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ENGINEERING AND CONSTRUCTION BULLETIN

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SUBJECT: TechNote: Guidance for Indirect Evaporative Cooling Applications in Army Buildings

CATEGORY: Guidance

1. **References**: Jesse Dean, Lesley Herrmann, Eric Kozubal, and Jesse Geiger (National Renewable Energy Laboratory) Mark Eastment (Eastment Consulting Inc.) Steve Slayzak (Coolerado). Dew Point Evaporative Comfort Cooling Summary Report. Energy and Water Projects Demonstration Plan SI-0821. ESTCP. TP-7A40-56256-2 November 2012.

http://www.rexresearch.com/maisotsenko/maisotsenko.htm

2. **Background.** Mechanical cooling provided by DX (Direct Expansion) units or chilled water systems is one of the major electric loads in buildings, particularly in southern climates. In many climate zones, the cooling load for many buildings could be satisfied most of the year without mechanical refrigeration by cooling the buildings' ventilation air using indirect evaporative cooling (IDEC). This would result in much lower operating costs, especially during peak electrical demand periods. In buildings with significant cooling loads, indirect evaporative cooling can be used in combination with DX units or chilled water coils to reduce the size (first cost) and the load (operating costs) of mechanical cooling systems by up to 65%. The primary advantage of the IDEC in relation to the other evaporative cooling units is that it cools without adding any moisture to the conditioned space. This advantage comes at a price, though; and not just in terms of initial cost. The heat and mass exchange modules have a very high resistance to flow, resulting in decreased delivered airflow and higher power consumption than other evaporative cooler systems, as evaluated under previous PG&E (Pacific Gas and Electric) Emerging Technologies projects. However, these units still use considerably less power than a conventional air conditioner, and will likely keep a space more comfortable than other evaporative coolers for more of the cooling season.

3. **Purpose.** There are mixed opinions regarding the performance of evaporative systems, and complaints regarding their maintenance. Most of these evaporative air coolers are based on old technologies, which have some maintenance issues. Also, there are many cases where evaporative cooling has been misapplied (direct evaporative cooling is not effective in humid climates) or where evaporative cooling should have been combined with DX units to cover peak loads or operational periods with a high relative humidity during spring and fall. Indirect evaporative cooling is accomplished by either an evaporative cooling pad or misting spray nozzles at the exhaust air inlet which is separated from the outside air stream by a water-proof layer within the heat exchanger. Unlike direct (DEC) evaporative coolers, the humidity of the ventilation air delivered to the building by an IDEC system is unchanged or even can be reduced. The purpose of this bulletin is to establish USACE guidance for using IDEC systems in new construction and renovation projects.

4. **Technology Description.** High efficiency IDEC cross-flow multistage heat exchanger which can operate in wet and dry modes and be used for cooling, preheating, and pre-cooling of the supply air into conditioned spaces.

There are high efficiency indirect evaporative coolers on the market today that utilize a HMX (Heat and Mass Exchanger) (Figure 1a) that uses the patented "M-cycle" process. The Maisotsenko cycle was realized in a uniquely designed plate wetting and channel system, which achieved optimum cooling temperatures and saturated working air with the highest enthalpy possible for the exhausted working air temperatures obtained. Due to its multi-stage (20 stages) airflow pattern, it allows the supply air to be cooled below the wet bulb temperature, approaching the dew point temperature of the incoming working air. Figure 11b shows a diagram of an actual perforated cross flow heat and mass exchanger with air flow paths.

