Optimizing the Reliability and Efficiency of POD Cooling

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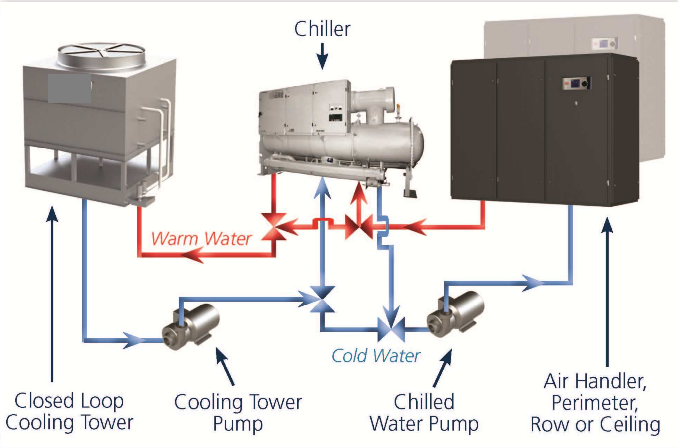
Agenda

Optimizing the Reliability and Efficiency of POD Cooling

1. Row and perimeter cooling equipment for POD applications
2. Enhancing the reliability and efficiency of cooling equipment
   1. ASHRAE TC9.9: benefits of hotter return air
   2. ASHRAE 90.1: benefits of water side economizers
   3. Controls: benefits of matching cooling to IT load

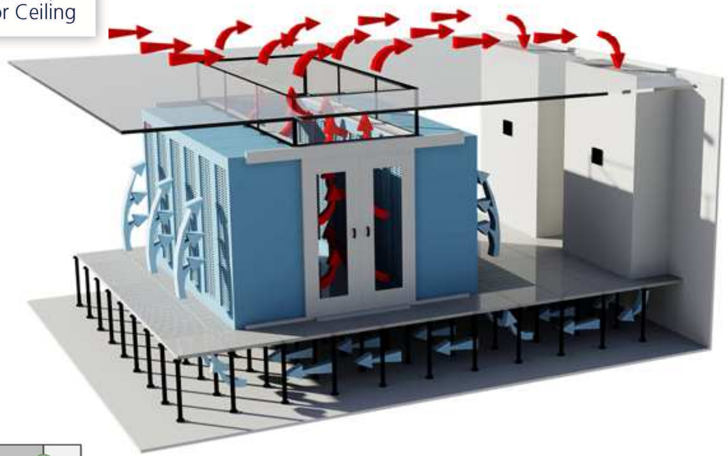
Data Center Designs



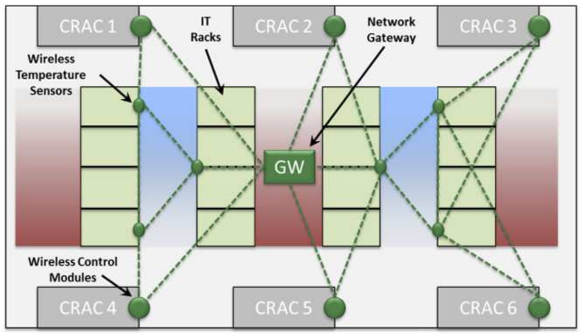
Water Side Economizer

Ultrasonic Humidification

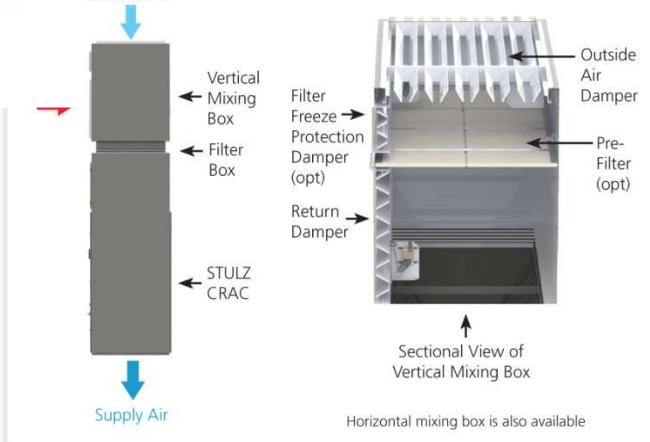
Containment Recommendations



DCIM and Controls



Air Side Economizer



ASHRAE TC 9.9

ASHRAE TC 9.9 Recommendations

- ASHRAE TC 9.9 Committee Thermal Guidelines for Data Processing Environments 2011 provides recommendations for temperature and humidity in the data center

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- **The standard is available for review**
  - Simply Google ASHRAE TC 9.9 2011 and you'll find it

ASHRAE TC 9.9

2011 Thermal Guidelines for

Data Processing Environments

– Expanded Data Center

Classes and Usage Guidance

Whitepaper prepared by ASHRAE Technical Committee (TC) 9.9

Mission Critical Facilities, Technology Spaces, and Electronic Equipment

ASHRAE TC 9.9

What Has Changed	Inlet Air Temperature	Moisture Content
2004 Recommended (old)	68-77.0^{0}F DB (25^{0}C)	40% RH to 55% RH
2011 Recommended (new)	64-80.6^{0}F DB (27^{0}C)	41.9^{0}F DP to 60% RH and 59^{0}F DP
2011 Allowable (A1)	59-89.6^{0}F DB (32^{0}C)	20-80% RH up to 62.1^{0}F DP(16.7^{0}C DP)

Psychometric Chart

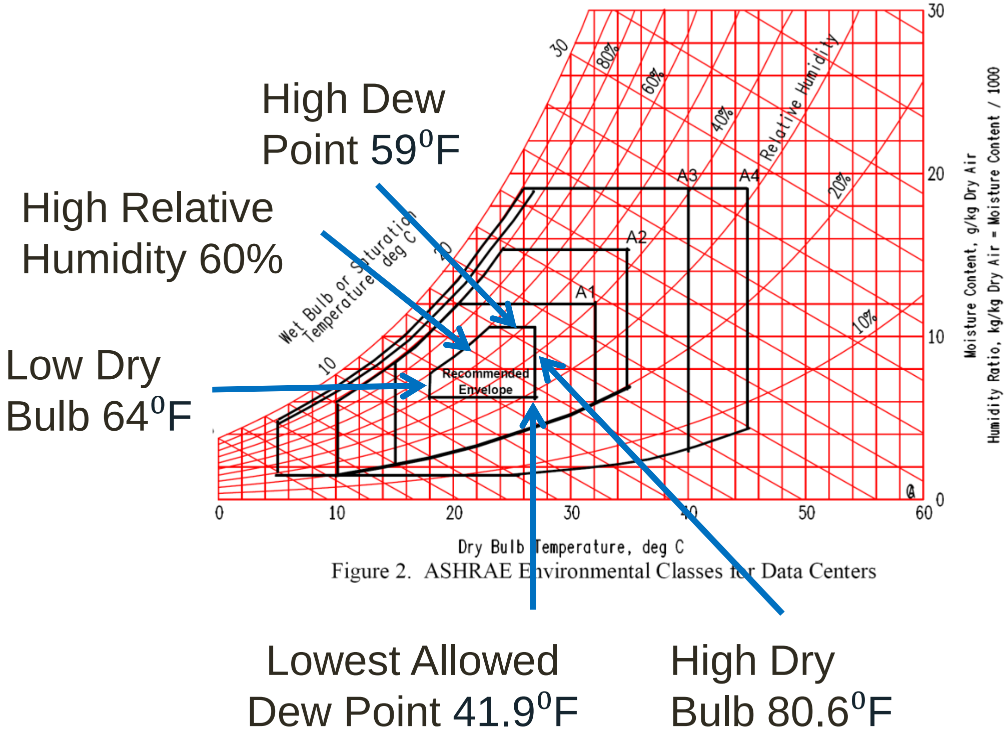
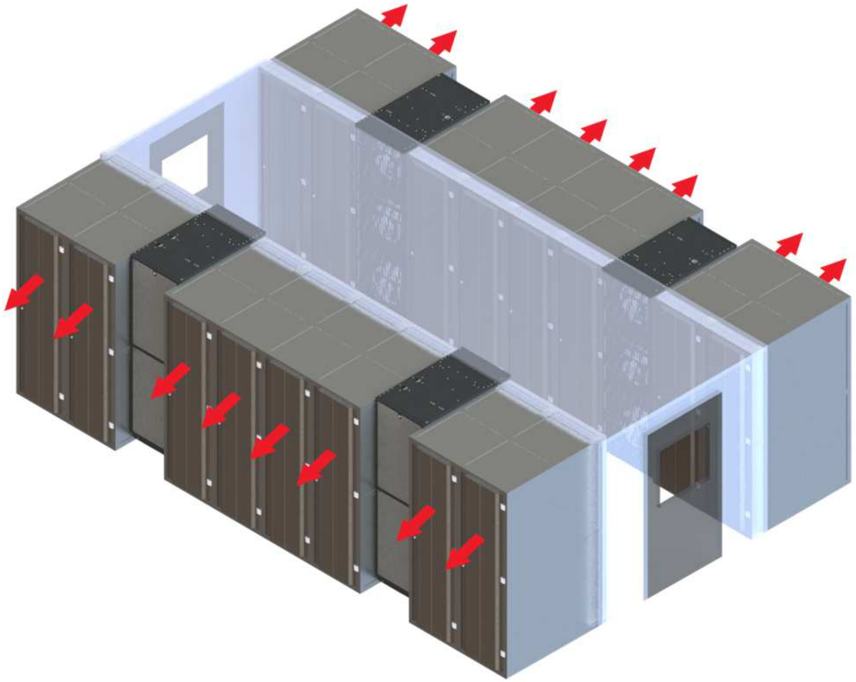


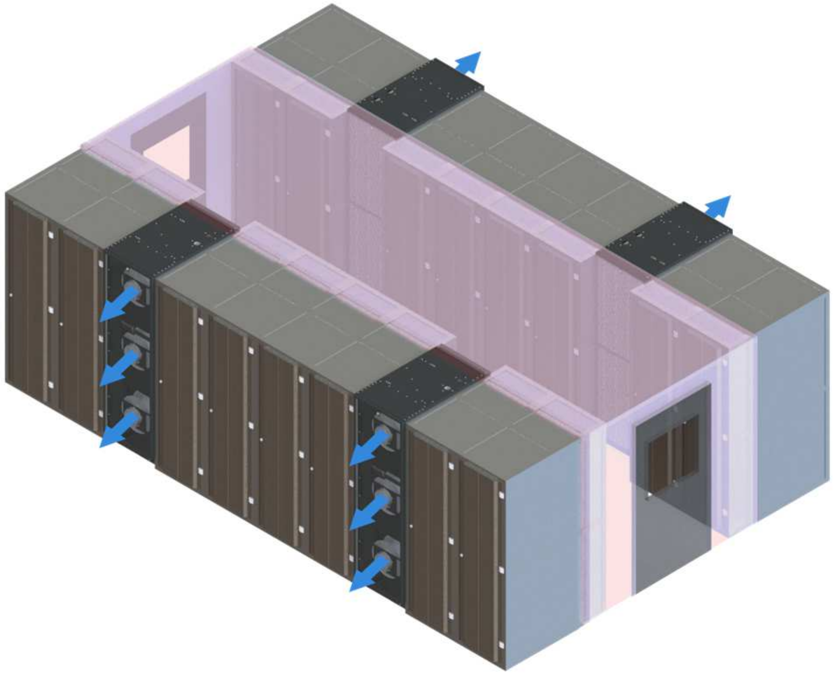
Figure 2. ASHRAE Environmental Classes for Data Centers

