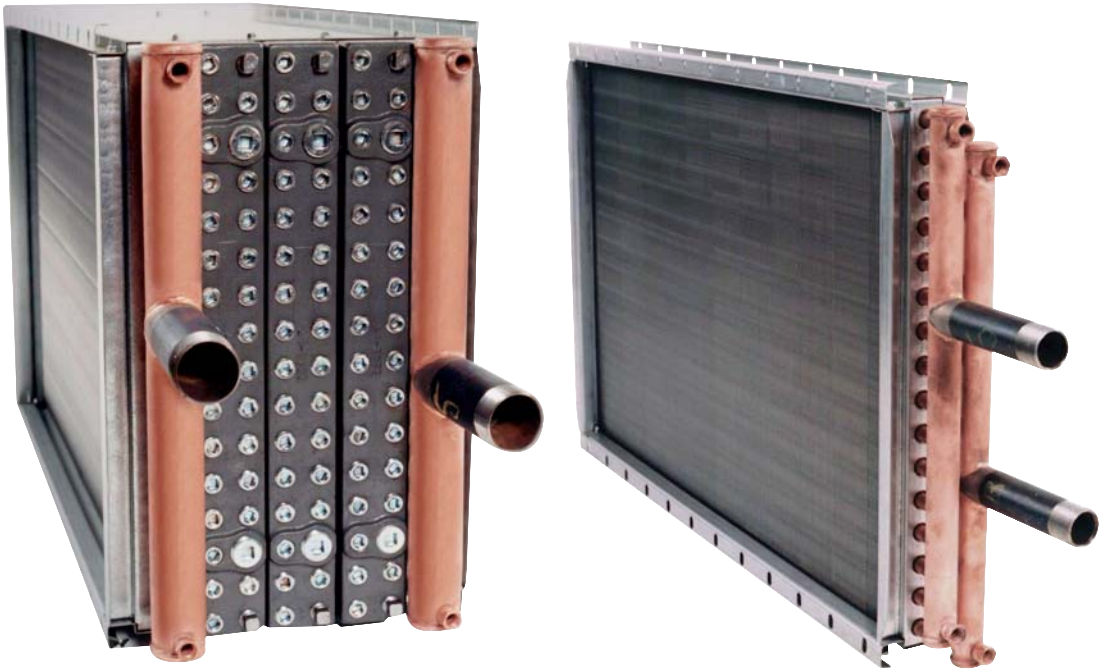
TRANE

Trane Engineers Newsletter Live

Coil Selection and Optimization

Presenters: Brian Hafendorfer, Todd Michael, John Murphy, Jeanne Harshaw (host)



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Agenda

Trane *Engineers Newsletter Live* Series

Coil Selection and Optimization

Abstract

In this ENL program, Trane engineers will discuss the application, selection, and optimization of both chilled-water and hot-water coils. Topics include a discussion about the impact of both water and air velocities on coil performance, a review of example selections for chilled-water and hot-water coils to demonstrate the tradeoffs of cost, pressure drop, and capacity, and an overview of various methods to prevent water coils from freezing during cold weather.

Presenters: Trane engineers Brian Hafendorfer, Todd Michael, and John Murphy

After viewing attendees will be able to:

1. Identify the various configuration and construction options for chilled-water and hot-water coils
2. Understand the impact of both water and air velocities on coil performance
3. Evaluate water coil selection choices at various water temperatures and flow rates
4. Understand the balance of coil face area, airside pressure drop, and waterside pressure drop when selecting a coil
5. Properly protect water coils from freezing, when necessary

Agenda

- Water and air velocity ranges
- Coil selection examples
  - Chilled-water coils
  - Hot-water coils
- Freeze protection
- Summary

Presenter biographies

Coil Selection and Optimization

Todd Michael | heat transfer engineer | Trane
Todd Michael joined Trane in 1989 and is a Heat Transfer Engineer for air-to-refrigerant heat exchangers.
His primary responsibility is to provide plate fin and round tube coil development expertise to project teams.

Todd received a Bachelor of Science Degree in Physics from Western Illinois University, and Bachelor Of Science and
Master of Science Degrees in Mechanical Engineering from the University of Illinois at Urbana-Champaign.
He is a member of ASHRAE and is the AHRI Forced-Circulation Air-Cooling and Air-Heating Coil Engineering Committee Chairman.

John Murphy | applications engineer | Trane
John has been with Trane since 1993. His primary responsibility as an applications engineer is to aid design engineers and Trane sales personnel in the proper design and application of HVAC systems. As a LEED Accredited Professional, he has helped our customers and local offices on a wide range of LEED projects. His main areas of expertise include energy efficiency, dehumidification, dedicated outdoor-air systems, air-to-air energy recovery, psychrometry, and ventilation.

John is the author of numerous Trane application manuals and Engineers Newsletters, and is a frequent presenter on Trane's Engineers Newsletter Live series. He has authored several articles for the ASHRAE Journal, and was twice awarded "Article of the Year" award.
As an ASHRAE member he has served on the "Moisture Management in Buildings" and "Mechanical Dehumidifiers" technical committees. He was a contributing author of the Advanced Energy Design Guide for K-12 Schools and the Advanced Energy Design Guide for Small Hospitals and Health Care Facilities, a technical reviewer for the ASHRAE Guide for Buildings in Hot and Humid Climates, and a presenter on the 2012 ASHRAE "Dedicated Outdoor Air Systems" webcast.

Brian Hafendorfer | applications engineer | Trane
Brian joined Trane in 2000 and spent 8 years as a product engineer focused on coils for heating and cooling air with water, steam, and refrigerant for use in air handling systems. After joining the applications engineering team in 2008 his primary focus has been coils and air cleaning with a responsibility for developing and supporting integrated HVAC product solutions for Trane customers and providing a link between the sales, design, and manufacturing organizations.

Brian a earned his Bachelor of Science in Mechanical Engineering from the University of Kentucky. As a licensed professional engineer he is an active member of ASHRAE and has served multiple committee positions for both "Ultraviolet Air and Surface Treatment" and "Gaseous Air Contaminants and Removal Equipment", and the project committee for ASHRAE Standard 62.1.

Coil Selection and Optimization

Trane Engineers Newsletter Live Series

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Learning Objectives

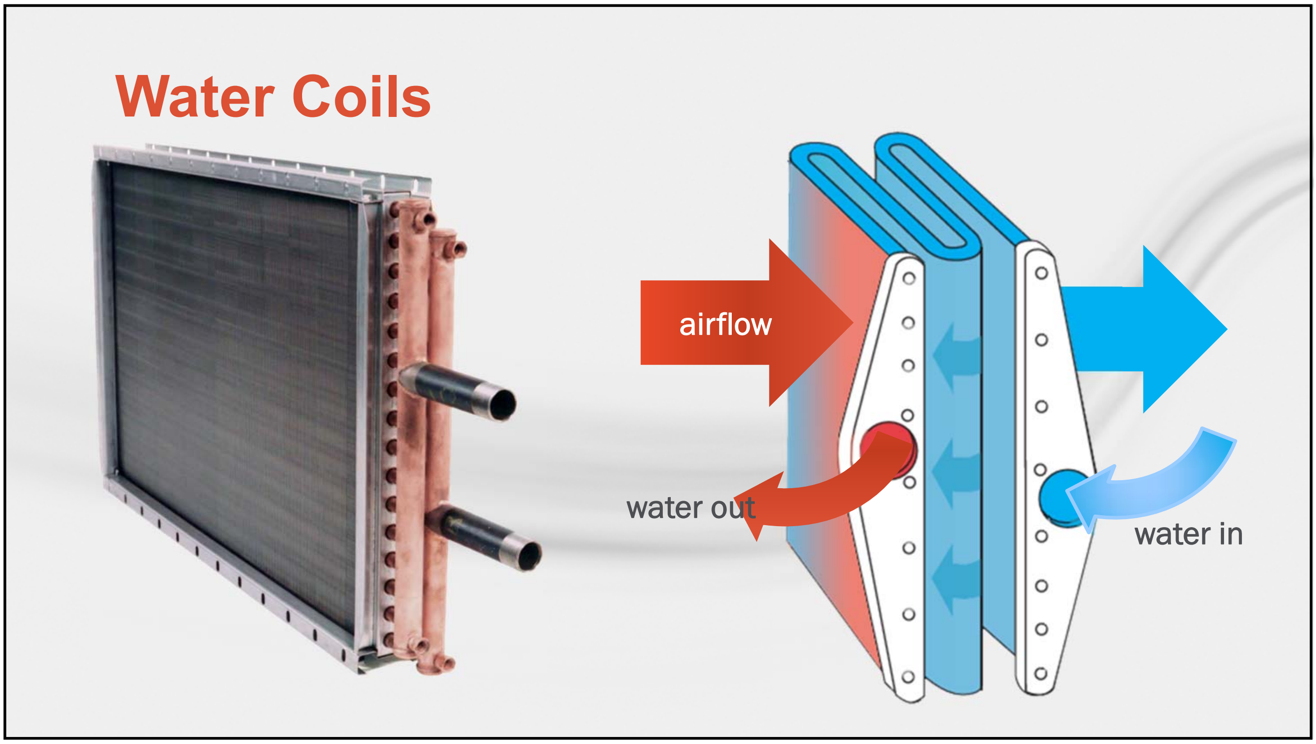
1. Identify the various configuration and construction options for chilled-water and hot-water coils
2. Understand the impact of both water and air velocities on coil performance
3. Evaluate water coil selection choices at various water temperatures and flow rates
4. Understand the balance of coil face area, air pressure drop, and water pressure drop when selecting a coil
5. Properly protect water coils from freezing, when necessary

Today's Presenters

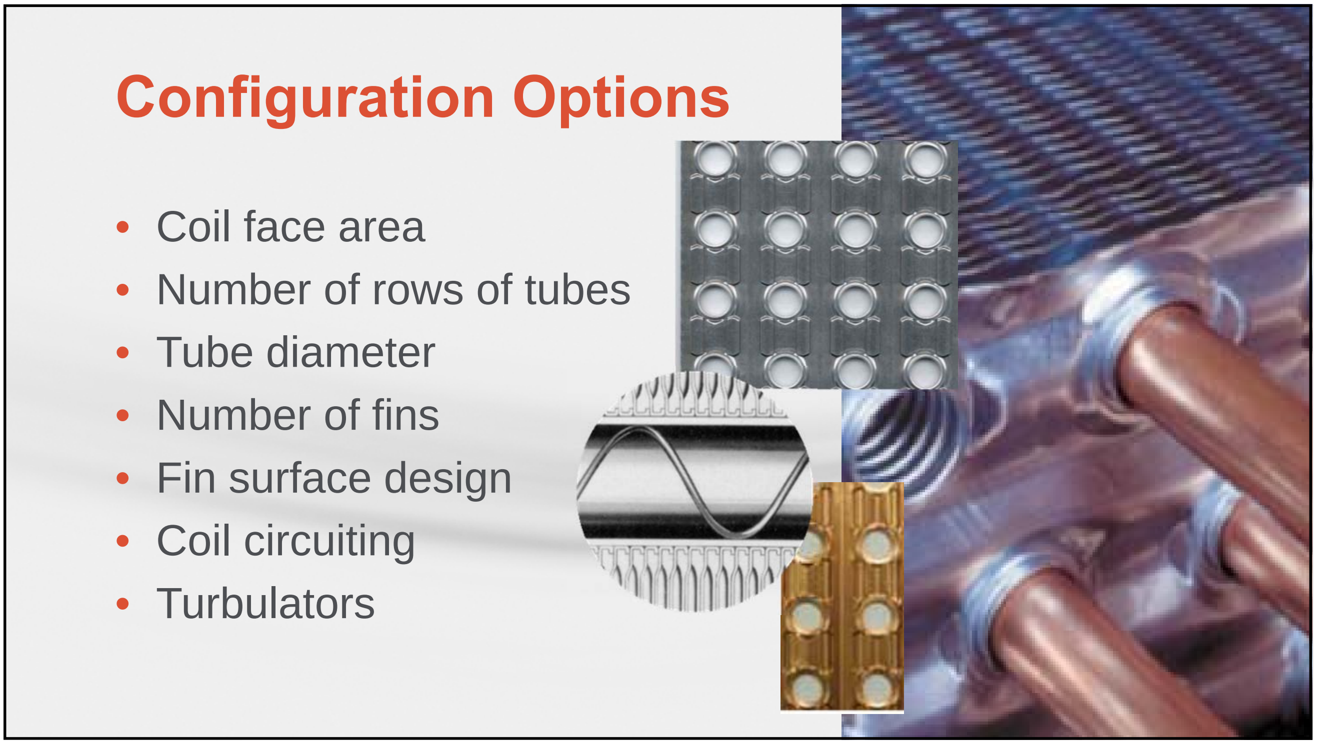
John Murphy
Applications Engineer

Brian Hafendorfer
Applications Engineer

Todd Michael
Coil Heat Transfer Engineer

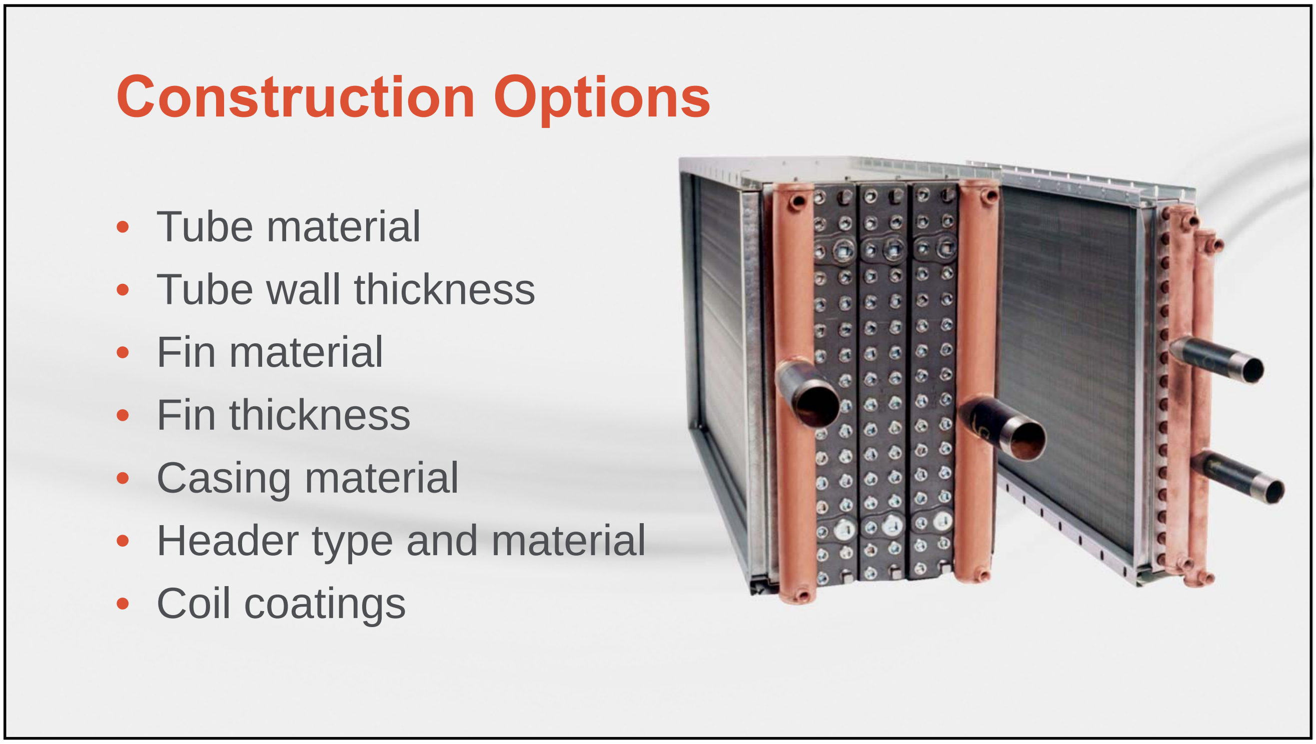


Water Coils



Configuration Options

- Coil face area
- Number of rows of tubes
- Tube diameter
- Number of fins
- Fin surface design
- Coil circuiting
- Turbulators