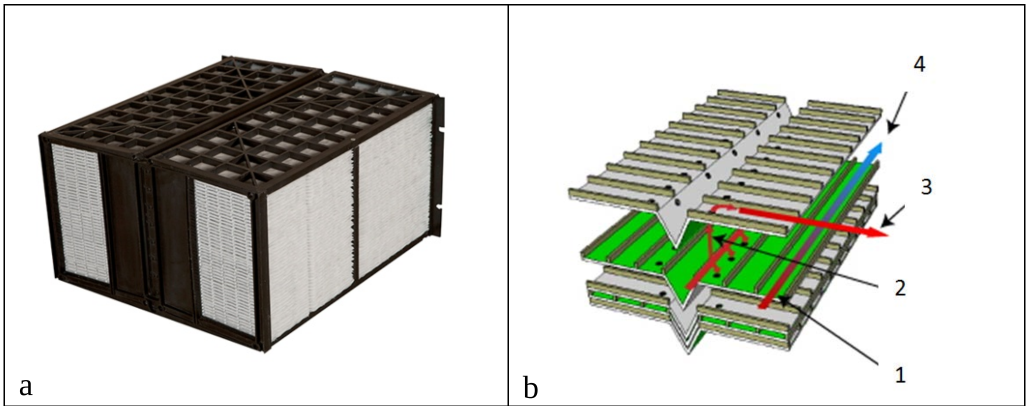

Figure 1. (a) indirect evaporative cooler HMX heat and mass exchanger; (b) diagram of HMX with air flow paths.

In Figure 1b, product air enters the HMX at Point 1. At Point 2, working air that has been cooled is repeatedly directed across the exchanger into the wet (gray) channels. At Point 3, working air that has been fractioned off into wet channels is rejected as exhaust. Heat from the product air has been transferred into this exhausted working air. At Point 4, the product air has travelled the length of the dry (green) channels transferring its heat to the working air. The product air is now close to the dew point temperature of the entering air without having increased in moisture content.

5. **System Configurations.** Depending on the climate, cooling and heating loads, the HMX heat exchanger can be used in different HVAC equipment configurations.

a. Configuration A: Stand-alone unit with HMX heat exchanger used for supply air cooling (outside air is cooled and supplied directly into the conditioned space (Figure 2) – ideal for make-up air applications.

b. Configuration B: Dedicated Outdoor Air System (DOAS) HMX installed in the return air duct, providing Energy Recovery Ventilation. The return air has a temperature around 72^{o}F and relative humidity around 50% in most climate conditions and applications. In cooling mode, the return air is utilized on the working side of the HMX and provides indirect cooling of the outdoor air passing on the other side of HMX heat exchanger. During the heating mode, there is no water supply to HMX unit. Return air has a temperature higher than the outside air flow and thus, HMX heat exchanger acts like a (dry) heat recovery device. During the entire year HMX is used for outside air preheating and pre-cooling/cooling. Configuration of HMX unit to be connected to supply and return air ducts is shown in Figure 2.

c. Configuration C: HMX cooling return air using outdoor air on the working side as an Indirect Air-Side Economizer. Taking advantage of new recommended data center operating envelopes enables HMX cooling under 0.15kW/ton without requiring unconditioned outdoor air be introduced to the data center. This approach can also cut cooling plant and corresponding power infrastructure capacity by 50%-90%.

