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MANAGING WATER OF ADIABATIC SYSTEMS

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Adiabatic coolers are becoming more common in the HVACR marketplace. Multiple designs are employed within the industry using different water system methodologies, the details of which can significantly impact the performance and maintenance requirements for the heat rejection equipment. This paper analyzes some of the pros and cons of the different designs available.

1. What is an Adiabatic Cooler?

An adiabatic cooler is an air-cooled heat exchanger that uses adiabatic pre-cooling to lower the dry bulb temperature of air entering the finned coils and enhance heat rejection. Process fluid is circulated through finned coils, where it is cooled by sensible (dry) heat transfer with the air moved over the outside surface of the finned coils. During times of peak load and/or peak ambient conditions, adiabatic pre-cooling can be engaged to improve the cooling performance by using water to humidify, and thus pre-cool, the entering air.

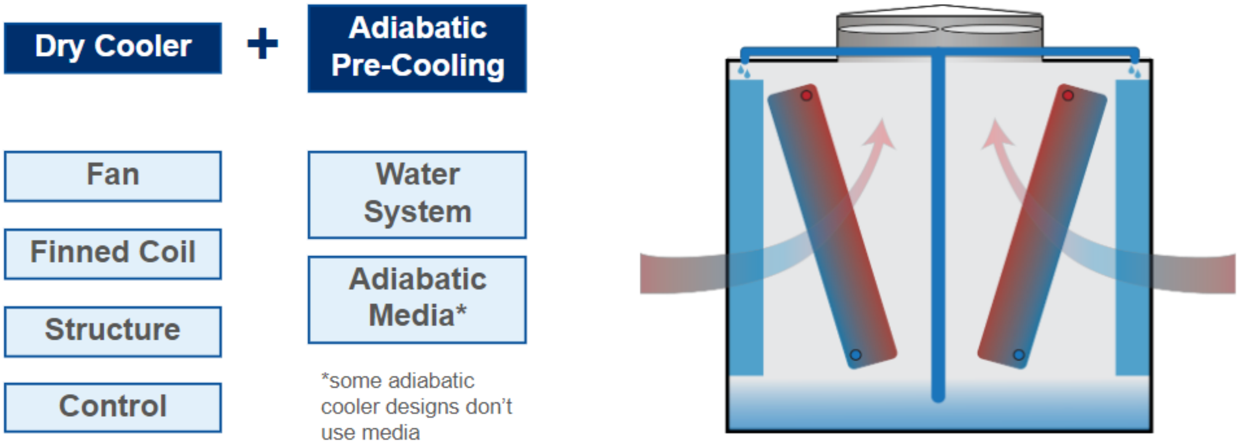


Figure 1: Diagram of Adiabatic Cooler

2. How Adiabatic Pre-Cooling Works

Adiabatic pre-cooling reduces the dry bulb temperature of the air by adding moisture without adding heat. On the psychrometric chart, the adiabatic humidification process follows lines of constant enthalpy toward the saturation curve, typically stopping short of the wet-bulb temperature. Saturation efficiency measures this proximity, which is the ratio of temperature drop across the media to the total difference between the starting dry-bulb and wet-bulb temperatures, expressed as a percentage. Figures 2 and 3 show an example calculation. Saturation efficiency can vary due to several factors, including media type, surface area, media depth, water loading and air velocity.

$$\frac{\text{Ambient DB} - \text{Precooled Air DB}}{\text{Ambient DB} - \text{WB}}$$

$$\text{Example} \quad \frac{95^\circ\text{F} - 83^\circ\text{F}}{95^\circ\text{F} - 78^\circ\text{F}} = 70.6\%$$

Figure 2: Equation of Saturation Efficiency

3. Why Would You Use Adiabatic?

Adiabatic coolers are designed to run dry most of the year with the adiabatic water distribution system off. Because of this, water reduction in an adiabatic cooler versus an evaporative cooling tower is up to 90%. The water distribution system will wet the media during peak dry-bulb temperatures (summer hours), when adiabatic operation commences. In instances where water and energy savings are top priorities, an adiabatic system can provide a balance between conserving water and limiting power.

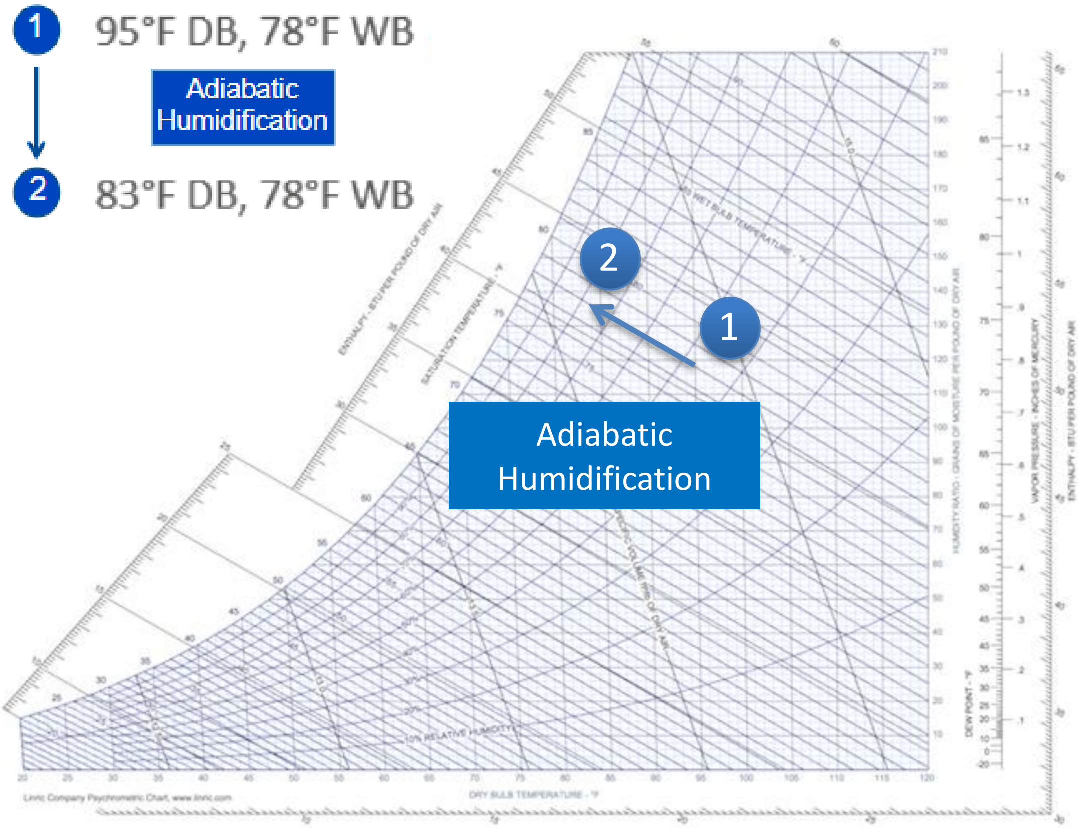


Figure 3: Adiabatic example calculation – Source: The Engineering Toolbox

4. Definitions

Make-Up

Make-up is the supply of water to the unit and is the sum of the water used in evaporation and the water sent to the drain. Depending on the type of unit, the water is either used once or reused. Units that reuse the water have lower makeup rates than their single-use counterparts, see section 7.1 & 7.2.
Makeup = Evaporation + Blowdown

Evaporation

In an adiabatic cooler, the amount of water evaporated in the adiabatic pre-cooling process is a function of the entering air properties, the airflow rate, and the saturation efficiency. Unlike an evaporative cooling tower, the heat load of the unit does not directly affect the amount of water evaporated. Warmer and/or lower humidity entering air, a higher airflow rate, or a higher saturation efficiency will result in an increased evaporation rate. The equation for calculating evaporation is:

$$Evaporation\ Rate(gpm) = (humidity\ ratio_{out} - humidity\ ratio_{in}) * density\ dry\ air_{in} * airflow/8.33$$

Blowdown (Drain)

As water evaporates, dissolved minerals are left behind, increasing the mineral content of the remaining water. To keep the mineral content of the water within safe operating limits for the equipment, a portion of the water is sent to the drain. The water sent to the drain is called blowdown. A blowdown conductivity limit is set in microsiemens per centimeter (µS/cm) with a controller that is using a probe to measure the conductivity of the water. Conductivity is a rough measure of water quality, and once the conductivity is over the setpoint, water will be sent to the drain. In a once-through system, any water that is distributed onto the media and is not evaporated is blowdown.

