A battery of adiabatic fluid coolers installed at a site in New Delhi for a 3000 ton air conditioning system. Photo courtesy of International Coil Ltd.

Use of Adiabatic Fluid Coolers for Large Air Conditioning Plants

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A greater awareness of global warming and depleting natural resources has led mankind to the "green" movement and the construction of "green" buildings that help to conserve energy. Conservation of water in the design of the air conditioning system for such buildings, however, has not received the emphasis it rightfully deserves.

With real estate booming, infrastructure development at its peak, and over-all growth of the economy pan-India, coupled with a lack of water and electricity, it is time to think out of the box, and stretch the engineering imagination to a level of no compromise. This article based on the author's experience on a recently commissioned project using dry coolers resulted in a rewarding experience, which not only benefitted the project in its entirety, but, would benefit the tenants, in terms of the operating costs, and the ground water resources for its life cycle.

Water – a Dwindling Resource

In earlier times, the ratio of the availability of water and the concentration of population or population density was such that it was possible for the infrastructural civic bodies to ensure adequate availability of water of potable quality to the entire population. But, now, the scenario has changed, and so should the approach towards a project design, especially from the energy and water consideration point of view.

Moreover, the waste water from occupied areas was invariably led back into the rivers which usually served as the source of water, and since the availability was relatively abundant and the use was relatively limited, the dilution in the rivers ensured a continuous availability of good quality water.

The rapid growth of the population in localized areas has created metropolitan cities where the demand invariably exceeds the supply.

This localized growth in

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population has increased the discharge of waste water, which has often resulted in further contamination of the water sources.

Consequently this has called for more intensive water treatment in order to bring the water to the desired quality, and has also reduced the availability of water.

This has invariably led to a severe burden on the infrastructural civic bodies and hence has caused an alarming shortfall of water supply.

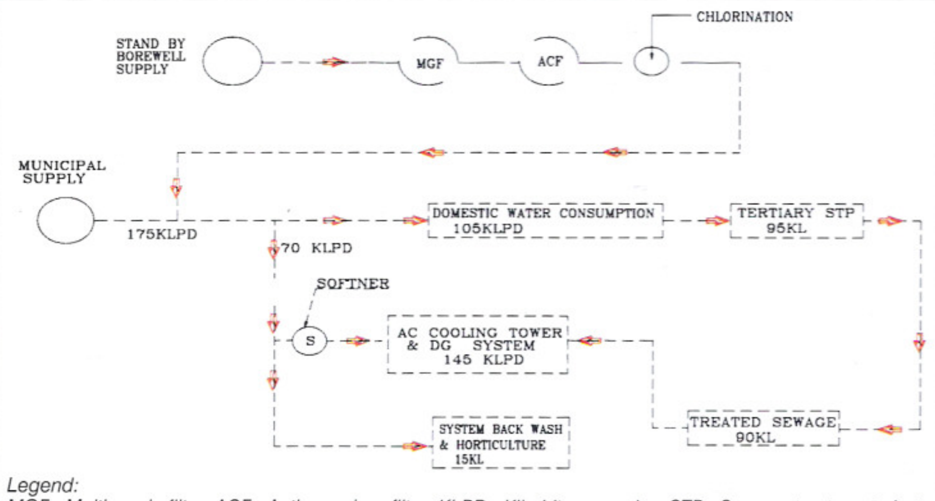
Water or Air for Heat Rejection

Conventionally, in the air conditioning industry, broadly speaking, there have been only two ways to reject the condenser heat – to water cooled in a cooling tower or air. The time has come create hybrid solutions, which are practical, executable and maintenance friendly, while not compromising with the system efficiencies.

There are many projects being planned and developed across the country, where theoretically a water balance at site is established, and water-cooled systems are installed. It has also been observed, that in larger projects, despite the fact that the water is being re-cycled, the first priority of re-distribution, after suitable and desired chemical treatment, is given to flushing and horticulture. So, if such a situation has to be religiously abided by, soft water make-up requirement for the heat exchangers (open circuit-cooling towers),has to be met by on-site generation from tube wells, or off-site resources. The problem still persists, if we look at this in a broader perspective. Ground water resource is anyways depleting, and our dependency on it cannot be avoided, but, for sure can be minimized.