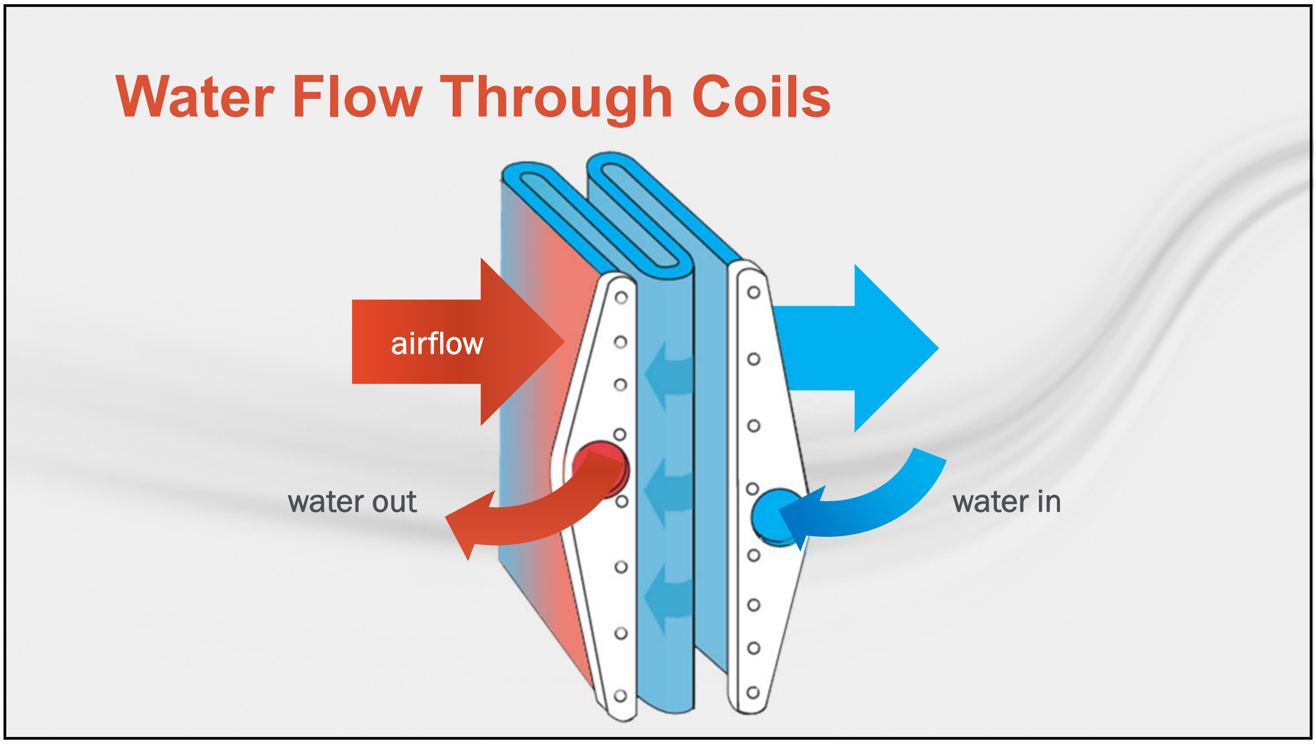


Construction Options

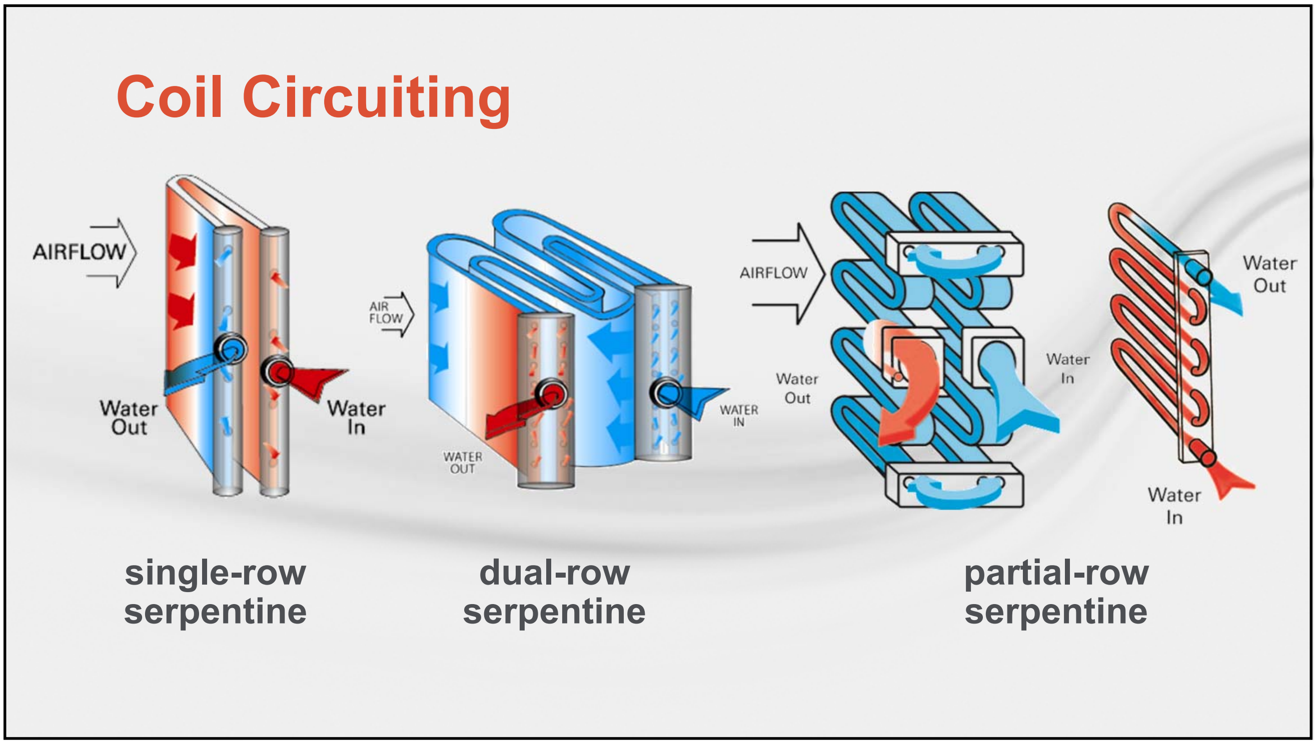
- Tube material
- Tube wall thickness
- Fin material
- Fin thickness
- Casing material
- Header type and material
- Coil coatings

Agenda

- Water and air velocity ranges
- Coil selection examples
    - Chilled-water coils
    - Hot-water coils
- Freeze protection



Water Flow Through Coils



Coil Circuiting

single-row serpentine

dual-row serpentine

partial-row serpentine

Water Velocity-Related Concerns

Water velocity too low:

- Tube fouling
- Air trapped in the coil
- Poor water distribution
- Risk of freezing

Water velocity too high:

- Tube erosion
- High water pressure drop
- Noise

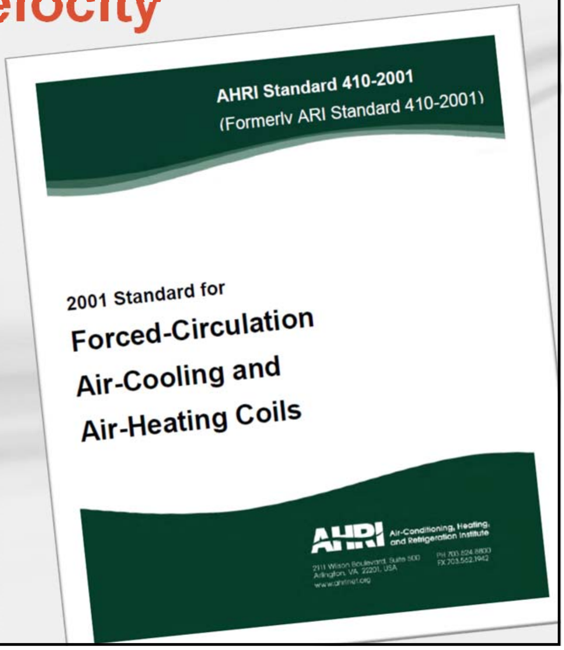
Guidelines for Water Velocity

AHRI Standard 410

Forced-Circulation Air-Cooling and Air-Heating Coils

AHRI CERTIFIED™
www.ahridirectory.org

Air-Cooling and Air-Heating Coils
AHRI Standard 410

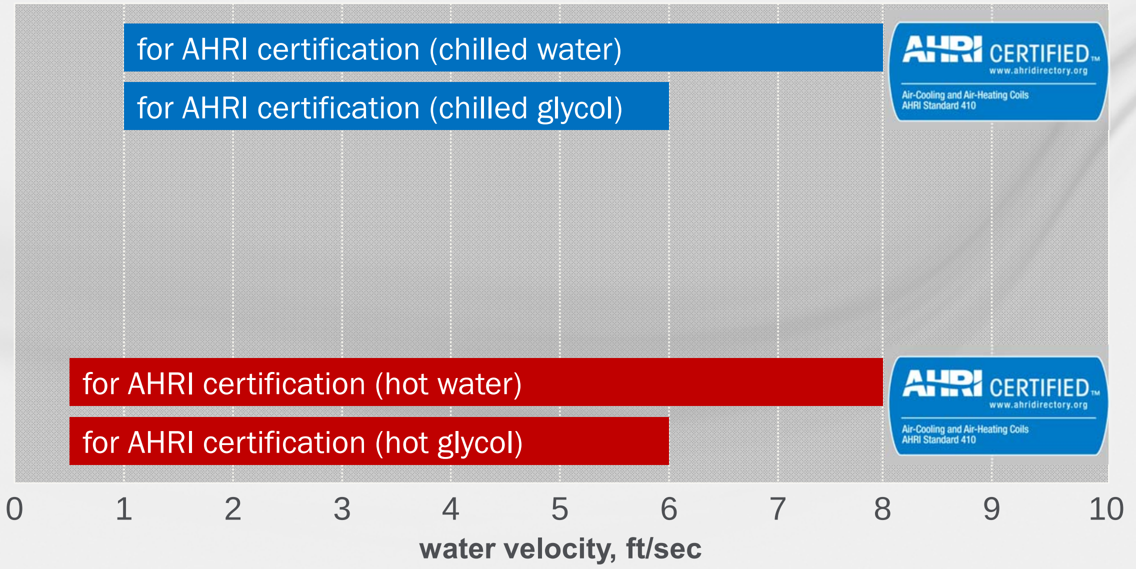


AHRI Standard 410-2001
(Formerly ARI Standard 410-2001)

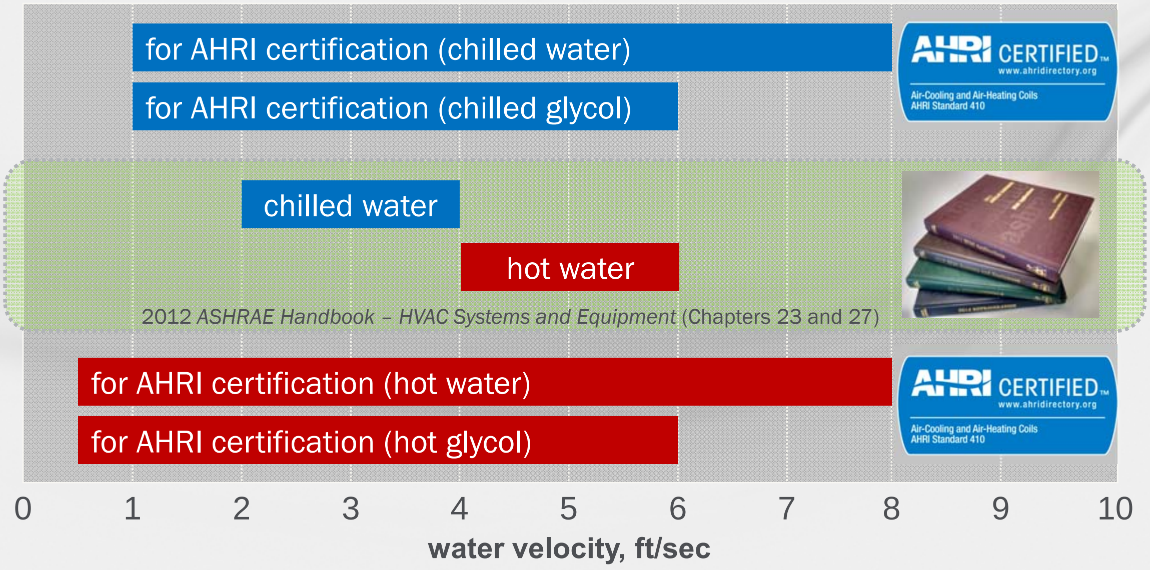
2001 Standard for
Forced-Circulation
Air-Cooling and
Air-Heating Coils

AHRI Air-Conditioning, Heating, and Refrigeration Institute
2111 Wilson Boulevard, Suite 500
Arlington, VA 22201, USA
www.ahrinet.org
PH 703.524.8800
FX 703.562.1942

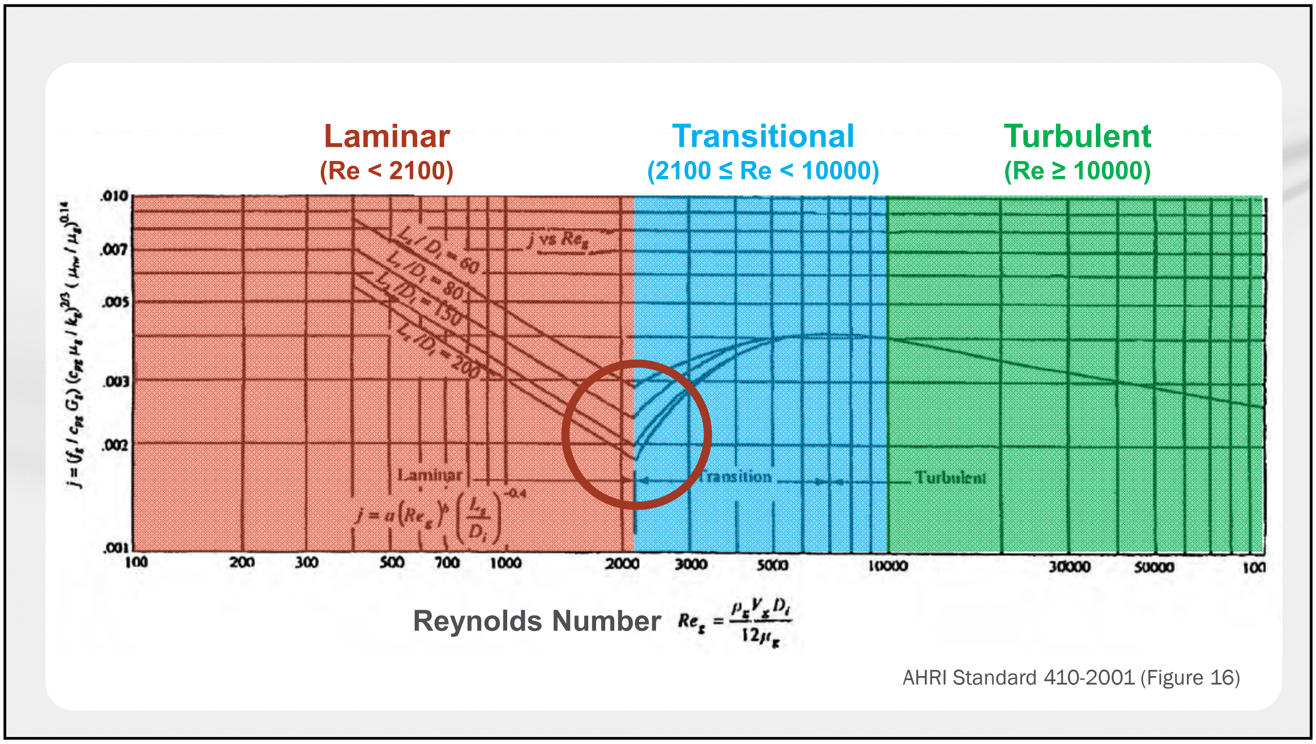
Guidelines for Water Velocity



Guidelines for Water Velocity



2012 *ASHRAE Handbook – HVAC Systems and Equipment* (Chapters 23 and 27)



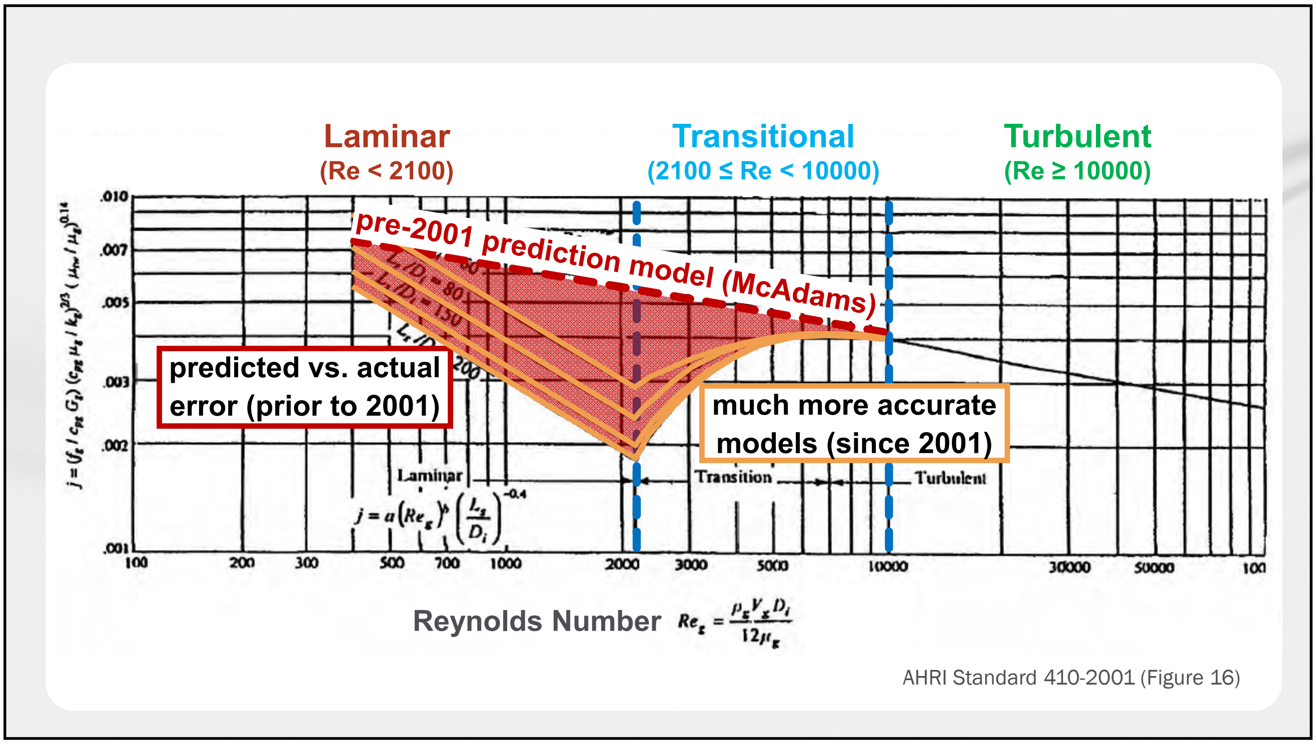
Laminar
(Re < 2100)

Transitional
(2100 ≤ Re < 10000)

Turbulent
(Re ≥ 10000)

Reynolds Number $Re_g = \frac{\rho_g V_g D_i}{12\mu_g}$

AHRI Standard 410-2001 (Figure 16)



Laminar
(Re < 2100)

Transitional
(2100 ≤ Re < 10000)

Turbulent
(Re ≥ 10000)

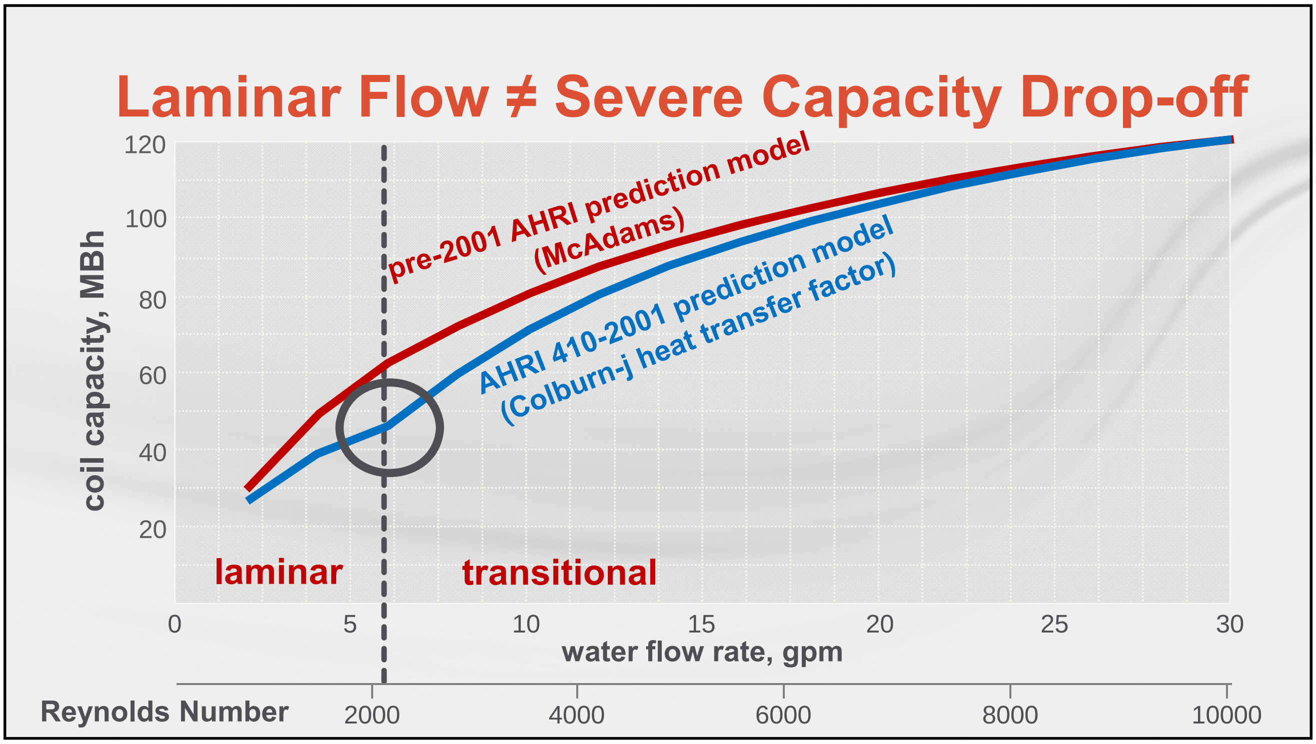
pre-2001 prediction model (McAdams)

predicted vs. actual error (prior to 2001)

