Adiabatic Fluid Coolers & Refrigerant Condensers: Impact of Pad System Design on Saturation Efficiency and Unit Operation

Introduction

- What are adiabatic pads and what do they do?
- What variables affect adiabatic pad performance?
- Is saturation efficiency all that matters to adiabatic fluid cooler or adiabatic condenser thermal capability?

Closed circuit coolers and refrigerant condensers which utilize air-cooled heat exchange are growing in popularity for various reasons, but mainly to conserve water. However, in climates with high ambient temperatures, air-cooled heat exchangers require too much capital cost, consume too much energy and/or require too much plan area. In many cases, incorporating adiabatic pads on an air-cooled heat exchanger (a.k.a., an adiabatic fluid cooler or refrigerant condenser) is the best solution to balance costs, energy consumption and the size or number of units required.

Figure 1: Adiabatic Air-cooled Heat Exchanger

Executive Summary

Evapco discovered a surprisingly wide range of claimed saturation efficiency for adiabatic pads while investigating various adiabatic pad designs and suppliers for use on its eco-Air Series product line. Therefore, in order to remain committed to providing fully rated products, Evapco conducted an extensive adiabatic pad test program to help understand actual/verified pad performance and the variables which impact pad performance. Realizing that adiabatic pad performance has a direct impact on adiabatic unit performance, Evapco considered verified pad performance to be a fundamental building block for a thermal ratings methodology which would yield 100% fully rated dry and adiabatic performance for Evapco units utilizing adiabatic pads.

Evapco's adiabatic pad test program included testing ten pad designs from four adiabatic pad suppliers (3 pad designs from each of two suppliers and 2 pad designs from each of the other two suppliers). We offer the independent research contained in this report for the benefit of the industries we serve, and to de-mystify some of the variables surrounding adiabatic cooling technology which have been misrepresented in the marketplace. It is important for manufacturers, specifiers and owners/end users to remember that an adiabatic fluid cooler or adiabatic refrigerant condenser is no more than an air-cooled heat exchanger that is sized to operate at a lower-than-ambient air dry-bulb temperature. The adiabatic air pre-cooling system uses water to depress the ambient air dry-bulb to a lower value, reducing the necessary size of the heat exchanger compared to a 100% air-cooled equivalent.

The following are specific recommendations which are borne from this research, broken down into the three broad categories of 1) Adiabatic Unit **Manufacturers**; 2) Adiabatic Unit **Specifiers**; and 3) Adiabatic Unit **Owners/End Users**.

1) Adiabatic Unit **Manufacturers** should be certain that their unit design accounts for the following conclusions which have been proven by this research.

    a) Saturation efficiency changes with air velocity – it is not a constant value!
        i. As shown in Figure 13, the <u>maximum</u> saturation efficiency achieved for the various adiabatic pad depths and designs tested in this program was:

Air Velocity [fpm]	Saturation Efficiency
400	78%
500	76%
600	74%
700	72%

    b) Saturation efficiency and air side pressure drop are <u>equally</u> important in rating the thermal performance of an adiabatic unit.
    c) Water flow rate and water temperature have very little impact on adiabatic pad saturation efficiency when measured on a full-size adiabatic fluid cooler or condenser.

2) Adiabatic Unit **Specifiers** must be aware of the following when preparing specifications for adiabatic units.

    a) The overstated saturation efficiency claims which are published by adiabatic pad suppliers are likely to cause unknowing adiabatic unit manufacturers to provide equipment which does not meet its specified performance.
    b) There are no independent third-party performance certification programs or field test standards published for adiabatic fluid coolers or refrigerant condensers.
    c) It is wise to specify an optional field performance test in an effort to provide a specification with the "teeth" that will cause suppliers to provide fully rated equipment.
        i. Recommended Language: See ATTACHMENT #1 at the end of this paper.
    d) To eliminate uncertainty regarding thermal capability, require adiabatic unit manufacturers to guarantee:
        i. Thermal capacity at the specified design point when operated adiabatically.
        ii. Thermal capacity at the specified dry switchover point with adiabatic pads installed.
        iii. Adiabatic Pad Saturation Efficiency at full fan speed.
            NOTE: <u>Actual</u> adiabatic pad saturation efficiency can be determined using Equation 1 by measuring the air dry-bulb temperature and wet-bulb temperature entering the face of the adiabatic pads and the air dry-bulb temperature exiting the coil or unit <u>without load</u> on the adiabatic unit.

3) Adiabatic Unit **Owners/End Users** ….

Adiabatic technology has been an accepted means of improving the thermal performance of air-cooled fluid coolers and refrigerant condensers for decades. After reading this paper and recognizing the facts behind the limitations and variables in adiabatic air pre-cooling systems, end-users and specifying engineers may be asking themselves:

Q: Why haven't more HVAC, Industrial Process, and Industrial Refrigeration Systems using adiabatic pad technology had more performance issues in the field?

A: The short answer is that the deficient unit capacity is often hidden by simply operating the unit in adiabatic mode at wet-bulb temperatures lower than promised by the unit manufacturer (i.e., more frequently than would be required for a properly sized unit).

When the presumed adiabatic saturation efficiency is not achieved, it's likely that the HVAC, Industrial Process, or Industrial Refrigeration <u>system</u> can still be satisfied throughout the year due to:

i. Prolonged run-time of the adiabatic pre-cooling system at a wet-bulb temperature lower than specified (greater annual water use compared to assumed design data);
ii. Increased run-time of fans or higher fan RPM requirements (greater annual energy consumption);
iii. Safety factors applied to load calculations;
iv. Conservative "worst case" design temperatures utilized for equipment selection; and
v. Chillers and compressors which can temporarily handle higher fluid and higher condensing temperatures.

However, in all of these circumstances, an adiabatic fluid cooler or refrigerant condenser with fully-rated performance will operate in adiabatic mode for fewer hours of the year (saving water) and will unload fans to lower part speed or cycle fans off (saving energy) for more hours of the year under every load profile and geographical location versus an adiabatic unit that incorporates over-stated saturation efficiencies.

Bottom line: fully-rated thermal performance saves end-users water and energy while reducing long-term maintenance of adiabatic pads and fan motors due to their less frequent operation.

Another common question by the Adiabatic Owners/End Users is:

Q: How do I get a specifying engineer to ensure I receive fully-rated adiabatic fluid coolers and refrigerant condensers in the absence of any third-party certification standards?

A: Request the specifying engineer to specify and require that adiabatic unit manufacturers guarantee thermal performance in both adiabatic mode and dry mode operation (see THERMAL CAPACITY section of ATTACHMENT #1).
AND
Request the specifying engineer to include language in the specification for an optional field performance test at the desire and expense of the owner if a performance deficiency is suspected (See THERMAL CAPACITY TEST GUARANTEE section of ATTACHMENT #1).

Editorial Note

Evapco has shared the test results contained in this report with the respective manufacturer of each adiabatic pad tested. Manufacturers have either agreed with or not refuted the results of the tests. Evapco recognizes that the adiabatic pads tested represent only a portion of the adiabatic pads currently available in the global market and will continue to test adiabatic pads in search of the next generation of best pads.

Adiabatic Cooling Operating Principle

The basic principle for any air pre-cooling system is to reduce the air dry-bulb temperature entering the coil. Figure 2 illustrates a basic arrangement where water is distributed over the entire adiabatic pad plan area to saturate the adiabatic media.

Ambient air passing through the wetted adiabatic pad increases in moisture content (i.e. increased relative humidity), cooling the entering air dry-bulb temperature toward the entering air wet-bulb temperature. The lower dry-bulb temperature exiting the adiabatic pad is referred to as the <u>depressed dry-bulb</u>.
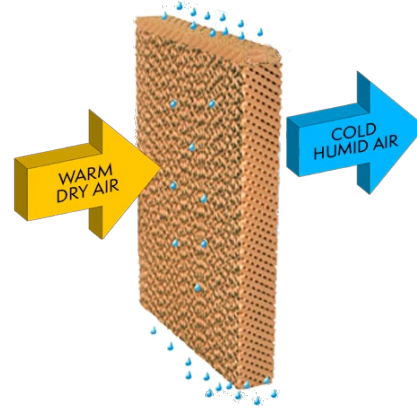
Figure 2: Adiabatic Cooling Operation

In an adiabatic fluid cooler or refrigerant condenser, the pre-cooled air with depressed dry-bulb travels through the tube and fin coil, offering a substantial increase in heat rejection capability.