Condition	Risk
High Moisture	Corrosion
Low Moisture	ESD
High Inlet Air Temp	Thermal Shutdown
Low Inlet Air Temp	Wasted Energy

Row Cooling Designs



Cooling with
Cold Aisle Capturing

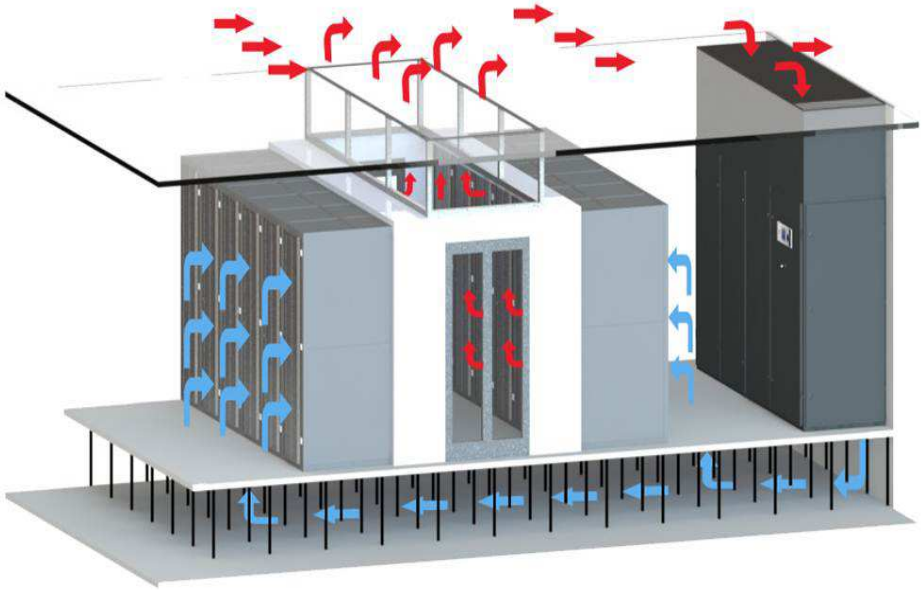


Cooling with
Hot Aisle Capturing

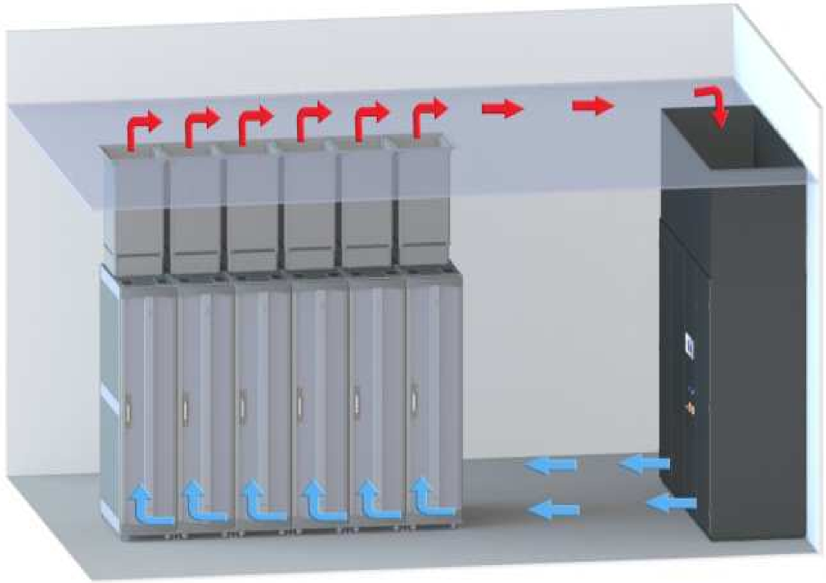
Indoor Cooling: Containment

Applications / Configurations

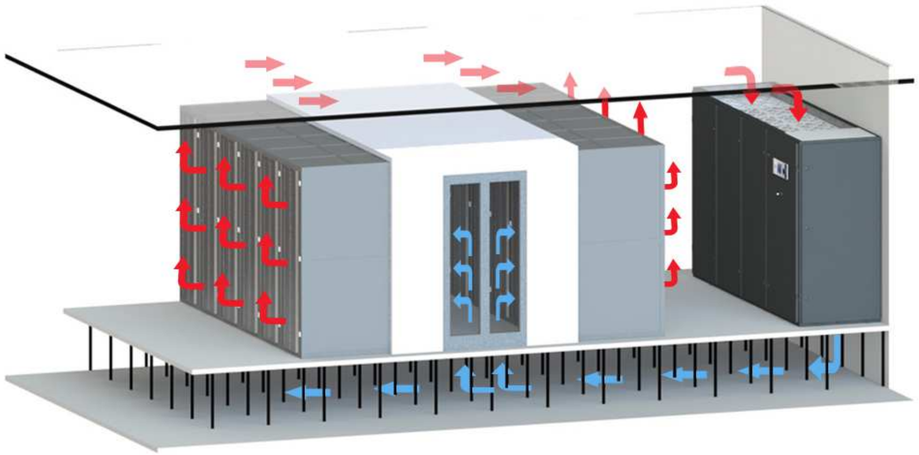
Raised floor with hot aisle containment and hot air return plenum



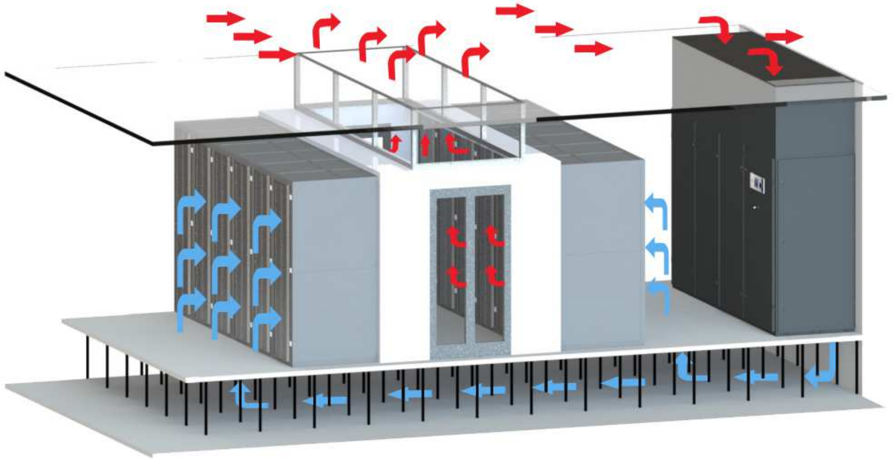
Slab floor with hot aisle chimney containment and hot air return plenum



Perimeter Cooling Designs



Cooling with
Cold Aisle Capturing

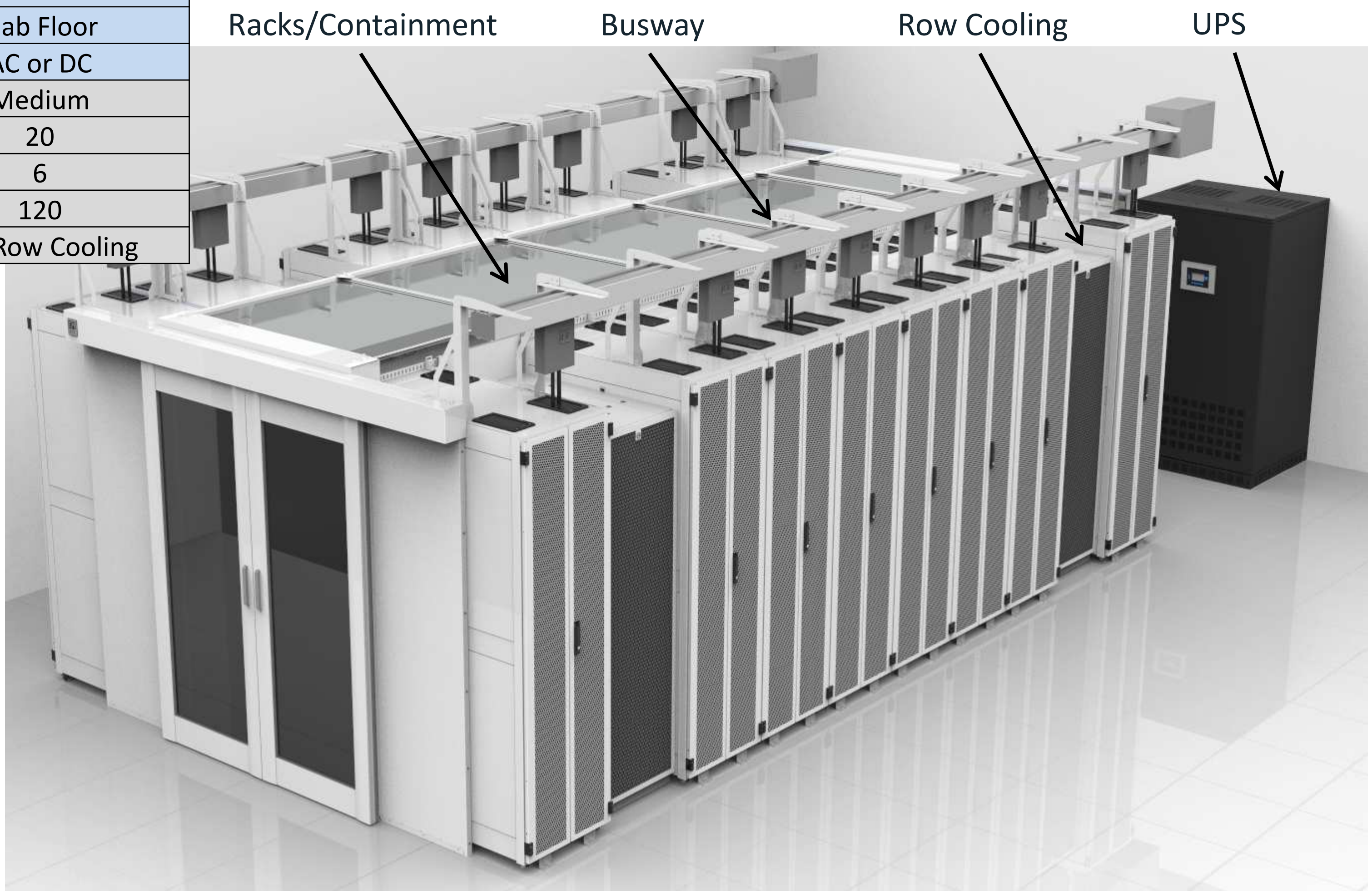


Cooling with
Hot Aisle Capturing

Cooling with
Cabinet Containment

Row Cooling

Type	POD Design
Containment	Cold Aisle
Floor	Slab Floor
Power	AC or DC
Density	Medium
Racks	20
Rack Density (kW)	6
Total Density (kW)	120
Cooling Type	3+1 Row Cooling