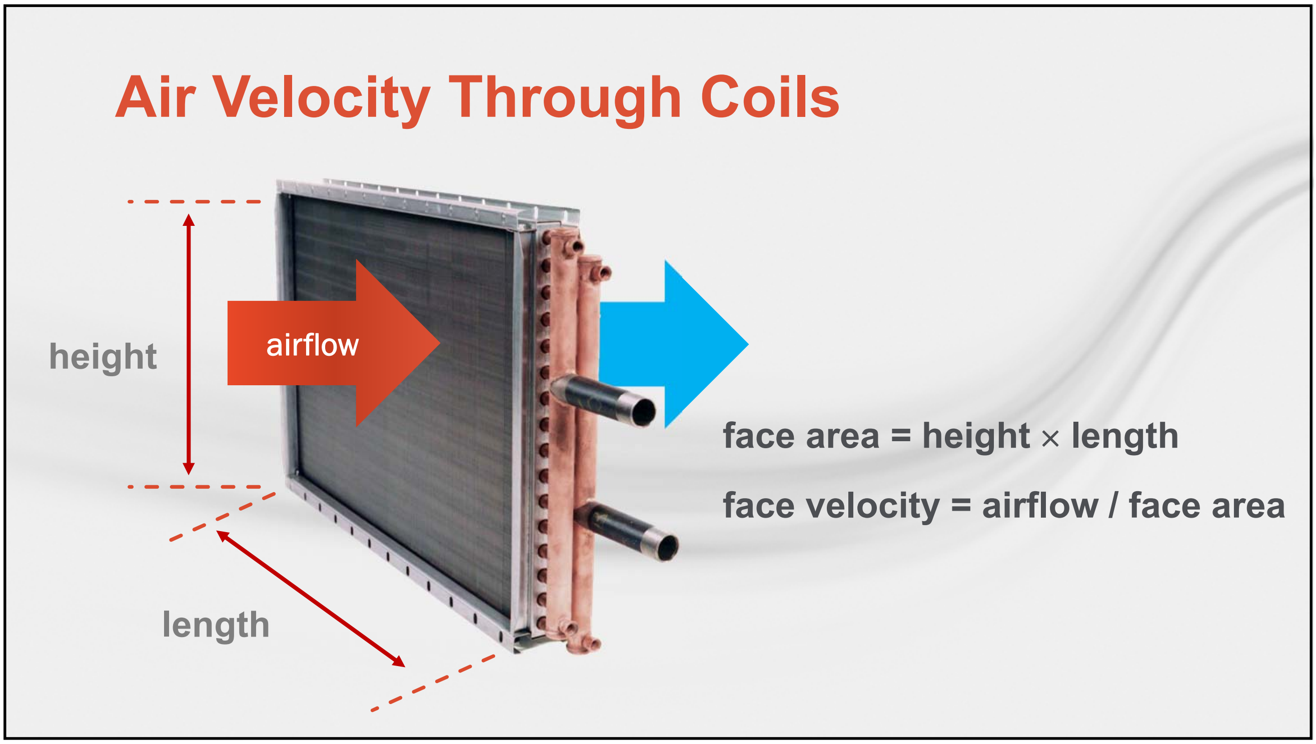
much more accurate models (since 2001)

Reynolds Number $Re_g = \frac{\rho_g V_g D_i}{12\mu_g}$

AHRI Standard 410-2001 (Figure 16)



Laminar Flow ≠ Severe Capacity Drop-off



Air Velocity Through Coils

face area = height × length

face velocity = airflow / face area

Air Velocity-Related Concerns

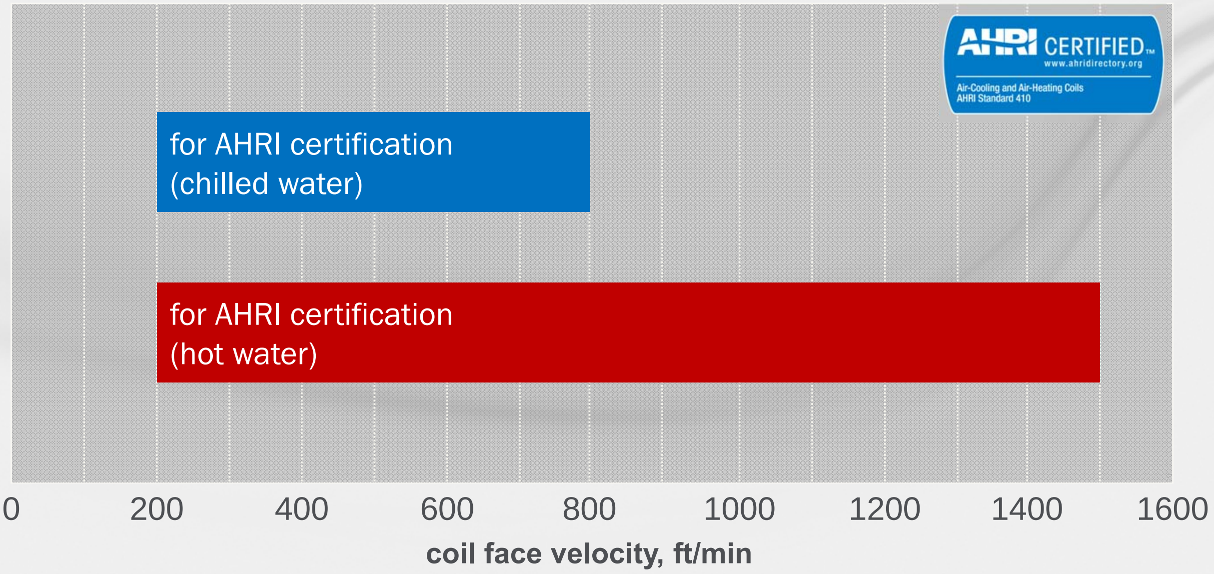
Air velocity too low:

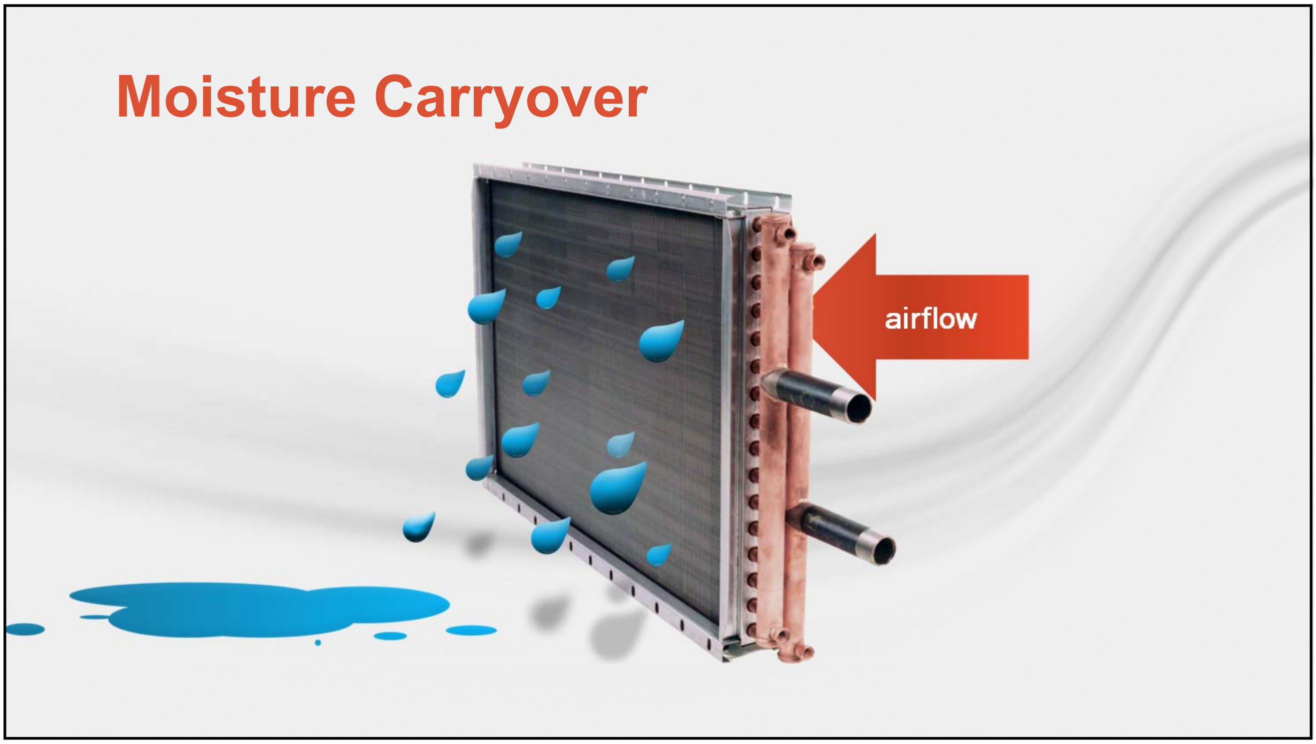
- Non-uniform leaving-air temperatures
- Less accurate prediction of coil capacity

Air velocity too high:

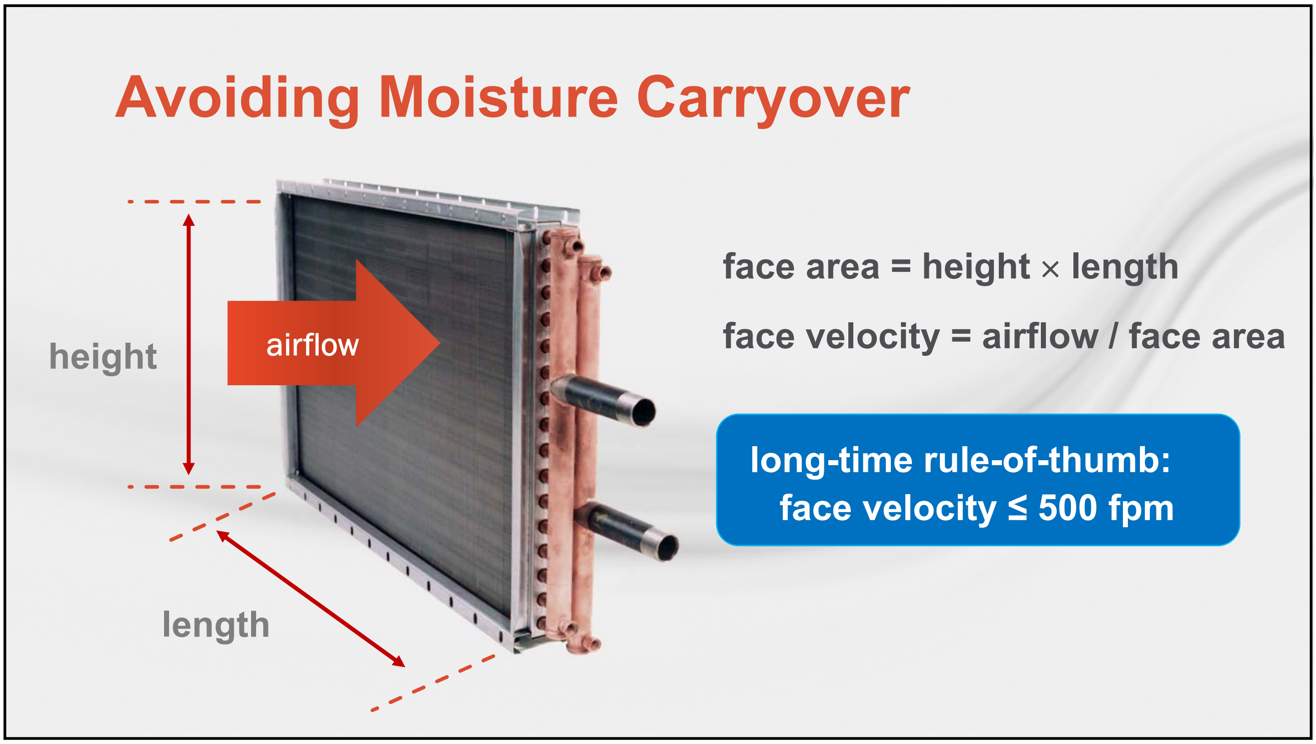
- Noise
- High air pressure drop
- Risk of moisture carryover

Guidelines for Air Velocity





Moisture Carryover



Avoiding Moisture Carryover

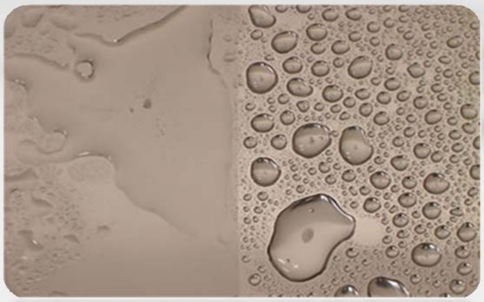
face area = height × length

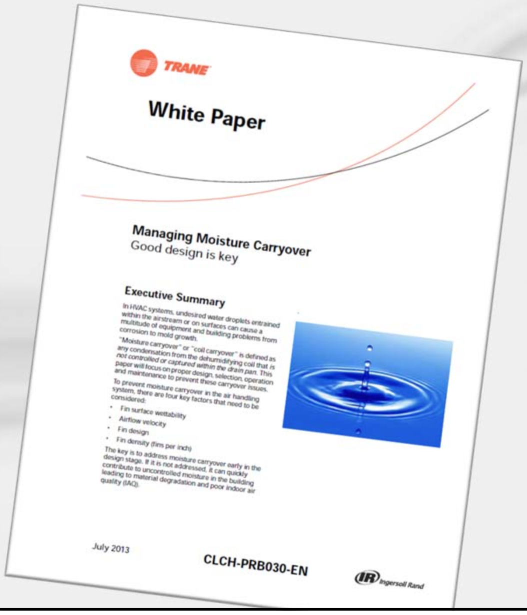
face velocity = airflow / face area

**long-time rule-of-thumb:
face velocity ≤ 500 fpm**

Factors Influencing Moisture Carryover

- Air velocity
- Fin design and material
- Number of fins
- Fin surface wettability





TRANE

White Paper

Managing Moisture Carryover
Good design is key

Executive Summary

In HVAC systems, undesired water droplets entrained within the airstream or on surfaces can cause a multitude of equipment and building problems from corrosion to mold growth.

"Moisture carryover" or "coil carryover" is defined as any condensation from the dehumidifying coil that is *not controlled or captured within the drain pan.* This paper will focus on proper design, selection, operation and maintenance to prevent these carryover issues.

To prevent moisture carryover in the air handling system, there are four key factors that need to be considered:

- Fin surface wettability
- Airflow velocity
- Fin design
- Fin density (fins per inch)

The key is to address moisture carryover early in the design stage. If it is not addressed, it can quickly contribute to uncontrolled moisture in the building leading to material degradation and poor indoor air quality (IAQ).

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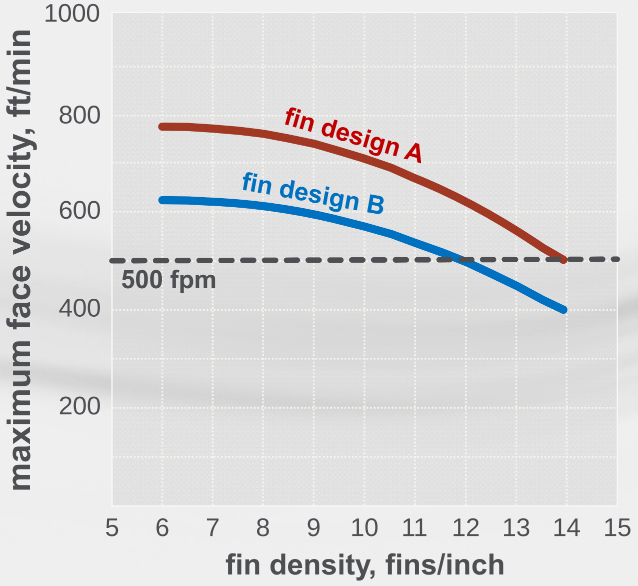
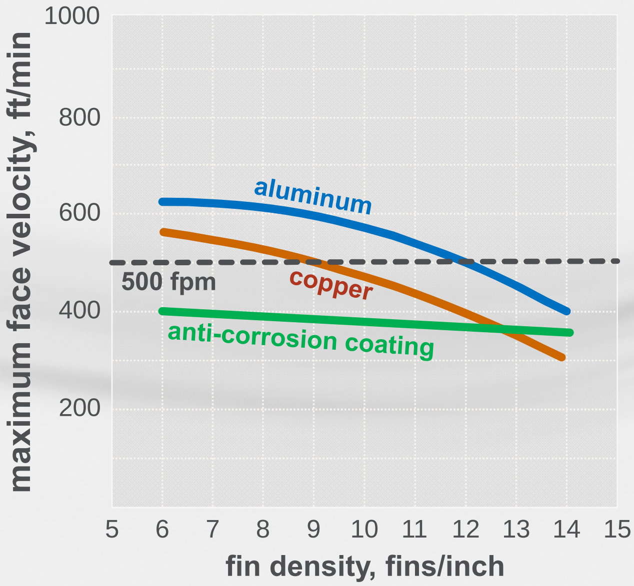
Same Fin Material, Different Fin Designs