Saturation Efficiency

Adiabatic pad manufacturers express the pad's ability to achieve an exiting air dry-bulb temperature for a known entering air dry and wet-bulb temperature as <u>saturation efficiency</u>. The dry-bulb temperature exiting the adiabatic pad media is calculated using Equation 1 below.

$$Equation\ 1: T_{DB\ exiting} = T_{DB\ entering} - \%_{Saturation\ Efficiency} * (T_{DB\ entering} - T_{WB\ entering})$$

The concept of saturation efficiency is further illustrated on the psychrometric chart, shown in Figure 3, and the example below. The air dry-bulb temperature reduces along a constant wet-bulb line [Point 1 to Point 2] when using an adiabatic pre-cooling system.
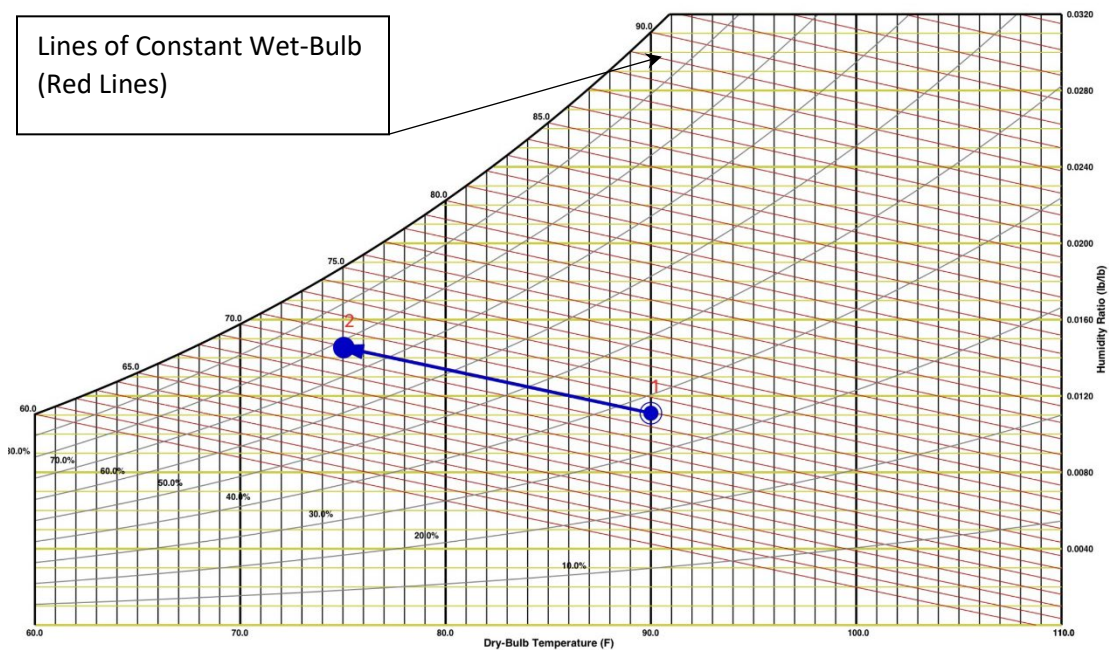

Figure 3: Psychrometric Chart

For the example shown in Figure 3:

$T_{DB\ entering}$ =	90 °F	[32.2 °C]	Point 1
$T_{WB\ entering}$ =	70 °F	[21.1 °C]	
$T_{DB\ exiting}$ =	75 °F	[23.9 °C]	Point 2
$T_{WB\ exiting}$ =	70 °F	[21.1 °C]	

In this example, adiabatic pad saturation efficiency is calculated by modifying Equation 1 to solve for efficiency:

$$\%_{Saturation\ Efficiency} = \frac{\left(T_{DB\ entering} - T_{DB\ exiting}\right)}{\left(T_{DB\ entering} - T_{WB\ entering}\right)}$$

$$\%_{Saturation\ Efficiency} = \frac{(90\ °F - 75\ °F)}{(90\ °F - 70\ °F)}$$

$$\%_{Saturation\ Efficiency} = \frac{(15\ °F)}{(20\ °F)}$$

$$\%_{Saturation\ Efficiency} = 75\%$$

When determining which adiabatic pad to incorporate in the eco-Air Series product line, Evapco studied several manufacturer's published saturation efficiency curves. The wide variation in published saturation efficiency related to adiabatic pad thickness for the different pad manufacturers prompted an extensive test program. As an example, Figure 4 below shows several adiabatic pad manufacturers' published/claimed saturation efficiency curves for 6" adiabatic pads with various flute angles and flute heights. As shown, published saturation efficiency curves are generally limited to entering air velocities from 100-600 fpm and the claimed saturation efficiencies range widely, from 65% to 97%. Please note, only some of these adiabatic pads were included in the ten adiabatic pads tested in the test program.
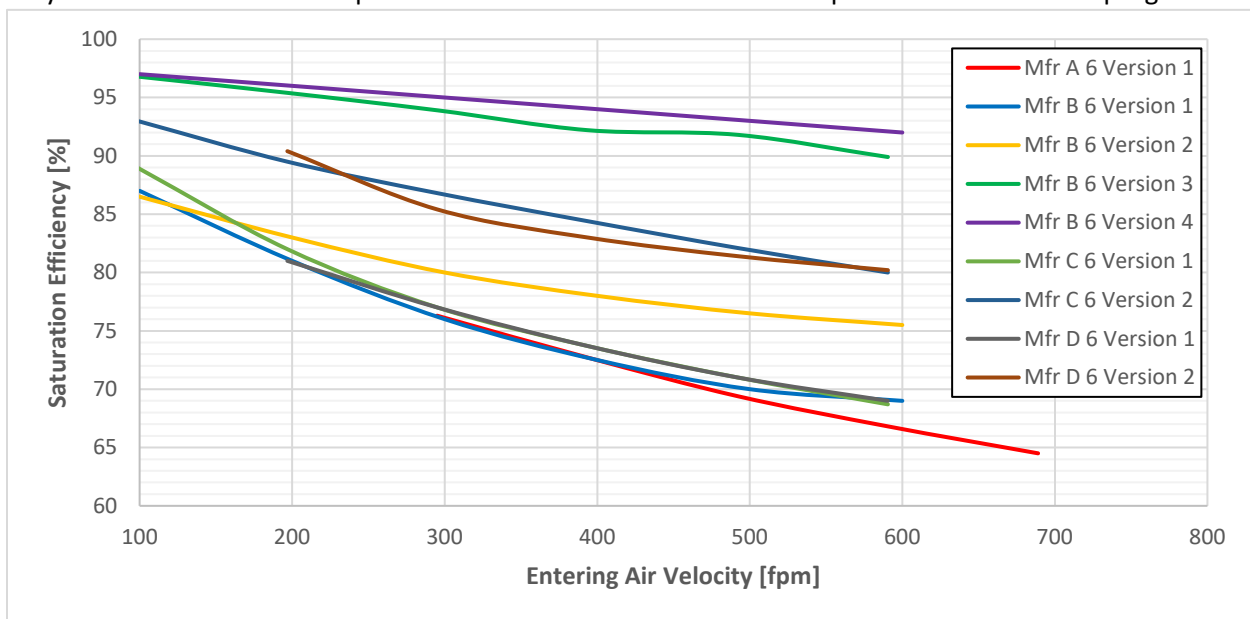

Fig. 4: Adiabatic Pad Suppliers' Published/Claimed Saturation Efficiency Curves (6" [150 mm] Pad Thickness)

Why is adiabatic pad saturation efficiency so critical to adiabatic cooler and refrigerant condenser performance? The thermal capability of an adiabatic unit is strongly influenced by the adiabatic pad saturation efficiency. Overstating adiabatic pad saturation efficiency will overstate unit performance, which will impact system operation. As an example, the resulting leaving fluid temperature using two different saturation efficiencies are compared in Table 1.1 below.

Design Conditions	Design	Actual
Saturation Efficiency	**90%**	**70%**
Entering Dry-Bulb Temperature, $T_{DB\ entering\ (before\ pad)}$	95 °F	95 °F
Entering Wet-Bulb Temperature, $T_{WB\ entering}$	75 °F	75 °F
Depressed Air Dry-Bulb Temperature, Entering Dry Coil, $T_{DB\ exiting}$ Calculated using Equation 1	= 95°F – 90%*(95°F-75°F) **= 77°F**	= 95°F – 70%*(95°F-75°F) **= 81°F**
Approach Temperature, T_{out} - $T_{DB\ exiting}$	13 °F	13 °F
Leaving Fluid Temperature, T_{out}	**90 °F**	**94 °F**

Table 1.1: Saturation Efficiency Impact on Leaving Fluid Temperature

Table 1.2 below shows that overstated adiabatic pad saturation efficiency can also have a significant impact when selecting a unit.

Design Conditions	Example 1	Example 2
Saturation Efficiency	**90%**	**70%**
Entering Dry-Bulb Temperature, $T_{DB\ entering\ (before\ pad)}$	95 °F	95 °F
Entering Wet-Bulb Temperature, $T_{WB\ entering}$	75 °F	75 °F
Depressed Air Dry-Bulb Temperature, Entering Dry Coil, $T_{DB\ exiting}$ Calculated using Equation 1	= 95°F – 90%*(95°F-75°F) **= 77°F**	= 95°F – 70%*(95°F-75°F) **= 81°F**
Design Leaving Fluid Temperature, T_{out}	90 °F	90 °F
Approach Temperature, T_{out} - $T_{DB\ exiting}$	**13 °F**	**9 °F**

Table 1.2: Saturation Efficiency Impact on Dry-Bulb Depression

Table 1.2 shows a 4°F difference in the calculated depressed dry-bulb temperature. The difference in unit size and horsepower required is generally inversely proportional to the calculated approach temperature. Therefore, if the same 90°F design leaving fluid temperature is used for both 90% and 70% saturation efficiency, ***the unit with a 70% saturation efficiency would need to be approximately 44% larger than the unit with a 90% saturation efficiency*** [13°F ÷ 9°F]. Table 1.3 below expands on this concept showing the difference in plan area, fan power, operating weight and cost of the units required to satisfy the same design condition by using different saturation efficiencies.

	Example 1	Example 2
Design Condition	1,500 MBH @ 90°F Condensing	
Saturation Efficiency	**90%**	**70%**
Depressed Dry-Bulb Temperature	**77°F**	**81°F**
Model Number	EAVCA-9110ZA288L7-421AUSP06	EAVCA-9114ZA288L7-421AUSP06
Plan Area	7.8' x 20'	7.8' x 28' [+40%]
Fan Power	39 hp	54 hp [+38%]
Operating Weight	9,410 lbs	12,550 lbs [+33%]
Unit Cost	$78,500	$102,000 [+30%]

Table 1.3: Saturation Efficiency Impact on Unit Selection

The Table 1.3 example above clearly illustrates the impact saturation efficiency has on unit selection, first cost and other key decision parameters.

Additionally, if the adiabatic pads do not achieve the saturation efficiency used to thermally rate the unit, the **system's operation will be negatively impacted.** These negative consequences include:

- Higher leaving fluid temperatures or refrigerant condensing temperatures
- Greater system energy consumption
- Prolonged adiabatic operation time
- Increased water use

To confidently offer fully rated adiabatic products, Evapco found it necessary to test multiple adiabatic pad designs and investigate other parameters that might have an impact on adiabatic pad saturation efficiency.

