cooled air at an uncontrolled relative humidity. At the end of the licensed period, the licensed operator “unplugs”
20 from the interface according to the present invention.

Figure 3A shows one embodiment of the present invention, being a one stage cooling system 90, comprising a fan cooled coil 100, having air directed 110 into the coils 115

by a fan 95. Chilled water is directed 120 into the coils, and exited 125, providing convective heat to the air passing through, and consequently producing cooled air 144.

Figure 3B shows an alternative arrangement for an outdoor cooling spot cooler with two-stage cooling system 92. The two-stage cooling system 92 is based upon evaporative cooling which is known to provide a useful means of cooling air in conditions where humidity is very low. For instance, in a dry arid climate such as the Australian desert, humidity is relatively low and so the differential between a dry bulb temperature and wet bulb is considerable. The cooling effect of the evaporative cooling is therefore highly effective. In the environments where the conditions are more humid and so little difference between dry bulb and wet bulb temperatures such as in Singapore, cooler with only evaporative systems are less useful. The alternative embodiment shown in Figure 3A is therefore for the implementation of outdoor spot cooler without the evaporative system where a potable water supply is not available, precluding the evaporative cooling.

For the present invention, the cooling system comprises a fan 95 for driving air through the cooling system. The first stage 100 involves directing a chilled water supply 120 into a water to air heat exchanger, similar to that shown in Figure 3A. As with the cooling system of Figure 3A, the water to air heat exchanger may include small diameter copper tube coils running from side to side within the heat exchanger 115. The tube coils may include metal fins to maximize heat transfer between the water and air mediums. The chilled water may, for instance, be tapped from the chilled water

return pipe of the district cooling system. Alternatively, when not associated with a district cooling system, another source of return chilled water may be provided for the first stage.

- 5 The second stage 105 uses an evaporative cooler whereby water from a supply 130 is pumped 125 so as to be applied to the medium 120. As air passes through the medium 120, water being delivered 140 to the medium, evaporates and thus both cools the air as well as raising relative humidity.
- 10 To aid in the circulation and supply of water for the second stage evaporative cooler, condensation developed in the first stage may be fed into the evaporative cooler reservoir.

The result of each stage of air passing through the two-stage cooling system may be
15 demonstrated by an example.

Ambient air entering the system 110 may have a dry bulb temperature of 32°C and wet bulb temperature of 26°C and a relative humidity of 62.5%. Having passed through the first stage, the air exiting the first stage heat exchanger 100 may have a dry bulb
20 temperature of 28°C and a wet bulb temperature of 24.4°C and a relative humidity of 75%. Air exiting 145 the second stage evaporative cooler may subsequently have a relative humidity of 100% and therefore saturated. Consequently both the dry bulb and wet bulb temperature may be 24.4°C.

The psychrometric chart shown in Figure 4 shows the effect on temperature and relative humidity for the two stage system of Figure 3B, as each stage is plotted on the chart. Thus, entering air 110 is conditioned in the first stage fan coil cooling unit to produce
5 air 144 at a higher relative humidity at lower temperature and thus corresponds to a “sensible plus latent cooling” transformation. This would be the same effect for a single stage cooling system, such as shown in Figure 3A. By then passing through the second stage evaporative cooling unit, the air 145 is transformed as an adiabatic humidification.

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By way of comparison, Figure 4 also shows the end result 150 of air undergoing only evaporative cooling. Ambient air at entry conditions 110 is subjected to evaporative cooling only, and consequently undergoes adiabatic humidification, corresponding to a high temperature. As ambient conditions include relatively high humidity, the result is
15 less effective. The two-stage cooling system thus produces air through evaporative cooling at a lower temperature, but higher humidity, enhancing the comfort of the end users. In applications where the end users are outdoor, the high relative humidity is largely irrelevant, with the cooling effect being the primary motivation. The two stage cooling system is therefore well suited for the branch application of Figures 1 and 2.

20 When the two stage cooling system is used in junction with the branch application, the cooled air provides relief to outdoor patrons.

By way of distinguishing from present invention from conventional HVAC systems, or the requirements of end users for the supply side of the district cooling system, the thermal comfort requirements 155, as set out by the ASHRAE Standard 55 is shown. It can be seen the one stage or two stage cooling systems of Figures 3A or 3B do not
5 comply with the ASHRAE Standard 55 for thermal comfort, but still meet the requirements of the branch application when provided for outdoor users, at a fraction of the energy or infrastructure costs of the prior art.

Whilst the one and two-stage cooling systems according to the present invention provide a useful benefit, its application to outdoor cooling is significant in that the
10 ordinarily ineffective evaporative cooling in a high humidity condition is transformed into a useful cooling system.

Claims

1. A district cooling system comprising:
 - a chilled water supply pipe for conveying cooling energy from a water chilling station to plurality of end users;
 - a chilled water return pipe for conveying the heat load from end users to the chilling station;
 - a branch application comprising a branch supply pipe and a branch return pipe both connected to the chilled water return pipe;
 - said branch application further including a heat exchanger, said heat exchanger arranged to receive water from the branch supply pipe and exit water to the branch return pipe;
 - wherein the heat exchanger is arranged to provide spot cooling for outdoor.
2. The district cooling system according to claim 1, wherein the heat exchanger is in fluid communication with an outdoor cooling unit, said outdoor cooling unit including a vent arranged to provide the cooled air.
3. The district cooling system according to claim 1 or 2, wherein the heat exchanger is in fluid communication with a distribution point, said distribution

point providing an interface arranged to receive ducting for the distribution of
said cooled air.

4. The district cooling system according to any one of claims 1 to 3, wherein the
5 heat exchanger includes a fan coil cooling unit.

5. The district cooling system according to any one of claims 1 to 4, wherein the
heat exchanger includes an evaporative cooling unit.

10 6. The district cooling system according to any one of claims 1 to 3, wherein the
heat exchanger is a two stage cooling system including both a fan coil cooling
unit and an evaporative cooling unit, said heat exchanger arranged to deliver
ambient air to the fan coil cooling unit, and subsequently deliver cooled air to
the evaporative cooling unit.

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7. The district cooling system according to any one of claims 1 to 6, wherein the
branch application requires less than 1% of the flow of the chilled water return
pipe.

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8. A method for cooling, the method comprising the steps of:

receiving chilled water from a chilled water return pipe in a district cooling system;

supplying the chilled water to a heat exchanger; and

5 returning the supplied chilled water to the chilled water return pipe in the district cooling system,

wherein the heat exchanger is arranged to cool air at an unconfined area.