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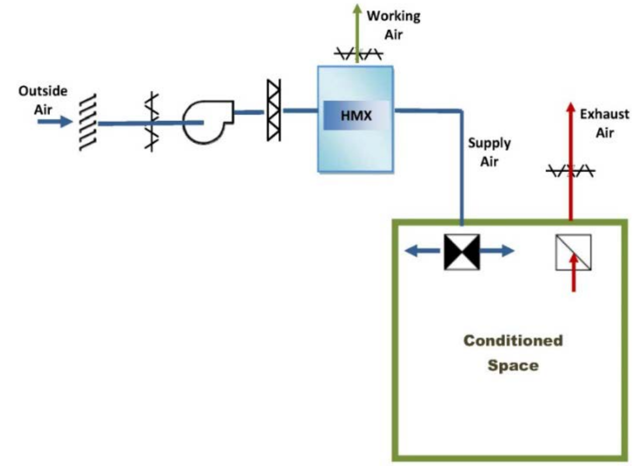
<tr><td>A</td><td></td><td>
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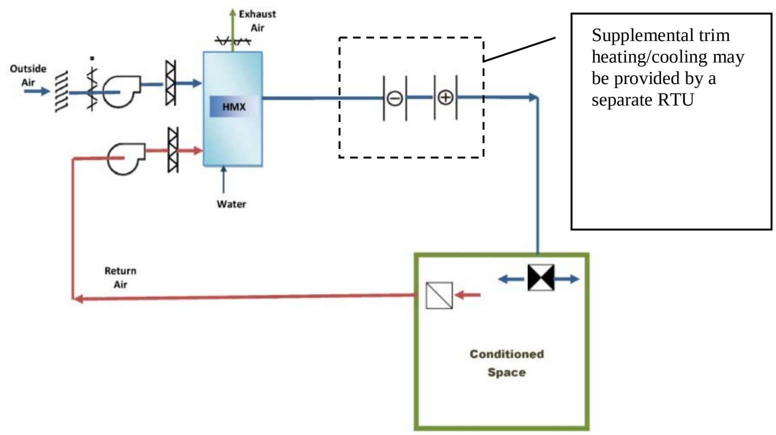
</td><td>
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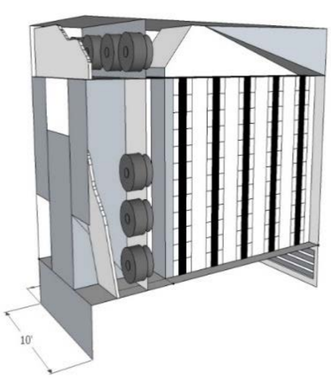
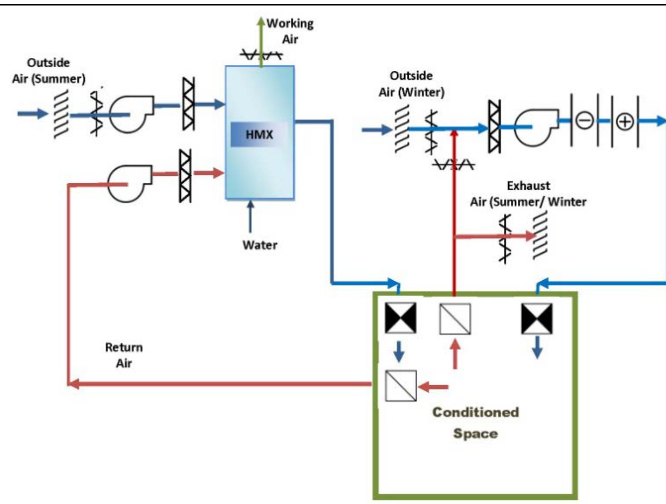
<tr><td>C</td><td>
</td><td>
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Figure 2. Configuration A: Hybrid heating and cooling system using HMX indirect evaporative cooling for enhanced Air-Side Economizing Configuration B: Hybrid DOAS using HMX indirect evaporative cooling and heating with energy recovery (ERV) Configuration C: Indirect Air-Side Economizer (IASE)