Parameters that [Potentially] Impact Adiabatic Efficiency

Several design parameters are commonly believed to influence adiabatic pad saturation efficiency. These include:

- Linear Adiabatic Pad Depth
- Entering Air Velocity
- Pad Configuration and Wetted Surface Area
- Supply Water Flow Rate
- Supply Water Temperature

Adiabatic pad manufacturers acknowledge the first three parameters listed above have a significant impact on saturation efficiency. The last two parameters are also commonly discussed in the industry by equipment suppliers and design engineers, but there is not an overwhelming industry consensus as to their impact.

Testing and Results by Evapco

To verify the impact that various parameters have on saturation efficiency and resulting adiabatic unit performance, Evapco performed numerous laboratory tests over several months at its Research Center in Taneytown, MD (USA). These tests and their results are described below.

Adiabatic Pad Test Chamber

Saturation efficiency testing was conducted in the adiabatic pad test chamber shown in Figure 5. The purpose and value of this chamber is to quickly evaluate and compare the accuracy of manufacturer's published data and to determine the impact performance variables, such as supply water flow rate and temperature, have on saturation efficiency. This testing was used to determine which pads were best suited for full-scale testing.

All thermal parameters were measured with precision platinum resistance temperature detectors (RTD) and recorded using an Agilent 34972A data acquisition unit. All RTD's have a resolution of 0.01°F (0.005°C). The chamber was instrumented with the following:

- Five (5) Entering Air Dry-Bulb RTD's
- Four (4) Entering Air Wet-Bulb RTD's
- Five (5) Leaving Air Dry-Bulb RTD's
- Two (2) Leaving Air Wet-Bulb RTD's
- Two (2) Inlet Water RTD's
- Two (2) Outlet Water RTD's

The test chamber incorporated a calibrated internal nozzle wall for accurate airflow measurement. The nozzle wall and airflow measurements meet the criteria outlined in Air Movement and Control Association International, Inc. (AMCA) Standard 210, Laboratory Methods of Testing Fans for Certified Aerodynamic Performance Rating. Air side pressure drop across the adiabatic pad media was measured with a differential pressure transmitter. Supply water flow rate was measured using an in-line flow meter.

Figure 5: Evapco Adiabatic Pad Test Chamber

The chamber was used to test a variety of adiabatic pad types and depths from several manufacturers. It was also used to determine the effects of water temperature and water flow rate. Test results proved to be consistent and repeatable, producing an overall test tolerance of ±2%. This tight tolerance provides a high level of confidence in the technical data presented in this report. Additionally, key small-scale test results were compared to full-scale unit testing to confirm the accuracy of both results.

Full-Scale Test Chamber

Testing of selected adiabatic pads on a full-scale unit was conducted in a thermal test chamber (Figure 6). Results from full-scale testing were compared to small scale testing and used to develop performance models to generate fully rated adiabatic fluid cooler and refrigerant condenser thermal capacities.

All testing was performed to meet the criteria of industry recognized test methods, such as:

Figure 6: Evapco Full-Scale Test Chamber

- ASHRAE Standard 20, *Method of Testing Remote Mechanical-Draft Air-Cooled Refrigerant Condensers*,
- European Standard EN 1048, *Air cooled liquid coolers ('dry coolers'). Test procedures for establishing the performance*,
- European Standard EN 327, *Forced convection air cooled refrigerant condensers. Test procedures for establishing performance*,
- CTI ATC-106, *Acceptance Test Code for Mechanical Draft Evaporative Vapor Condensers*, or
- CTI ATC-105-DS, *Acceptance Test Code For Air Cooled Closed Circuit Cooling Towers*

Similar to tests conducted in the Adiabatic Pad Test Chamber, all thermal parameters were measured with precision platinum resistance temperature detectors (RTD) temperature probes and recorded using an Agilent 34972A data acquisition unit. All RTD temperature probes have a resolution of 0.01°F (0.005°C). Fluid flow was measured using a magnetic flow meter or venturi tube for water and a Coriolis flow meter for ammonia. Fan motor input power was measured with a calibrated digital kilowatt meter at the motor disconnect. Atmospheric pressure was taken during the test using a mercury barometer.

Linear Adiabatic Pad Depth

According to adiabatic pad manufacturer's published data, the most influential design parameter for adiabatic pad saturation efficiency is the pad's linear depth (Figure 7). Evapco tested three pad depths from one manufacturer in the adiabatic pad test chamber and on a full scale unit to validate this observation. Each point in Figure 8 represents the calculated efficiency from test data gathered in Evapco's full-scale lab with the solid line representing the best fit line to the data. The test data from the adiabatic pad test chamber and full scale unit testing confirmed that linear pad depth does indeed have a significant impact on saturation efficiency, regardless of air velocity.
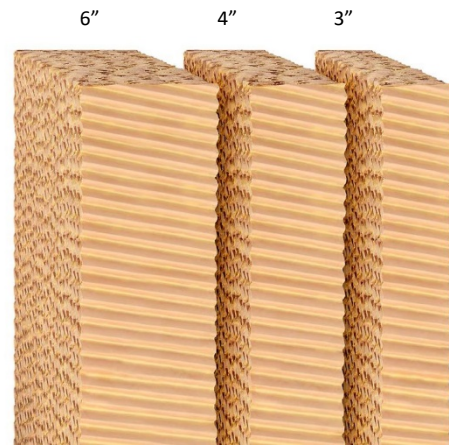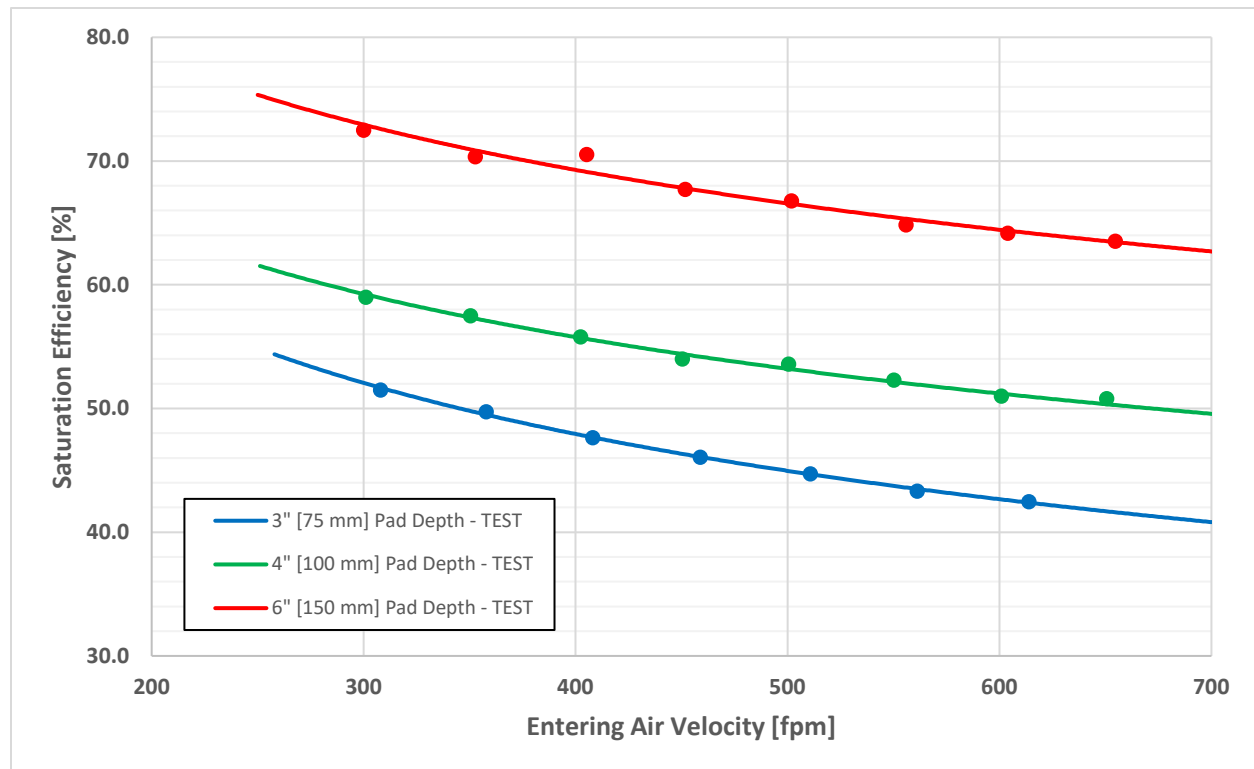

Figure 7: Example Adiabatic Pad Depths

Figure 8: Saturation Efficiency for Multiple Pad Depths

Entering Air Velocity

Saturation efficiency varies significantly with entering air velocity, regardless of adiabatic pad design or pad depth. This effect was confirmed by the Evapco test data associated with every test performed (e.g., Figures 8, 9, 12.1-12.8, and 13). Therefore, it is inaccurate to apply a constant adiabatic pad saturation efficiency independent of entering air velocity as part of the unit rating methodology.