Cycles of Concentration (COC)

COC is the ratio of dissolved solids in the blowdown to the dissolved solids in the makeup. To set a blowdown limit, a water quality analysis is typically completed to determine the appropriate operating COC based on mineral content within the makeup water. Water savings increase as COC increases,

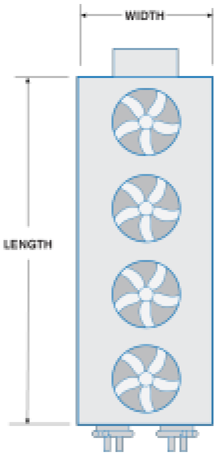


Figure 4: Plan View of Adiabatic Unit

however, there is a diminishing return (see figure 5, showing how water savings increases for a 4-fan unit shown in figure 4.)

Saturation efficiency
Saturation efficiency is a measure of how well the adiabatic humidification process occurred. *See 2. How Adiabatic Pre-Cooling Works*.

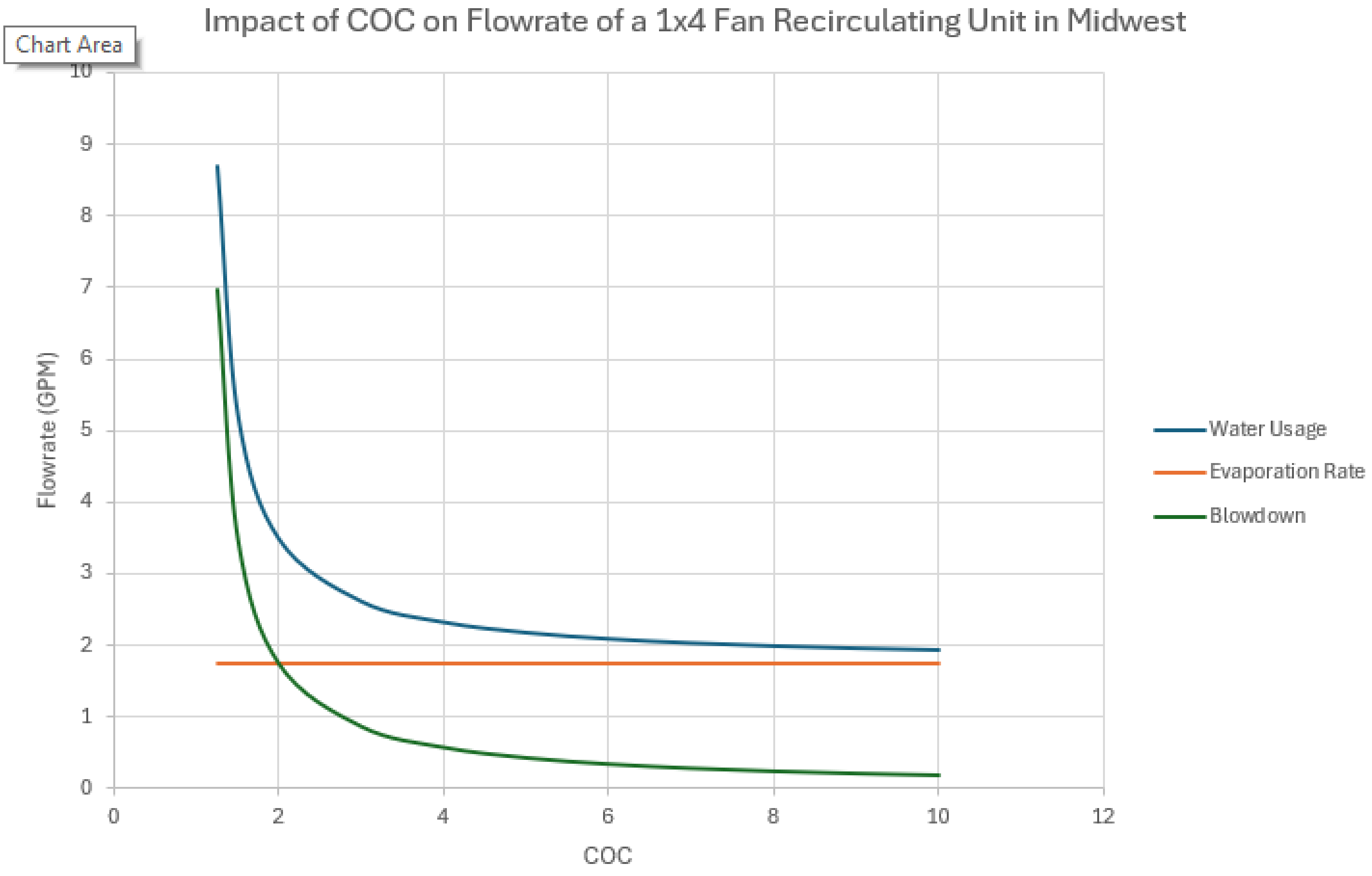


Figure 5: Impact of COC

5. Types of Adiabatic Systems

Adiabatic coolers can be grouped according to the characteristics of their water system:

Once-Through
Once-through (or single-use) systems only distribute water once, and any water not evaporated is either sent to a drain or settles in the surrounding environment.

Recirculating
Recirculating systems use a collection basin and pump to capture and re-distribute water not evaporated.

Media Cooled
Media cooled systems distribute water over cellulous media that provides surface area for the adiabatic pre-cooling.

Spray Cooled
Spray cooled systems distribute water directly into the air using atomizing nozzles.

There are three main types of adiabatic products currently in the marketplace, each of these can have variations. They are discussed below:

5.1 Once-Through, Media-Cooled Systems (OTMC) (Fig. 6)

In this system, makeup is delivered to the top of the media and as the water travels down, it interacts with the air, evaporating a portion of the water. The water not evaporated is sent to the drain. In this configuration: makeup = distribution system = evaporation + drain. Both the distribution and drain are coupled and cannot be optimized independently of the other. The water distribution rate over the media can vary with control strategy.

A) Variable Flow

These systems typically vary the flow based on ambient parameters and process fluid temperatures. When ambient conditions increase, water loading over the media will increase. These systems attempt to keep water loading as low as possible, to maximize water savings. However, when evaporation increases, water loading will need to also increase. If water loading is not increased to fully wet the media, scaling issues can become more of a problem due to the conductivity of the water increasing as the water flows down the media. See figure 12.

B) Staged Flow

Staged flow systems typically operate with two or more set “flowrates.” These typically can be adjusted and can change based on ambient conditions. The same considerations as variable flow systems must be applied; however, the control of outlet water quality is less precise due to the step-like manner of operation. See figure 12.