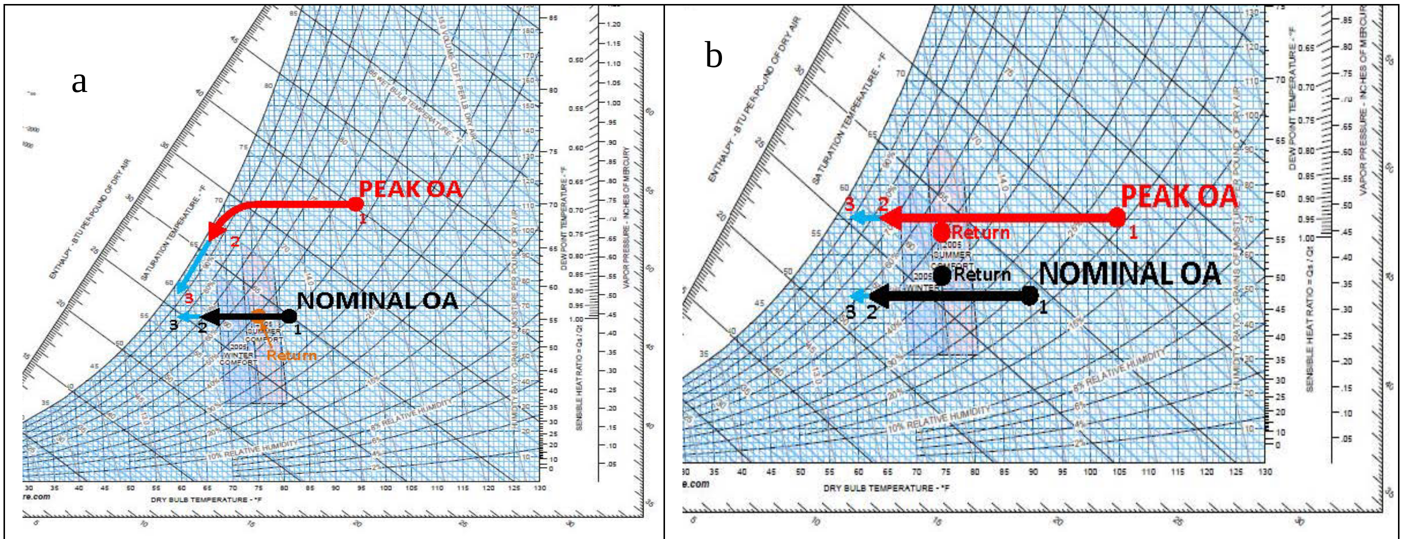


Figure 3. Thermodynamic process of a hybrid DOAS configuration with energy recovery: 1 – outside air; 2 – air after HMX heat exchanger; 3 – supply air: a - East (humid) climate zones; b – West (dry) climate zones.

6. **Practical Applications.** Commercial and Institutional buildings with cooling needs, including but not limited to data centers, food service, health care, schools, government offices, warehouses, maintenance facilities, etc.

a. Configuration A: Air cooling of buildings located in DOE climate zones 2b-5b with high internal cooling loads and ventilation/makeup needs and a possibility to install multiple cooling units.

b. Configuration B: Air cooling and heating of buildings (DOAS with Energy Recovery) located in DOE climate zones 1-6 (a, b and c), 7 and 8.

c. Configuration C: Indirect Air-Side Economizer cooling for data centers in DOE climate zones 1-6 (a, b and c), 7 and 8.

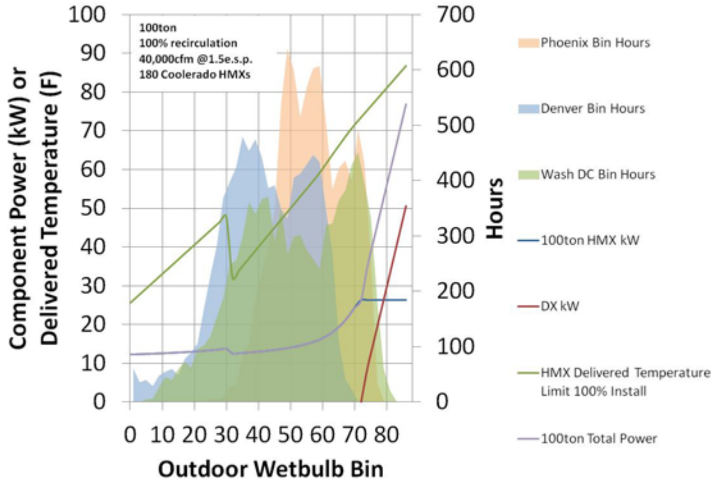


Figure 4. IASE for cooling applications in data centers.

7. **Economics.** Studies conducted by NREL for configuration A show, that in "dry " (b) climate zones HMX Units provide comfort cooling at 0.3kWh/tonh annually (40 EER) (Table 1). Data has been obtained for configuration A assuming that fresh air rate is 20% and the stand-alone peak efficiency reflects the some oversizing necessary to hold setpoint during the southwestern monsoon season. OA and Return conditions are as depicted in respective psychrometric process charts (Figure 4).