Perimeter Cooling

Type	POD Design
Containment	Cabinet Containment
Floor	Slab Floor
Power	AC
Density	Medium
Racks	20
Rack Density (kW)	6
Total Density (kW)	120
Cooling Type	Perimeter Cooling

ASHRAE TC 9.9

	6r6p60cv
Entering Air DB (℉)	75
Entering Air WB (℉)	61.1
Coil Leaving Air DB (℉)	51.0
Coil Leaving Air WB (℉)	50.5
Gross Total Capacity (Btuh)	513,800
Gross Sensible Capacity (Btuh)	461,200
Net Total Capacity (Btuh)	493,800
Net Sensible Capacity (Btuh)	441,200
Air flow (ACFM)	18,000
External Static Pressure (in)	0.30
Altitude (ft)	0
Entering Fluid Temp. (℉)	45
Fluid Type	Water
Percent Glycol(%)	0
Fluid Flow (GPM)	105
Leaving Fluid Temp.(℉)	55
Coil Fluid Pressure Drop (FT-H2O)	10.2
Unit Fluid Pressure Drop (FT-H2O)	23.3
Estimated Unit Power (kW)	**5.3**

1 2 3 4

1. Base Coil Run

Raising entering (return) air temperatures by 20^{o}F (11.2 ^{o}C) …

2. Increases CRAH sensible capacity by **66%**
3. Same or better sensible capacity with only **49% of the original fan power**
4. Allows higher chilled water temperature for **22%+ more efficient chiller operation**

ASHRAE TC 9.9

What does this all mean?

- Higher return air temperature allows cooling equipment to operate more efficiently
  - Increasing return air temperature from 75^{o} to 95^{o}F = 66% increased efficiency
  - Improved efficiency leads to…
    - less energy, lower operating cost, and lower carbon footprint
  - Rack containment is a good way to increase return air temperature
- Higher return air temperature…
  - increases the hours of available free cooling, allowing further efficiency improvement

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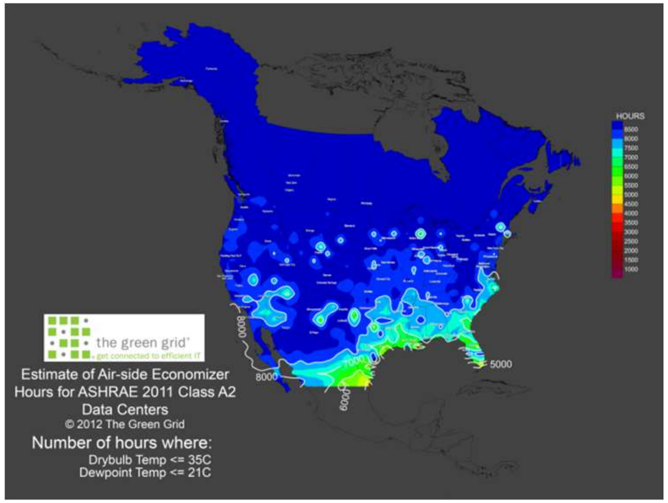
    3. Controls: benefits of matching cooling to IT load

ASHRAE 90.1-2010

ASHRAE 90.1–2010 Standard

- ASHRAE 90.1-2010 Energy Efficiency for Buildings requires the use of air and water economizers in many locations

- The process cooling exemption is gone
  - Data Centers consume ~3% of total energy
- Water economizer must meet 100% of the expected load at:
  - Cooling towers: 40°F dry bulb / 35°F wet bulb
  - Dry coolers: 35°F dry bulb



LOCATION, LOCATION, LOCATION

Weather conditions are of primary concern when selecting an economizer type

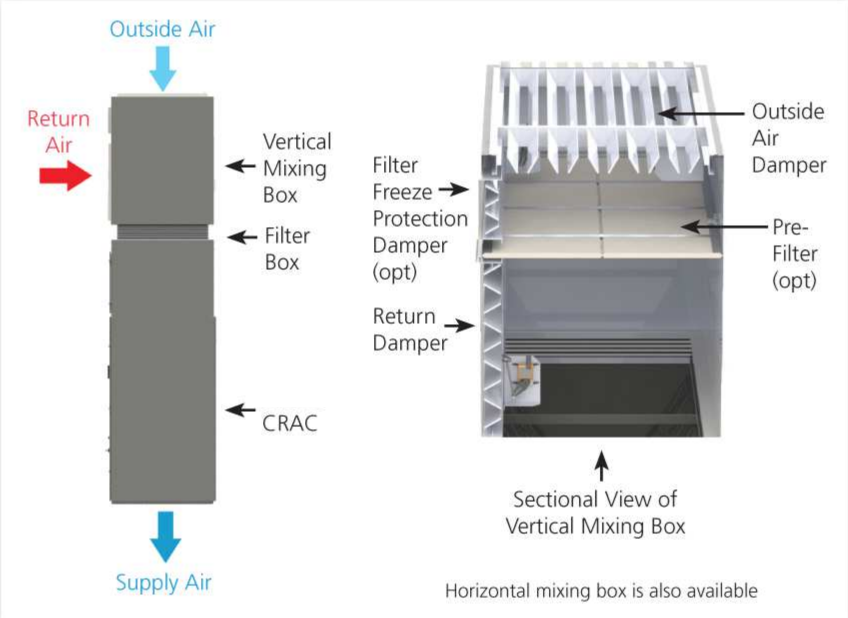
ASHRAE 90.1-2010 Standard

- Huge impact on energy efficiency
- Leading-edge solutions
- Requires supporting equipment and controls
- New SCOP (sensible co-efficient of performance) requirements (replaces EER)

Air Side Economizers

- CRACs or CRAHs with an integrated mixing box and damper controls provides free cooling.
- Units attached to the top of a CRAC or CRAH in a vertical or horizontal position.
- Pre-filter and freeze protection damper options
- Mixes outside and return air depending on outside air conditions
- Full economizer controls provided by the CRAC or CRAH

Side Economizers



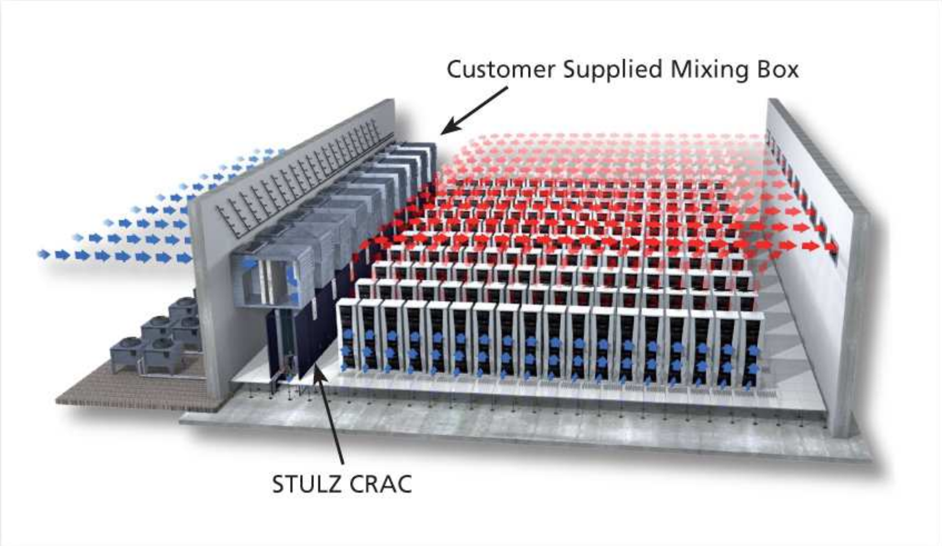
CRAC / CRAH with Economizer Mixing Box

Air Side Economizers - Cooling with Mixing Box

CRACs or CRAHs with an integrated mixing box and damper controls providing free cooling. Units attaches to the top of a CRAC or CRAH in a vertical or horizontal position.

Outside Air & Moisture	Operation
Warmer / High Humidity	Dampers close & the CRAC/CRAH reverts to traditional operation
Within Proper Range	Outside air is directly introduced through the dampers in the mixing box
Colder than Desired	Dampers mix outside air & return air to achieve desired temperature
Below Freezing	Warm return air mixes with outside air before the filter to prevent freezing

Air Side Economizers Control



Air Side Economizer	Outside Temp.	OA Damper	Exhaust Damper	Return Damper	CRAC Fan	CRAC Compressor	Energy Use
FC (Free Cooling)	Cold	Variable	Variable	Variable	Variable	Off	Low
MIX (Compressor & Free Cooling)	↓	Variable	Variable	Variable	Variable	Step	↓
DX (Compressor Cooling)	Hot	Closed	Closed	Open	Max	On	High

How Controller manages this solution:

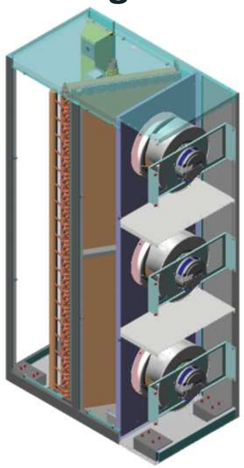
- Controls (variable 0-10V DC proportional control):
    - Outside Air Intake
    - Exhaust Damper or Fan
    - Return Air Damper
    - CRAC EC Fan
- Individual Control Selections
    - Fan
    - Outside Air Damper
    - DX Cooling

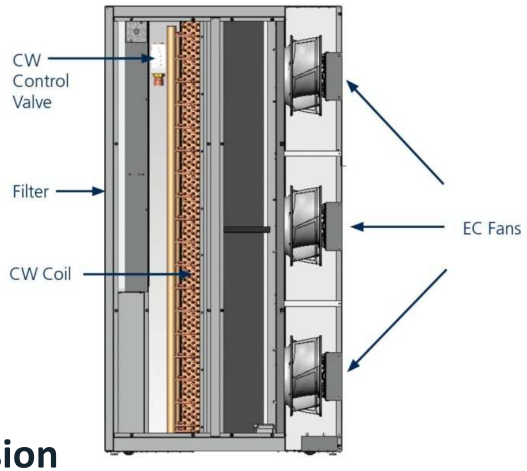
(Monitor contained aisle, outside air, supply air, return air, and a mix of outside and return air)