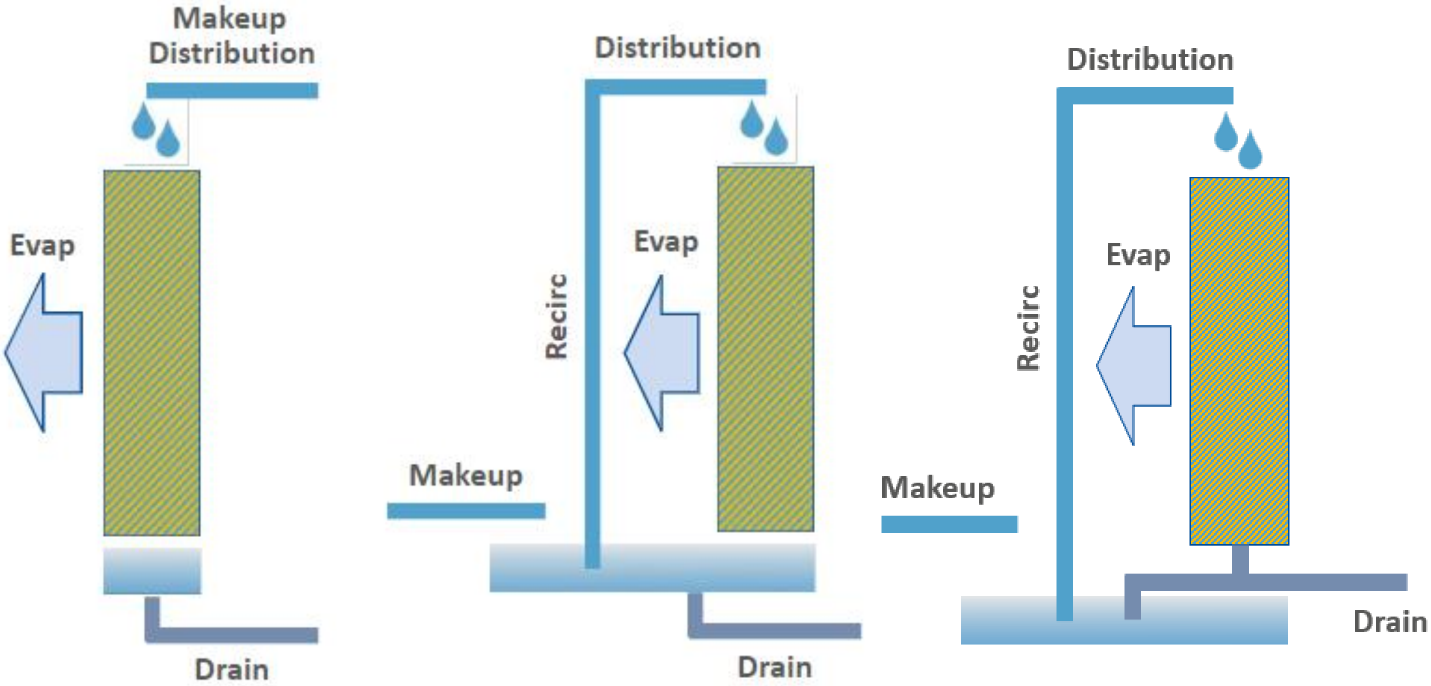


Figure 6: Once-through media cooled (left) Recirculating media-cooled with blowdown at basin (middle) Recirculating media-cooled with blowdown at basin (right)

C) Very Low Water Delivery Rate (VLWDR)

This system is defined by a water delivery rate so low that saturation efficiency is negatively impacted. Typically, less than 0.9 GPM/SF. Additionally, scaling can be an issue for systems operating at VLWDR, but if incomplete wetting occurs this also impacts scale formation. As water loading decreases so does scale tendency. Therefore, what can typically be observed in the field is streaking. See figure 7. Keep in mind both variable flow and stagged flow will operate in this range, either in whole or in part. See section 7.1 and figure 12.

5.2 Recirculating, Media-Cooled Systems (RMC) (Fig. 6)

In an RMC system, makeup of the unit is typically delivered to the basin. A recirculating pump delivers the water to the top of the media, as the water travels down it interacts with the air, evaporating a portion of the water. The rest of the water is collected in the basin and reused until the conductivity of the water reaches the drain setpoint and a portion of the water is drained. In this configuration the makeup = evaporation + drain, but the distribution and drain are decoupled, allowing independent optimization.

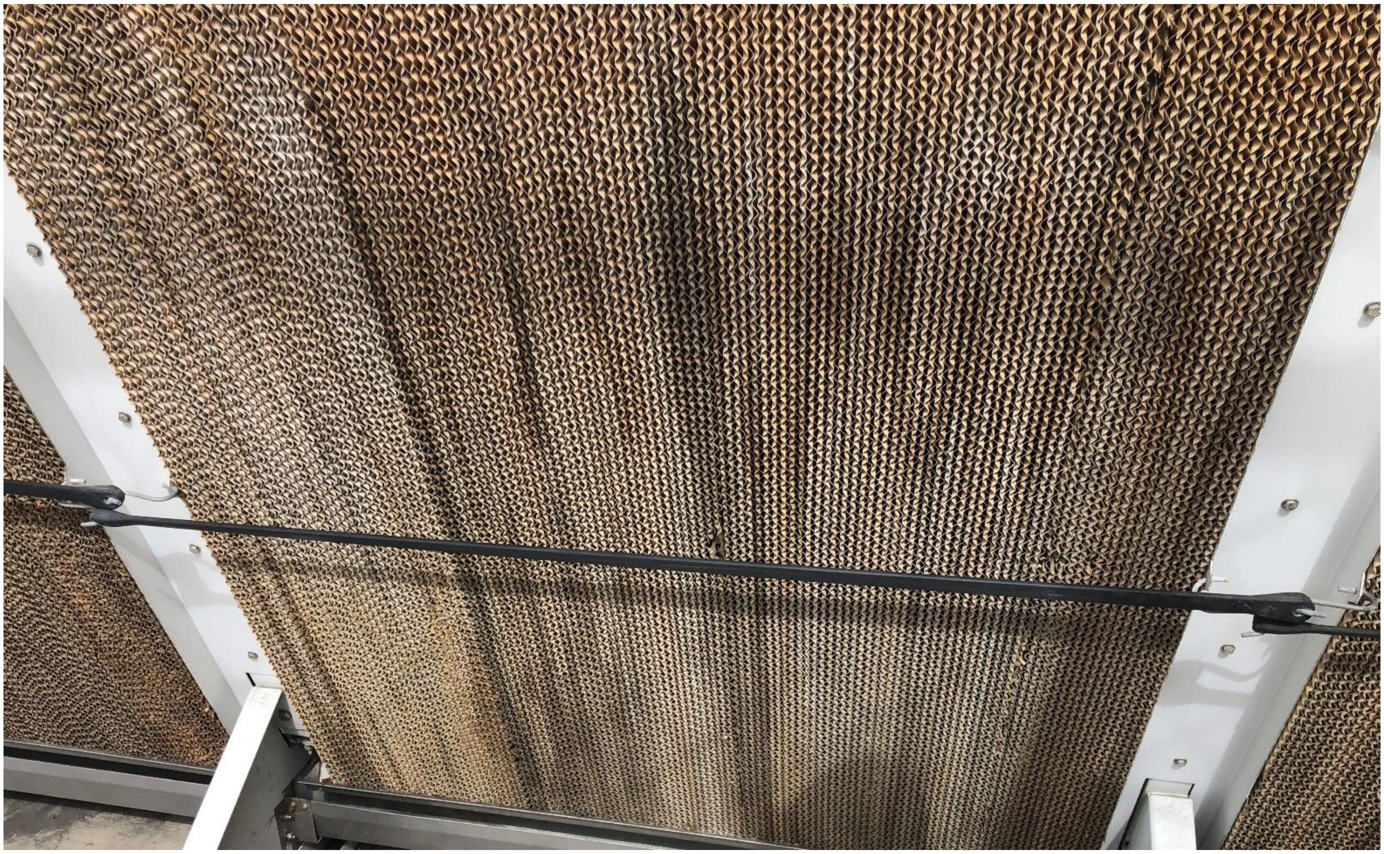


Figure 7: Example of Streaking on Media

A) Low Water Delivery Rate (LWDR)
LWDR systems are defined as being less than the media manufacturer's recommendations (1.5 GPM/SF (2012)), but high enough to reach peak saturation efficiency (>0.9 GPM/SF), see figure 10 & 12. Scaling tendency is highest for these systems.

B) High Water Delivery Rate (HWDR)
HWDR systems are above the media manufacturer's recommendations of 1.5 GPM/SF, but not too high that water cannot be managed correctly on the media (i.e. drift or splash out). This range is typically 1.5 GPM/SF – 2.0 GPM/SF. Shown in figure 10 & 12. For reference, as of the writing of this paper, all media manufacturer's recommended water delivery rates that were readily available online, are in the HWDR zone (2022) (2020).

C) Blowdown at Basin (BAB) (Fig. 6)
This is the traditional location of discharging to the drain. Blowdown of the fully mixed bulk water occurs at the collection basin.