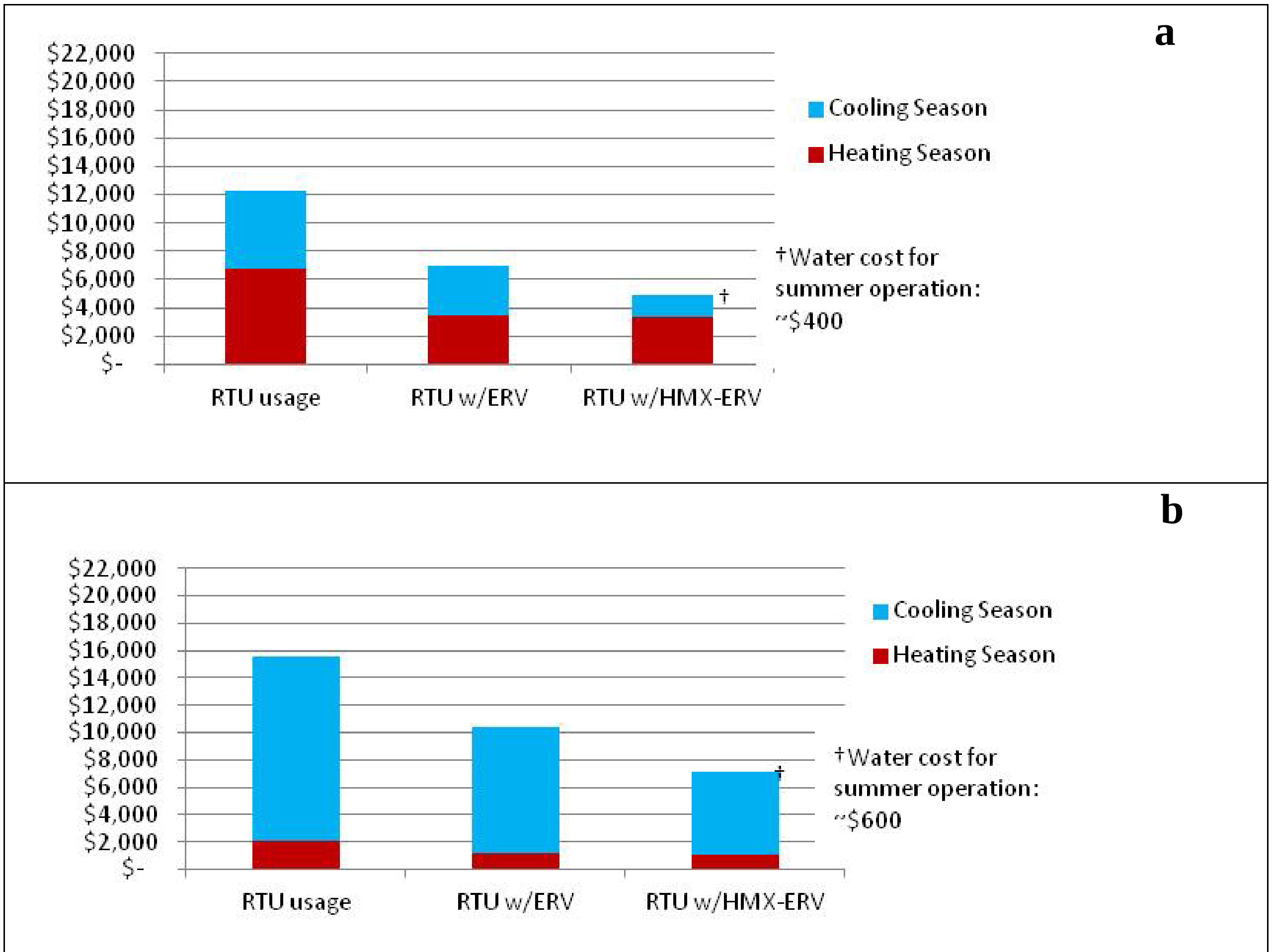
Trim cooling supplies air at 60F and is provided at 1.5kW/ton on peak, and 1.2kW/ton at nominal summer conditions. Effective Annual efficiency assumes trim is required for half the ton-hrs supplied throughout the year. Different weightings may be appropriate for various locations and applications, and none of the figures above account for efficiency gains from variable speed operation.

Energy cost comparison between configuration C and a standard RTU in different climates for the case when heating coil is connected to hot water heating system, cooling coil – to the DX system and efficiency of heat recovery is 70% is shown on graphs in Figure 5.

This technology typically delivers annual comfort cooling with an EER of about 60. This is five times as efficient as DX (80% savings) and four times as efficient as a water-cooled hydronic system (75% savings). In high temperature applications, like a data center or industrial process exhausting around 100F, they can produce EERs over 100.

Table 1. Approximate Hybrid IDEC System Energy Efficiency Ratios

Climate Zone	**Configuration**	**kW/ton (EER)**				
		Peak	**Nominal**	**Peak w/trim**	**Nominal w/trim**	**Effective Annual**
West (2b-6b)	A	0.40 (30)	0.24 (50)	1.28 (9)	0.66 (18)	**0.45 (34)**
West (all)	B	0.15 (80)	0.21 (57)	0.30 (40)	0.37 (32)	**0.29 (45)**
East (all)	B	0.19 (63)	0.33 (36)	0.64 (19)	0.49 (25)	**0.41 (30)**
All	C	0.17 (75)	0.05 (240)	0.60 (19)	0.10 (120)	**0.07 (180)**