Supply Water Flow Rate

Supply water flow rate is a parameter that is often discussed in conjunction with adiabatic system performance. To quantify the impact flow rate has on adiabatic system performance, Evapco varied the supply water flow rate over one of the adiabatic pads and calculated the saturation efficiency from the measured temperatures. Tests were performed at flow rates ranging from 50% below to 50% above the manufacturer's recommended water flow rate with the results presented in Figure 9.
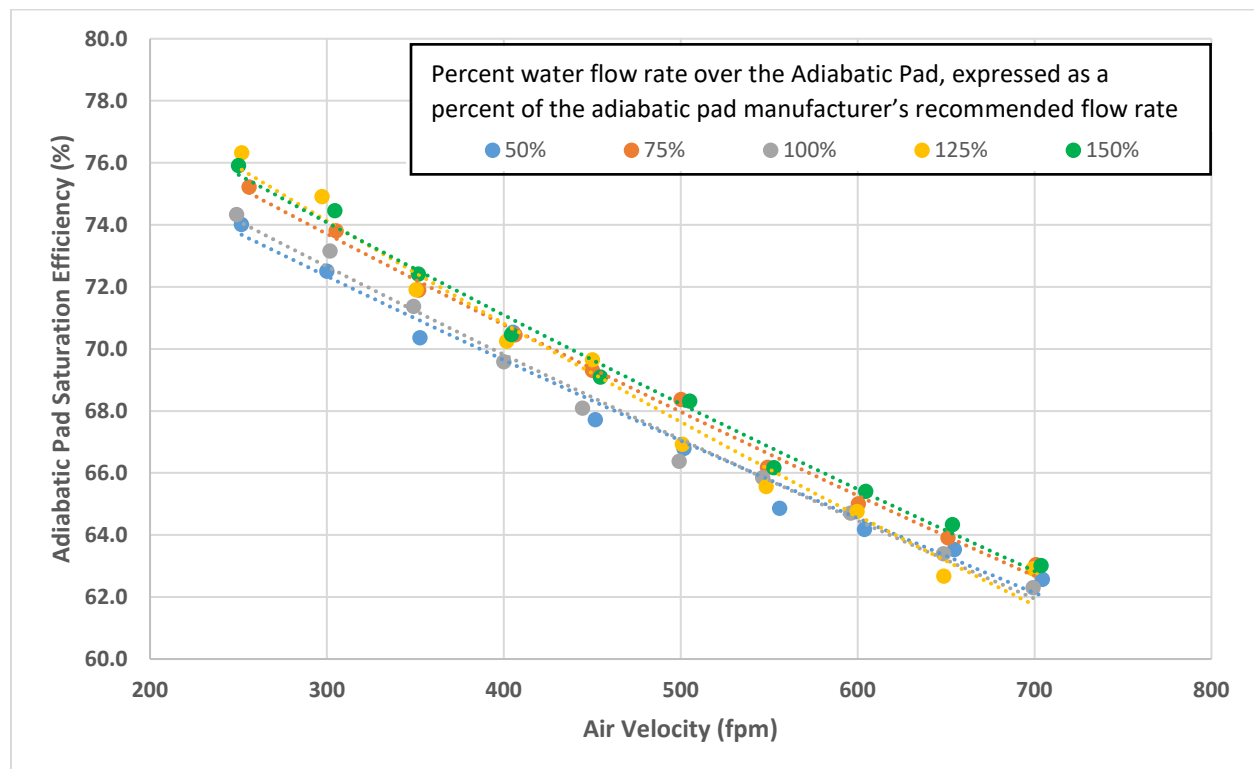

Figure 9: Adiabatic Pad Saturation Efficiency at Multiple Water Flow Rates

The test results provided in Figure 9 suggest that **increasing the water flow rate per pad plan area has minimal effect on the resultant depressed dry-bulb and, therefore, minimal impact on saturation efficiency**. However, it should be noted, increasing the supply water flow rate over the pad increases water use unnecessarily. An optimally designed adiabatic unit uses the minimum threshold water flow rate which will keep the adiabatic pad(s) fully wetted, thus maintaining effective air dry-bulb temperature reduction while using the least amount of water possible.

Supply Water Temperature

The supply water temperature hitting the adiabatic pad is another parameter marketed as influential to saturation efficiency. Evapco tested supply water temperatures ranging from approximately 40°F to 90°F on a full scale adiabatic unit. Table 2.1 below exhibits measured adiabatic pad saturation efficiency for the range of water temperatures tested.

Water Supply Temperature to Adiabatic Pad	Difference from Entering Wet-Bulb	Saturation Efficiency	Capacity Effect
96.5 °F	+27.4 °F	66.2%	-3.2%
86.3 °F	+17.2 °F	66.4%	-2.9%
67.0 °F	-8.6 °F	68.4%	Baseline
57.4 °F	-17.5 °F	69.4%	+1.5%
44.2 °F	-30.6 °F	70.8%	+3.6%

Table 2.1: Adiabatic Pad Saturation Efficiency at Multiple Water Supply Temperatures

The testing and data suggest water temperature has a small impact on adiabatic pad saturation efficiency and unit capability.

Evapco hypothesized the reason water temperature is marginally effective in increasing adiabatic pad saturation efficiency is because it equalizes to the entering air wet-bulb temperature. To confirm this hypothesis, the entering <u>and leaving</u> water temperature were measured and compared to the entering air wet-bulb temperature. Table 2.2 exhibits the entering and leaving water supply temperatures associated with the full scale testing where the adiabatic pad height is about 78".

Water Supply Temperature Entering Adiabatic Pad	Entering Wet-Bulb	Water Supply Temperature Leaving Adiabatic Pad v. Entering Wet-Bulb
96.5 °F	69.1 °F	+0.2 °F
86.3 °F	69.1 °F	+0.1 °F
67.0 °F	75.6 °F	-0.1 °F
57.4 °F	74.9 °F	-0.1 °F
44.2 °F	74.8 °F	-0.2 °F

Table 2.2: Entering and Leaving Water Temperatures at Multiple Water Supply Temperatures

The adiabatic pad test chamber using a 24" tall adiabatic pad was used to evaluate how quickly the supply water temperature equalizes to the entering wet-bulb temperature. In the most extreme example tested (a 36 °F difference between the entering water supply temperature and entering air wet-bulb temperature), the water temperature equalized to within 6 °F of the entering wet-bulb temperature after 24" of pad travel.

The rapid equalization of supply water temperature to air wet-bulb temperature explains the marginal impact on full scale adiabatic pad saturation efficiency and thermal capability.

Wetted Surface Configuration and Area

The surface configuration and fluting pattern of an adiabatic pad can have a significant impact on saturation efficiency as represented by each manufacturer via published literature.

Most adiabatic pad manufacturers utilize a 15/45 or 45/45 degree opposing flute angle configuration for adjacent corrugated sheets (15/45 example shown in Figure 10). Corrugation (flute) height ranges from 5 mm to 7 mm and the flute is continuous in the air direction, from the entering to leaving edges. These numerical values are typically incorporated into each brand's catalogue description.
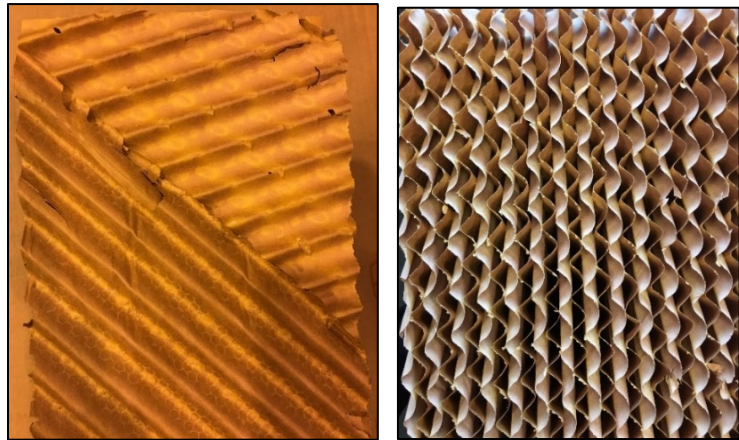
Figure 10: 15/45 Degree Opposing Flute Angle Configuration

Figure 11: 45/45 Degree Opposing Flute Angle Configuration

One particular adiabatic pad utilizes a 45/45 degree opposing flute angle configuration for adjacent corrugated sheets as shown in Figure 11. The corrugation (flute) height is 7 mm. However, the 45-degree (air direction) flute angle is non-continuous in the air direction, from entering to leaving edges. The 45-degree angle is continuous for the first 2", linear pad depth, followed by a horizontal flute section, also 2" in depth, and then continuing at a 45-degree angle (parallel to the first 2") until reaching the leaving edge.

The adiabatic pads tested and reported in this document use essentially the same total surface to achieve entering air dry-bulb cooling due to the flute height and shape being approximately the same. The main difference is that one adiabatic pad exhibits two air directional changes whereas the other adiabatic pad designs do not change air direction once the air stream enters a flute(s).

