An IDEC unit (photo courtesy A.T.E. Enterprises)

Indirect Evaporative Cooling in Contemporary HVAC Design

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Introduction

Evaporative cooling is not new to mankind; it has been around for centuries. The earliest recorded use of evaporative cooling dates back to Egypt circa 2500 B.C. A peep into the rich history of India will reveal how effectively the technology was used to cool the palaces and forts of royal families. It is ironical that this age old technology does not get due attention in contemporary HVAC designs. Today, when HVAC designers and users are struggling to bring down building energy consumption on account of air conditioning by some fractions of a percentage, a thoughtful integration of evaporative cooling can help reduce it substantially – in multiples of what is being achieved by incorporating such numerous small measures.

About the Author

Sunil Tiwari, a mechanical engineering graduate, is an HVAC professional with expertise in alternative cooling technologies, primarily focused on evaporative cooling. A keen follower of sustainable practices, he has spent considerable time in promoting energy efficient cooling solutions for buildings and industries. In his current role at HMX Business Unit of A.T.E. India, he heads Global Sales & Marketing for a wide range of innovative and eco-friendly products built around indirect evaporative cooling, which have the potential to significantly reduce global energy consumption.

Direct Evaporative Cooling

The major apprehension a designer has while thinking of evaporative cooling is the moisture addition to air in the process. Direct Evaporative Cooling (DEC) is a trade-off between sensible heat and latent heat of air, wherein the latent heat is increased by an amount equal to the sensible heat removed, keeping the total heat or enthalpy of the air constant.

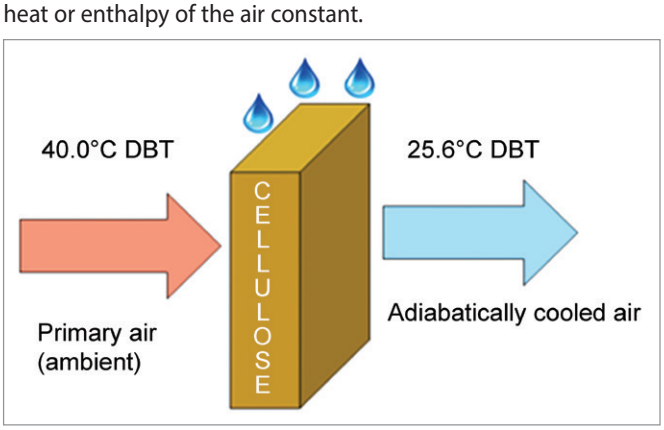

Figure 1: Adiabatic evaporative cooling of air

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As a stand-alone cooling solution, evaporative cooling brings down the temperature of air and creates the cooling effect by combining lower temperature and increased air velocity around the occupants. This works very well when outdoor air is hot and dry, but fails to meet comfort expectation during the relatively humid days.

Indirect Evaporative Cooling – Overcoming the Limitations

These limitations on the use of evaporative cooling have been overcome to some extent by the introduction of indirect evaporative cooling (IEC). In the IEC process, air is first cooled in an indirect manner where air and the evaporated mass of water do not come in contact with each other. This keeps the moisture (grains) of air unchanged; however, the dry bulb and wet bulb temperature of air are reduced and so is the enthalpy.

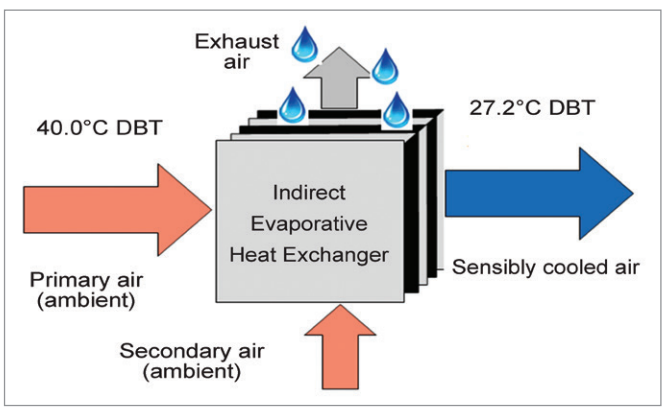

Figure 2: Indirect evaporative cooling

Indirect evaporative cooling has helped bridge the gap between evaporative cooling and air conditioning to some extent. However, due to the lack of structured information on the subject, the concept has still not percolated adequately to the users.