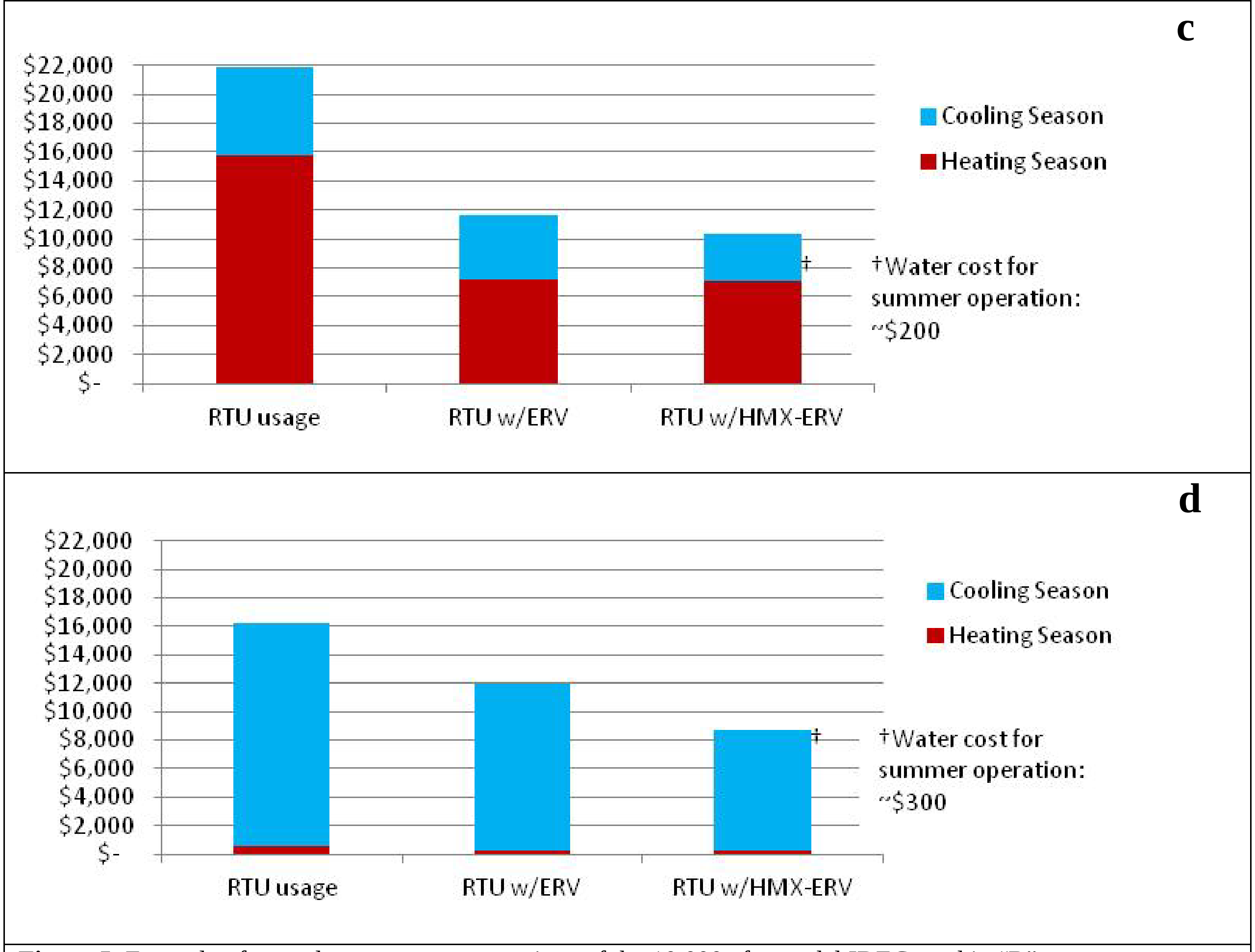


Figure 5. Example of annual energy cost comparison of the 10,000 cfm model IDEC used in "B" energy recovery configuration with the standard roof top unit (RTU) in the Mountain West (a), Southwest (b), Northeast (c) and Southeast (d)

8. **Special O&M Requirements.** For continuing high performance, and to minimize possible equipment failure, periodic maintenance must be performed on this equipment. Frequency of maintenance may vary depending upon geographic areas, such as high dust, pollen or air pollution. Pay close attention to cleanliness of the unit's filters and heat exchangers. In addition to standard maintenance requirements to fans, filter, heat exchanger and unit housing, special attention shall be paid to the water system maintenance. Failure to follow these instructions will shorten the life of the heat exchanger and result in poor performance of the system.

a. Water System Maintenance

(1) Water delivery devices and piping should be inspected to insure proper water flow. This includes all pipes leading to the air conditioner as well as the internal tubes that deliver water to the heat exchangers.