D) Blowdown at Media (BAM) (Fig. 6)
These systems can save even more water or reduce scale tendency than the typical RMC product because they drain concentrated water from the discharge of the media. A traditional RMC drains from the collection basin after the water has mixed. Draining higher concentrated water vs, the mixed bulk water allows for higher water savings or reduction of scale tendency. These options are effective because the ratio of the evaporation stream to the circulating stream is high compared to a traditional cooling tower.

5.3 Once-Through, Spray Cooled Systems (OTSC) (Fig. 8)

In this system, makeup is delivered via automizing nozzles in the air inlet of the unit. The atomized water precools the air adiabatically and any unused water settles on surrounding surfaces. Additionally, water can directly contact the coil, while improving performance via evaporative cooling, but also causing scale and

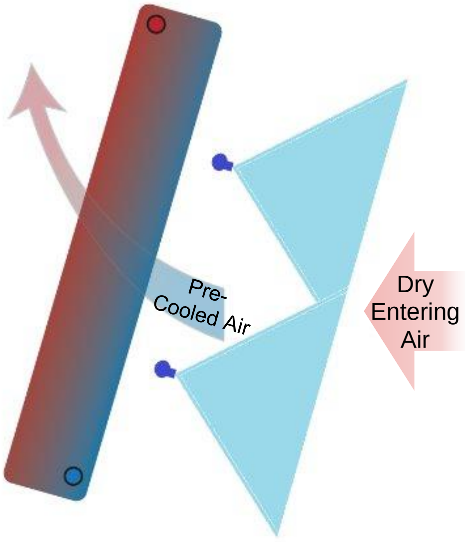


Figure 8: Once-through spray cooled

corrosion issues. In this configuration: makeup = distribution = evaporated + unevaporated water.

6. **Impact of Water System Design on Key Factors Affecting the Performance of the Equipment:**
    1. **Water Usage**
    2. **Saturation Efficiency (dry bulb depression)**
    3. **Media Life Expectancy**
    4. **Additional Pressure Drop of the Airflow (and in turn reduction of the equipment capacity)**
    5. **Water Quality Restrictions**

6.1 Water Usage

The primary goal of adiabatic coolers is to reduce water usage, while maintaining thermal performance. Water usage is minimized by either operating in a dry mode (without water) for most of the year or managing the unevaporated water in adiabatic mode. When in adiabatic operation, water usage is a function of evaporation rate, and the amount sent to the drain. As shown in section 5, once-through and spray adiabatic coolers can inherently use more water which is inherent to the design, while recirculating units can optimize water usage by capturing unevaporated water and reusing it until it is sent to the drain.

WATER USAGE EQUATION:

Water Usage = Evaporation + Blowdown (Drain)

6.2 Saturation Efficiency (dry bulb depression)

The purpose of the water used by an adiabatic cooler is to pre-cool the air entering the unit to enhance heat transfer. The degree of dry bulb temperature reduction achieved is a function of the media characteristics (geometry, size, etc.) as well as the water distribution and airflow rate. The more the air and water can interact within the media, the more reduction in dry-bulb temperature. The water distribution rate is a key factor in achieving the optimum saturation efficiency from the media. If the water distribution rate is too low, the media surface is not fully wetted and the interaction of air and water is diminished, limiting the moisture exchange and resulting in a higher dry-bulb temperature being delivered to the coil. A higher dry-bulb temperature and/or excessive air pressure drop requires the adiabatic cooler to move more air (and consume more power) to satisfy the heat rejection or may even make it impossible for the unit to satisfy the process setpoint, resulting in a higher process fluid temperature and increasing the power consumption of other process equipment (compressors, chillers, etc.). As stated above, the recommended water delivery rate from the media manufacturer is 1.5 GPM/SF. This value is consistent across manufacturers and cross-sectional dimensions. See figure 12 for more information.

6.3 Media (Pad) Life

The life expectancy of the adiabatic media, or pads, have many factors that impact it: hours of adiabatic operation, on/off cycles, water quality, water delivery rate, installation environment, frequency of maintenance & handling. In most circumstances, adiabatic pads should be replaced every 2-5 years.

Factors Affecting Pad Life Include:

Hours of Adiabatic Operation

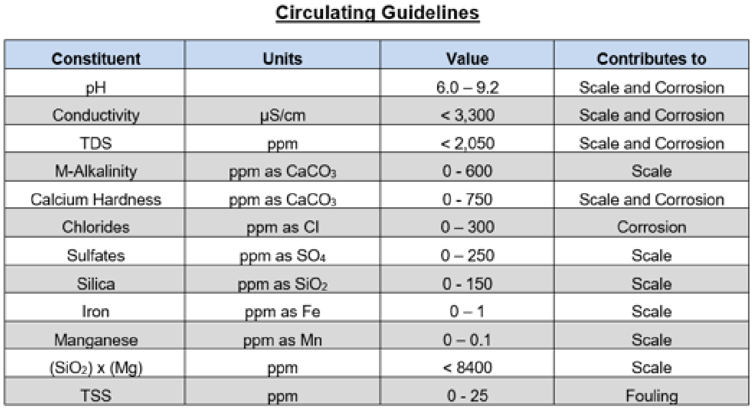
The number of hours an adiabatic cooler operates in adiabatic mode annually impacts the life expectancy of the cooling media. Operating more frequently increases the total interaction time between air and water. Whenever air and water interact, evaporation is occurring. With evaporation comes the chance for scale deposit on the media, thus shortening life expectancy for the media. Rate of scale growth can be changed based on water delivery rate. See figure 13 for scale vs. run hours and figure 14 for photos of scale growth.

On/Off or Wet/Dry Cycle

An on/off cycle refers to an adiabatic cooler switching between dry and adiabatic operation. During every cycle, a small amount of water with mineral content is left behind which can cause scale growth as the media dries out. The amount of annual on/off cycles are dependent on location and annual heat load profile.

Water Quality

The source of the water is a big factor that determines the COC, water usage, mineral scaling tendency and corrosion. Many locations in the US have high mineral content impacting how efficiently the water can be used. Due to this, many adiabatic product providers issue water quality guidelines. See figure 9 for an example. Following the manufacturer’s guidelines ensures low risk with water-based issues.



Circulating Guidelines

Constituent	Units	Value	Contributes to
pH		6.0 – 9.2	Scale and Corrosion
Conductivity	µS/cm	< 3,300	Scale and Corrosion
TDS	ppm	< 2,050	Scale and Corrosion
M-Alkalinity	ppm as $CaCO_3$	0 - 600	Scale
Calcium Hardness	ppm as $CaCO_3$	0 - 750	Scale and Corrosion
Chlorides	ppm as Cl	0 – 300	Corrosion
Sulfates	ppm as SO_4	0 – 250	Scale
Silica	ppm as SiO_2	0 - 150	Scale
Iron	ppm as Fe	0 – 1	Scale
Manganese	ppm as Mn	0 – 0.1	Scale
(SiO_2) x (Mg)	ppm	< 8400	Scale
TSS	ppm	0 - 25	Fouling

Figure 9: Example of adiabatic water quality guidelines – Reference SPX/Marley

Water Delivery Rate (Water Loading)

The amount of water used in adiabatic coolers is critical. Once-through units tend to have multiple water delivery rates when in operation, while RMC units have one setpoint for water rate. Water delivery rate affects both scale formation **(1)** and saturation efficiency **(2)**:

1) The amount of water impacts the wet/dry areas of the media. This can cause mineral scale to form on the media, changing the life expectancy and thermal performance. For RMC designs, a HWDR keeps the surface of the media wet enough to prevent scale, while a LWDR can have more scale formation due to larger wet/dry interface. (See figure 10 & section 7.3 below.) Optimal usage of water is tied to the mineral limit of the water. If the water is discharged from the unit before the mineral limit is reached, the water is not used to its full potential. If the water is rejected above that limit, scaling issues will occur. LWDR products may have smaller pumps and basins due to their water rate, lowering capital and operating cost and providing an attractive reason for this product in the marketplace.