Typically, a site would rely on the municipal and bore-well supply, for its water requirements. With sewage treatment plants (STP) being deployed in almost all new constructions, some respite to the ground water sources and municipal supply, has come, but, much more needs to be done, in this field, since the quantity of re-cycled / re-claimed water from the STP is also dependent on the sewage generated at the site.

Fresh water,after necessary treatment (filtration and chlorination) is consumed at site for various activities, which then, in the form of sewage, finds its way to the sewage treatment plant. The STP reclaims the water from the sewage, and after tertiary treatment (re-claimed water fit for use in horticulture, heat exchanger and flushing), supplies it back to the water distribution network of the building, as explained schematically in *Figure 1*.



Legend:
MGF : Multi grade filter; ACF : Active carbon filter; KLPD : Kilo Litres per day; STP : Sewage treatment plant

Figure 1 : Schematic representation of 175 KLPD water balance equation of a site.

With cost of treated soft water suitable for heat exchangers at 10 paisa / litre which seems "insignificant", the average cost, for a 3000 TR water cooled chiller plant would be Rs 143 lakhs per annum as per calculation shown below. This operating cost also does not consider the cost of de-scaling the condensers. Thus, it is time that we started taking this "insignificant" cost per litre of soft water really seriously. This necessarily does not mean that the only option left is an air-cooled system!

Sample calculation for the cost of soft water make-up, assuming cooling water flow rate of 4 US gallons per minute per TR, and the cumulative (evaporative, drift and bleed-off) losses in a cooling tower @ 1.5% of the water flow rate, for an average of 12 hour operation for a 365 day working, and allowing for 80% diversity (since the losses are not constant through out a year) is as follows:

3000TR * 4 USGPM/TR * 1.5% * 3.7854 * 60 min *12 hrs * 365 days 0.10 Rs / ltr * 80% = Rs 1,43,25,165.00

(1 USGPM = 3.7854 litre / minute)

A Typical Water Conservation Approach in a Building Air Conditioning System Consists of:

1. Minimising the drift losses at the cooling tower.
2. Using chemicals to minimise blow-down from the cooling towers.

Ground Reality

Despite the above two-pronged common approach towards conservation of water, in terms of soft water make-up to cooling towers, it has been found that the

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results do not help to reduce the ever growing demand of water. Thus, it becomes imperative that designers and manufacturers deploy resources to find a more sustainable and effective solution to the inevitable crisis in the offing.

Fluid Coolers – A New Approch

An up-market mall in the capital city of New Delhi located in a very eco-sensitive area, set the design team's brains jogging for an innovative idea of conserving water, without making a dent in the energy bills and over-all operating costs.

To meet the air conditioning system requirement of the project, a concept of co-generation (using gas engines with heat recovery vapor absorption machines along with water cooled centrifugal chillers was proposed by us. The gross total installed capacity being 3000 TR.

The water balance equation of the site,after re-cycling the sewerage and waste water, allowed for only 1000 TR soft water make-up for air conditioning cooling towers.

To adapt to this site constraint, posed due to scarcity of soft water make-up, we proposed to use "improvised" fluid coolers (adiabatic coolers), as an alternate to conventional cooling towers, intentionally ignoring the much-so-obvious alternate choice of air cooled chillers, for the balance 2000 TR. The word "improvised" is being used, since, an adiabatic stage was introduced into these dry coolers, to counter the in-efficiency of the otherwise air cooled fluid cooler.

Conventional dry fluid coolers cannot provide water, cooled close to, or below the design dry bulb air ambient temperature. The cooled water temperature with a conventional dry fluid cooler is generally, at best, the dry bulb temperature +3.0°C.

The adiabatic cooler however enables lower cooled water temperatures to be achieved, somewhere between the dry bulb air ambient temperature and the wet bulb air ambient temperature.