Combinations of Indirect Cooling

Multiple combinations are possible using indirect evaporative cooling along with direct evaporative cooling or air conditioning, the most popular being the three basic concepts:

1. Stand-alone cooling with Indirect-Direct Evaporative Cooling (IDEC) or Two Stage Evaporative Cooling.
2. Treated Fresh Air (TFA) units using indirect evaporative cooling for pre-cooling of fresh air.
3. Hybrid air conditioning using indirect evaporative cooling and Chilled Water (CHW) or Direct Expansion (DX) coils.

While the basic objective of each of the above combinations is to save energy and maximize the content of fresh air in the building, the three approaches are used in different situations depending on the application needs.

Indirect-Direct Evaporative Cooling

IDEC or Two Stage Evaporative Cooling cools the air by combining the indirect and direct evaporative cooling processes in series.

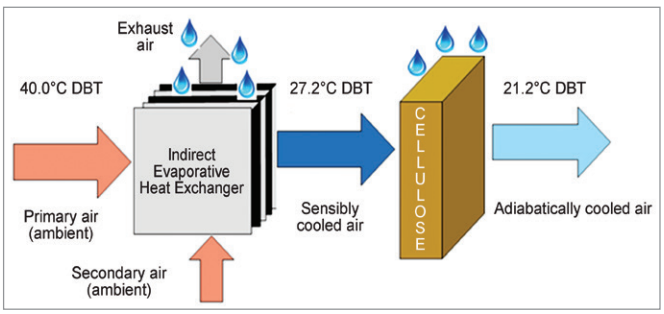

Figure 3: Indirect-direct evaporative cooling

In IDEC, the supply air contains less moisture compared to DEC and the temperature is 4-5°C lower than that delivered by DEC. This superior cooling performance has significantly broadened the application area of evaporative cooling. Cooling applications where excessive moisture is undesirable can now be relooked at with IDEC solutions. Many industrial as well as commercial building cooling applications have adopted DEC to meet their cooling needs energy-efficiently while ensuring high levels of indoor air quality with 100% fresh air.

Case Study: LEED Gold Rated Office of A.T.E. Group

One such application is the cooling system installed in LEED Gold rated Green building of A.T.E. Group's office in Pune.

Established in 1939, A.T.E. is a multifaceted engineering group offering products and solutions spanning several segments. Most of A.T.E.'s business divisions focus on green technologies and products. The technologies include machine-to-machine (M2M) technology, waste water treatment, cooling solutions and solar solutions.

A.T.E. wanted to create a world class office and to apply for Green certification to IGBC. A.T.E. office in Pune has implemented various energy efficiency measures, including the use of natural lighting, LED bulbs, reflective coating on the roof, water-cooled building structure, IDEC system, rain water harvesting and shading, which make the building highly energy-efficient.

Description of the Office

The office area has ground and mezzanine levels, with an approximate area of 5,000 square feet. The ground floor

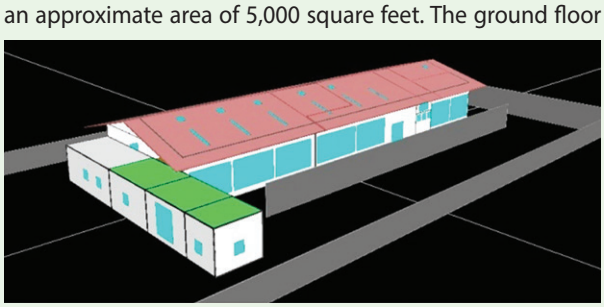

Figure 4: A 3D representation of the facility

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Figure 5a: Front part of office showing the mezzanine

Figure 5b: Rear part of office housing senior employees

houses software, hardware and semi-private workstations, cubicles, conference rooms, external verandahs, general storage, IT room and toilet areas. The mezzanine level has informal meeting space, software workstation and a meeting table.

Design Approach

- The entire office is designed to provide maximum fresh air to the employees and to reduce energy consumption without compromising on comfort. IDEC units provide 100% fresh air within the designated area without the use of any refrigerants harmful to the environment.
- In order to reduce heat gain from the roof and walls, they are painted with a heat reflective paint. Under deck insulation with low emissivity aluminium film is also provided. The insulation helps to reduce the noise from GI roof during the monsoon.