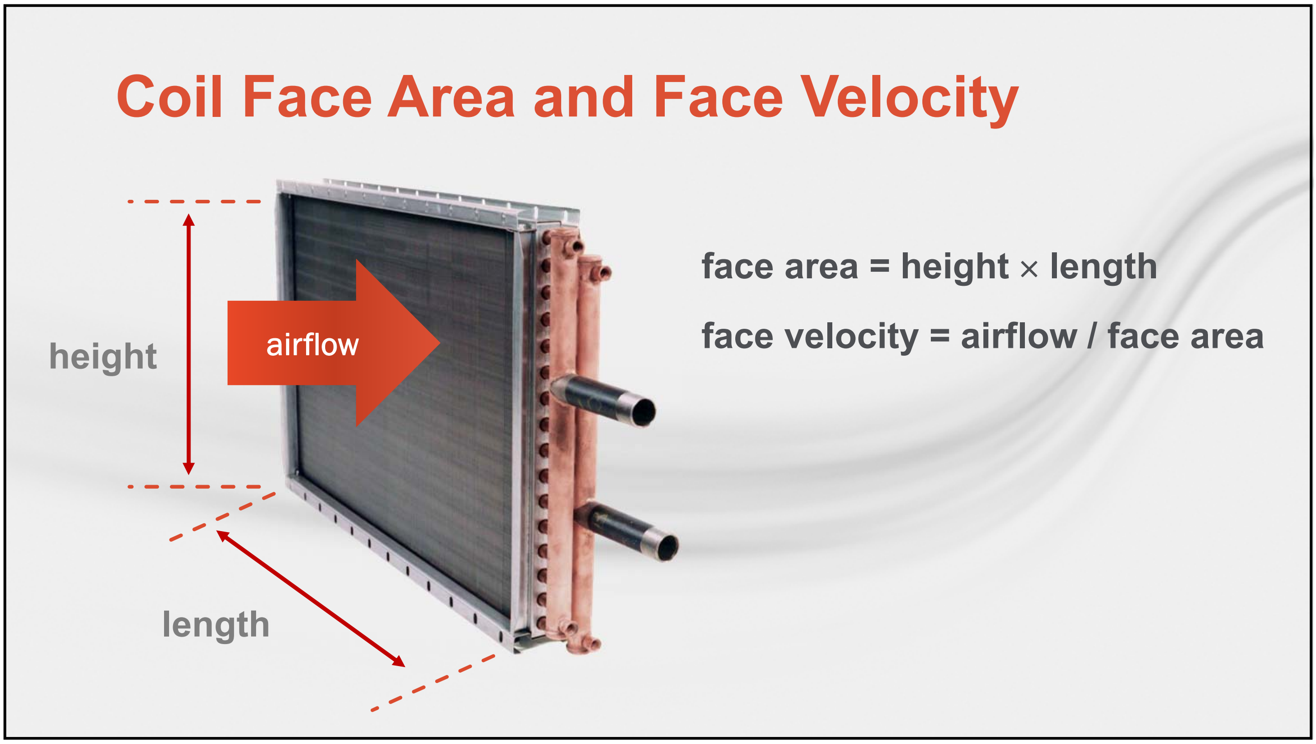


Different Fin Materials, Same Fin Design



Agenda

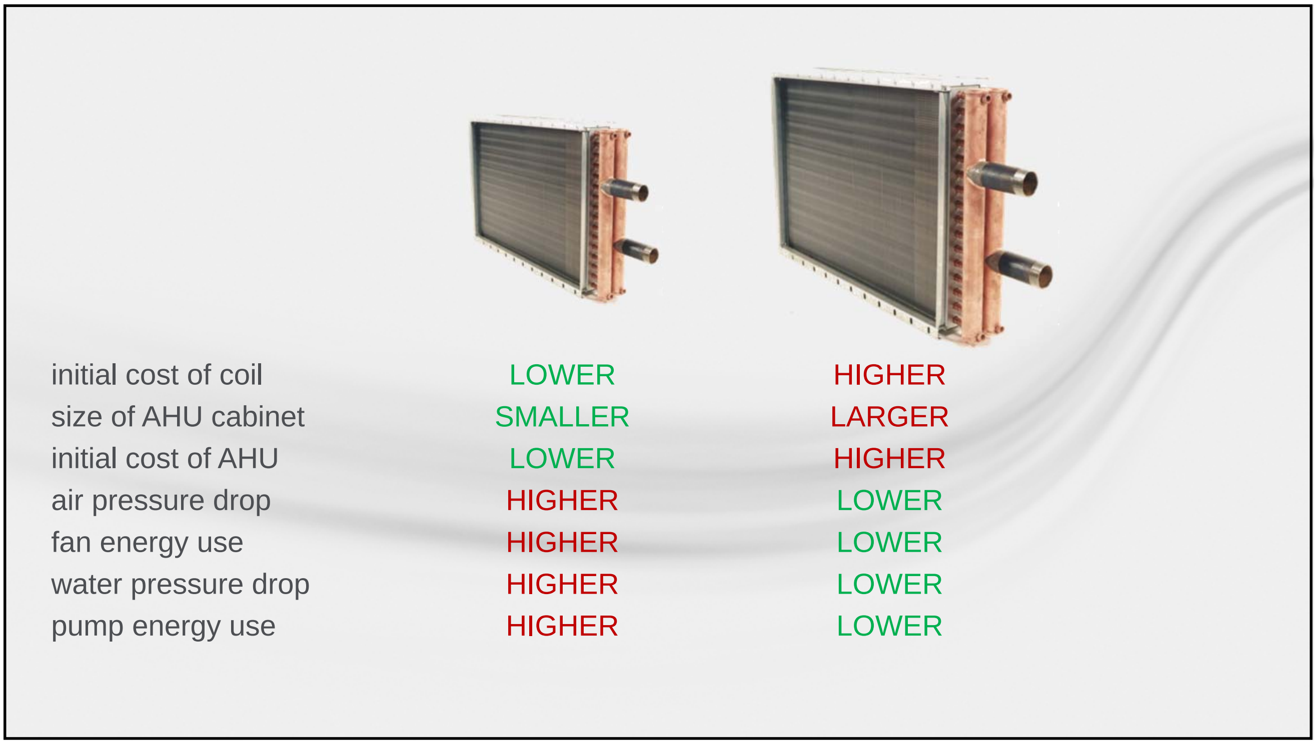
- Water and air velocity ranges
- Coil selection examples
    - **Chilled-water coils**
    - Hot-water coils
- Freeze protection



Coil Face Area and Face Velocity

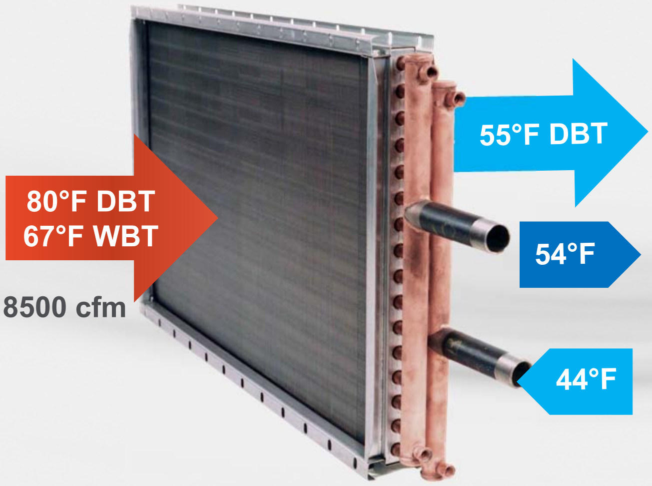
face area = height × length

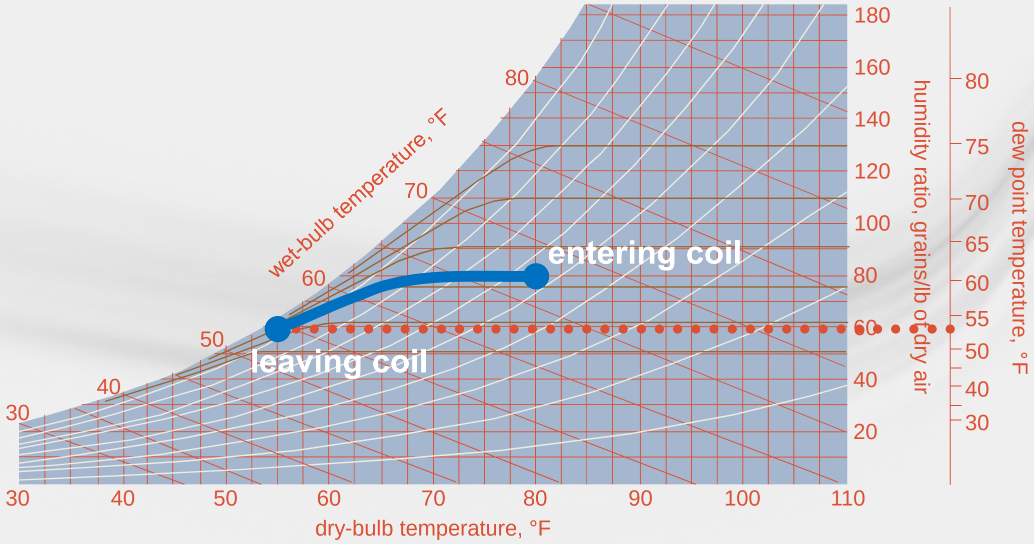
face velocity = airflow / face area

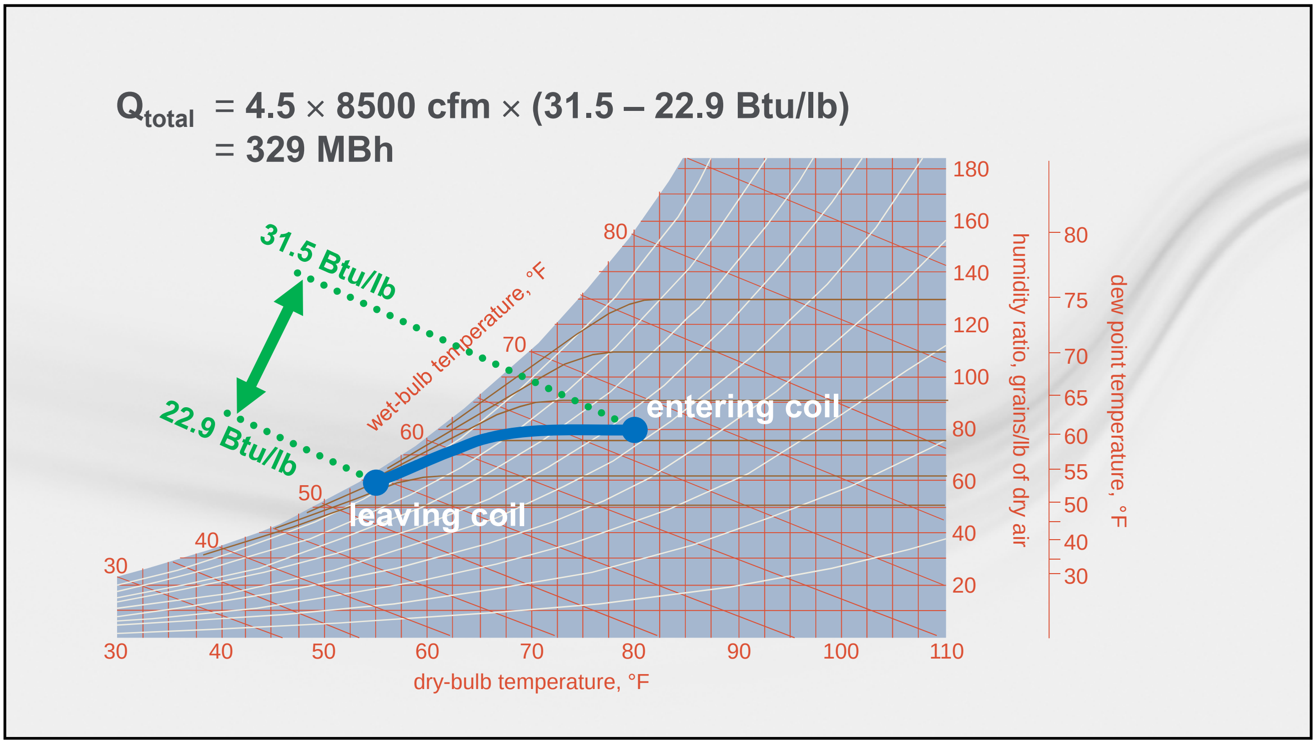


initial cost of coil	LOWER	HIGHER
size of AHU cabinet	SMALLER	LARGER
initial cost of AHU	LOWER	HIGHER
air pressure drop	HIGHER	LOWER
fan energy use	HIGHER	LOWER
water pressure drop	HIGHER	LOWER
pump energy use	HIGHER	LOWER

Example #1: Coil Face Area





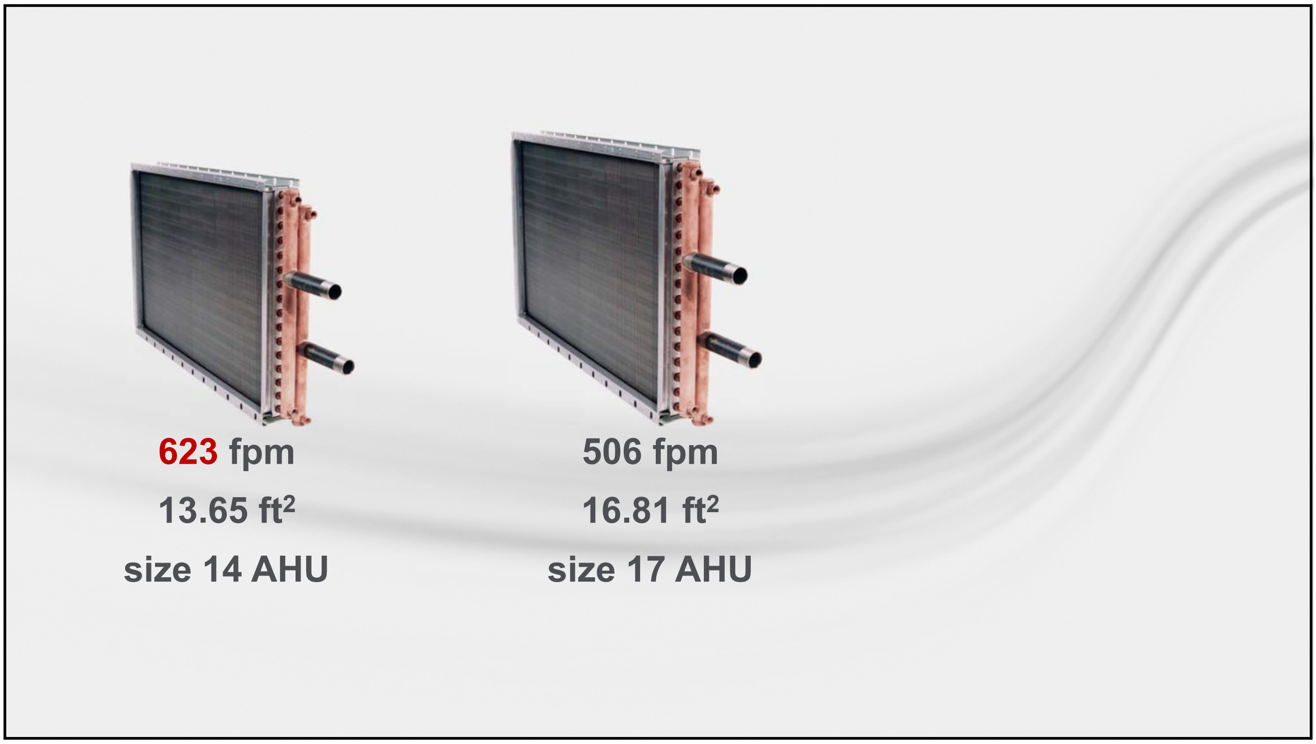


$$Q_{total} = 4.5 \times 8500 \text{ cfm} \times (31.5 - 22.9 \text{ Btu/lb})$$
$$= 329 \text{ MBh}$$