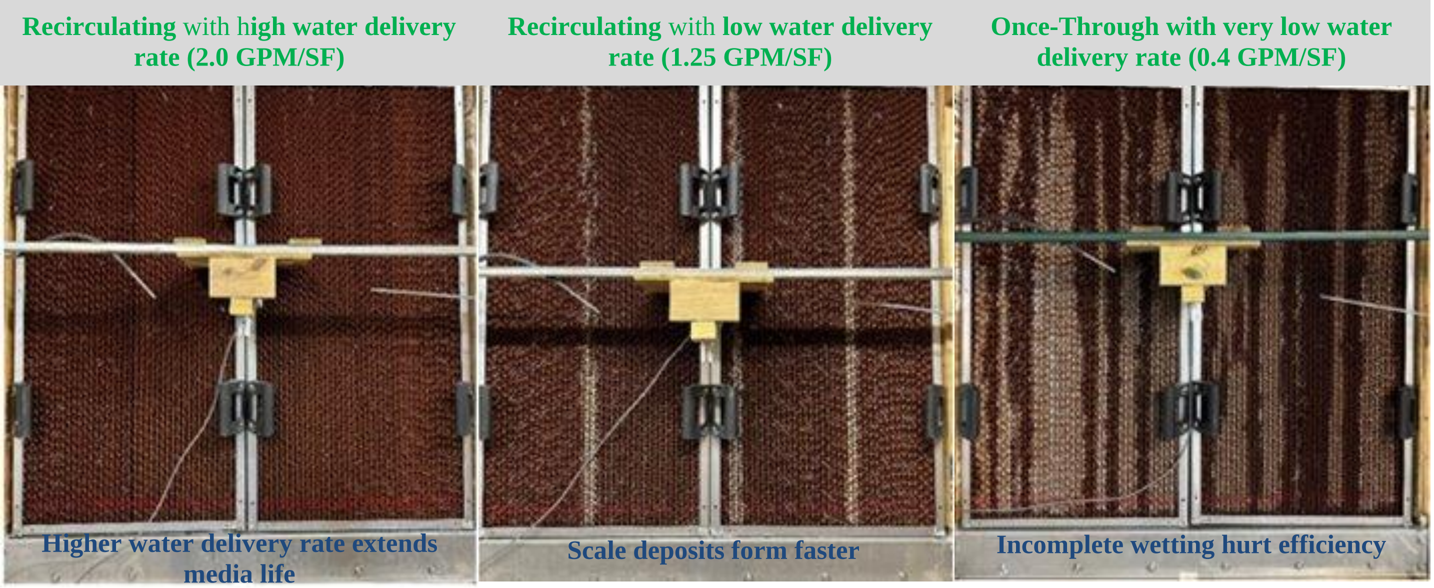
2) Water delivery rate also impacts saturation efficiency as stated above. With water delivery rates that are too low to wet out the media, streaks will occur. See figure 10 & section 7.1 below for more info.

In figure 10 we see a visual indication of water loading. The HWDR and LWDR images show a uniform wetting of the media. Both units per figure 12 would obtain high saturation efficiency. However, the VLWDR unit shows a non-uniform wetting of the media. This unit would exhibit a sub-optimal saturation efficiency per figure 12.

Installation Environment

Factors in the surrounding environment can impact the life expectancy of the cooling media too. Adiabatic coolers are great air scrubbers, therefore any debris in the environment can adhere to the surface of the media and can negatively impact the life expectancy.

Frequency of Maintenance & Handling



Recirculating with **high water delivery rate (2.0 GPM/SF)**

Recirculating with **low water delivery rate (1.25 GPM/SF)**

Once-Through with very low water delivery rate (0.4 GPM/SF)

Higher water delivery rate extends media life

Scale deposits form faster

Incomplete wetting hurt efficiency

Figure 10: Visual aid of various water delivery rates

The frequency of media maintenance can vary from site to site based on many of the aforementioned factors. Thorough and gentle handling of the media is recommended. Rough handling or handling too frequently decreases the media's life expectancy.

6.4 Additional Pressure Drop of the Airflow (and in turn reduction of the equipment capacity)

The water delivery rate has an immediate and a long-term impact to pressure drop. The immediate effect is based on the presence of water on the media, increasing the pressure drop across the media. The long-term impact varies based on water delivery rate as discussed above. Scale growth can occur over time, slowly choking off the air supply, causing the fans to work harder. Figure 11 shows a chart of run time vs pressure drop across the media using Kansas City, MO water at 4 COC. This compares a LWDR RMC vs a HWDR RMC system targeting an inlet face velocity within the normal operating range for adiabatic products. Within each unit's normal run time wet/dry cycles would occur to mimic typical operating conditions. Run time shown is a summation of the total wet operating time. The pressure drop difference after approximately 6 months of operation is about 25% more using a fan common to the industry.

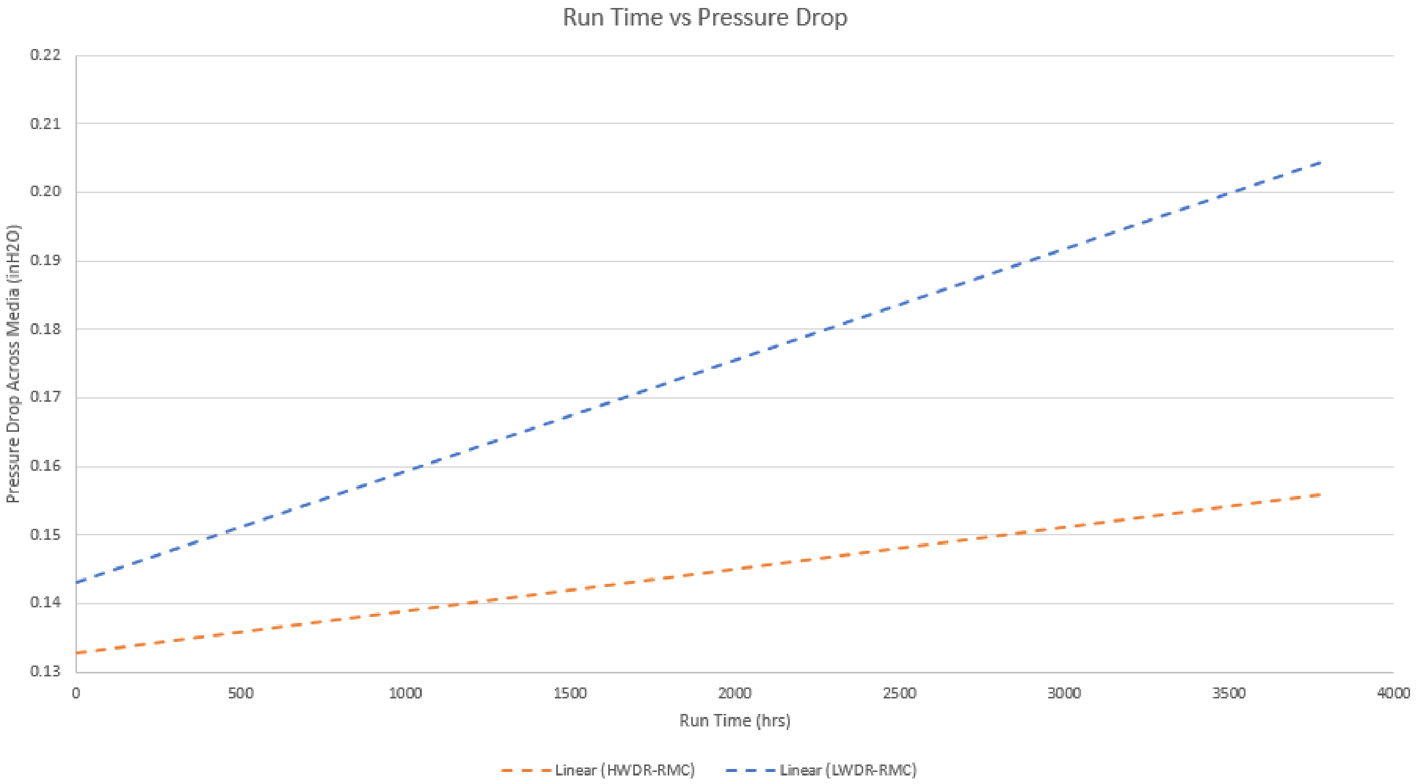


Figure 11: Run Time vs Pressure Drop of Varying Water Delivery Rates of RMC Products