A simple cost benefit analysis (refer *Table 3*), was carried out to convince the management, on the pay-back time required for the additional capital cost being incurred on this account.

Demystifying the Fluid Cooler

Fluid coolers also known as dry coolers, have been abundantly used in cold climate regions, process applications and for generator cooling.

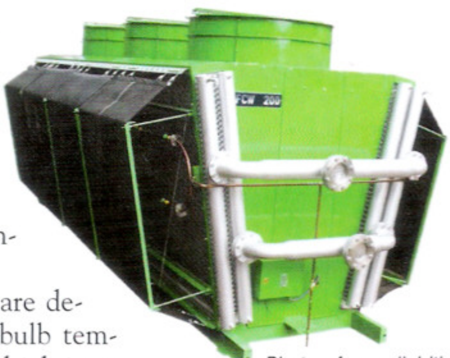

Photo of an adiabltic fluid cooler

Fluid coolers are dependent on dry bulb temperature of air which is generally between 5 to 15°C higher than the wet bulb temperature, depending on the geographical location.

Traditionally, for comfort air conditioning applications, with large heat rejection, cooling towers are the preferred means of condenser cooling, but, now, due to shortage of water, the time has come to explore different means of heat rejection, in comfort cooling applications.

A huge premium is being paid in terms of cost on account of soft water make-up to the cooling towers, to derive the benefits of wet bulb cooling efficiency, which is available for a part of the working hours. Since cooling towers are designed for a continuous operation on a

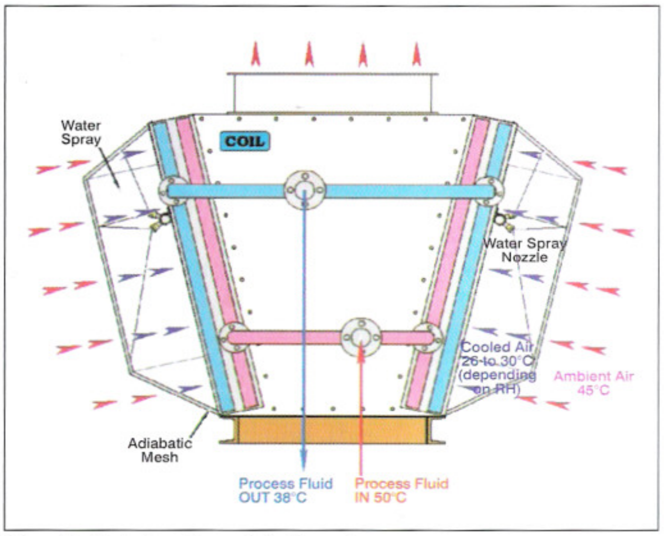

Figure 2 : End view of an adiabatic cooler.

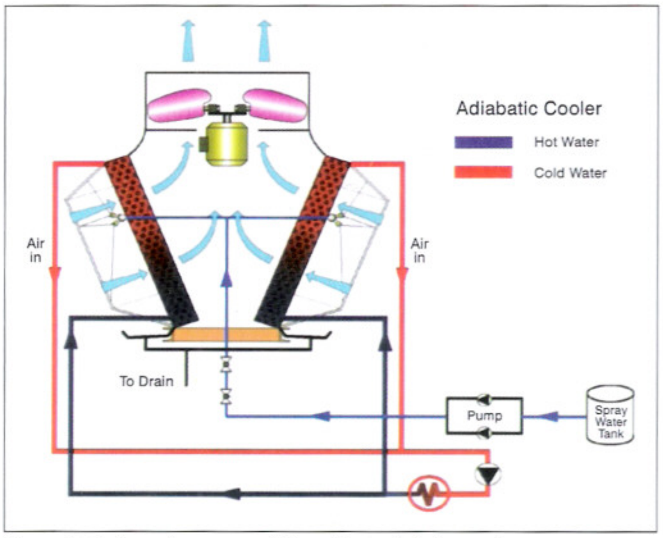

Figure 3 : Schematic representation of an adiabatic cooler.