Traditional Selection at 500 fpm

Q_{total} = 329 MBh

face area = airflow / face velocity
= 8500 cfm / 500 fpm
= 17 ft^2



623 fpm

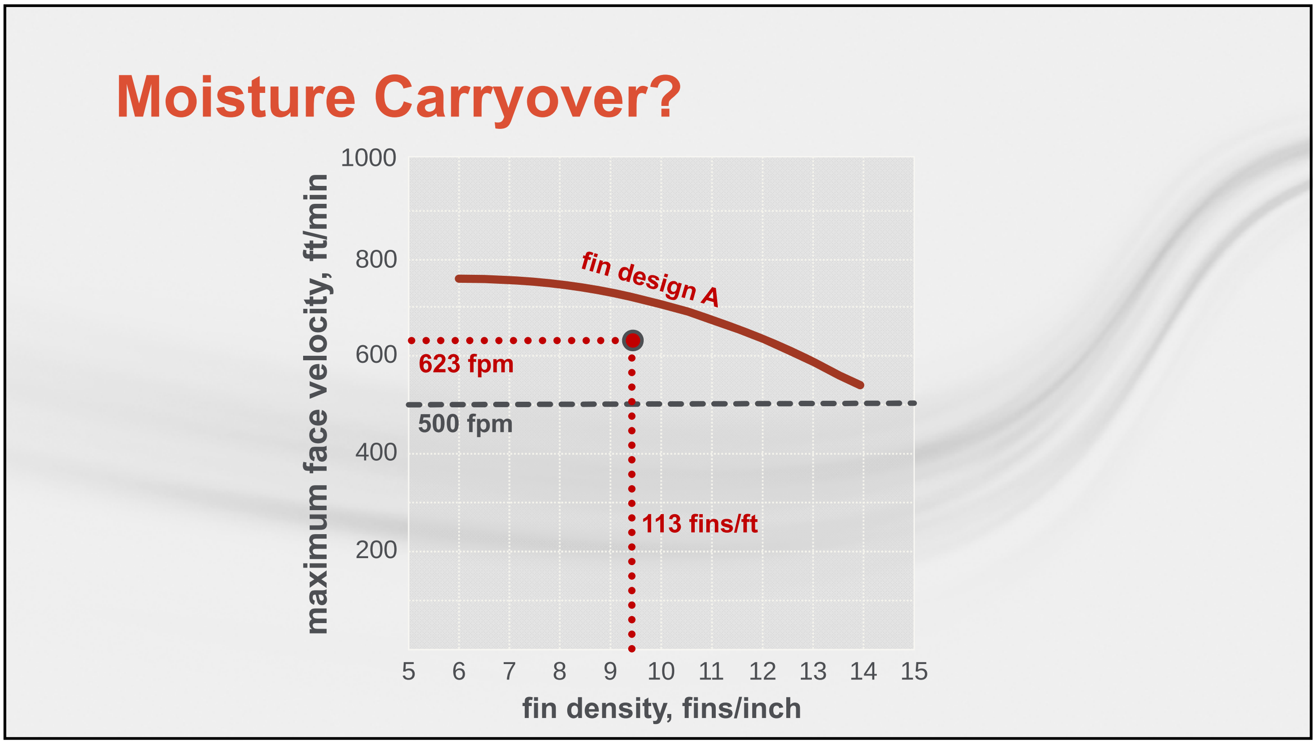
13.65 ft^2

size 14 AHU

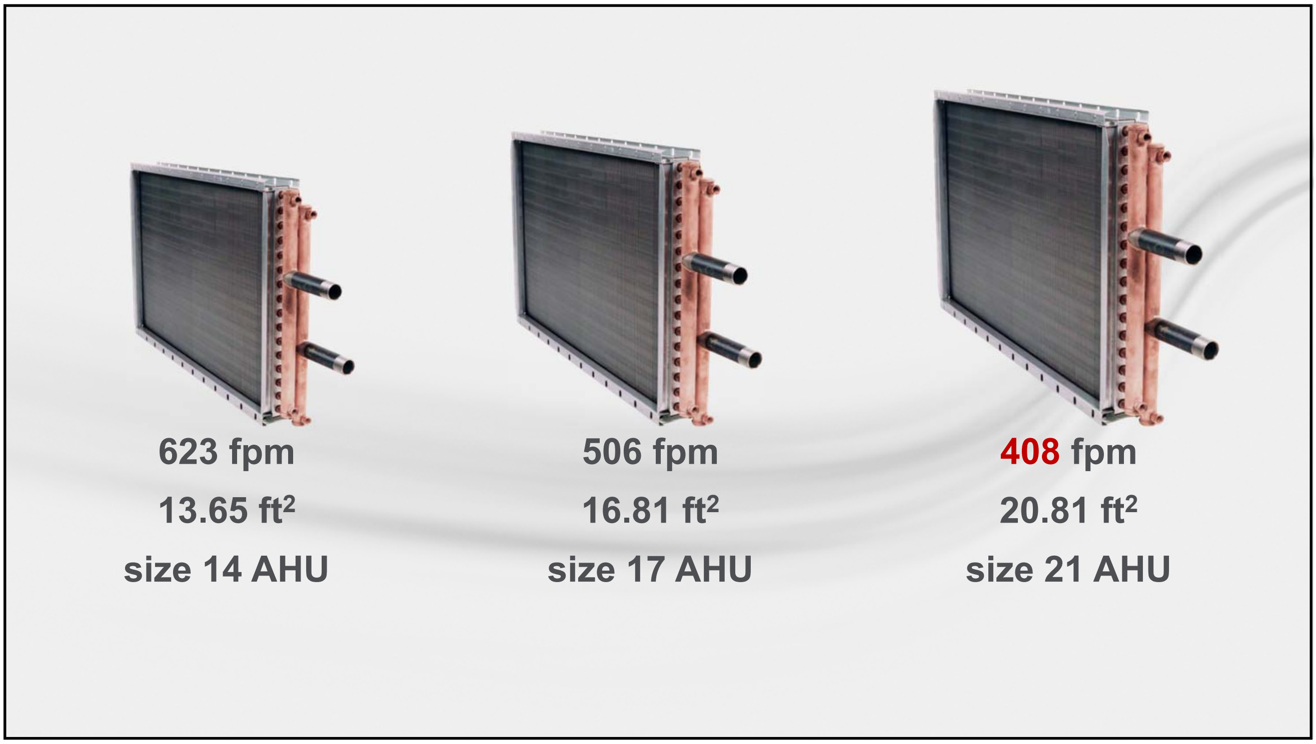
506 fpm

16.81 ft^2

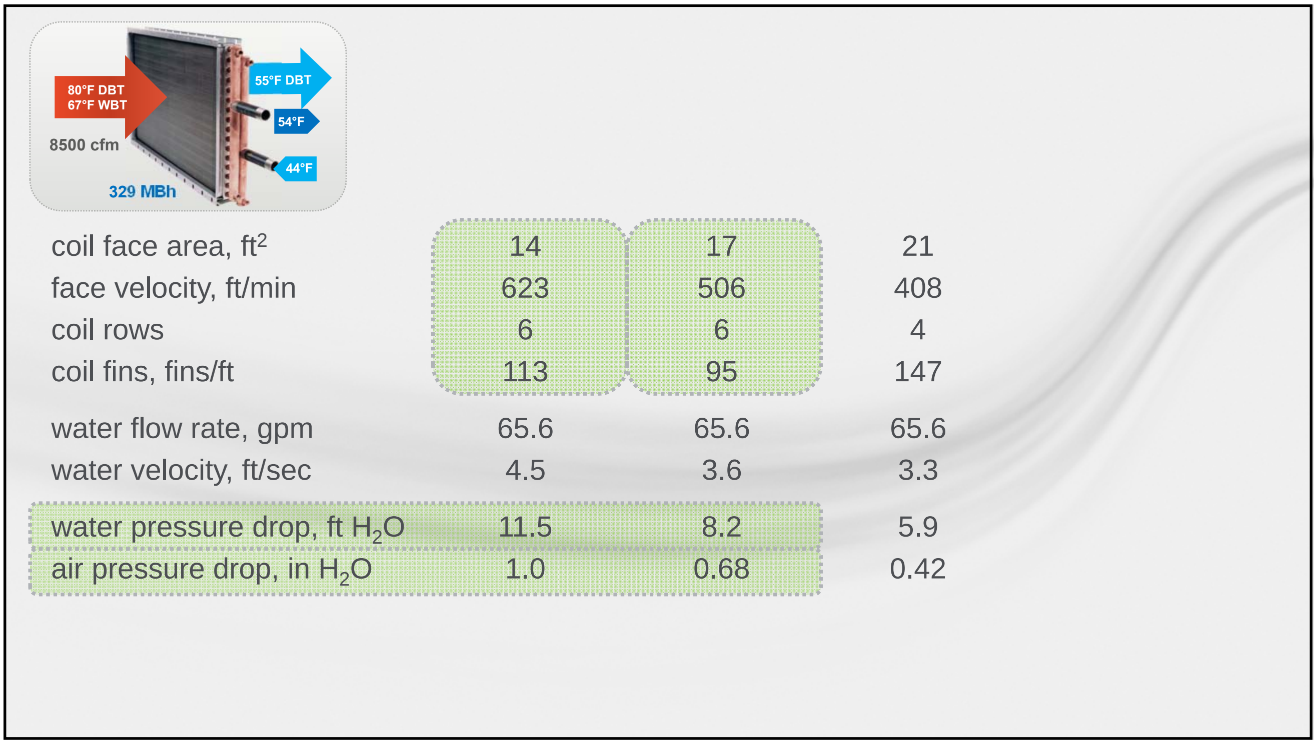
size 17 AHU



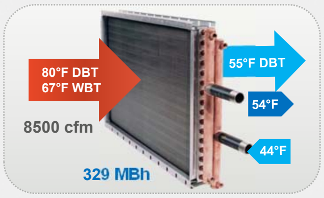
Moisture Carryover?



623 fpm	506 fpm	408 fpm
13.65 ft^2	16.81 ft^2	20.81 ft^2
size 14 AHU	size 17 AHU	size 21 AHU



coil face area, ft^2	14	17	21
face velocity, ft/min	623	506	408
coil rows	6	6	4
coil fins, fins/ft	113	95	147
water flow rate, gpm	65.6	65.6	65.6
water velocity, ft/sec	4.5	3.6	3.3
water pressure drop, ft H_2O	11.5	8.2	5.9
air pressure drop, in H_2O	1.0	0.68	0.42



coil face area, ft^2	14	17	21
face velocity, ft/min	623	506	408
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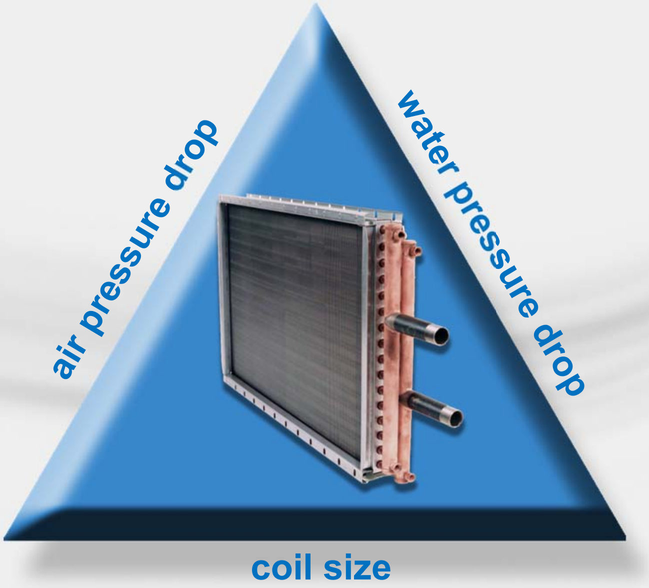
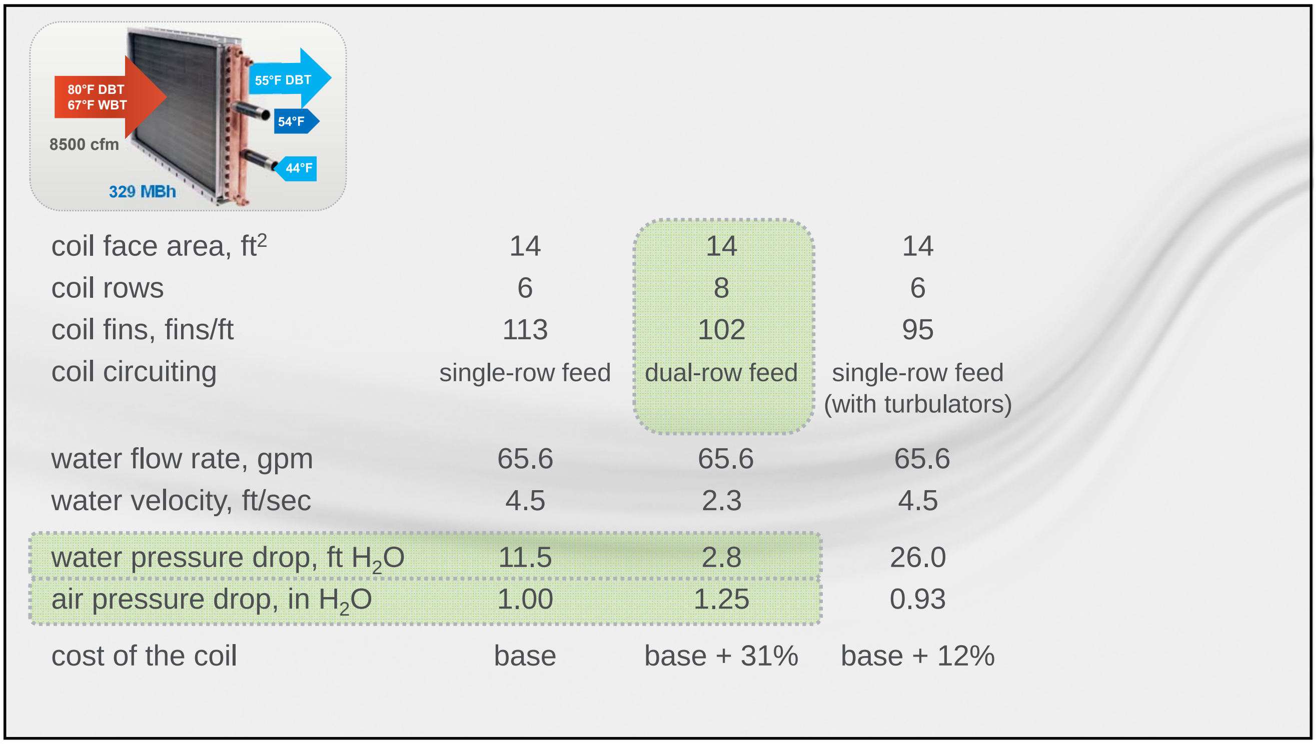
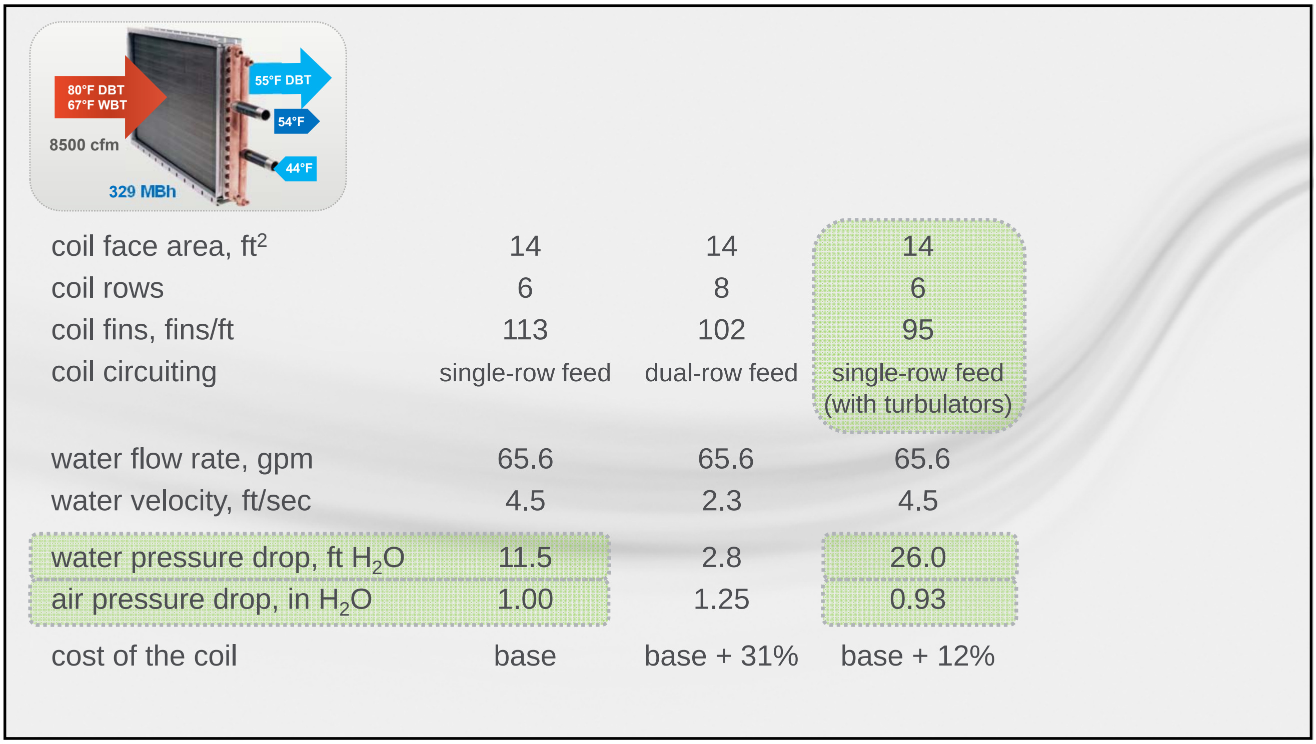
water velocity, ft/sec	4.5	3.6	3.3
water pressure drop, ft H_2O	11.5	8.2	5.9
air pressure drop, in H_2O	1.0	0.68	0.42

Example #2: APD versus WPD



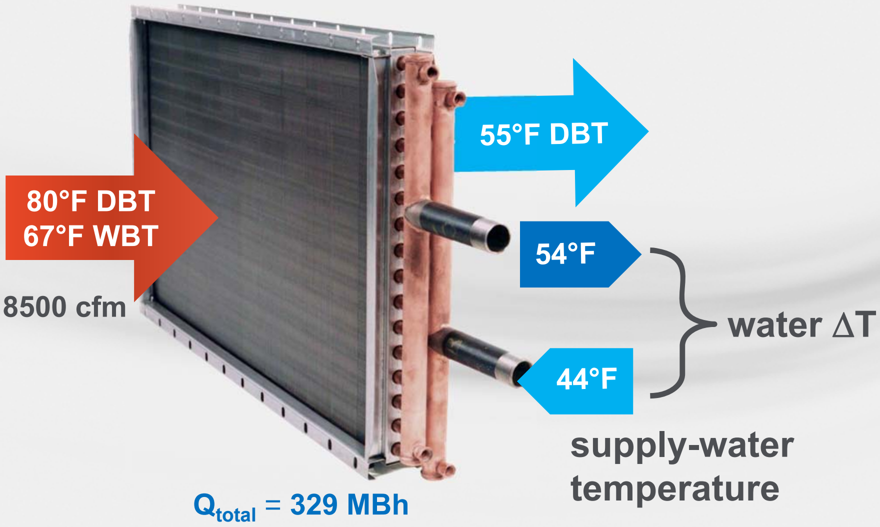


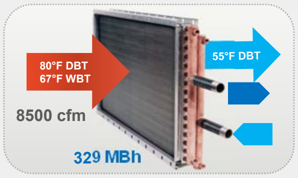
coil face area, ft^2	14	14	14
coil rows	6	8	6
coil fins, fins/ft	113	102	95
coil circuiting	single-row feed	dual-row feed	single-row feed (with turbulators)
water flow rate, gpm	65.6	65.6	65.6
water velocity, ft/sec	4.5	2.3	4.5
water pressure drop, ft H_2O	11.5	2.8	26.0
air pressure drop, in H_2O	1.00	1.25	0.93
cost of the coil	base	base + 31%	base + 12%



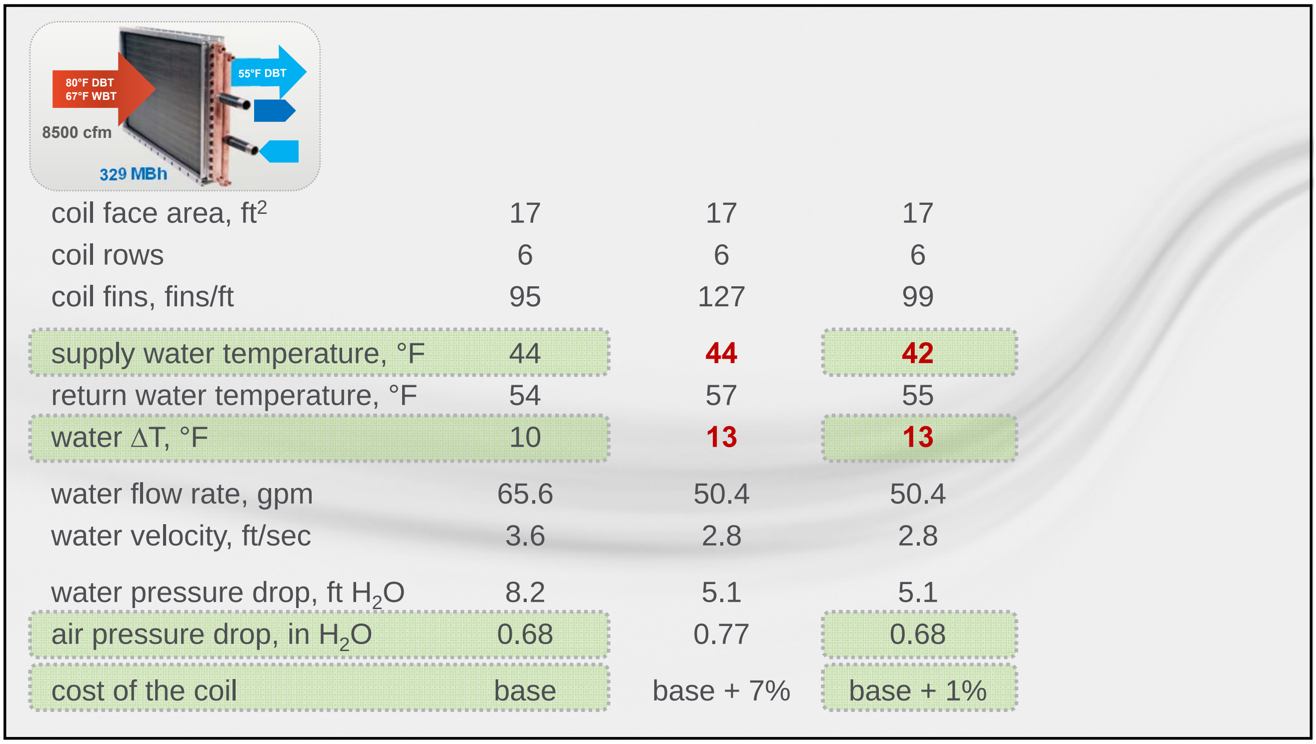
coil face area, ft^2	14	14	14
coil rows	6	8	6
coil fins, fins/ft	113	102	95
coil circuiting	single-row feed	dual-row feed	single-row feed (with turbulators)
water flow rate, gpm	65.6	65.6	65.6
water velocity, ft/sec	4.5	2.3	4.5
water pressure drop, ft H_2O	11.5	2.8	26.0
air pressure drop, in H_2O	1.00	1.25	0.93
cost of the coil	base	base + 31%	base + 12%