Air Side Economizers Control

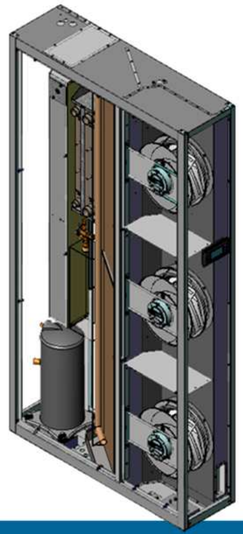
Row Cooling

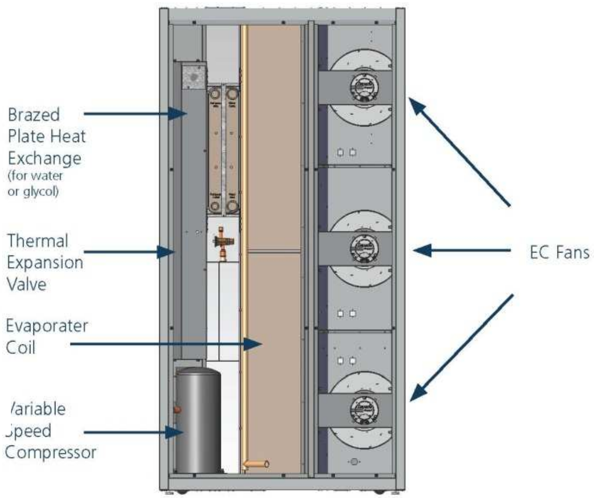
Row Cooling – Chilled Water





Row Cooling – Direct Expansion





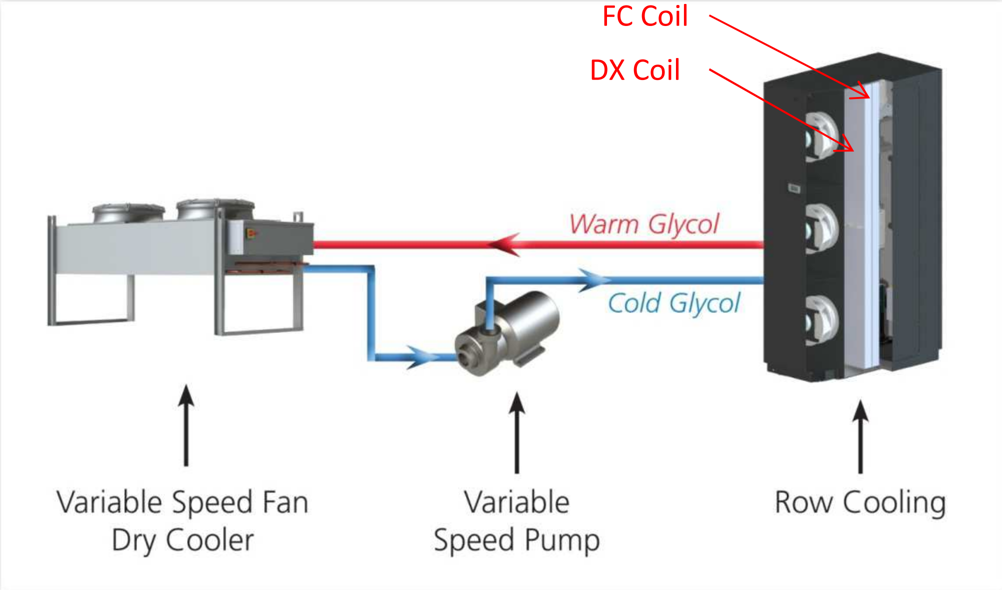
CW heat rejection options:

1. Chiller (air or water cooled)
2. Cooling Tower

DX heat rejection options:

1. Air cooled condenser (shown)
2. Glycol cooled condenser
3. Water cooled cooling tower

Water Side Economizer



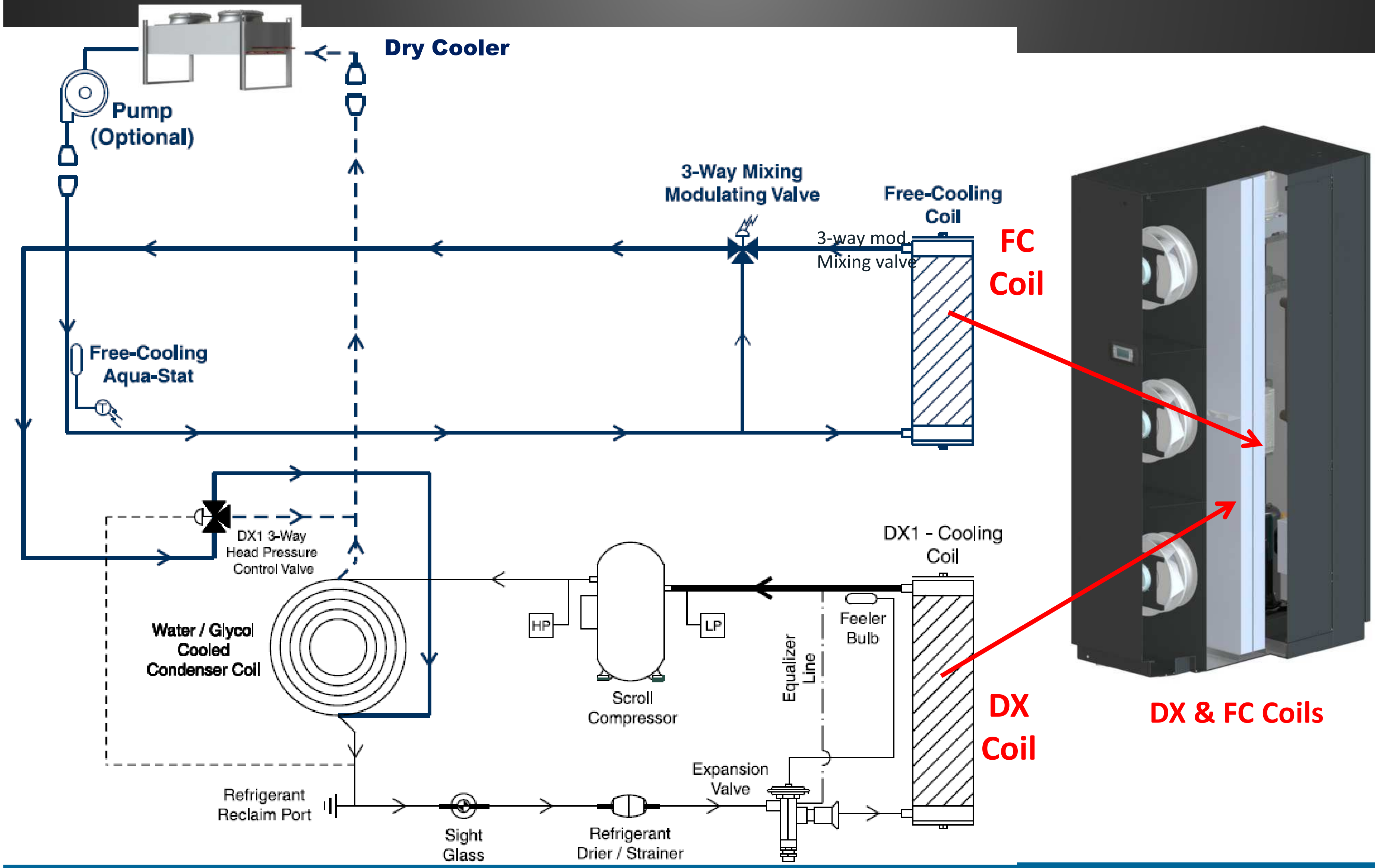
Glycol Cooled DX
Dynamic free cooling with variable speed dry cooler and pumps

Dynamic Free Cooling

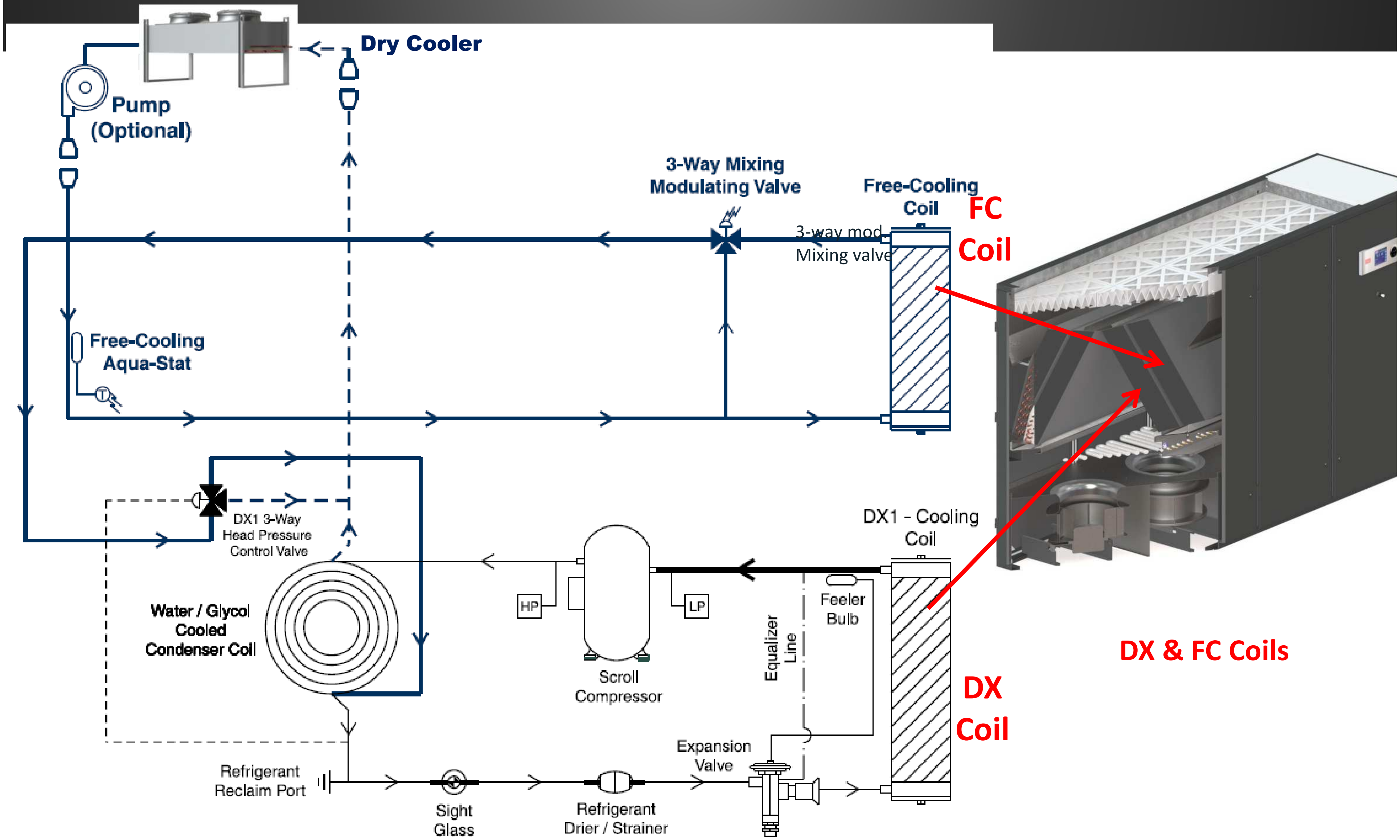
Comprised of a variable fan speed dry cooler, variable speed pumps, and glycol cooled free cooling row-based cooling unit with both a DX and a glycol free cooling coil.