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wetted surface, irrespective of the weather conditions, it causes enormous amount of wastage of water, which, is now a precious commodity and resource.

The flexibility of operating air conditioning systems, based on dry bulb or wet bulb cooling, can be easily achieved by using an adiabatic cycle on a fluid cooler.

Working Principle

Adiabatic cooling is an age-old principle, that has been incorporated on air-cooled condensers to improve their cooling efficiency.

The key to the successful use of this system lies with the minimization of pressure losses, corrosion proofing of the fluid cooler coils and chassis, thereby reducing the fan input power required to move the moist air across the cooling coils.

Based on the low temperature requirement with an air-cooled system, we introduced the latest technology of a unitized cooling system in which the water outlet temperature can be maintained much below the ambient, even in peak summers.

It is the acceptance and adaptability of these adiabatic coolers with chillers, both centrifugal and absorption, which is of more significance, than the product itself.

The installation at DLF Emporio and Promenade in New Delhi proves that fluid coolers with adiabatic cooling can be efficiently used on centrifugal chillers and absorption chillers, without compromising much on the total input power to the central plant as compared with the alternate air-cooled systems, wherever, there is a scarcity of water, by, just carefully selecting the chillers (adequately de-rating), and defining the realistic operating conditions.

As opposed to a conventional dry fluid cooler, the adiabatic cooler can also reduce the footprint area, otherwise taken up by the dry fluid cooler, since the on-coil air temperature is reduced. But, to move the moist air due to higher specific gravity across its fluid cooling coils, it requires higher power input, thus, loading the sub-system input power.(refer *Table 1*), which adds to the "in-efficiency" of the adiabatic fluid cooler, when compared to a cooling tower. This "in-efficiency" in terms of the operational cost is covered up by the lower amount of water consumed to effect the desired cooling water inlet temperature to the chiller.

A conventional cooling tower loss amounts to 1.5% of the water flow rate (generally at 4 USGPM / TR), which, as an average, is 11 litres/hr. Refer *Table 2* for the theoretical calculation of the water consumed by the adiabatic cooler, which indicates that the average water consumed is approximately 4 litres/hr.

This amount of water required, is subject to the design of the system, and also on the ambient conditions. The consumption of water is not a continuous phenomenon. The adiabatic cooler operates as a conventional dry fluid cooler for a large part of the year, when the prevailing dry bulb air ambient temperature is below the required design cooled water temperature.

Using an adiabatic fluid cooler does reduce the air inlet temperature to the cooling coil, but, due to the system limitation, the temperature of cooling water at the outlet is to be carefully watched. Adapting a centrifugal chiller and a waste heat recovery VAM with the proposed system is a challenge. While centrifugal chillers have a low lift, VAMs have their own sensitivity.

While this system was introduced by us for this project as an alternate to a cooling tower, it took us a while to convince the management not to compare it with a water-cooled system power input, but, to compare it with an air-cooled chiller system power input.

Various options evaluated are shown in *Table 1*:

Option - 1	Water-cooled chiller with cooling towers
Option - 2	Air-cooled chiller
Option - 3	Water cooled chiller with "improvised" fluid coolers (Adiabatic cooling).

No.	Description	Unit	Option-1	Option-2	Option-3
1.1	Chiller input power	kW/TR	0.64	1.45	0.68
1.2	Condenser water pump input power	kW/TR	0.1	0	0.1
1.3	Cooling tower input power	kW/TR	0.05	0	0
1.3	Dry cooler input power	kW/TR	0	0	0.20
1.5	Total sub-system input power index	kW/TR	0.79	1.45	0.98

Chilled water pumps not considered in the above comparison.

Table 1 : indicative input electric power to various chiller plant options, based on Delhi / NCR ambient conditions.

As is apparent from *Table 1*, the total sub-system input power for Option-3, is somewhere in between the power consumed at peak loads between air cooled and water cooled systems, which elucidates the point made earlier, that this system is an alternate potential solution for all projects, where water resource is a constraint and installed capacity of chillers is large enough to not qualify as an air cooled system (keeping in mind energy costs).