6.5 Water Quality Restrictions

Adiabatic products are unique due to the fact they typically negate the need for water treatment. This fact reduces the amount of maintenance costs. However, adiabatic products aren't without issues common to evaporative products, and due diligence must still be performed to mitigate these issues. Adiabatic products offer a novel approach to reduce water-based challenges. As expected, this novel approach has a wide range of success, which is tied to the variety of designs and water quality (see table 1 – reference SPX/Marley). Additionally, the product type's ability to mitigate water issues vary:

Table 1: Typical Municipal Water Values

State	City	pH	Conductivity (µS/cm)
CA	Los Angeles	7.3	670
FL	Miami	9.2	290
NY	New York	6.6	100
IL	Chicago	7.3	330
AZ	Phoenix	7.6	930
GA	Atlanta	7.3	70

Some municipalities have higher conductivity and/or pH compared to other locations. Higher levels of conductivity and pH in general will increase the scaling tendency (however there are always exceptions to this rule) and this impacts performance and life expectancy of adiabatic products. Due to the variance in water quality, clear direction must be provided to limit corrosion and scale issues. This is why each manufacturer provides end users with Water Quality Guidelines to help maintain the product. As expected, these guidelines vary and depend on the type of adiabatic cooler.

Table 2 shows a comparison of Water Quality Guidelines. We see that water parameters may be reported as makeup or circulating values. Therefore, a COC of 3 was assumed for the OTMC system.

Table 2: Comparison of Water Quality Guidelines

Type	**OTMC**		**OTSC***	**RMC**
Water quality basis	**Makeup** (2018)	**Circulating**	**Makeup** (2020)	**Circulating (SPX)**
pH	6.5 - 8.5	6.5 - 8.5	6.0 – 9.0	6 - 9.2
Conductivity (µS/cm)	450	1350	1500	0 - 3300
Calcium Hardness (ppm)	170	510	350	50 - 750
Chlorides (ppm)	50	150	175	0 - 300
Total Alkalinity (ppm)	170	510	250	0 - 600
Sulfate (ppm)	150	450	225	0 - 250
Silica (ppm)	25	75	150	0 - 150
Iron (ppm)	0.2	0.6		0 - 1
TDS (ppm)	550	1650		0 - 2050
TSS (ppm)	5	15		0 - 25

*Only allowed for process fluids equal to or less than 120°F.

Observation from table 2:

- In general, more aggressive waters can be used with RMC as mineral scale is typically a bigger issue for once through systems. RMC systems tend to have higher flow rates than once-through systems and the higher water rates reduce the tendency to scale.
- Considering an OTMC, water quality guidelines are so restrictive that approximately 31% of US municipalities – based on readily available water data – would be unable to meet the required guideline. This water quality guideline is restrictive.
- Water quality guideline for an OTSC allows for a very high conductivity and appear less restrictive, but there are many limitations manufacturers can require for these products, such as: process fluid temperatures above 120°F are not allowed, annual wet hours are limited to 200 hours and even occasionally requiring deionized water for use with OTSC systems.

7. Managing Water of Adiabatic Systems

There are two water management characteristics to discuss when comparing once-through and recirculating systems: 1) thermal performance 2) water usage

7.1 Once-Through Media-Cooled (OTMC) vs Recirculating Media-Cooled (RMC)

The management of water is critical to the efficiency of an adiabatic cooler. Poor water management will either waste water or thermally derate the product. Specifically, with once-through systems, either the variable flow or staged flow must decide between wasting water or lower thermal performance, due to the coupling of the drain and distribution systems. Shown below in figure 12 is comparison of OTMC and RMC products, both from a water usage and thermal standpoint. To develop the saturation efficiency data, two different distribution systems are used to handle the full water loading range. A standard density 6” depth pad is used at a constant air rate of 500 FPM. For the water usage data, a 10-fan unit is used as a comparison. Both adiabatic coolers are in ASHRAE climate zone 4A and for the RMC unit a COC of 3 is used. The saturation efficiency curve applies to either OTMC or RMC units. Therefore, at a water loading of 1 GPM/SF an OTMC unit can achieve a high saturation efficiency. However, comparing the water usage of the OTMC to an RMC unit shows significantly higher water usage.

A previous white paper on the subject submitted by Evapco (2018) showed little to no impact on saturation efficiency when varying water loading. The author’s data covered a range of 50% below to 50% above the media manufacturer’s recommendation. Therefore, this should be 0.75 GPM/SF to 2.25 GPM/SF. In the flow range tested, our data largely agrees. However, a more thorough investigation of water loadings by common manufactures in the industry also shows many manufacturers operating below the range tested in the white paper. In Figure 12, the arrows under the chart for variable flow once through, staged flow once through, LWDR-RMC, and HWDR-RMC represent the media manufacturer’s recommended water loadings.