Example #3: Supply-Water Temp and ΔT

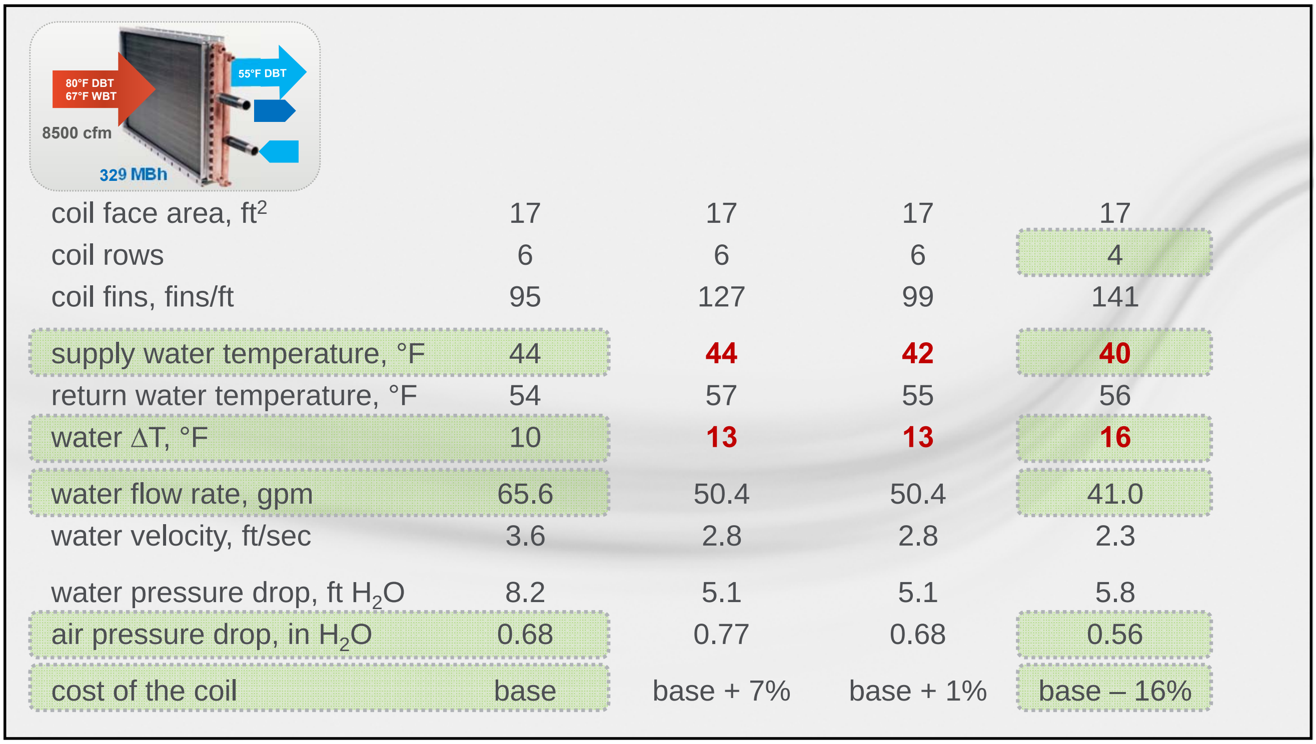




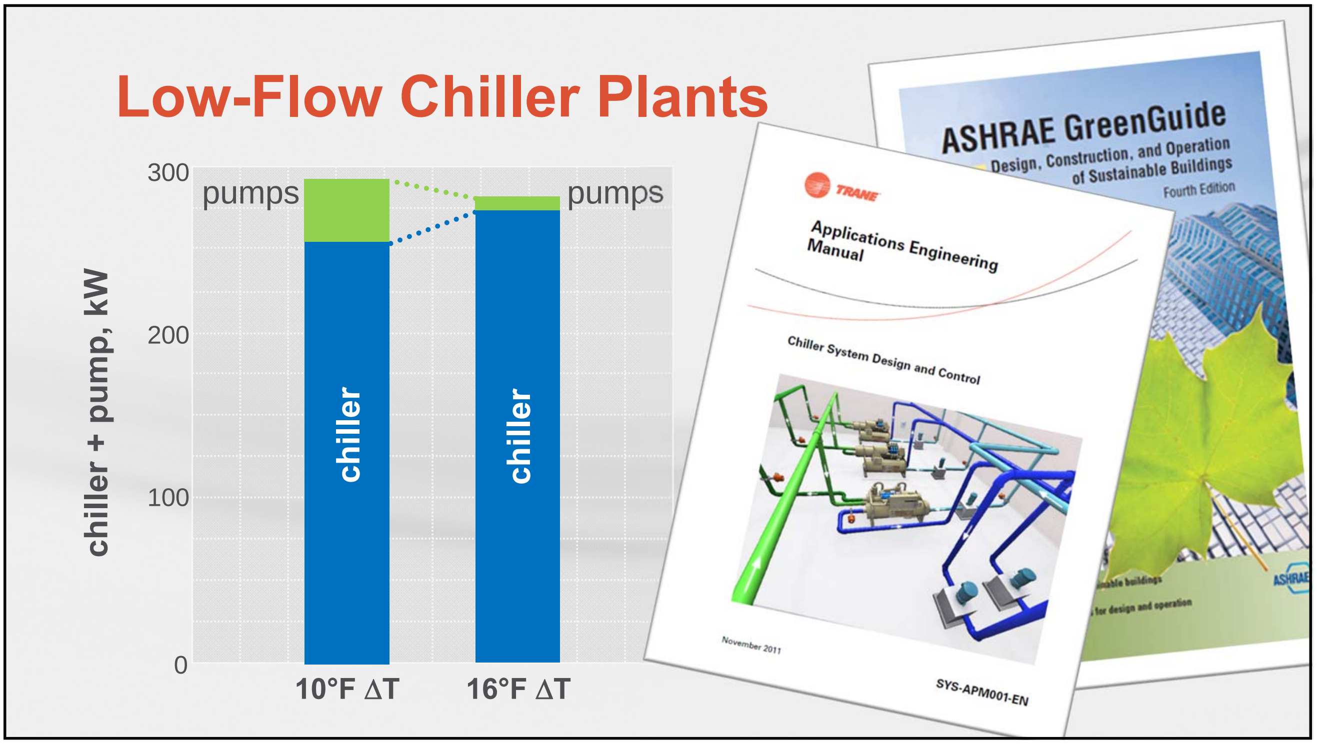
coil face area, ft^2	17	17
coil rows	6	6
coil fins, fins/ft	95	127
supply water temperature, °F	44	**44**
return water temperature, °F	54	57
water ΔT, °F	10	**13**
water flow rate, gpm	65.6	50.4
water velocity, ft/sec	3.6	2.8
water pressure drop, ft H_2O	8.2	5.1
air pressure drop, in H_2O	0.68	0.77
cost of the coil	base	base + 7%



coil face area, ft^2	17	17	17
coil rows	6	6	6
coil fins, fins/ft	95	127	99
supply water temperature, °F	44	**44**	**42**
return water temperature, °F	54	57	55
water ΔT, °F	10	**13**	**13**
water flow rate, gpm	65.6	50.4	50.4
water velocity, ft/sec	3.6	2.8	2.8
water pressure drop, ft H_2O	8.2	5.1	5.1
air pressure drop, in H_2O	0.68	0.77	0.68
cost of the coil	base	base + 7%	base + 1%



coil face area, ft^2	17	17	17	17
coil rows	6	6	6	4
coil fins, fins/ft	95	127	99	141
supply water temperature, °F	44	**44**	**42**	**40**
return water temperature, °F	54	57	55	56
water ΔT, °F	10	**13**	**13**	**16**
water flow rate, gpm	65.6	50.4	50.4	41.0
water velocity, ft/sec	3.6	2.8	2.8	2.3
water pressure drop, ft H_2O	8.2	5.1	5.1	5.8
air pressure drop, in H_2O	0.68	0.77	0.68	0.56
cost of the coil	base	base + 7%	base + 1%	base – 16%

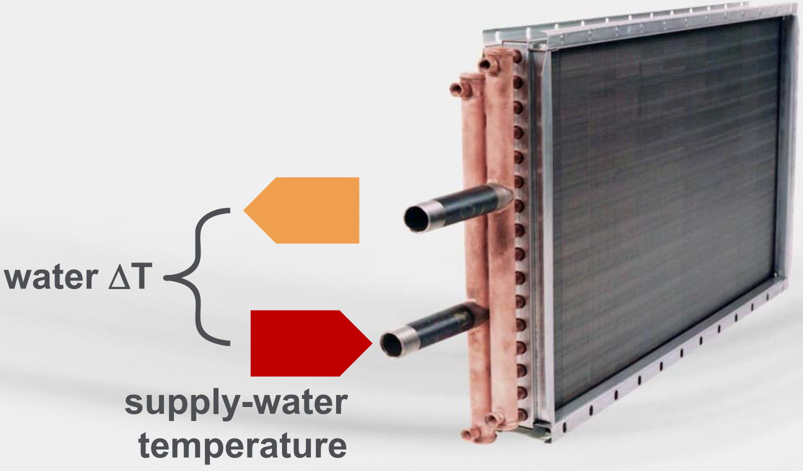


Low-Flow Chiller Plants

Agenda

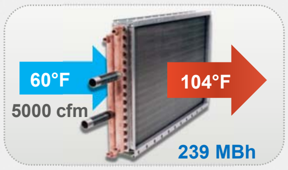
- Water and air velocity ranges
- Coil selection examples
    - Chilled-water coils
    - **Hot-water coils**
- Freeze protection

Hot-Water Coils



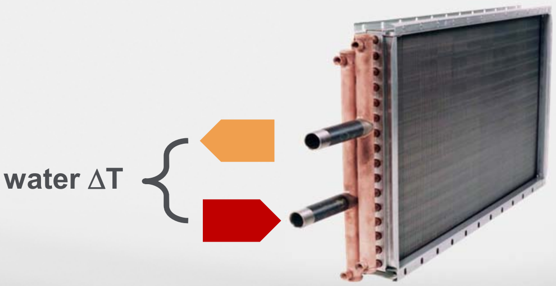
water ΔT

supply-water temperature

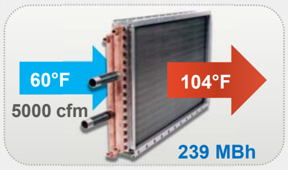


coil face area, ft^2	10	10	10
coil rows	2	2	2
coil fins, fins/ft	79	95	118
supply water temperature, °F	180	180	180
return water temperature, °F	160	150	140
water ΔT, °F	20	**30**	**40**
water flow rate, gpm	23.8	15.9	11.9
water velocity, ft/sec	1.9	1.2	0.9
water pressure drop, ft H_2O	0.94	0.44	0.25
air pressure drop, in H_2O	0.14	0.15	0.16
cost of the coil	base	base + 2%	base + 6%

Selecting HW Coils with a Larger ΔT



water ΔT	SMALLER	LARGER
initial cost of coil	LESS	MORE
air pressure drop	LESS	HIGHER
water flow rate	HIGHER	LOWER
water pressure drop	HIGHER	LOWER



coil face area, ft^2	10	10	10
coil rows	2	4	4
coil fins, fins/ft	79	72	89
supply water temperature, °F	180	**150**	**150**
return water temperature, °F	160	120	110
water ΔT, °F	20	**30**	**40**
water flow rate, gpm	23.8	16.0	12.0
water velocity, ft/sec	1.9	1.2	0.9
water pressure drop, ft H_2O	0.94	0.64	0.38
air pressure drop, in H_2O	0.14	0.28	0.29
cost of the coil	base	base + 75%	base + 80%

Types of Boilers

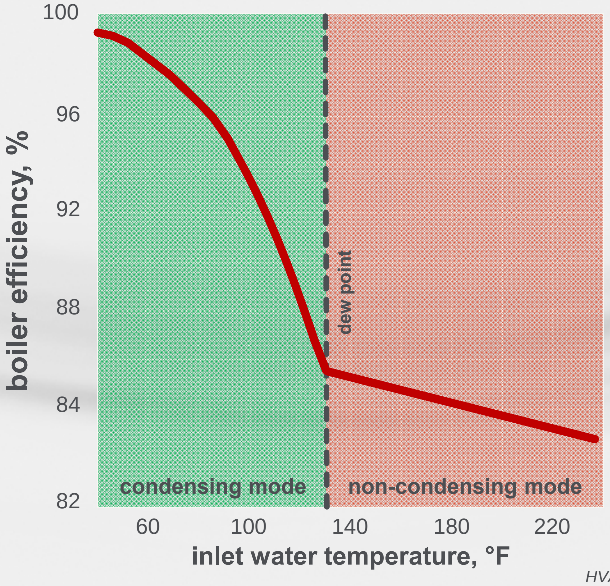
non-condensing boilers

- Avoids condensing of flue gas (uses only sensible heat value of the fuel)
- Designed and operated to ensure water returns ≥ 140°F

condensing boilers

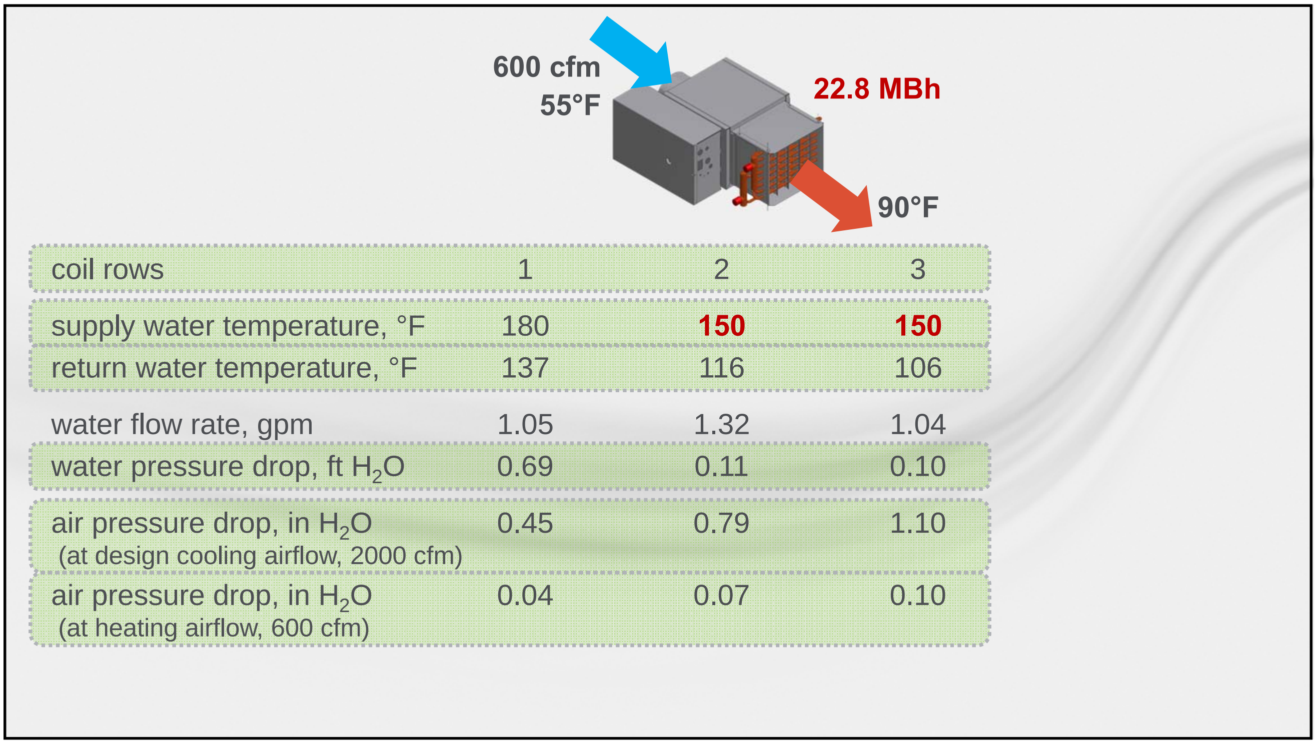
- Allows condensing of flue gas (uses some of the latent heat value of the fuel)
- More efficient with a lower return-water temperature

Condensing Boiler Efficiency



natural gas = 1050 Btu/ft^3
stoichiometric air = 17.24 lb/lb of fuel
(10% excess air)

source: 2012 *ASHRAE Handbook – HVAC Systems and Equipment*, Chapter 32, Figure 6

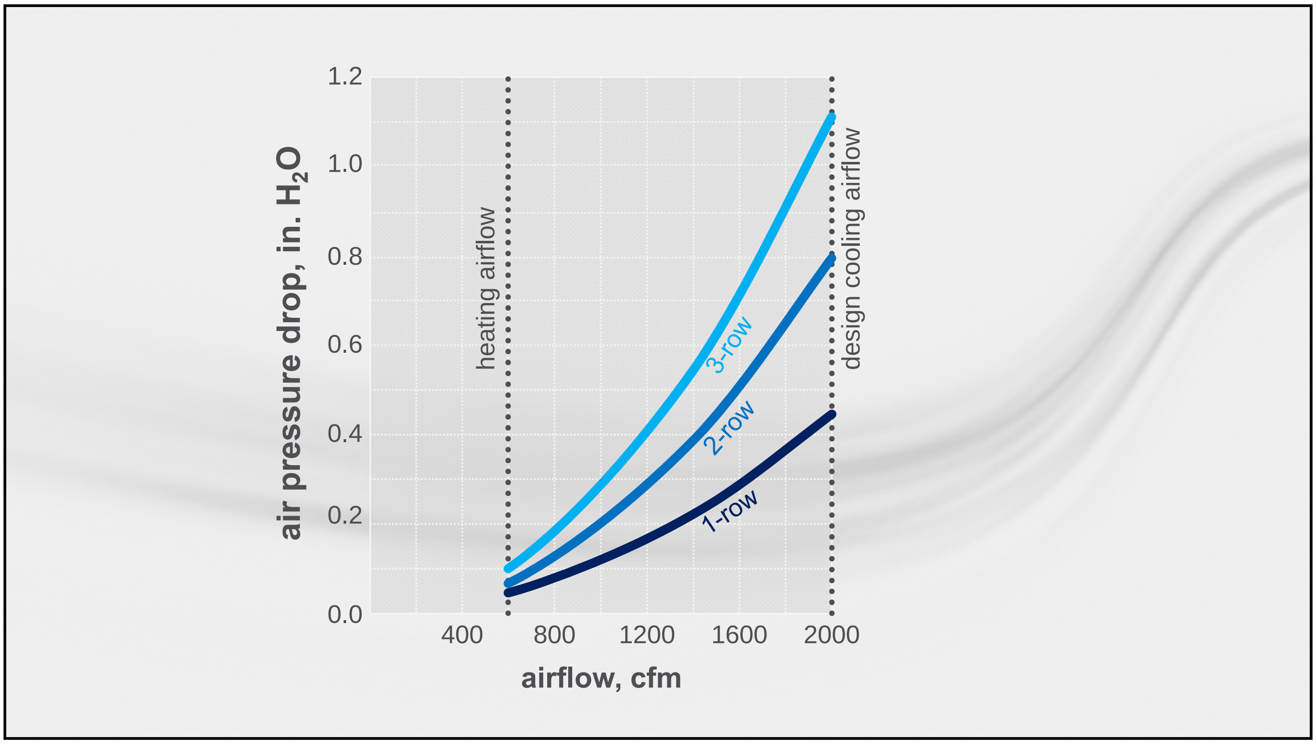


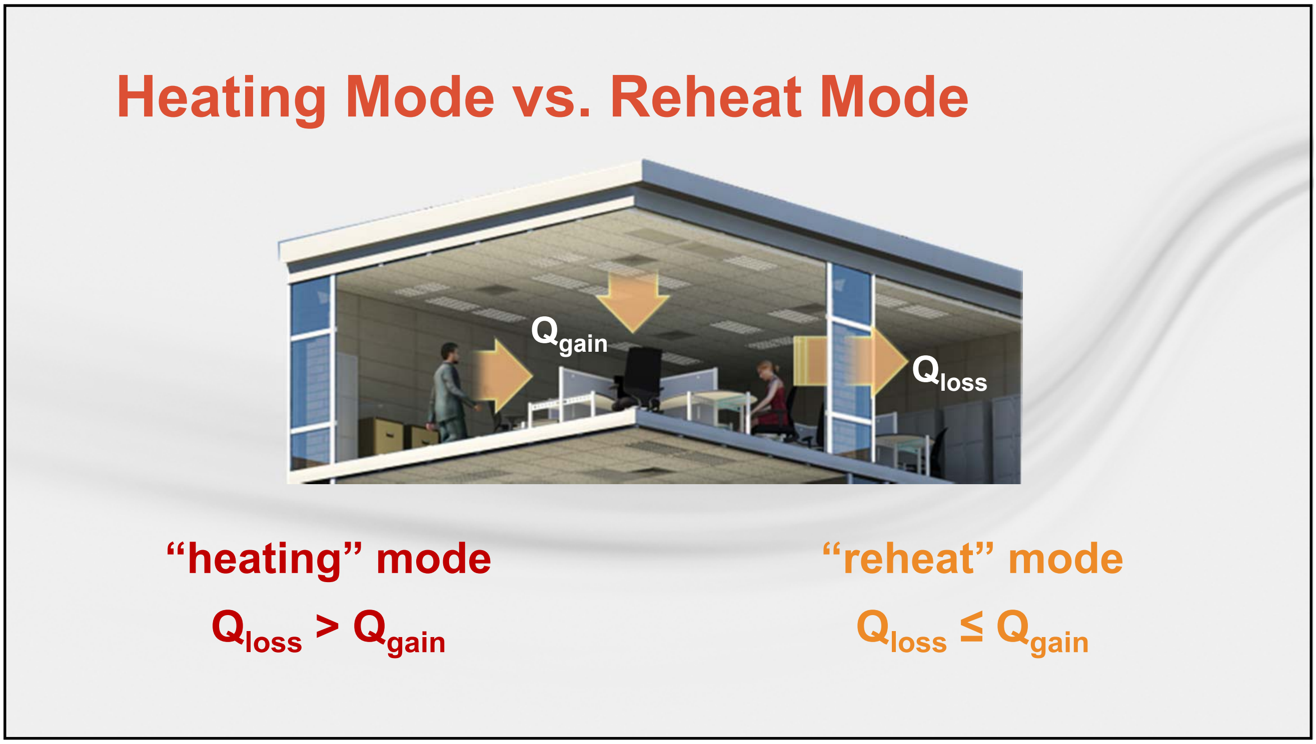
600 cfm
55°F

22.8 MBh

90°F

coil rows	1	2	3
supply water temperature, °F	180	**150**	**150**
return water temperature, °F	137	116	106
water flow rate, gpm	1.05	1.32	1.04
water pressure drop, ft H_2O	0.69	0.11	0.10
air pressure drop, in H_2O (at design cooling airflow, 2000 cfm)	0.45	0.79	1.10
air pressure drop, in H_2O (at heating airflow, 600 cfm)	0.04	0.07	0.10