Outside Air	Operation
Warm Weather Months	Unit acts as traditional DX; dry cooler supplies glycol to unit condenser
In-between Months	Combination of glycol free cooling coil and one DX compressor (trim)
Cold Weather Months	Cooled glycol transferred to free cooling coil; compressor off

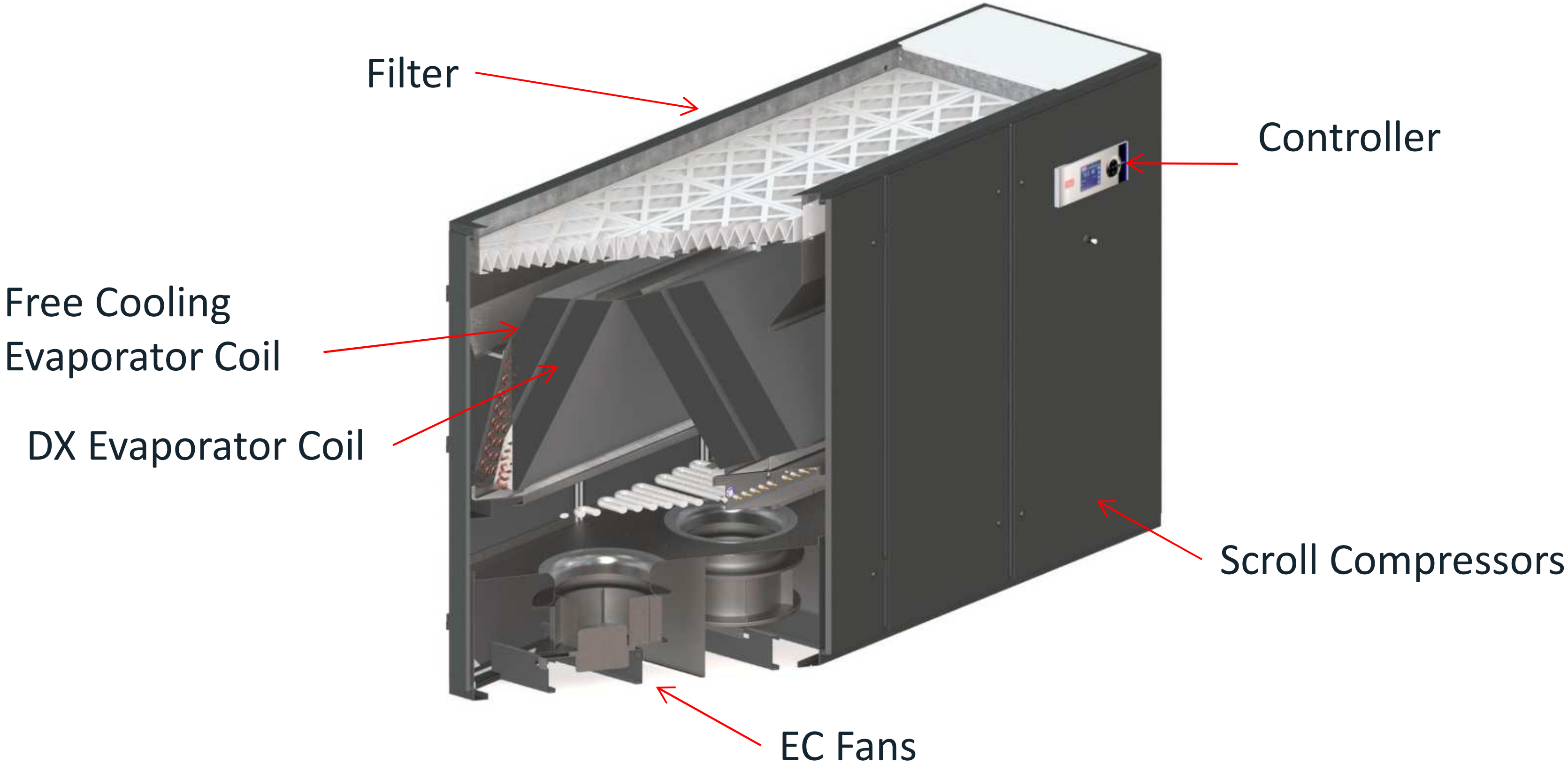
Water Side Economizer



Water Side Economizer

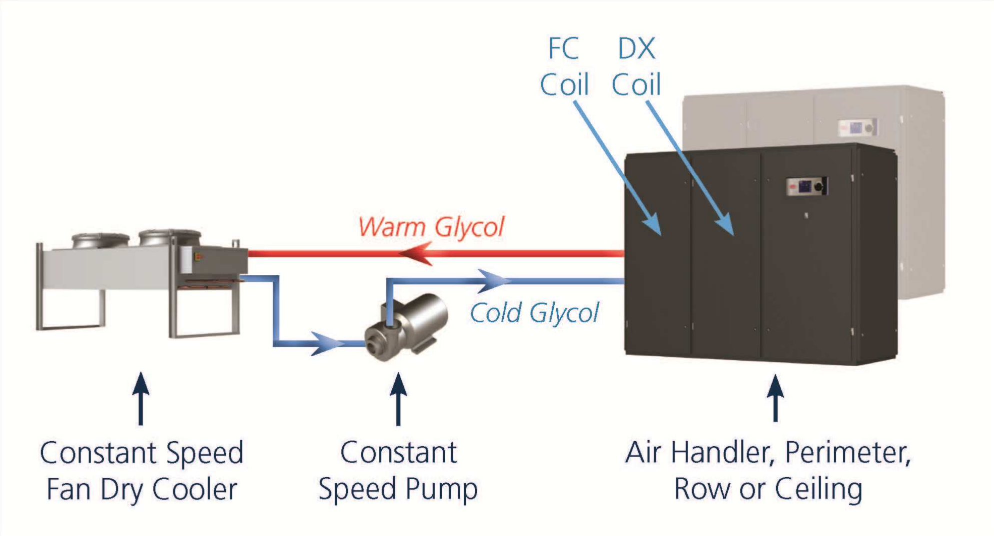


Perimeter Cooling



Perimeter Cooling Unit
DX with FC Economizer Coil

Water Side Economizers



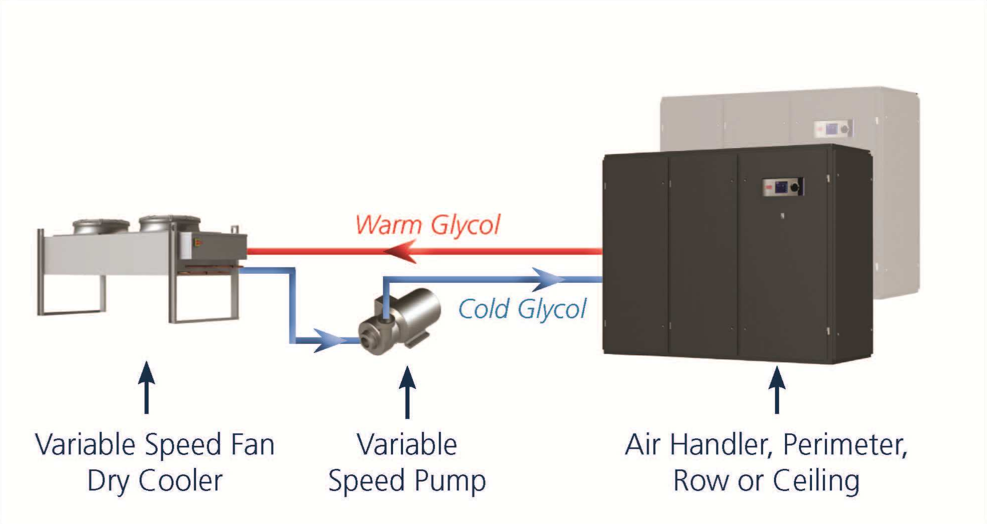
Glycol Cooled DX
Traditional free cooling with **constant** speed dry cooler and pumps

Traditional Free Cooling

Comprised of a constant fan speed dry cooler, constant speed pumps, and glycol cooled free cooling CRACs consisting of both a DX and a glycol cooling coil.

Outside Air	**Operation**
Warm Weather Months	Unit acts as traditional DX; dry cooler supplies glycol to unit condenser
In-between Months	Combination of glycol free cooling coil and one DX compressor
Cold Weather Months	Cooled glycol transferred to free cooling coil; compressor off

Water Side Economizers



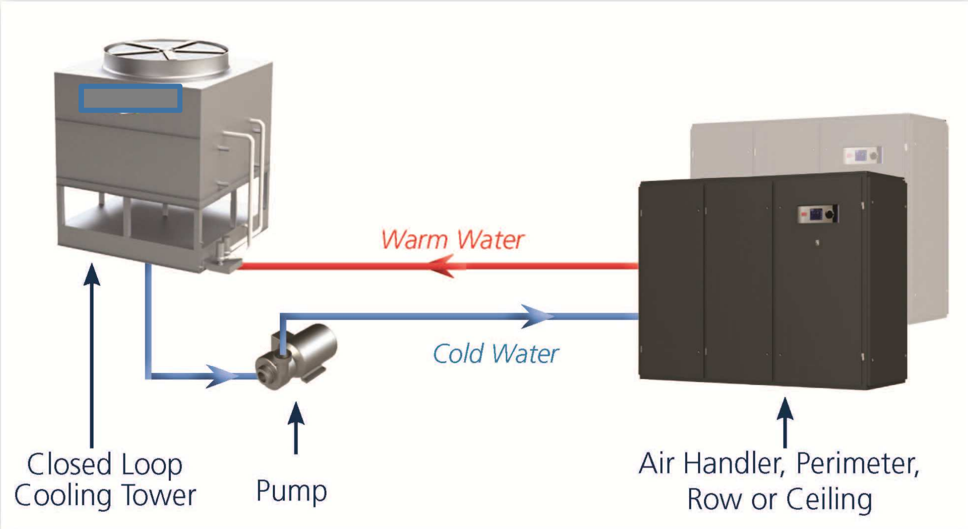
Dynamic Free Cooling

Comprised of a variable fan speed dry cooler, variable speed pumps, and glycol cooled free cooling CRACs consisting of both a DX and a glycol cooling coil.