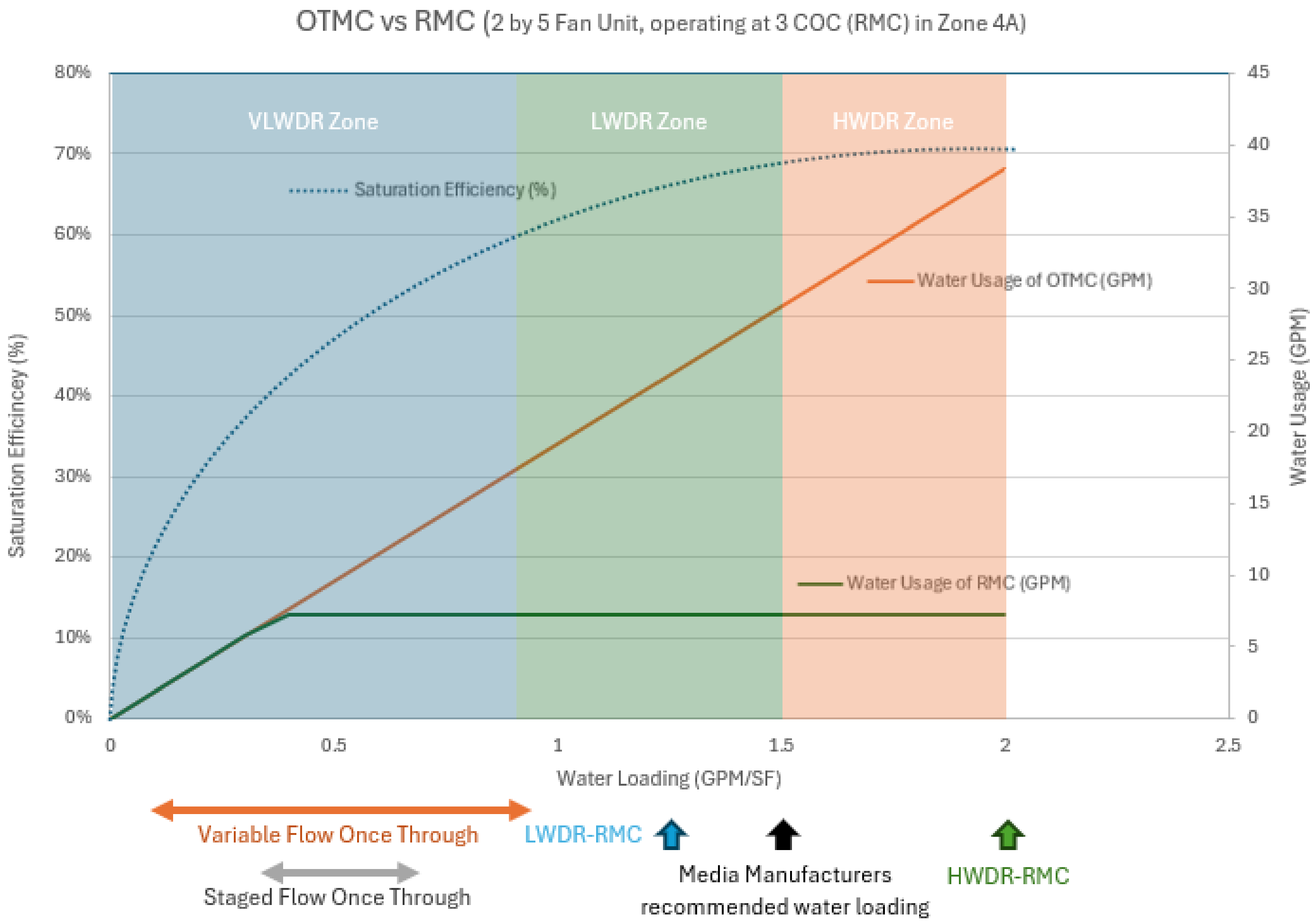


Figure 12: Saturation Efficiency and Water Usage vs Various Products @ 500 FPM

OTMC designs tend to operate at very low water loadings to keep water usage as low as possible, however this causes low saturation efficiency. With respect to the variable flow system, both a low water usage and a high saturation efficiency can be claimed, but not both at the same time. For any once-through system it is impossible to operate at both a high saturation efficiency and low water usage concurrently. Additionally, both the HWDR and LWDR designs operate in low water usage, optimal thermal performance manner.

7.2 Once-Through Spray Cooled (OTSC) vs Recirculating Media-Cooled (RMC)

Water management of a spray cooled system shares similarities with an OTMC system. Both systems are unable to operate at both a high saturation efficiency and low water usage manner concurrently. However, with spray cooling, the idea is to use even less water than the OTMC system. This is accomplished by atomization of the water. In theory, using a uniform fine mist allows for efficient humidification of the air. Application of a fine mist in ambient conditions is tenuous, and once the water is emitted it is impossible to control, causing unevaporated water to settle on any surrounding surface, which creates a new set of issues:

- Water contact of the coil.
- Water settling on surrounding surfaces.

Water settling on the adiabatic coil causes evaporative fluid cooling to occur, which in the short term brings a thermal benefit, but long term this causes scale, corrosion and eventually a thermal derate. To mitigate these issues, many manufactures of OTSC systems have required limitations on water quality, many of which were stated in section 6.5. One such method is limiting annual wet hours to a maximum of 200 hrs. This hinders the products ability to provide a thermal benefit in many locations. Table 3 shows the number of hours above a dry switch point of 80°F for several cities. For example, in table 3 if an annual limit of 200 hrs is imposed, most locations will struggle to meet the design duty and will, in turn, consume more energy – the one exception being Los Angeles.

Table 3: Annual Wet Hours Evaluation

City	ASHRAE Handbook 2021 0.4% DB (°F)	ASHRAE Handbook 2021 MCWB (°F)	Dry-bulb Switch Temp Dry to Adiabatic Operation	Hours above 80°F (adiabatic operation)
Los Angeles, CA	84.7	63.3	80°F	107
Miami, FL	92.0	77.7	80°F	3084
New York City, NY	92.6	73.9	80°F	673
Chicago, IL	91.2	74.1	80°F	535
Pheonix, AZ	110.5	69.2	80°F	3685
Atlanta, GA	93.7	73.8	80°F	1147

The second major issue with OTSC products is water settling on surrounding surfaces. This can cause corrosion of nearby equipment, unsightly mineral scale to appear on surrounding surfaces and walking surfaces to become a safety hazard. This issue is a symptom of inefficient water usage and is no different than splash-out in an evaporative product. Water usage for OTMC, OTSC and RCM designs are in table 4.

Table 4: Water Usage Comparison

Spray Cooled Once-Through System (GPM)	Media Cooled Once-Through System (GPM)	Media Cooled Recirculating System (GPM)
5.4	17.25	3.2
This is a direct comparison between each unit type operating in the ASHRAE Zone 4C. The unit had 10 fans, 2 by 5. RMC is operating at 3 COC. For OTMC I used 0.9 GPM/SF.		

7.3 Low Water Delivery Rate (LWDR) Recirculating Media-Cooled (RMC) vs High Water Deliver Rate (HWDR) Recirculating Media-Cooled (RMC)

For the RMC design, the challenge of sacrificing water usage vs thermal performance isn't an issue because both can be optimized independently of one another. However, there can still be water management issues for RMC products. The main issue for these products is scale growth on pre-cooling media. Therefore, how the water is managed is crucial to mitigating the tendency of mineral scale growth.

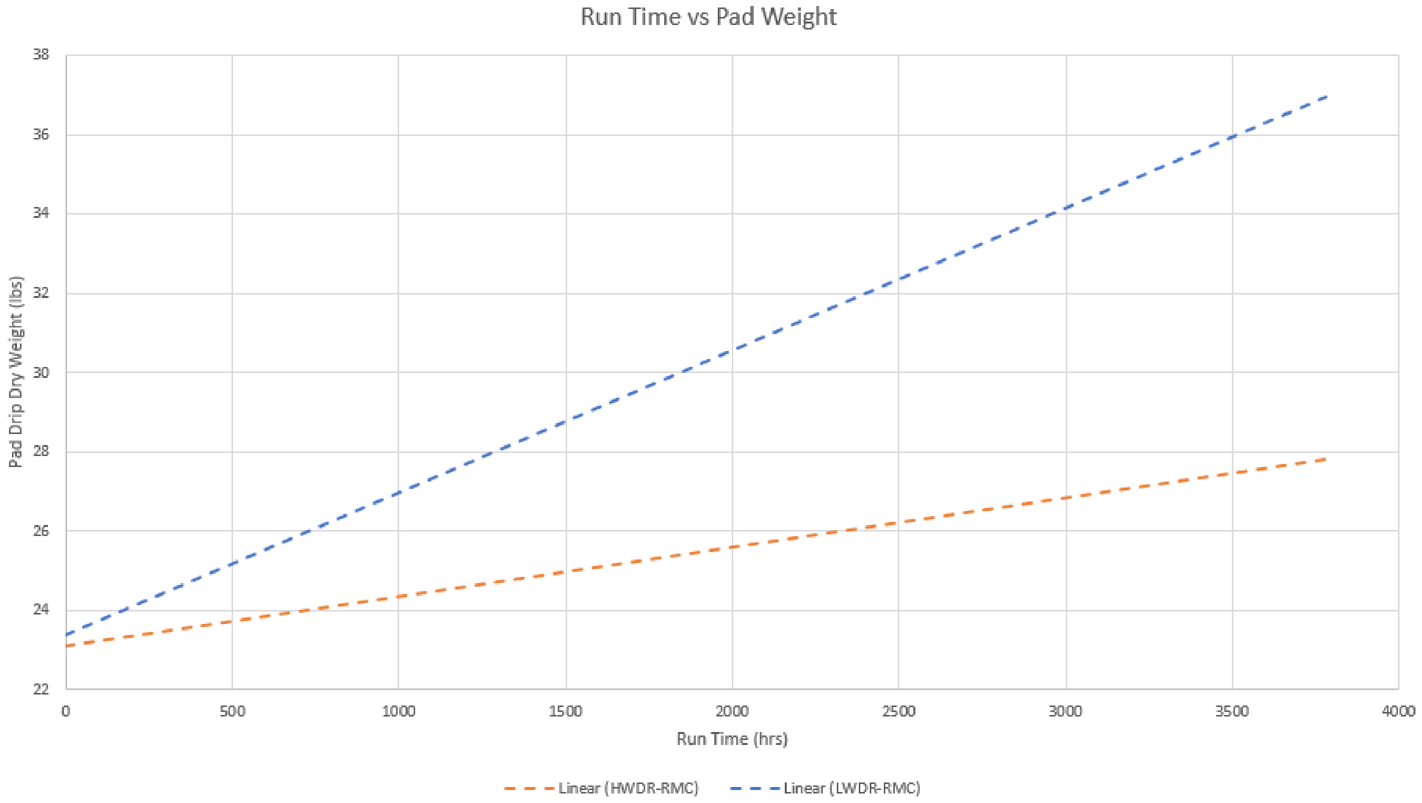


Figure 13 – HWDR and LWDR RMC units operating with 4 COC of KCMO water. 4000 hours is approximately 6 months.