The variation in published adiabatic pad saturation efficiencies for different wetted surface configurations (refer to Figure 4) again validated the need for the extensive test program. The following figures 12.1 – 12.8 illustrate the adiabatic pad saturation efficiencies as determined in Evapco's adiabatic pad test chamber compared to the manufacturer's published/claimed efficiency curves.
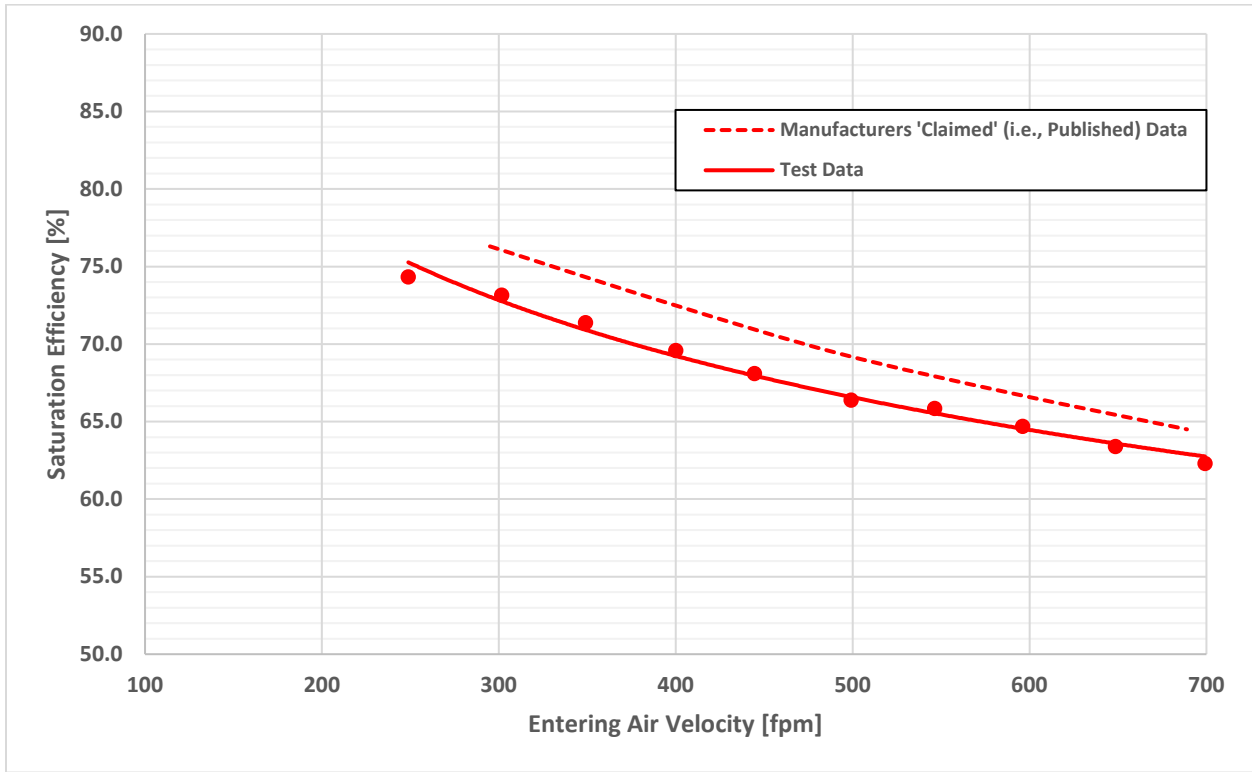
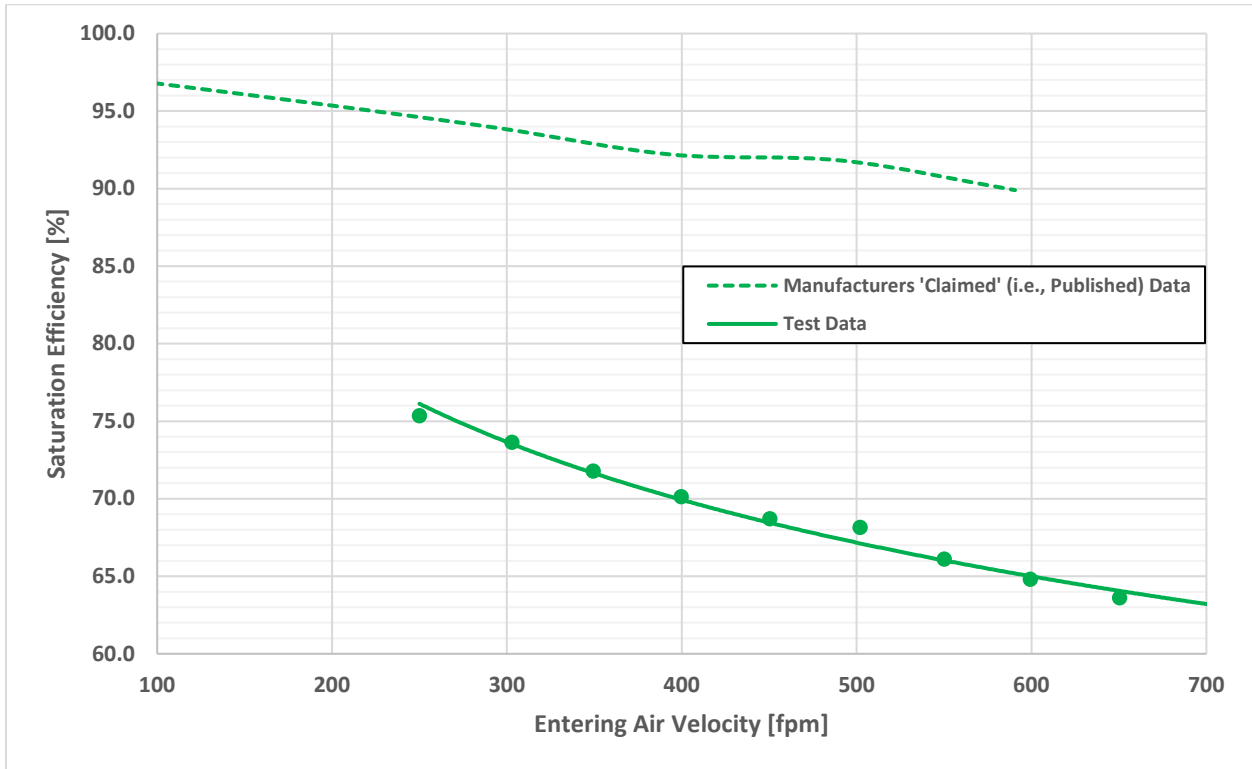**Figure 12.1: Saturation Efficiency for Manufacturer A – 6" (Version 1 Flute Configuration)**

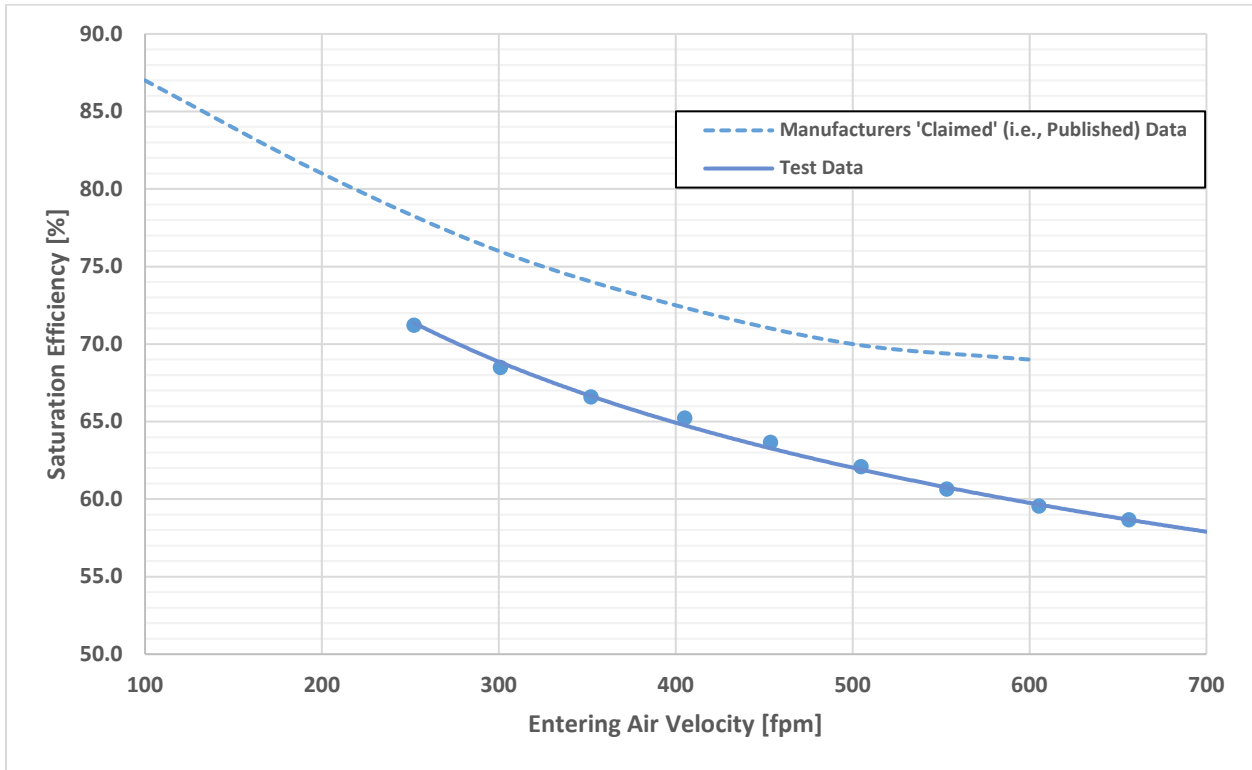**Figure 12.2: Saturation Efficiency for Manufacturer B – 6" (Version 3 Flute Configuration)**