Outside Air	**Operation**
Warm Weather Months	Unit acts as traditional DX; dry cooler supplies glycol to unit condenser
In-between Months	Combination of glycol free cooling coil and one DX compressor
Cold Weather Months	Cooled glycol transferred to free cooling coil; compressor off

- fans on dry coolers and pumps operate at lowest possible speeds to supply required cooling, using the least amount of energy
- as ambient increases, fans on dry coolers and pumps increase speed to extend available free cooling

Water Side Economizers



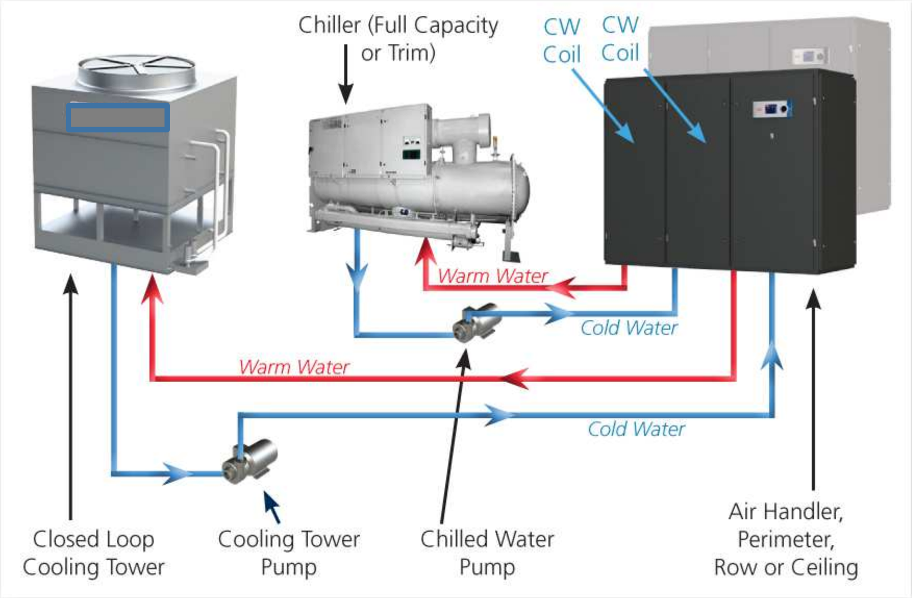
Water Cooled DX
Free cooling with evaporative cooling tower and water filtration system

Evaporative Tower Free Cooling

Comprised of an evaporative cooling tower, constant speed pumps, and water cooled free cooling CRACs consisting of both a DX and a water cooling coil.

Outside Air & Moisture	Operation
Warm Weather Months	Unit acts as traditional DX; cooling tower supplies unit condenser
In-between Months	Combination of water free cooling coil and one DX compressor
Cold Weather Months	Cooled water transferred to free cooling coil; compressor off

Water Side Economizers



CW Units
Free cooling with evaporative cooling tower, water filtration system, and chiller

Free Cooling with Dual Chilled Water Coils

Comprised of an evaporative cooling tower, cooling tower pumps, chiller, chiller pumps, control valves, and chilled water cooled CRAHs.

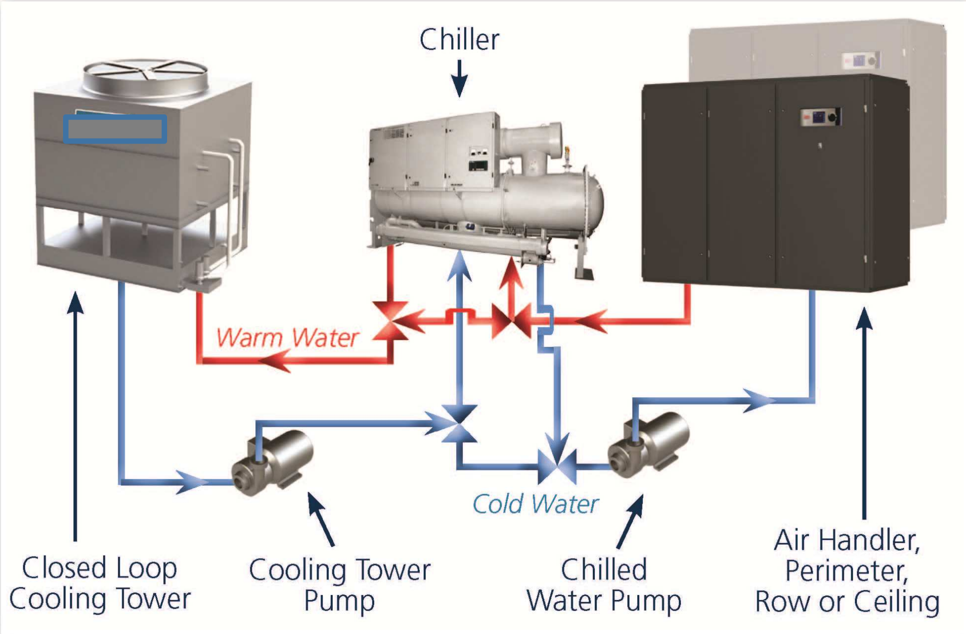
Outside Air & Moisture Operation

Warm/Humid Weather Months Chiller supplies CRAH

In-between Months Combination of water free cooling and partial chiller operation

Cold/Dry Weather Months Cooling tower directly supplies CRAH; chiller compressor off

Water Side Economizers



CW Units
Free cooling with evaporative cooling tower, water filtration system, and chiller

Free Cooling with Chilled Water

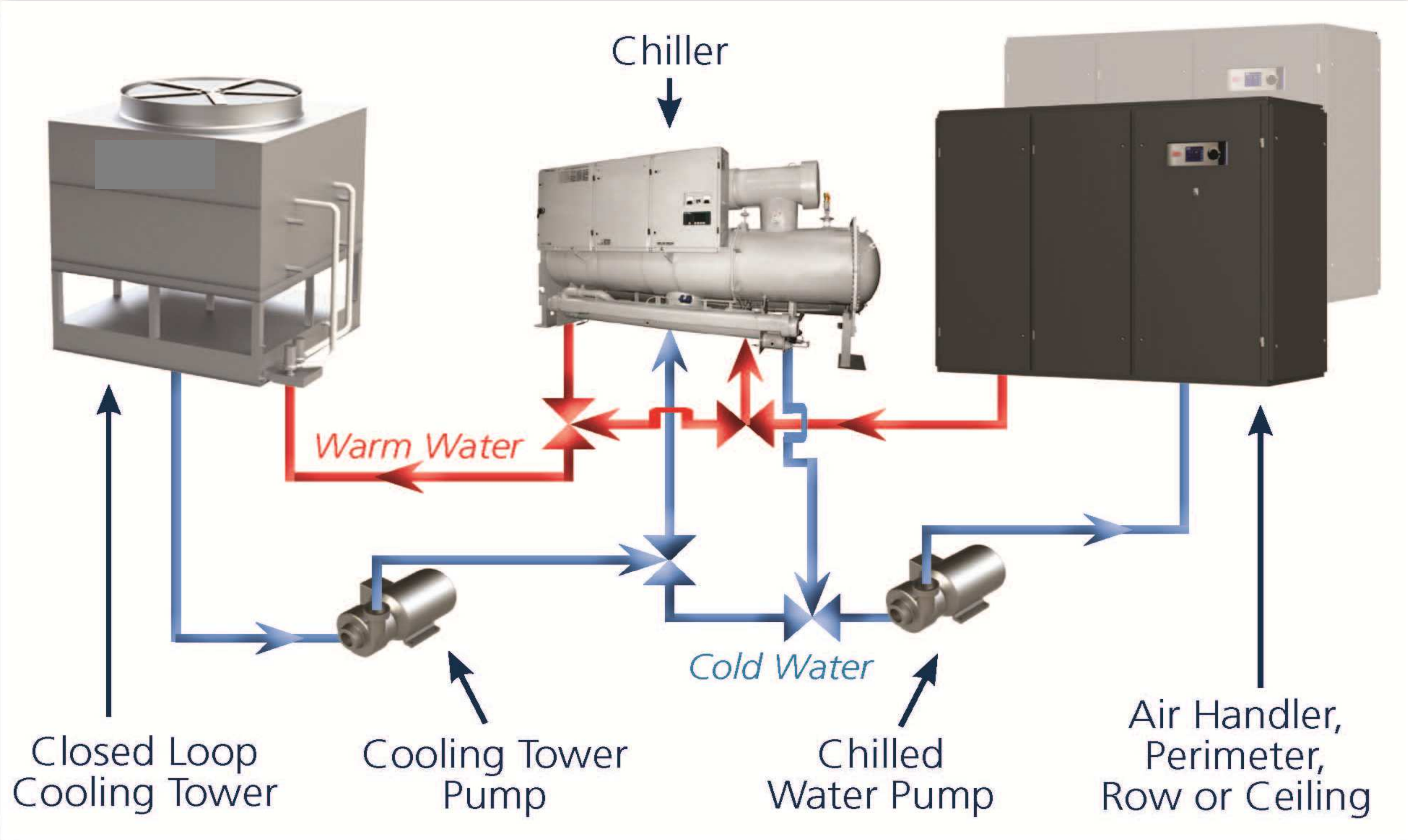
Comprised of an evaporative cooling tower, cooling tower pumps, water cooled chiller, chiller pumps, control valves, and chilled water cooled CRAHs.

Outside Air & Moisture Operation

Warm Weather Months Cooling tower supplies chiller; chiller supplies CRAH

Cold Weather Months Cooling tower directly supplies CRAH; chiller compressor off

Water Side Economizer Control

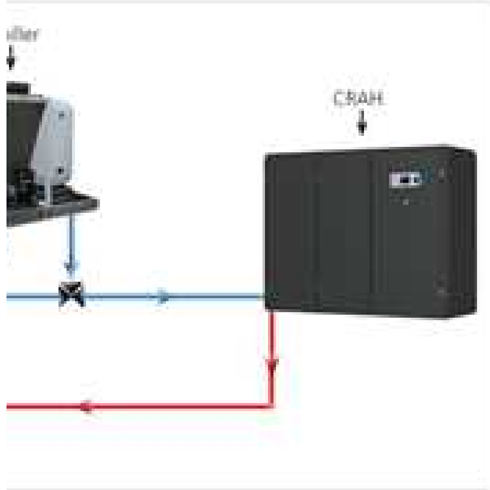


Warm Water Cooling

Water Tower Cooling Oper

	6R12P60CV
Oversized unit with Optimized Coil at Non-Standard Conditions	
Entering Air DB (°F)	103
Entering Air WB (°F)	67.5
Coil Leaving Air DB (°F)	76.0
Coil Leaving Air WB (°F)	58.1
Gross Total Capacity (Btuh)	318,500
Gross Sensible Capacity (Btuh)	318,500
Net Total Capacity (Btuh)	306,500
Net Sensible Capacity (Btuh)	306,500
Air Flow (SCFM)	10,800
External Static Pressure (in)	0.3
Fan Power (kW)	3.5
Altitude (ft)	0
Entering Fluid Temp. (°F)	69
Fluid Type	Water
Percent Glycol(%)	0
Fluid Flow (GPM)	25
Leaving Fluid Temp.(°F)	94.5
Coil Fluid Pressure Drop (FT-H2O)	2.3
Unit Fluid Pressure Drop (FT-H2O)	6.5
Pump Power (kW)	0.06
Total Power (kW)	3.6
Total Power to Usage to Match Standard Units Net Sensible (kW)	**7.8**

ooling Operation



ASHRAE 90.1-2010

What does this all mean?