Figure 13 shows results from SPX product testing where 2 different configurations of adiabatic products are tested in conjunction with one another. These systems are designed to mimic common adiabatic designs found in industry to compare each design’s inherent ability to mitigate long term scale growth of the media.

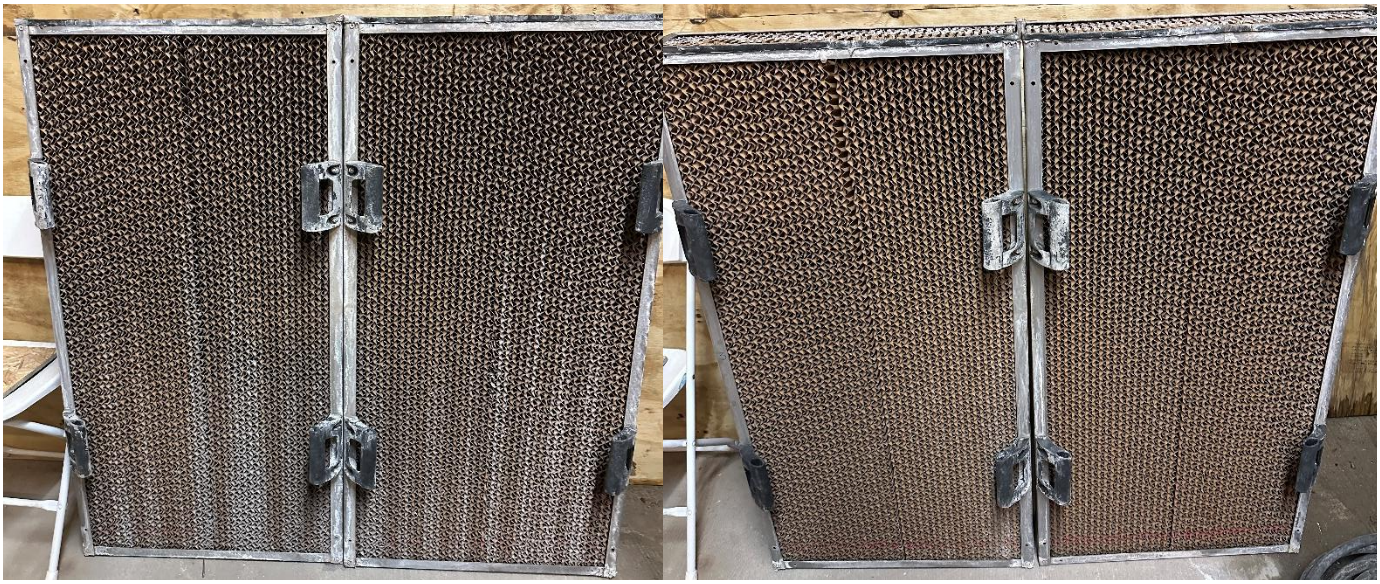


Figure 14 – LWDR-RMC (left) and HWDR-RMC (right) after 6 months

From figures 13 and 14 the HWDR RMC products mitigate scale growth better than the LWDR counterparts. This is because of the wet/dry interface with the bulk water. Increasing the water loading on the pad decreases the wet/dry interface, which prevents scale growth by increasing the amount of bulk water at the air inlet. Operating at ~2 GPM/SF water rate prevents scale growth and therefore maintains long-term thermal efficiency. LWDR systems will produce scale at a higher rate and therefore require more frequent maintenance to maintain thermal performance.

7.4 Recirculating Media-Cooled (RMC) with Blowdown at Media (BAM) vs Recirculating Media-Cooled (RMC) with Blowdown at Basin (BAB) (Standard RMC)

Figure 15 shows a simple mass balance, drawn about a 2’ wide 6” deep, adiabatic media yielding an upper media area of 1 SF. This system has a blowdown setpoint of 1100 µS/cm. Assuming a water rate of 2 GPM/SF, with a moderate evaporation rate of 0.2 GPM coming off the media, yields 1.8 GPM of unevaporated water that will flow out of the bottom of the media. If a conductivity reading of 1000 µS/cm enters the media at the top, by the time the water exits the media, the conductivity will be 1111 µS/cm because the evaporation stream is pure water. This means the concentration factor (a simple ratio of inlet conductivity/outlet conductivity) with respect to the media is 1.11. Taking this simple mass balance and applying it to a 4-fan adiabatic cooler with other common water delivery rates and evaporation rates yields Table 5. Table 5 shows how important the discharge stream from the media is. Blowing down this concentrated water first helps to mitigate scale issues, as the water entering the media is less than the setpoint.

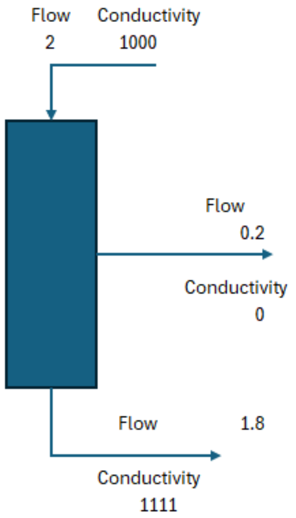


Figure 15 – Adiabatic Media Mass Balance

Another consideration with adiabatic systems is understanding how the relative size of the evaporation vs unevaporated streams can cause additional scaling issues. As the evaporation rate changes, if the unevaporated stream is too small, the concentration factor of the constituents within the water will be above water quality guideline’s limits within the media, causing scale issues. Looking at the VLWDR column in table 5 shows that with some evaporation rates, 4x factor can occur with only one pass through the media. Depending on the incoming water, this could cause major scaling issues.

Table 5: 4-fan Adiabatic Unit – Evaporation Concentration Factors						
	HWDR (2 GPM/SF)		LWDR (1.25 GPM/SF)		VLWDR (0.4 GPM/SF)	
Evaporation Rate (GPM)	Flow over Media (GPM)	Concentration Factor of Media	Flow over Media (GPM)	Concentration Factor of Media	Flow over Media (GPM)	Concentration Factor of Media
1.6	32	1.05	20	1.09	6.4	1.33
3.2	32	1.11	20	1.19	6.4	2
4.8	32	1.17	20	1.32	6.4	4
6.4	32	1.25	20	1.47	6.4	All Water Evaporated

8 Summary

Table 6: Summary Table				
	Once-Through		RMC	
	Media Cooled	Spray Cooled	LWDR	HWDR
Water Usage	Water loading dependent	Moderate	Low	Low
Cooling Efficiency	Water loading dependent	Flowrate dependent	High	High
High Quality Water Required	Yes	Yes	No	No
Scaling Risk	Moderate	High	High	Low
Limited Adiabatic Operation	No	Yes	No	No
High Temperature Process Fluids Allowed	Yes	Limited	Yes	Yes

Table 6 shows a summary of the topics covered within the paper which are:

- Once-through systems cannot operate at both peak thermal performance and high-water savings at the same time. These two features are linked and cannot be optimized independently of the other.
- Once-through spray cooled systems have numerous limitations on their design making them challenging to use and operate. These systems also use more water compared to their recirculating counterparts.
- Recirculating media cooled systems operate a peak thermal performance and high-water savings. Both features can independently be optimized.
- Low water delivery rate recirculating units operate a peak thermal performance but can struggle with scale growth impacting their long-term performance compared to their high-water delivery rate counterparts.
- Scale growth in once-through media-cooled systems can also be an issue, especially as the ratio of evaporated water to water not evaporated moves closer to 1. Spray cooled systems can also exhibit scale issues due to direct water contact of the coil.
- Blowdown at media systems can provide additional scale tendency reduction.
- Understanding an adiabatic manufacturer's water quality guideline is important. Some systems designs are naturally more robust than others and can withstand higher stress waters.

In conclusion, adiabatic systems efficiently use water to pre-cool air, but these systems can still fall prey to the common water issues such as scale, corrosion and water usage. Understanding the differences in system design, how these systems operate and taking careful note of each manufacturer's water quality guidelines is necessary to guaranteeing long-term success.

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