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Psychrometric condition of dry air at entry

DBT	:	40°C
Rh	:	40%
gms/kg of dry air	:	19.5

Psychrometric Condition of moist air at exit

gms/kg of dry air	:	23
Thus, grains of moisture added	:	3.5 gm/kG

Specific gravity of moist air at 90% efficiency is 1.2 kg/m³

For an air qty of 204,000 CMH/adiabatic cooler, 856 Ltr of water is added.	:	Thus, 4.037 Ltr/Hr is added at peak ambient of 42°C

Table 2 : Theoretical calculation of quantity of water required for the adiabatic process in an adiabatic fluid cooler

Capital investments		Option-1	Option-2	Option-3
Air conditioning	Rs (in lacs)	900.00	950.00	1300.00
DG sets	Rs (in lacs)	296.00	543.00	356.00
Substation cost	Rs (in lacs)	81.00	149.00	98.00
Deposit to Elec. board	Rs (in lacs)	9.00	16.00	11.00
Tentative total capital investments	**Rs (in lacs)**	**1,286.00**	**1,658.00**	**1,765.00**
Operating cost : Power				
Average cost of electricity consumed though a year	Rs (in lacs)	300.00	482.00	362.00
Soft water make-up (diversified) for cooling tower.	K Ltr/yr	82,786.00	-	
Cost / year of soft water	Rs (in lacs)	83.00	-	
Cost of water for adiabatic effect on dry coolers	Rs (in lacs)			26.00
Total cost of water /year	Rs (in lacs)	83.00	-	26.00
Total operating cost	**Rs (in lacs)**	**383.00**	**482.00**	**388**
Total capital cost	**Rs (in lacs)**	**1,286.00**	**1,658.00**	**1,765.00**

Table 3 : Simple cost benefit analysis between the three options as described in Table 1. This sample analysis has been done for 3000 TR installed capacity of chillers.

This simple cost benefit analysis indicates, the viability of using adiabatic fluid coolers, for projects where water shortage is acute.

It is also evident from the simple cost benefit analysis, based on the capital expenditure and the operating costs,that the system is a convenient mid-way between the air cooled and water cooled systems, and forms a potential for further development and deployment in new as well as in any retrofit project, which have constrained water resources, without compromising much on the capital and operating costs.

Water Quality Required for Adiabatic Coolers

It should be noted that the mains water used for the adiabatic process ***must*** fall within the following parameters:

Total iron	: Count is less than 0.3ppm (0.3mg/l)
Hydrogen sulphide	: Count is less than 0.05ppm (0.05mg/l)
Suspended solids	: Count is less than 10ppm (10mg/l)
Manganese	: Count is less than 0.05ppm (0.05mg/l)
Hardness	: Count is less than 7gpg
pH	: pH6 to pH 8, and hardness < 130 ppm

If the water is hard then calcium scale can be built up on the coil block. In such an event, softened water or de-ionised water should be used for the adiabatic side as hard calcium scale will adversely effect the cooler performance.

Other Considerations when using Adiabatic Coolers

If a centrifugal chiller has to be operated using dry coolers with adiabatic process, then, the compressor, should be capable of operating at a higher condenser water inlet, to avoid surging.

The area required to install these dry coolers, must be incorporated at the conceptual stage of architecture.

Conclusions

Adiabatic fluid coolers with water cooled chillers are an efficient alternate to air cooled chiller option, as they do not increase the over-all operating cost of the system, as compared to an air cooled chiller system, if the project site faces acute water shortage.

While the cited example is for an installation in New Delhi (with high dry-bulb condition), and the adiabatic process benefits from this condition, it is the author's opinion, that dry type (not adiabatic) fluid coolers could be used in coastal areas (having high wet bulb conditions), without compromising much with the system input power.

Prior to taking a decision on the usage of adiabatic/dry fluid coolers, a keen analysis of the same, in the form of a cost benefit calculations, which establishes the initial and operating costs should be done between the three options, as detailed in *Table 3*, on the basis of the system input power (*Table 1*) for coastal area conditions.