- ASHRAE 90.1 2010 will have a huge impact on data center design
- Water-side economizer solutions
  - available for both row and perimeter cooling
  - optimized with rack containment
  - provide a huge improvement on cooling efficiency
    - Depending on your location and operating conditions, there is the potential to…
      - turn off compressors (CRAC or Chiller) for 80% of the year
      - 70% savings in overall energy usage

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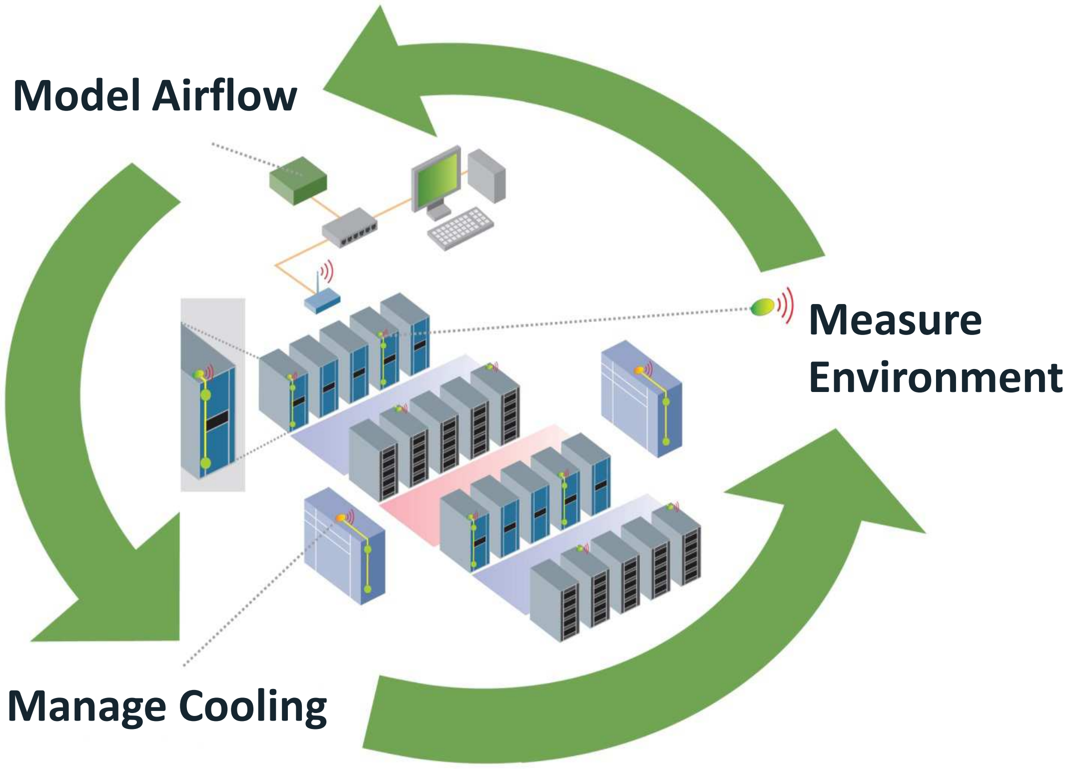
Advanced Controls

- Advanced Controls has a big impact on data center design
  - Cooling output dynamically matched to IT Load
    - Improves cooling operational reliability
    - Improves cooling efficiency and energy savings



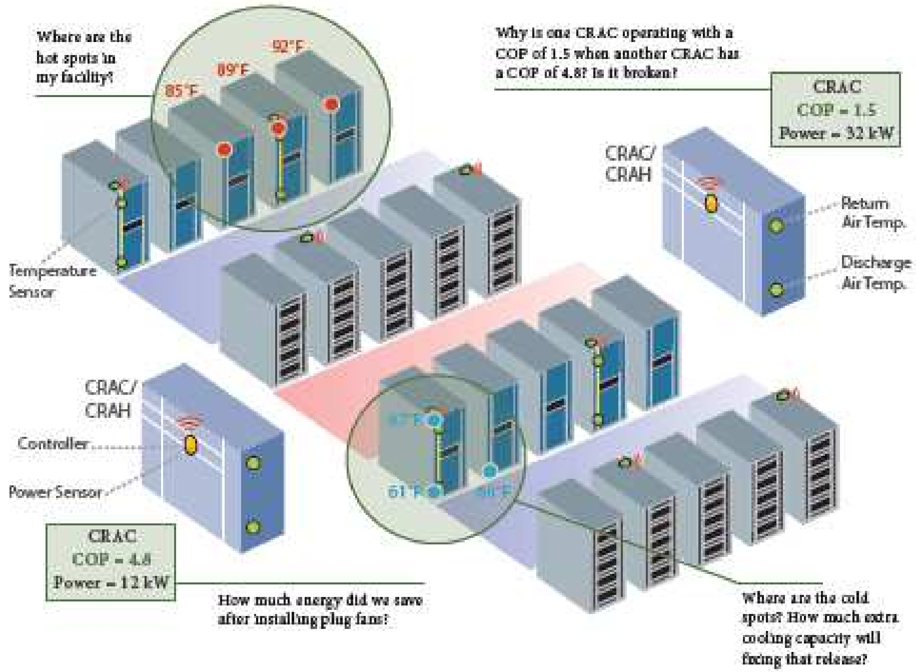
Advanced Controls

Advanced Controls ties system together for maximum reliability and efficiency

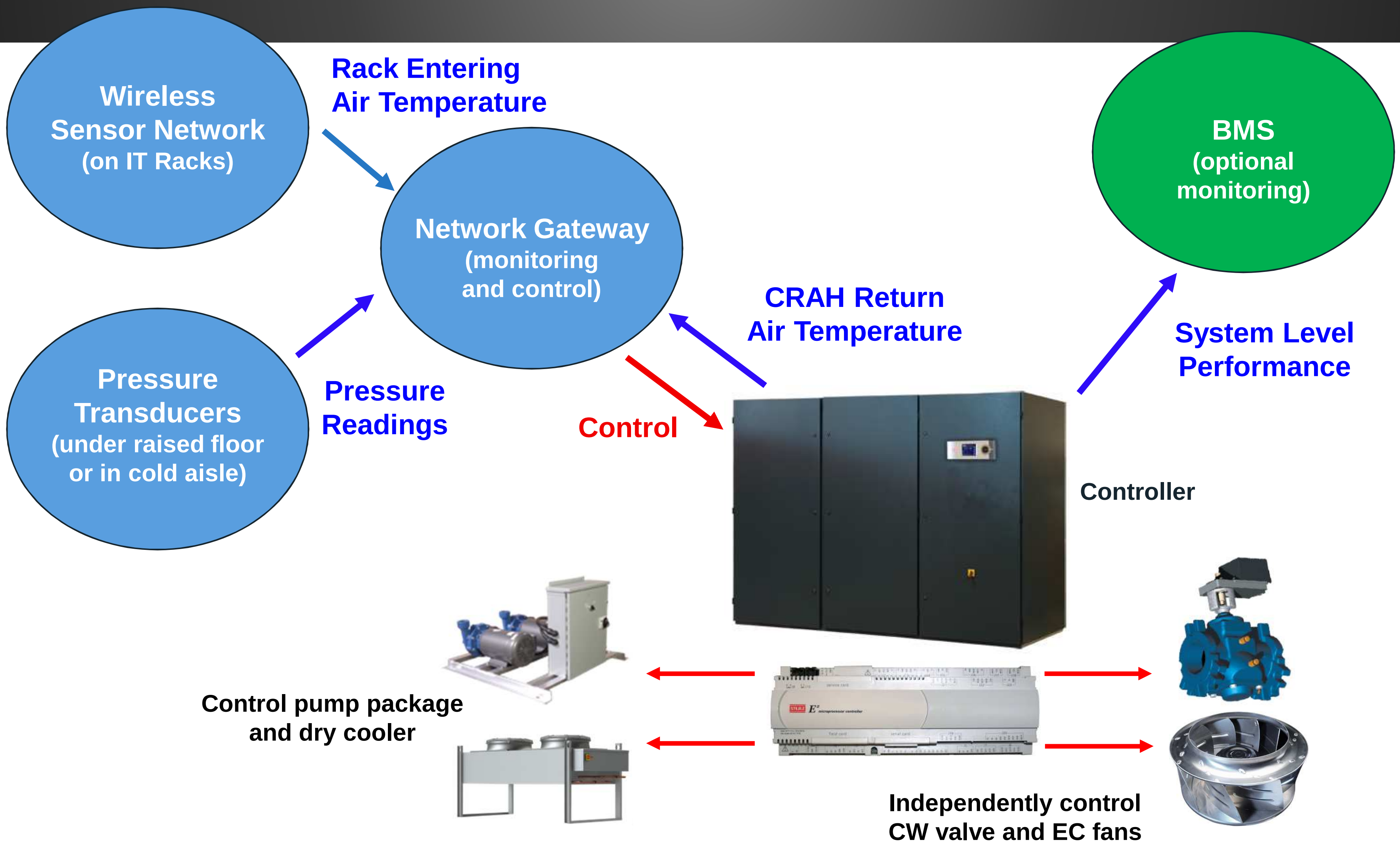
- Inputs to the Network Gateway (monitor)
  - Wireless Temperature Sensors on the racks (rack entering air temp)
  - Pressure Transducers under the floor or in the cold aisle (pressure readings)
  - Wireless Control Modules on the CRAH's (supply or return air temperature)
- Outputs from the Network Gateway (control)
  - Controllers inside the CRAH's
- Controllers maximize reliability, free cooling, and energy savings
  - EC fans (speed controls)
  - Chilled Water Valves (GPM flow)
  - Variable Speed Pumps (GPM flow)
  - Variable Speed Dry Coolers (fan speed)