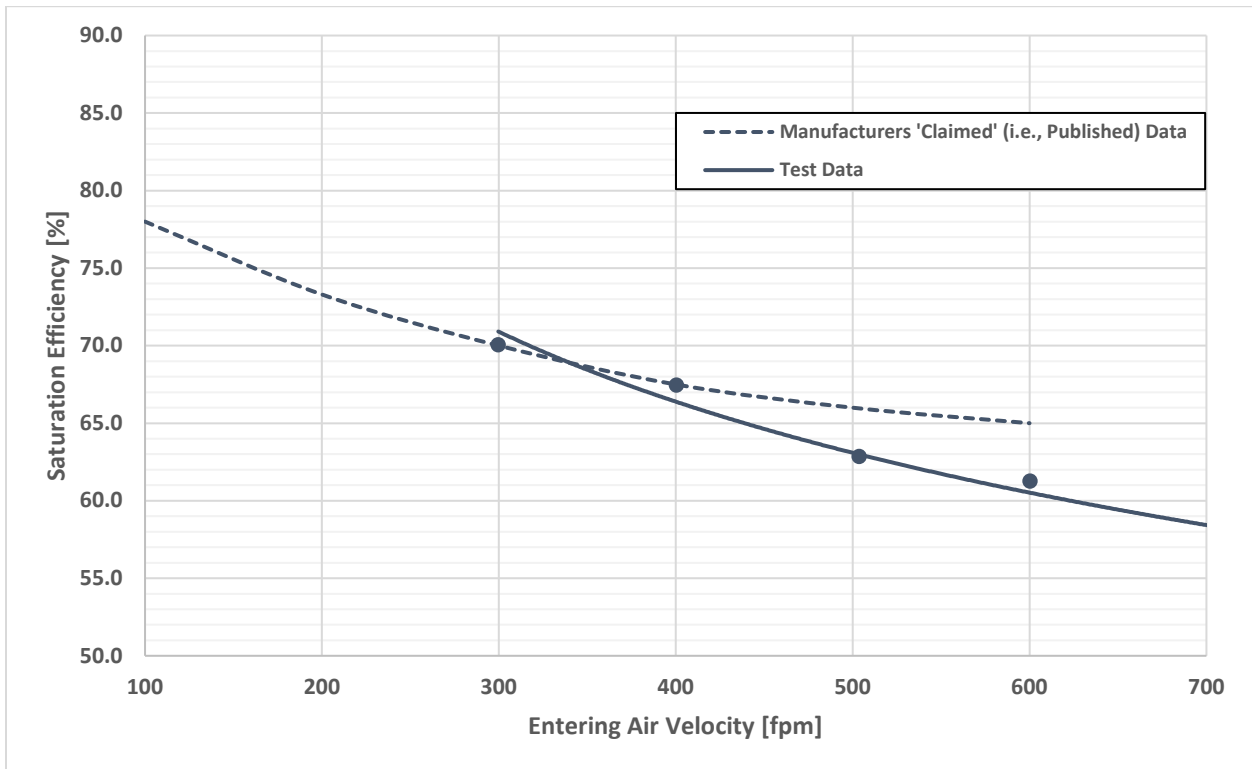**Figure 12.3: Saturation Efficiency for Manufacturer B – 6" (Version 1 Flute Configuration)**

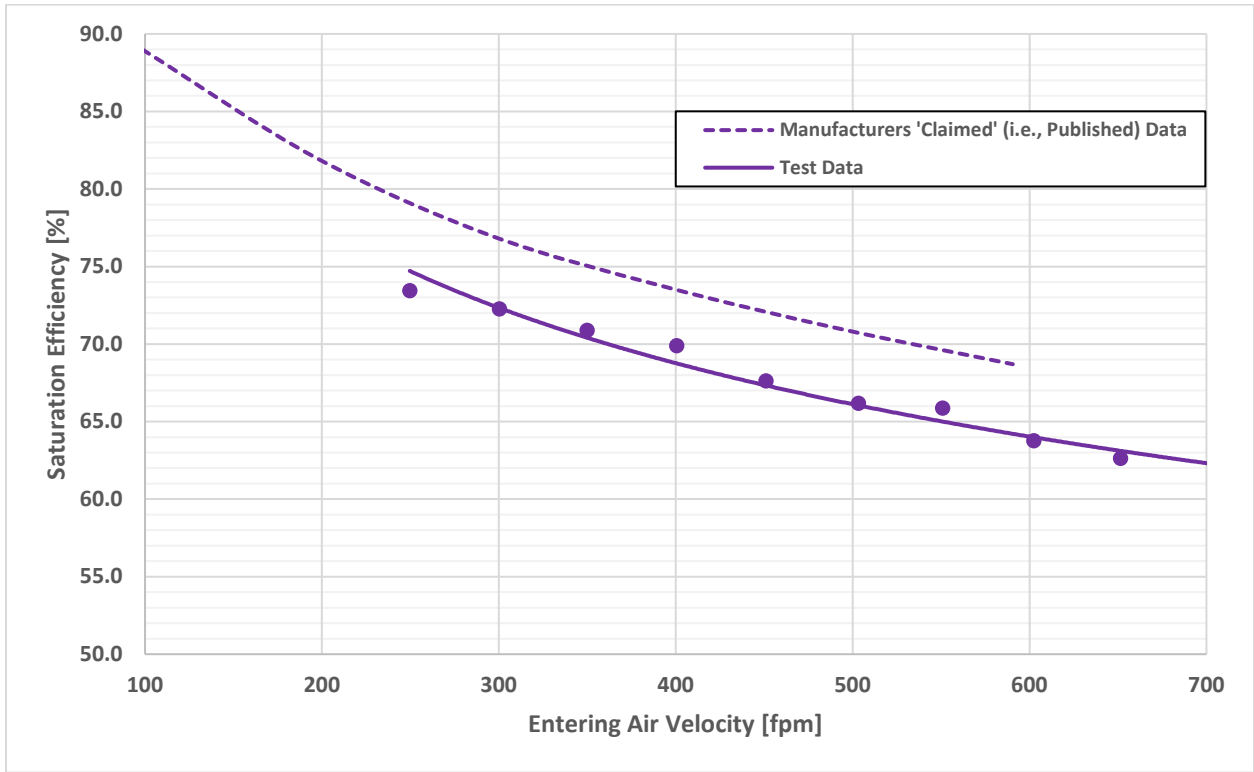**Figure 12.4: Saturation Efficiency for Manufacturer B – 4" (Version 2 Flute Configuration)**

Figure 12.5: Saturation Efficiency for Manufacturer C – 6" (Version 1 Flute Configuration)
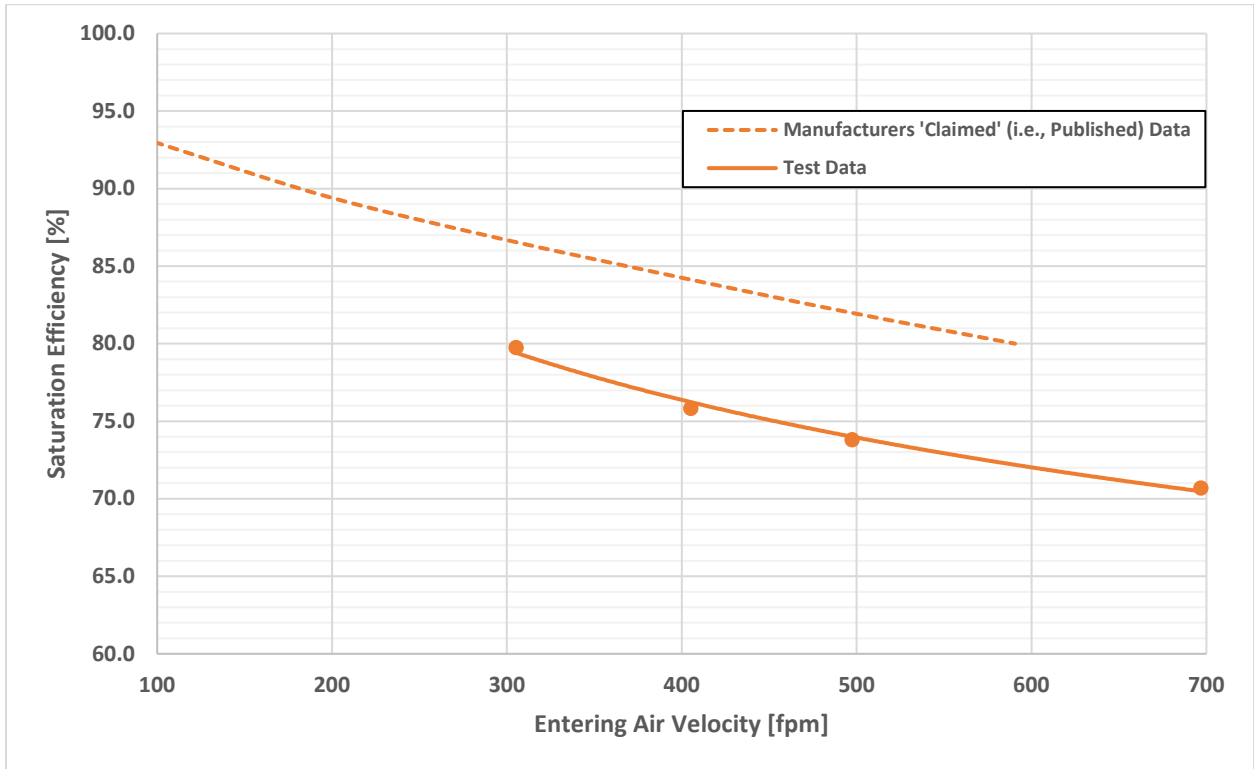