(2) Check the water supply system for leaks, and repair if needed. Any leaks should be repaired immediately to assure proper water delivery to the unit. With the air filters removed, check the internal tubes of the water distribution system for leaks. Proper and consistent water flow is essential for efficient and proper unit operation. Water overflowing from the top of the drain pan may indicate that the drain is partially plugged. If this is the case, remove the elbow from the bottom of the drain pan and clean.

(3) Caution (from most manufacturers): The water pressure must be maintained between 25 psi and 80 psi (172 and 552 kPa). Below 25 psi (172 kPa) the fan will turn off automatically to prevent drying out of Heat and Mass Exchangers.

b. Water Quality

(1) Water quality can be difficult to quantify, as there are different factors that must be considered. To ensure proper performance of the Heat and Mass Exchangers (HMXs), prolong the life of equipment components and to avoid increased maintenance, the below water criteria must be considered and evaluated before installation.

(2) Solids: All water supplies have the potential to have un-dissolved solids from water line repairs, additions and maintenance. Solids in the water supply must be filtered out when above 30 microns to prevent plugging of the water distribution system or Heat and Mass Exchangers (HMXs).

(3) IDEC with HMX typically uses 30 micron water filters with each unit. Installation of the manufacturer's supplied 30 micron filter or equivalent is required on all installations to filter un-dissolved solids.

(4) Organics: HMX plate material are typically manufactured with polypropylene that is not a food source for molds; the plate material also has a biocide impregnated into it to prevent organics from growing. Typically the biocide supplied from a potable water supply district will be enough to prevent any mold growth. However, if supply water that does not contain biocides is being used, like well water, both the air and maybe the water will have organics that can sustain molds, generally in the form of a slime that can grow in the water distribution system and on the wet portion of the HMX plate surface. In these cases a biocide such as chlorine may be required.

(5) Water temperature: When water is heated, dissolved minerals like calcium will come out of solution and form scale; the reason hot water heaters and pipes build up scale. For this reason we recommend water supply pipes to the HMX units be kept in cool places or insulated when exposed to the sun.

(6) Dissolved minerals: There are a lot of dissolved minerals in water, however we are most concerned with the hardness of water made up mostly of calcium but can include

magnesium. Hard water causes two problems. First, it prevents soap from creating suds and leaves soap scum on sinks, etc. The second, and maybe the bigger problem for any evaporative equipment, is the formation of scaling most generally in the form of calcium carbonate; the magnesium will stay in solution under much higher concentrations. Calcium carbonate can close off water lines, collapse cooling towers from the weight of scale build up and in general cause many problems. The key here is the amount of calcium water hardness. In low quantities of hard water is not a problem. How hard water is generally defined as:

Classification	Hardness, ppm
Soft	0-60
Moderately Hard	61-120
Hard	121-180
Very Hard	>180

(7) Water that is Moderately Hard or greater should be treated with a sodium-based water softener. The water should be tested to properly address any water quality concerns, contact your local water utility to determine the total harness of your water or have the water tested at a water laboratory.

9. **Conclusion.** This designer will need to weigh the energy saving benefits with the special operation and maintenance requirements and first cost in their complete life cycle cost analysis (LCCA) when considering indirect evaporative cooling systems. This ECB can assist the designer in completing their LCCA by pointing out the technical and economic aspects of indirect evaporative cooling.

10. **Update.** Any new requirements will be included in the next appropriate policy document update prior to the expiration of this ECB.

11. **Points of Contact (POC).** POC for this action are Dr. Alexander Zhivov, ERDC-CERL 217-373-4519, Alexander.M.Zhivov@usace.army.mil and Mr. Timothy Gordon, CECW-CE, 202-761-4125, Timothy.D.Gordon@usace.army.mil.

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