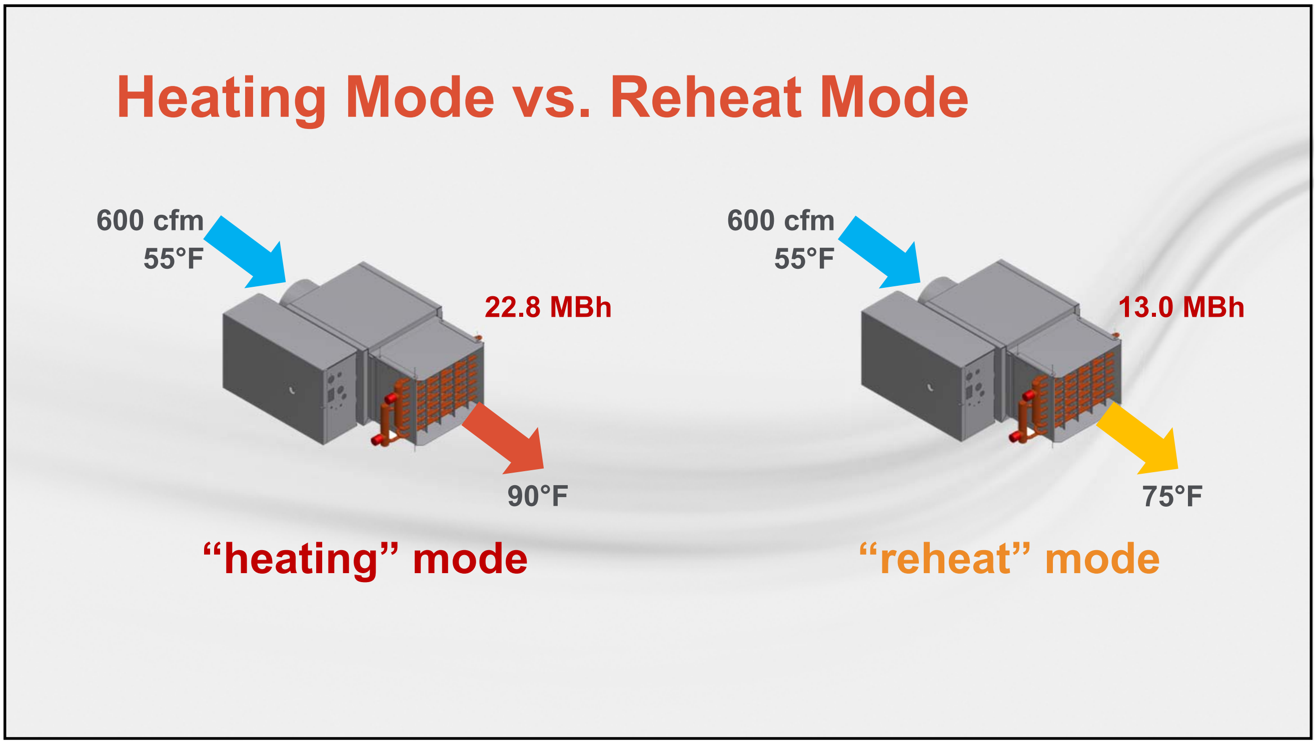
Heading Mode vs. Reheat Mode

“heating” mode

$Q_{loss} > Q_{gain}$

“reheat” mode

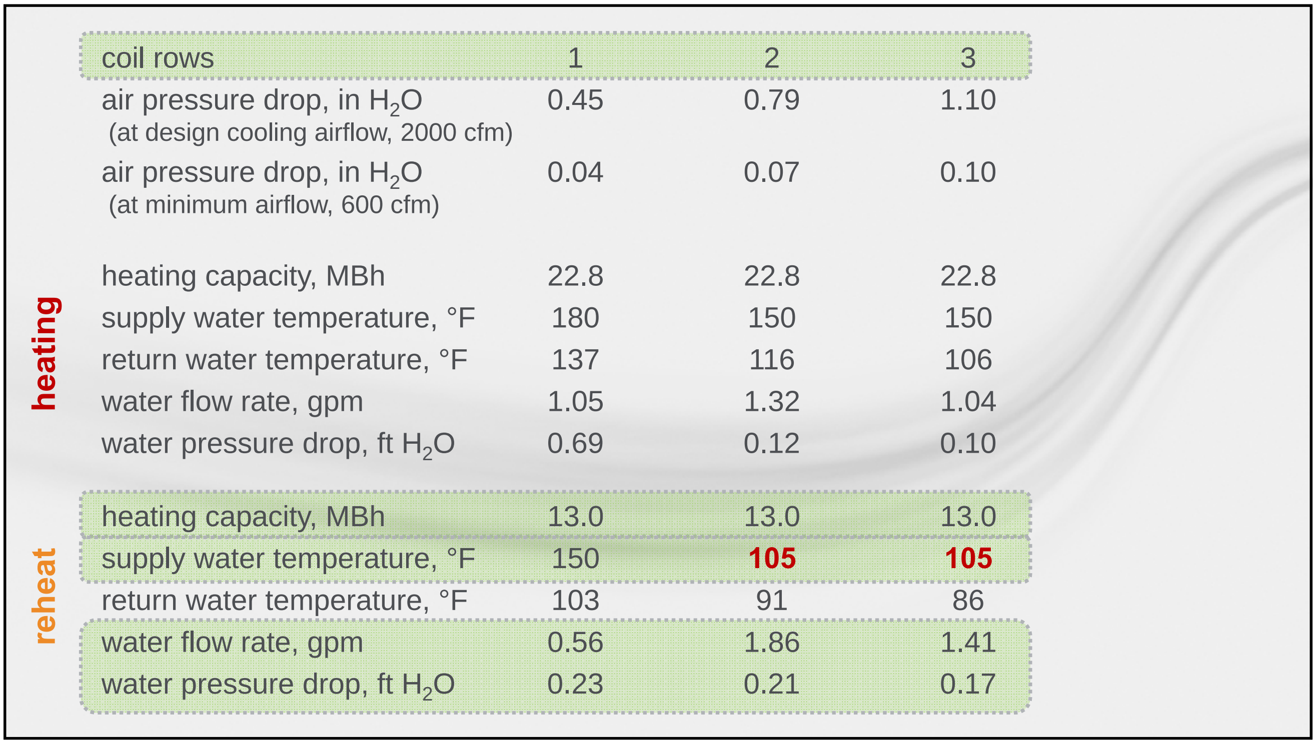
$Q_{loss} \leq Q_{gain}$



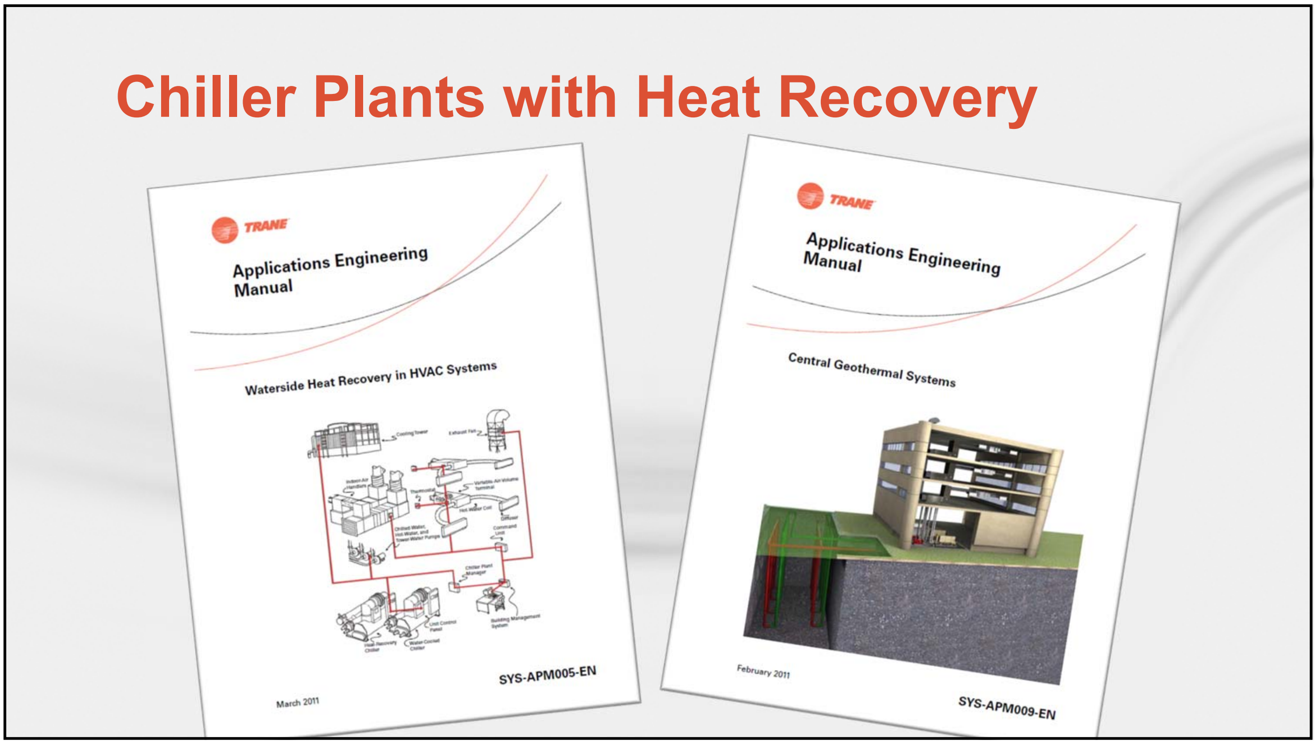
Heating Mode vs. Reheat Mode

“heating” mode

“reheat” mode



	coil rows	1	2	3
	air pressure drop, in H_2O (at design cooling airflow, 2000 cfm)	0.45	0.79	1.10
	air pressure drop, in H_2O (at minimum airflow, 600 cfm)	0.04	0.07	0.10
heating	heating capacity, MBh	22.8	22.8	22.8
	supply water temperature, °F	180	150	150
	return water temperature, °F	137	116	106
	water flow rate, gpm	1.05	1.32	1.04
	water pressure drop, ft H_2O	0.69	0.12	0.10
reheat	heating capacity, MBh	13.0	13.0	13.0
	supply water temperature, °F	150	**105**	**105**
	return water temperature, °F	103	91	86
	water flow rate, gpm	0.56	1.86	1.41
	water pressure drop, ft H_2O	0.23	0.21	0.17



Chiller Plants with Heat Recovery

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Waterside Heat Recovery in HVAC Systems

March 2011

SYS-APM005-EN

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Central Geothermal Systems

February 2011

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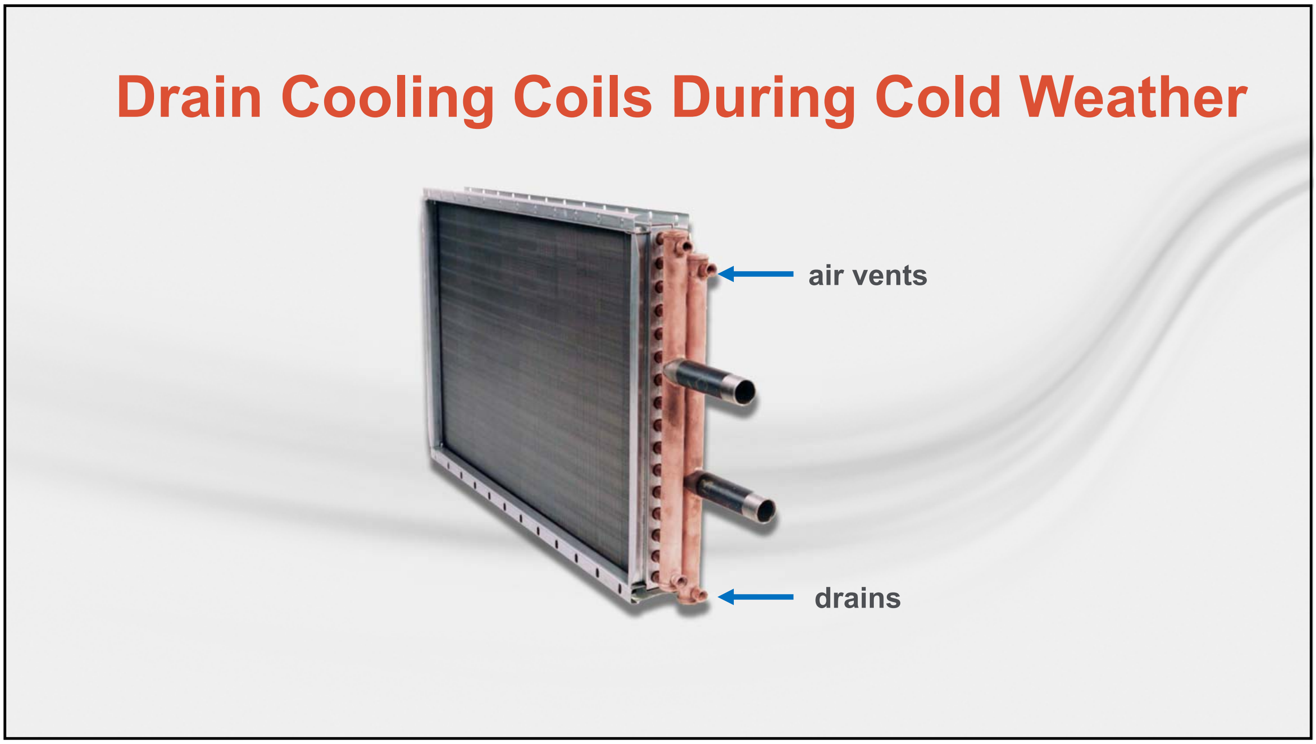
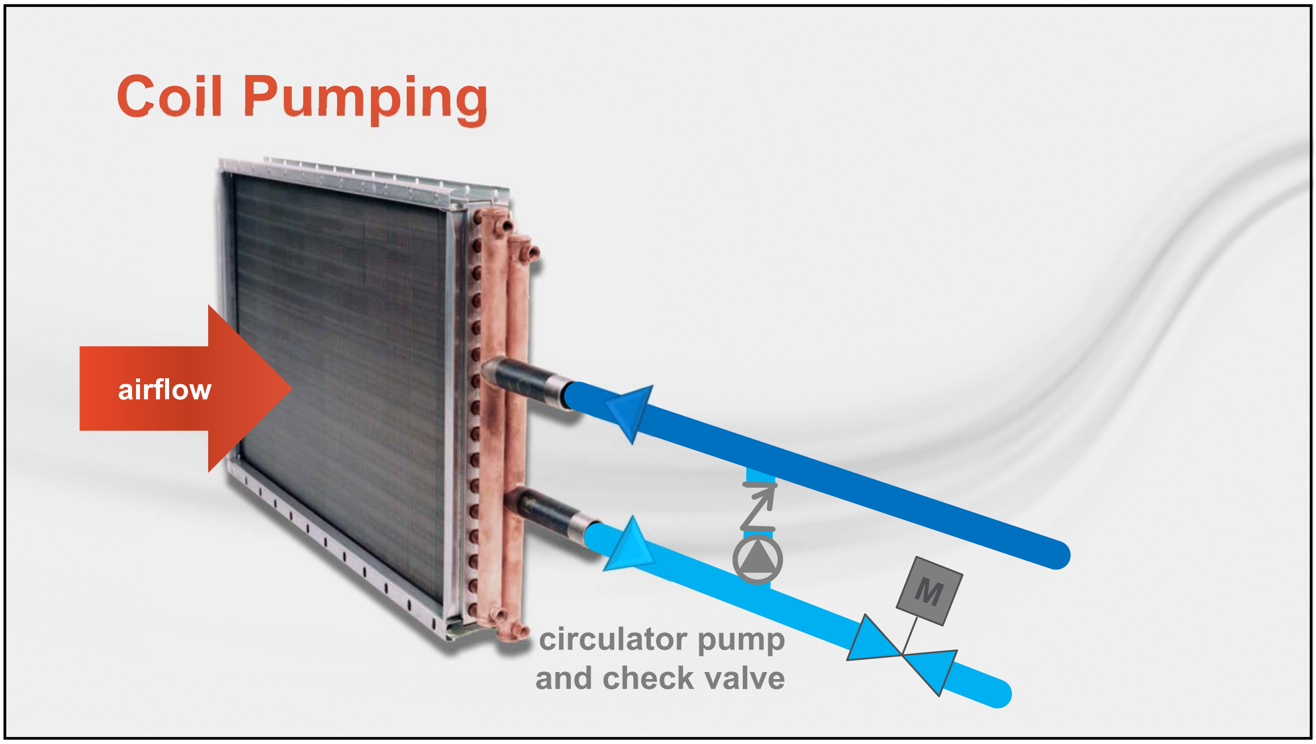
Agenda