Solution

1. *IDEC units*
   To meet the desired comfort conditions inside the office space, two IDEC units of 16,000 cfm each (total 32,000 cfm) are provided. They cover the main office area. Both the units are provided with Variable Frequency Drives (VFDs) to control supply air quantity inside the space depending on the requirement. Air is distributed to all areas by running the ducting parallel and throwing air with the help of jet nozzles.
2. *Over Deck Heat Reflective Paint and Under Deck Insulation with Lamination*
   High heat reflective paints have been applied over the GI roof and brick walls, with higher solar reflective index (SRI) that helps to reflect most of the solar heat and reduce heat gain to the building. The under deck roof insulation further helps to reduce solar heat gain. Combining the effect of heat reflective paint coating with under deck insulation provides comfort conditions inside the space. To maintain the effectiveness of the reflective paint, the roof is cleaned regularly by sweeping or water spraying. Provision is made for easy access to the roof for cleaning and a proper drain system is provided.

Modes of Operation

Depending on the conditions to be maintained inside, set point inputs (temperature and RH) can be given to the machines. The machines can run in the following four modes depending on the parameters set in the control panel. The VFD helps the units to switch modes automatically.

1. *Indirect Direct Evaporative Cooling*
   In the summer, the units run in IDEC mode and provide cool air. Most of the room air gets exhausted through door openings, and the remaining through turbo ventilators installed on the roof.
2. *Indirect Evaporative Cooling*
   During the monsoon, the units run in IEC mode only providing cool air without adding moisture to the supply air.
3. *Direct Evaporative Cooling*
   In moderate climates, when the temperature is close to comfortable and the RH is low, the units work on DEC to

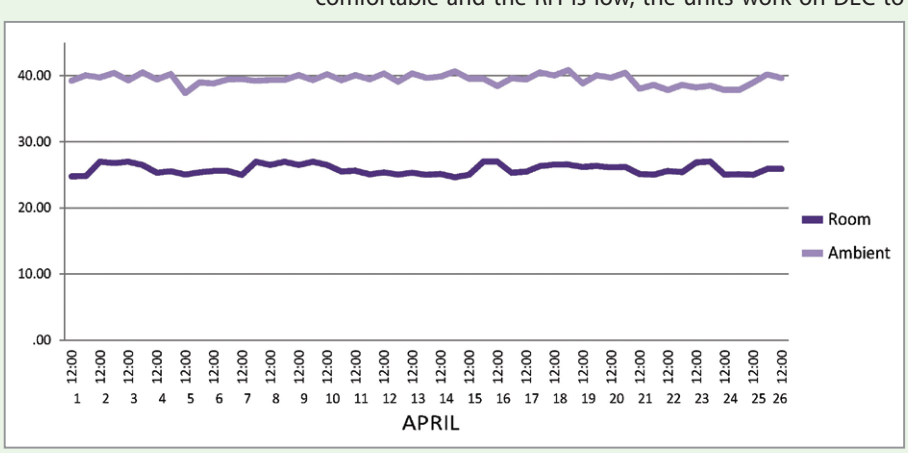

Figure 6 : Ambient vs. room temperature conditions for April 2016

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maintain set temperatures and to add a little moisture to the air to enhance the quality of indoor air.

4. *Ventilation*

During the winter, ambient air temperature is cool enough for comfort and the units provide controlled air quantity with the help of VFD, depending on room conditions.

Additional Energy Saving Features

Night Ventilation

Four wall mounted fans of 5000 cfm capacity each have been installed to cool the structure during night. These fans gets automatically switched on with a timer at night for only two hours (from 3 am to 5 am), and pump the ambient cool air into the building. The fan is covered with ducting from outside and filters are provided to avoid dust infiltration.

HVLS Fans

High Volume Low Speed (HVLS) fans have been installed to augment and churn the air as required. The fans do not add any cooling, but the increased air velocity enhances the feeling of comfort substantially.

Natural Lighting

Openings and fenestrations on the roof allow sun-rays to enter and illuminate the area. Hence the office does not require any artificial lighting during the day.

Conclusion

The A.T.E. facility has been in operation since January 2014. It has achieved the coveted Gold certification from Indian Green Building Council under the Leadership in Energy and Environmental Design (LEED) program. Apart from its energy efficiency and sustainability, employees and visitors vouch for its excellent cooling and indoor environmental quality (IEQ). The green features of the building are summed up as follows:

- Natural day-lighting (openings and fenestrations, skylights)
- LED lights
- Reflective roof
- Low-ε coating on the roof
- Evaporative cooling system (IDEC)
- Rain water harvesting
- Cool and fresh air supply
- Passive ventilation
- CO_2 monitoring
- Plants