Figure 12.6: Saturation Efficiency for Manufacturer C – 6" (Version 2 Flute Configuration)
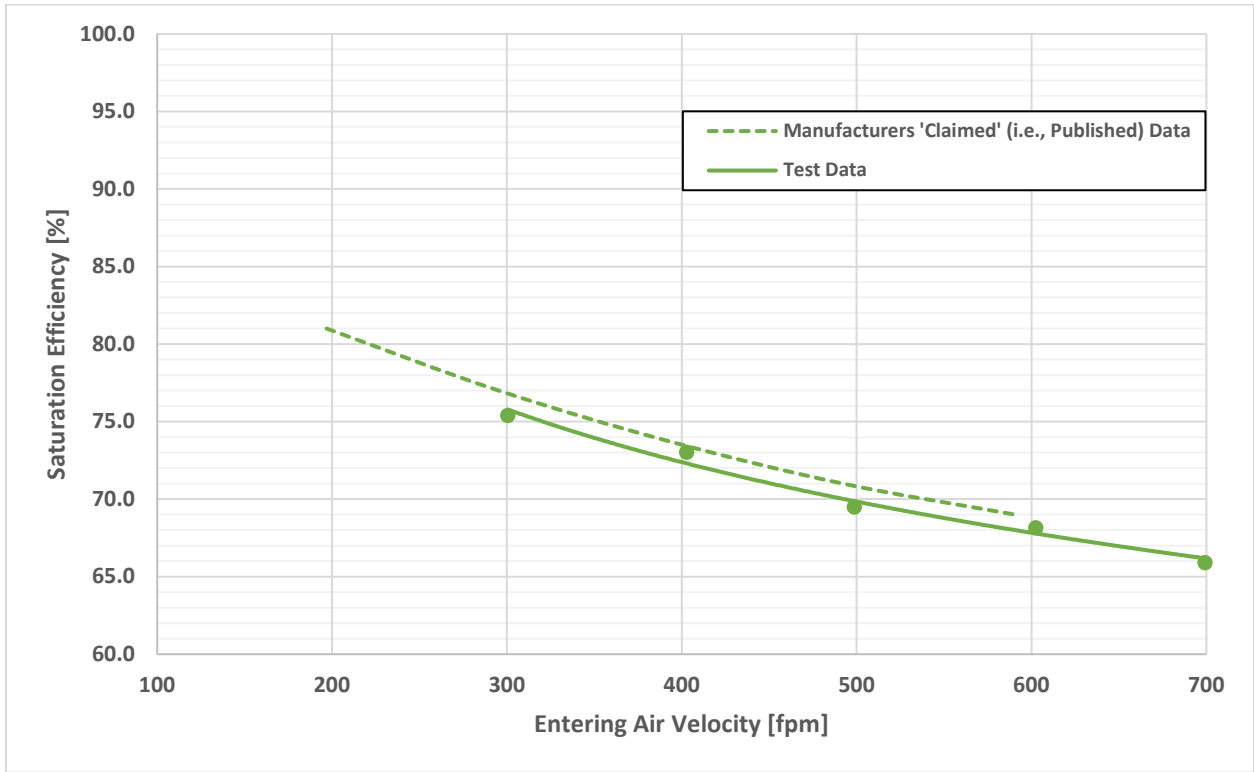
Figure 12.7: Saturation Efficiency for Manufacturer D – 6" (Version 1 Flute Configuration)
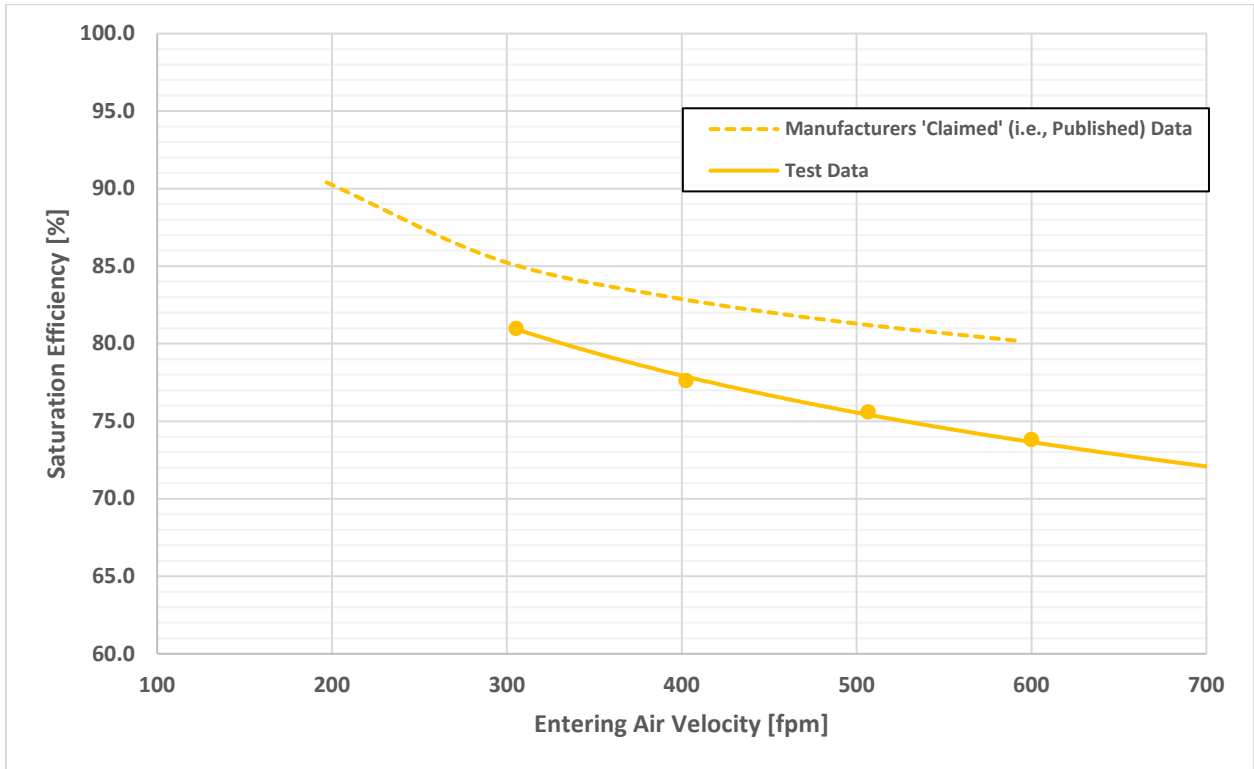

Figure 12.8: Saturation Efficiency for Manufacturer D – 6" (Version 2 Flute Configuration)

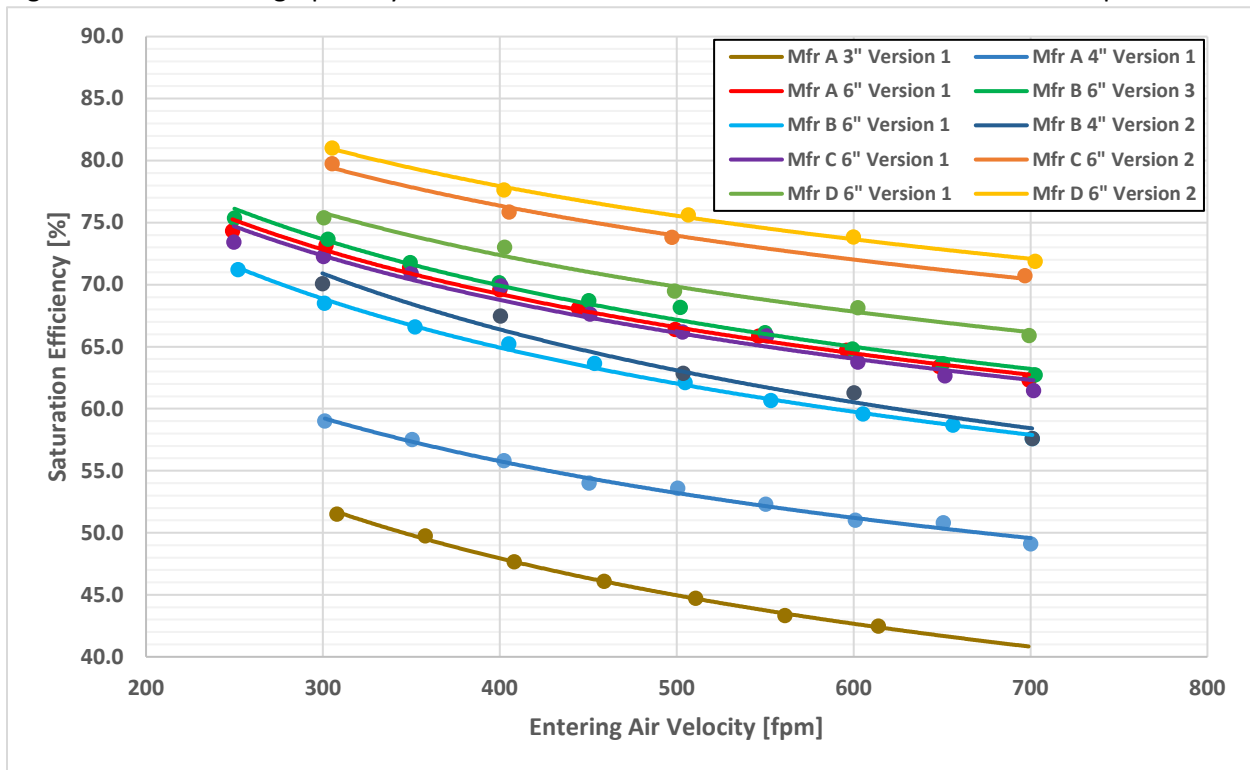Figure 13 summarizes graphically the tested saturation efficiencies for the various adiabatic pads tested.

Figure 13: Measured Saturation Efficiency of Tested Adiabatic Pads

Effect of Air-Side Pressure Drop

The difference in wetted surface configurations results in different saturation efficiencies, but choosing the highest efficiency adiabatic pad may not result in the highest unit thermal capacity **because air side pressure drop is just as important to unit thermal capacity as saturation efficiency**. The benefit of installing an adiabatic pad that achieves a high saturation efficiency can be negated or even detrimental if the air side pressure drop across the pad results in less airflow. In addition, air side pressure drop across the pads also affects unit performance when operating in dry mode during periods of low ambient temperature conditions and/or reduced system load.