- Water and air velocity ranges
- Coil selection examples
  - Chilled-water coils
  - Hot-water coils
- **Freeze protection**

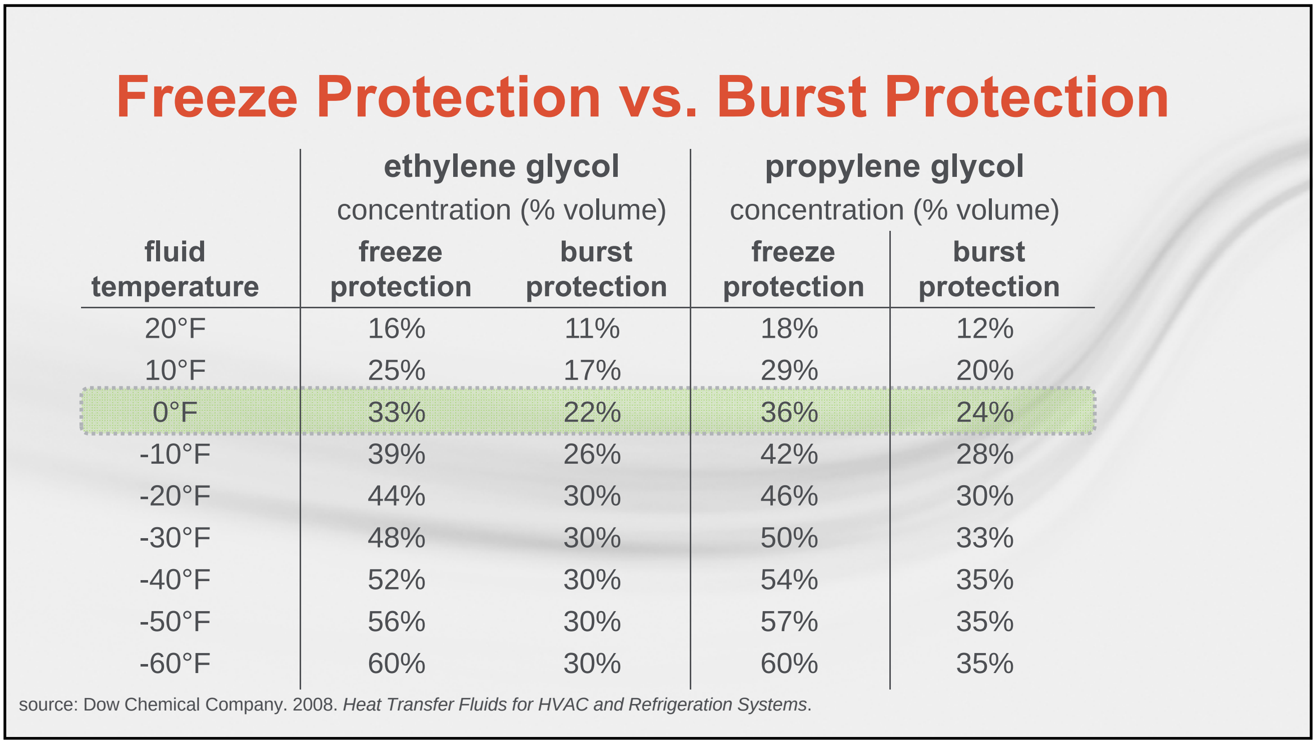


Drain Cooling Coils During Cold Weather



Coil Pumping

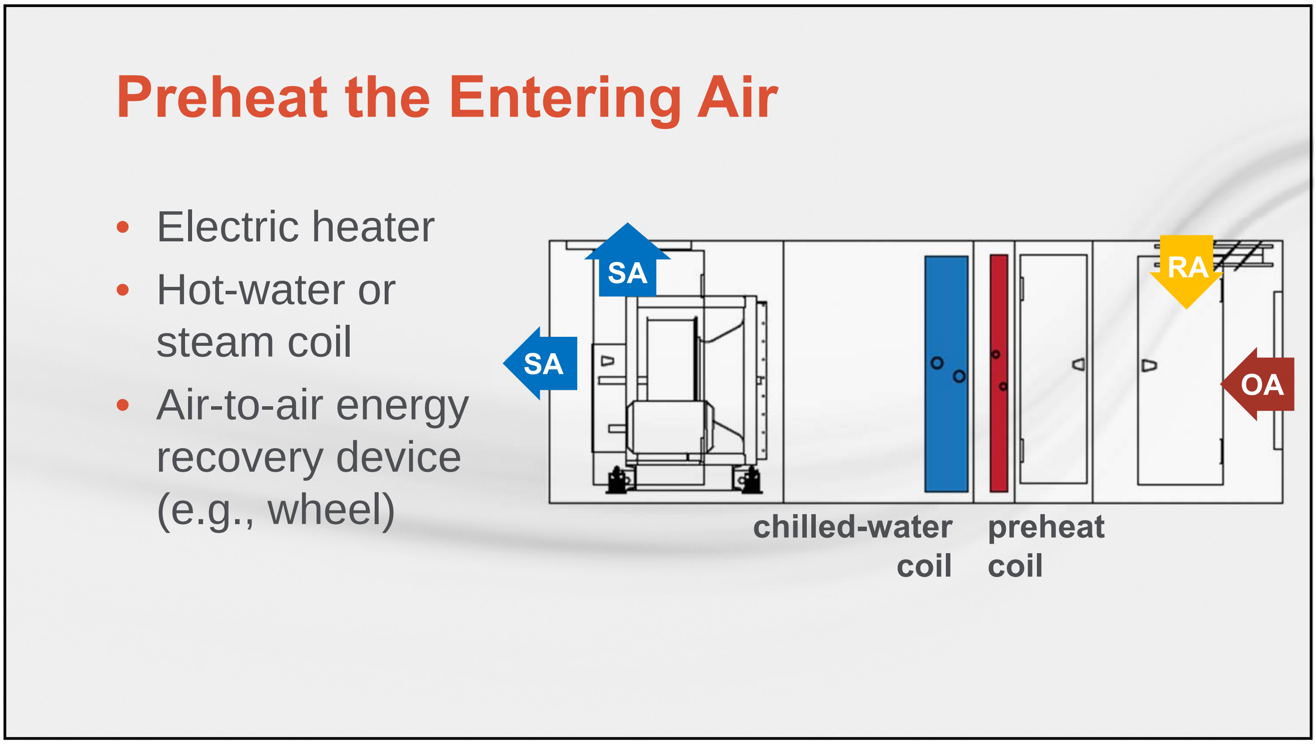
Add Antifreeze (e.g., Glycol)



Freeze Protection vs. Burst Protection

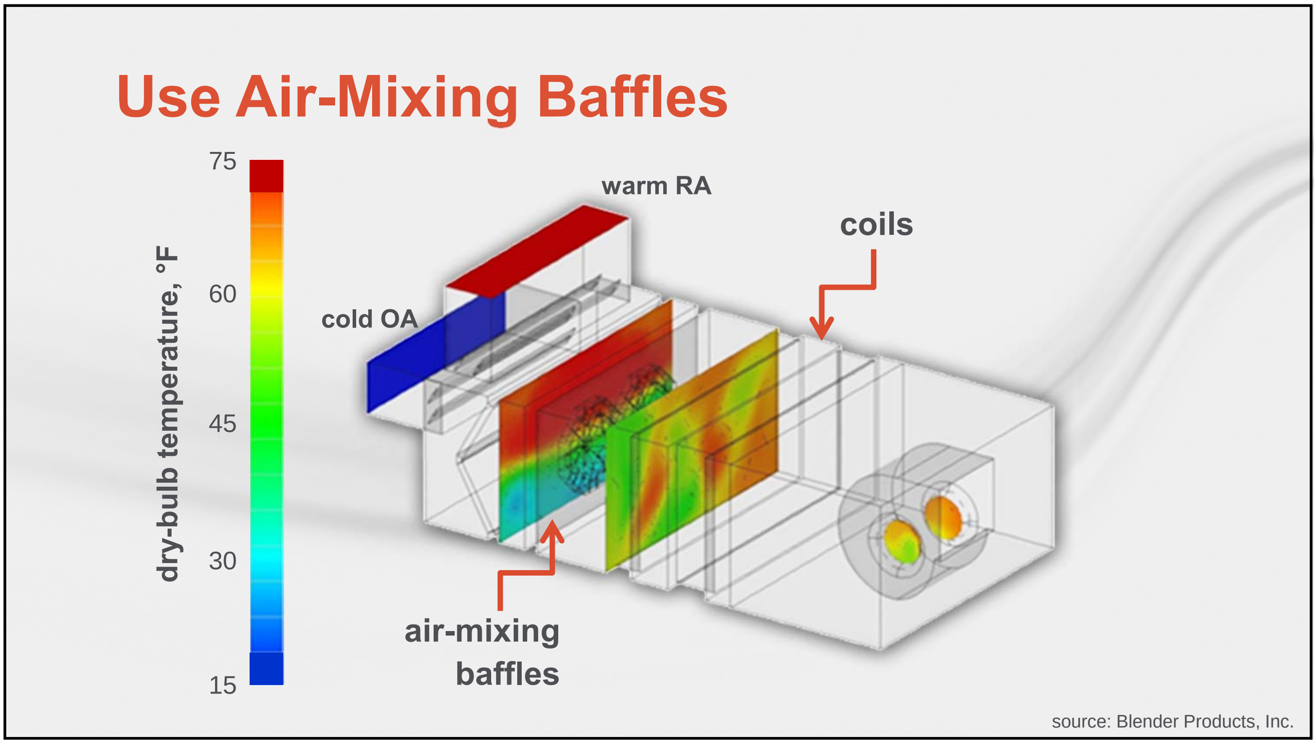
	ethylene glycol concentration (% volume)		propylene glycol concentration (% volume)	
fluid temperature	**freeze protection**	**burst protection**	**freeze protection**	**burst protection**
20°F	16%	11%	18%	12%
10°F	25%	17%	29%	20%
0°F	33%	22%	36%	24%
-10°F	39%	26%	42%	28%
-20°F	44%	30%	46%	30%
-30°F	48%	30%	50%	33%
-40°F	52%	30%	54%	35%
-50°F	56%	30%	57%	35%
-60°F	60%	30%	60%	35%

source: Dow Chemical Company. 2008. *Heat Transfer Fluids for HVAC and Refrigeration Systems*.



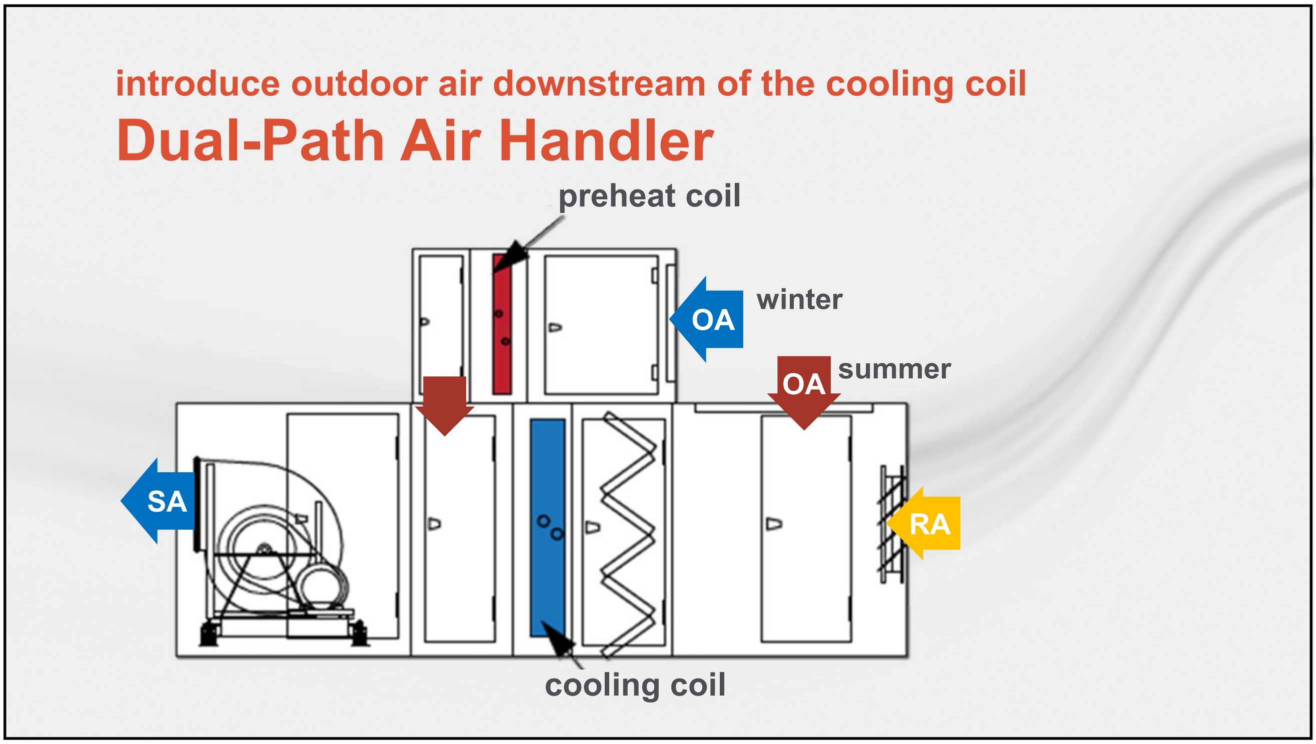
Preheat the Entering Air

- Electric heater
- Hot-water or steam coil
- Air-to-air energy recovery device (e.g., wheel)



Use Air-Mixing Baffles

source: Blender Products, Inc.



introduce outdoor air downstream of the cooling coil

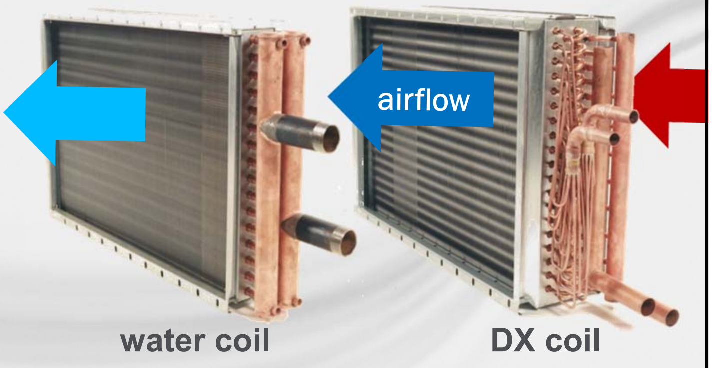
Dual-Path Air Handler

Coil Freeze Protection Options

- Drain chilled-water coils during cold weather
- Coil pumping
- Add antifreeze to the chilled- or hot-water system
- Preheat the entering air
- Use air-mixing baffles
- Introduce outdoor air downstream of the cooling coil

Water Coil Downstream of a DX Coil

- Low airflow through the DX coil?
- Compressor operating when the fan is off?
- Split system resulting in too low a SST?
- Too low of temperature entering DX coil?



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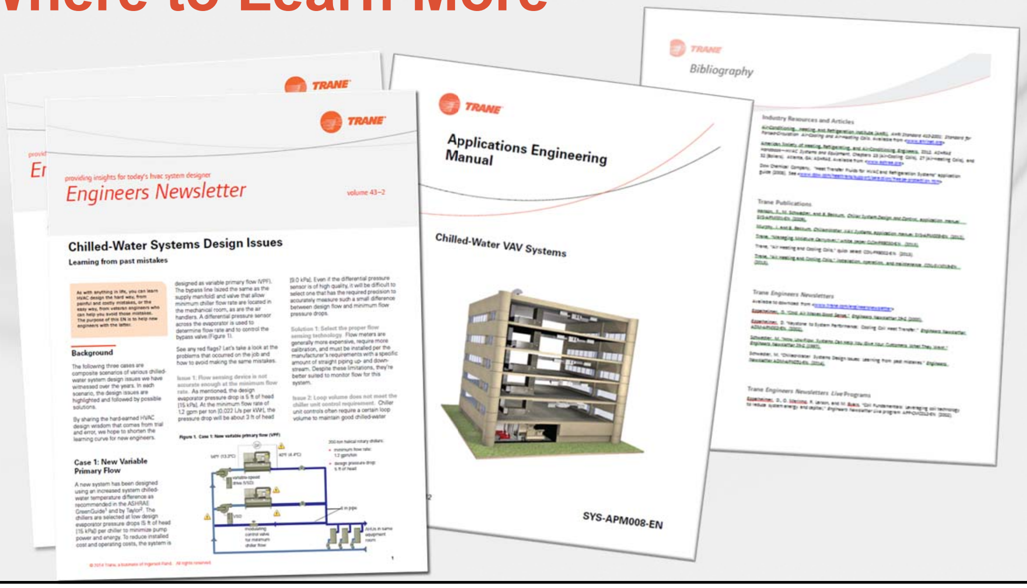

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Trane *Engineers Newsletter LIVE: Coils Selection and Optimization*

APP-CMC054-EN QUIZ

1. Which industry standard establishes a common set of testing and rating requirements for determining the capacity and pressure drops of cooling and heating coils?
   a. ASHRAE Standard 62.1
   b. AHRI Standard 410
   c. AHRI Standard 550/590
   d. ASHRAE Standard 90.1
2. Which of the following are concerns regarding too high of water velocity through the tubes of a coil? Choose all that apply.
   a. Risk of water droplets blowing off the outer surfaces of the fins (i.e., carryover).
   b. Risk of erosion on the inside surfaces of the tubes.
   c. Too much noise.
   d. Air can become trapped inside the coil tubes, degrading heat transfer.
3. Which of the following are concerns regarding too high of air velocity through the face of the coil? Choose all that apply.
   a. Risk of water droplets blowing off the outer surfaces of the fins (i.e., carryover).
   b. Risk of erosion on the inside surfaces of the tubes.
   c. Excessive air pressure drop.
   d. Air can become trapped inside the coil tubes, degrading heat transfer.
4. True or False: Laminar water flow through the tubes of a coil results in a SEVERE drop-off in capacity.
5. Which of the following factors influence moisture carryover (water droplets blowing off the outer surfaces of the fins)? Choose all that apply.
   a. Air velocity through the face of the coil.
   b. How densely the fins are packed together.
   c. Material the fins are made of.
   d. Whether or not the surface of the fins have a coating applied to them.
6. True or False: As long as dehumidifying coils are selected for a face velocity less than 500 ft/min, no moisture carryover will occur, regardless of the fin material or fin density.
7. When selecting a cooling coil to provide the same required capacity, which of the following are benefits of selecting a coil with a larger face area (lower face velocity)? Choose all that apply.
   a. Less fan energy use.
   b. A smaller air handler cabinet is required to house the coil.
   c. A warmer entering-air temperature.
   d. Lower air pressure drop.
8. True or False: When selecting a cooling coil to provide the same required capacity, selecting the coil with a lower water flow rate (larger ΔT) results in more pumping energy and requires upsizing piping, valves, and pumps.
9. True or False: Newer, condensing-style boilers are more efficient when the temperature of the water entering the boiler is lower.
10. True or False: When specifying the amount of glycol to use in a chilled-water system, the concentration required to provide “burst” protection (to protect equipment from damage) is lower than the concentration required to provide “freeze” protection (to prevent any ice crystals from forming).