Figure 14 summarizes the air side pressure drop associated with each of the pads illustrated in Figure 13.
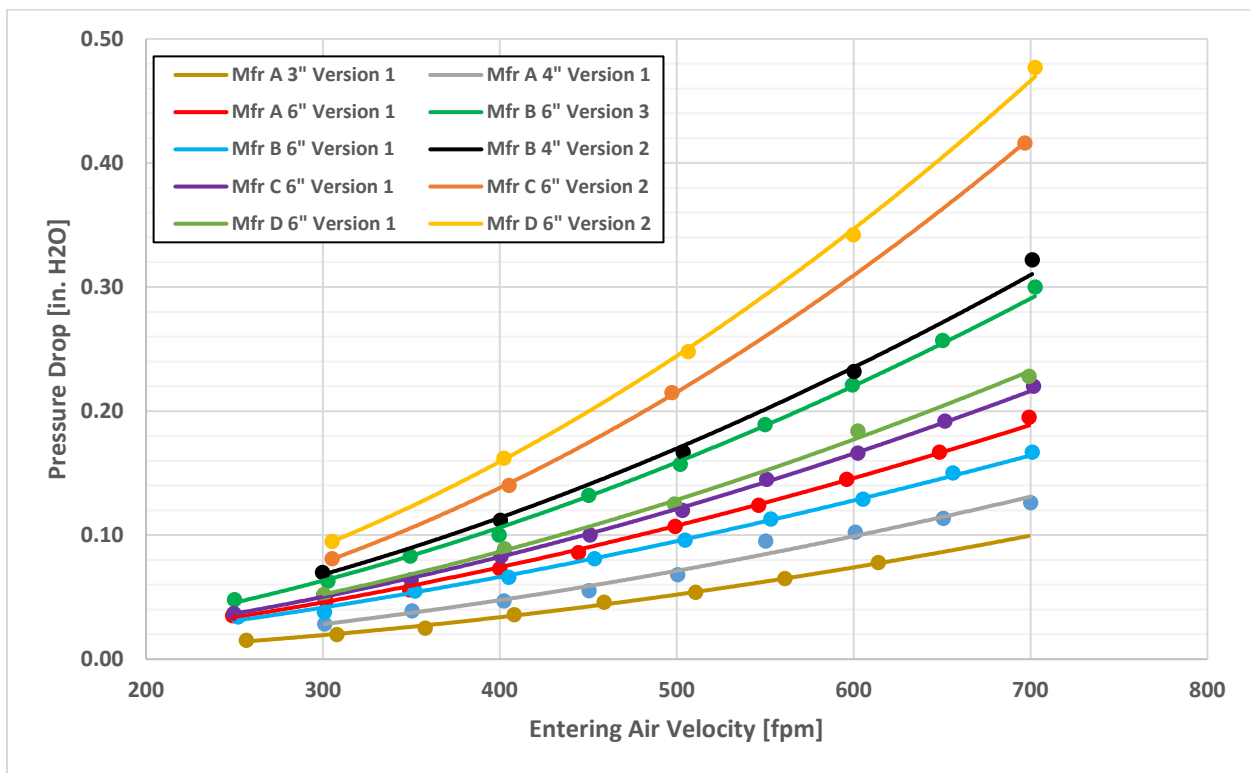
Figure 14: Measured Pressure Drop for Multiple Manufacturer's 6" [150 mm] Adiabatic Pads

Most adiabatic fluid coolers and condensers are selected to satisfy the design operating point with an inlet air velocity around 600 feet per minute. Table 3 below presents saturation efficiency and air side pressure drop at 600 fpm for the adiabatic pads tested in this study.

Manufacturer	Pad Thickness	Flute Configuration	Pressure Drop ["H$_2$O]	Saturation Efficiency
D	6" [150 mm]	Version 2	0.342	73.8%
C	6" [150 mm]	Version 2	0.310	72.1%
B	4" [100 mm]	Version 2	0.232	61.3%
B	6" [150 mm]	Version 3	0.221	64.8%
D	6" [150 mm]	Version 1	0.184	68.1%
C	6" [150 mm]	Version 1	0.166	63.8%
A	6" [150 mm]	Version 1	0.145	64.7%
B	6" [150 mm]	Version 1	0.129	59.6%
A	4" [100 mm]	Version 1	0.102	51.0%
A	3" [75 mm]	Version 1	0.070	43.0%

Table 3: Saturation Efficiency and Pressure Drop of Tested Adiabatic Pads at 600 fpm Air Velocity

In general, the adiabatic pads with the higher saturation efficiencies were found to have the higher air side pressure drop values. Evapco selected an adiabatic pad that resulted in the best unit thermal capacity for use in the eco-Air product by balancing saturation efficiency and resultant airflow based on the results of this extensive test program.

Closing Comments

Evapco has shared the test results contained in this report with the respective manufacturer of each adiabatic pad tested. Manufacturers have either agreed with or not refuted the results of the tests. Evapco recognizes that the adiabatic pads tested represent only a portion of the adiabatic pads currently available in the global market and will continue to test adiabatic pads in search of the next generation of best pads.

Reiterating points raised in the paper:

- Water flow rate and water temperature have little to no effect on adiabatic pad saturation efficiency when evaluated on a full size adiabatic fluid cooler or condenser.
- Adiabatic pad depth impacts adiabatic pad saturation efficiency.
- Adiabatic pad saturation efficiency changes with air velocity – it is not a constant value!
- Adiabatic pad saturation efficiency and air side pressure drop are equally important in evaluating adiabatic unit thermal performance.
- None of the adiabatic pads tested in this research achieved a 90% saturation efficiency in the normal operating entering air velocity range for this type of equipment.
- Specifying independent field or full scale laboratory testing using industry recognized test methods confirms adiabatic fluid cooler or condenser thermal performance to required operating conditions in the absence of strict certification programs.

As stated in the introduction, engineers and end-users face an unknown stumbling block when trying to apply adiabatic technology. This is due to the widespread variation in "claimed" adiabatic pad saturation efficiency in the global marketplace, which can result in a dramatic impact on the size or performance of the air-cooled closed circuit cooler or refrigerant condenser. Additionally, **adiabatic unit manufacturers commonly apply a constant adiabatic pad saturation efficiency when selecting adiabatic units, regardless of actual entering air inlet velocity.** Much to Evapco's surprise, we noted "claimed" adiabatic pad saturation efficiencies of 80-95% on datasheets from adiabatic fluid cooler and refrigerant condenser manufacturers. Based on the results of our testing, even 80% adiabatic pad saturation efficiency was not achieved <u>at typical entering air velocities for most adiabatic fluid cooler and refrigerant condensers</u>. **<u>Evapco applies the full scale laboratory tested saturation efficiency based on the unit's actual air inlet velocity to calculate actual adiabatic unit performance</u>**.

Evapco is committed to providing fully rated products including air cooled and adiabatic fluid coolers and refrigerant condensers. Unfortunately, there are no "adiabatic specific" third-party performance verification test standards or certification programs for adiabatic coolers, adiabatic condensers or the adiabatic pads – hence ATTACHMENT #1 is offered as a reasonable means of specifying thermal capability and testing given currently available test standards. Overstating thermal performance is common where third party verification or certification programs do not exist. Additionally, end-users often do not mandate thermal performance guarantees into specifications. Increased (and unnoticed) frequency of adiabatic operation at wet-bulbs lower than promised by the manufacturer masks underperforming adiabatic fluid coolers and refrigerant condensers. Until strict certification programs exist, Evapco strongly encourages end-users insist on field or full scale laboratory acceptance testing and capacity calculation to determine if the adiabatic <u>and</u> dry thermal capacity of the unit meets or exceeds specified design conditions.

– ATTACHMENT #1 –

SUGGESTED SPECIFICATION: ADIABATIC COOLER THERMAL CAPACITY AND TEST GUARANTEE

THERMAL CAPACITY:
Unit(s) shall be selected and guaranteed to satisfy the following two design conditions.

I. Dry Mode:
When operating in dry mode (i.e. adiabatic pre-cooling system OFF), unit(s) shall be guaranteed to cool a design flow rate of ____USGPM of water (___% glycol, if applicable) from ____°F entering fluid temperature to____°F leaving fluid temperature at a ___°F entering dry-bulb temperature. Coil pressure drop shall not exceed ___psi at the design flow rate.

II. Adiabatic Mode:
When operating in adiabatic mode, the unit(s) shall be guaranteed to cool a design flow rate of ____ USGPM of water (___% glycol, if applicable) from ___°F entering fluid temperature to____°F leaving fluid temperature at an entering air condition with an entering air wet-bulb temperature of ___°F and simultaneously occurring entering air dry-bulb temperature of ___ °F.

THERMAL CAPACITY TEST GUARANTEE:
Unit(s) shall be guaranteed to provide the Dry Mode THERMAL CAPACITY specified above when field tested in accordance with CTI ATC-105DS, Field Thermal Test Procedure for Dry Coolers.

If the units are suspected to be deficient in thermal capacity, the owner/user has the right to request a Dry Mode field thermal performance test per CTI ATC-105DS, Field Thermal Test Procedure for Dry Coolers, at their own expense. The test shall be conducted by an independent third-party test agency per the ATC-105DS test procedure within one year from date of shipment. In recognition of a +/- 2% field test tolerance, if the CTI Standard ATC-105DS field test results report a capacity of 98% or greater the unit shall be deemed to have satisfied the guaranteed THERMAL CAPACITY.

The third-party test agency shall be a CTI licensed thermal test agency (http://cti.org/licensedTestingAgencies.php).

The manufacturer shall be given a minimum thirty (30) day notice prior to the test date and shall be allowed to both pre-inspect the unit and witness the test.

If the field thermal performance test results report the unit capacity to be less than the guaranteed THERMAL CAPACITY, the equipment manufacturer shall reimburse the owner for the cost of the field performance test. Additionally, the manufacturer shall absorb all costs to make corrective measures to increase unit capacity to guaranteed THERMAL CAPACITY or greater without exceeding the specified total fan motor energy of the unit(s). Corrective measures must be completed by the equipment manufacturer within six (6) months of a test which finds the unit to be less than guaranteed THERMAL CAPACITY.

The equipment manufacturer shall then pay to have the modified/corrected units re-tested per ATC-105DS to confirm the corrective actions have improved capacity to the guaranteed THERMAL CAPACITY. If the retest results report the capacity to still be less than the guaranteed THERMAL CAPACITY, the manufacturer shall provide new units which provide the specified thermal capacity free of charge and absorb all costs for removing and replacing the thermally deficient units.

The manufacturer shall pay to have the new/replacement unit's field thermal performance tested per ATC-105DS to confirm they meet the guaranteed THERMAL CAPACITY. If the test on the new/replacement units reports capacity to be less than the guaranteed THERMAL CAPACITY, the manufacturer shall repeat the process (at their own expense) of providing new units and field tests per ATC-105DS until a field test result reports that the installed units meet or exceed the guaranteed THERMAL CAPACITY without exceeding the specified total fan motor energy of the unit(s).