Variable Speed Dry Cooler

Variable Speed Pump

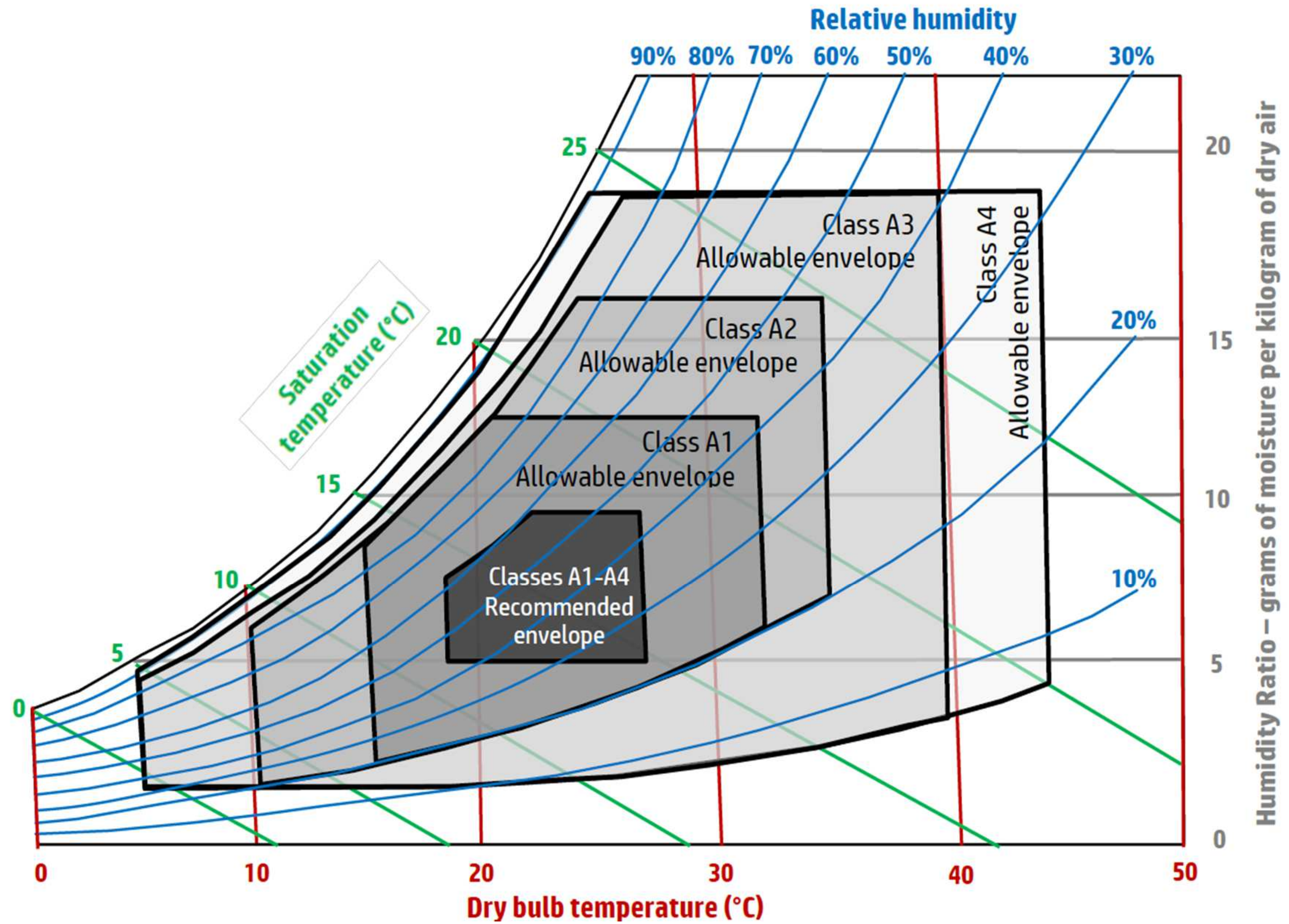


Advanced Controls



Economizers Control

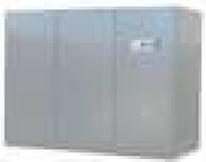
Figure 2. This illustration shows the data center recommended and allowed operating envelopes for ASHRAE classes A1 thru A4.



Advanced Controls – Active Redundancy

Examples

1.) 3 x CRAH's @ 75° F / 50% EAT with 45° F water **operating with 1/3 standby capacity**



Standby

Two Units @ 370,000 Btu/Hr each = total 740,000 Btu/Hr

Airflow:

2 x 17,000 cfm = 34,000 CFM

Fan energy consumption
2 x 9.1 = **18.2 kW**

2.) 3 x CRAH's @ 75° F / 50% EAT with 45° F water **each operating at the same time**

Three Units @ 275,000 Btu/Hr each = total 825,000 Btu/Hr

Airflow:

3 x 11,333 cfm = 34,000 cfm

Fan energy consumption
3 x 2.69 = **8.07 kW**

Operating all CRAH's at a lower fan speed provides better redundancy and energy savings

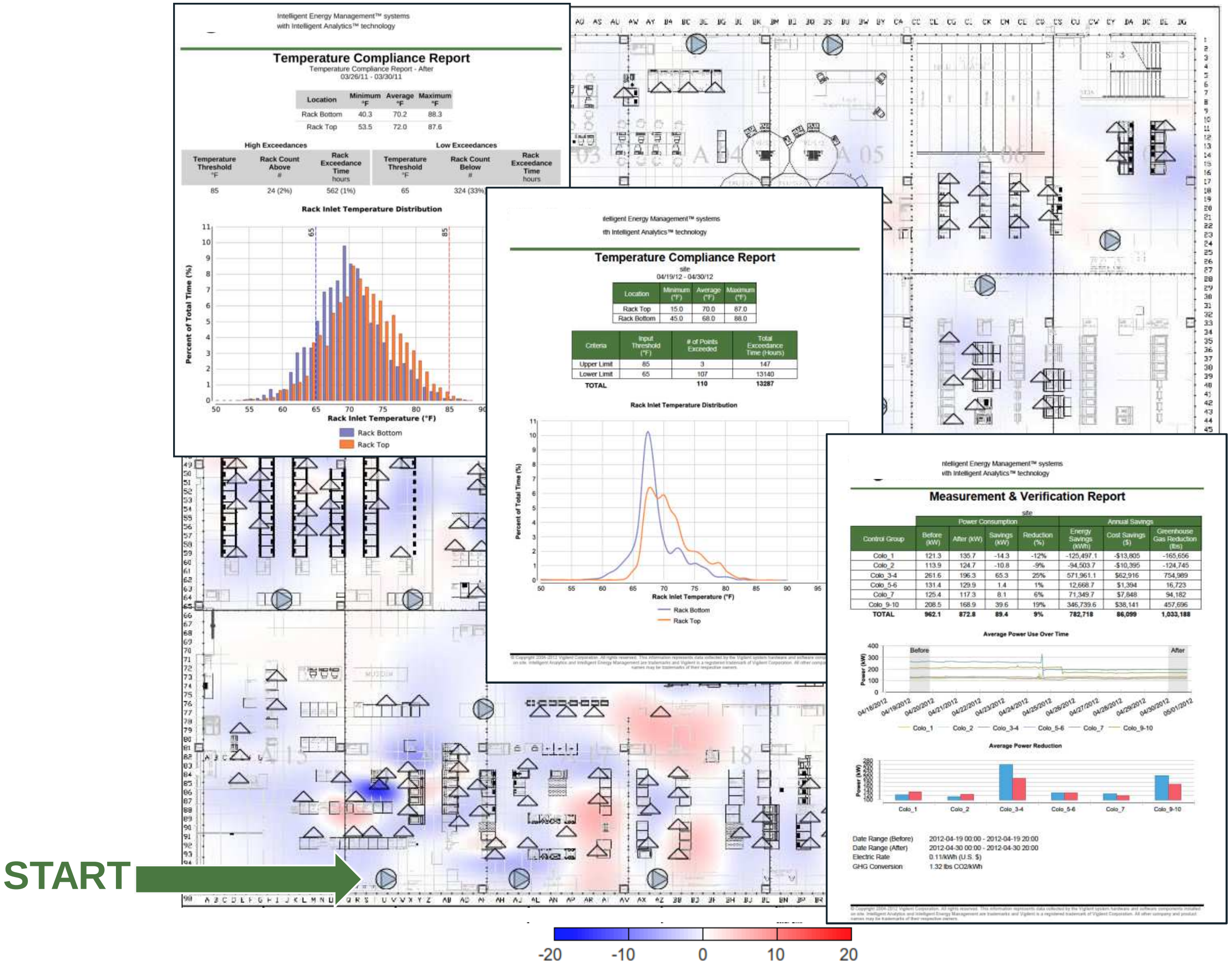
Delta of 10.13 kW / year =

$8,874 energy savings / year

(@ $0.10 / kWh)

Cooling Complexity

Advanced Controls measures and models changing heating and cooling conditions during commissioning, additions, and changes



System Monitoring

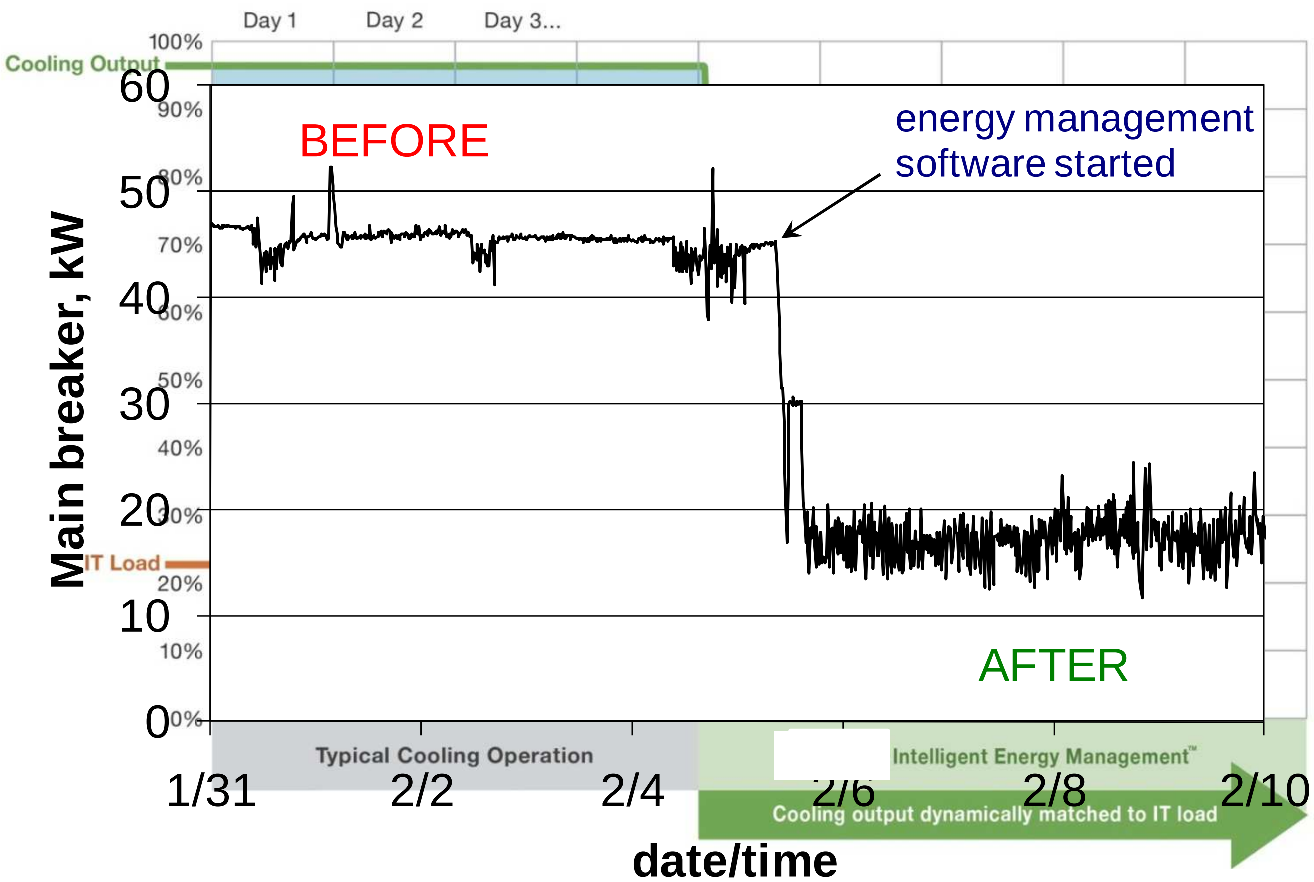
- Detailed reporting of data center cooling operations
- Trending, performance, and compliance
- Displays rack temperatures and temp. distribution
- Identifies areas of unused capacity

System Control

- Real-time cooling capacity management
- Cooling output dynamically matched to IT Load
  - shuts down unnecessary CRAC units
  - Optimizes CRAH fan speed and water flow
- Cooling output dynamically matched to IT Load

Advanced Controls

Advanced Controls measures, models, and manages data center cooling infrastructure



Increased Reliability

- Customizable alarms
- Instant, automated response to cooling problems

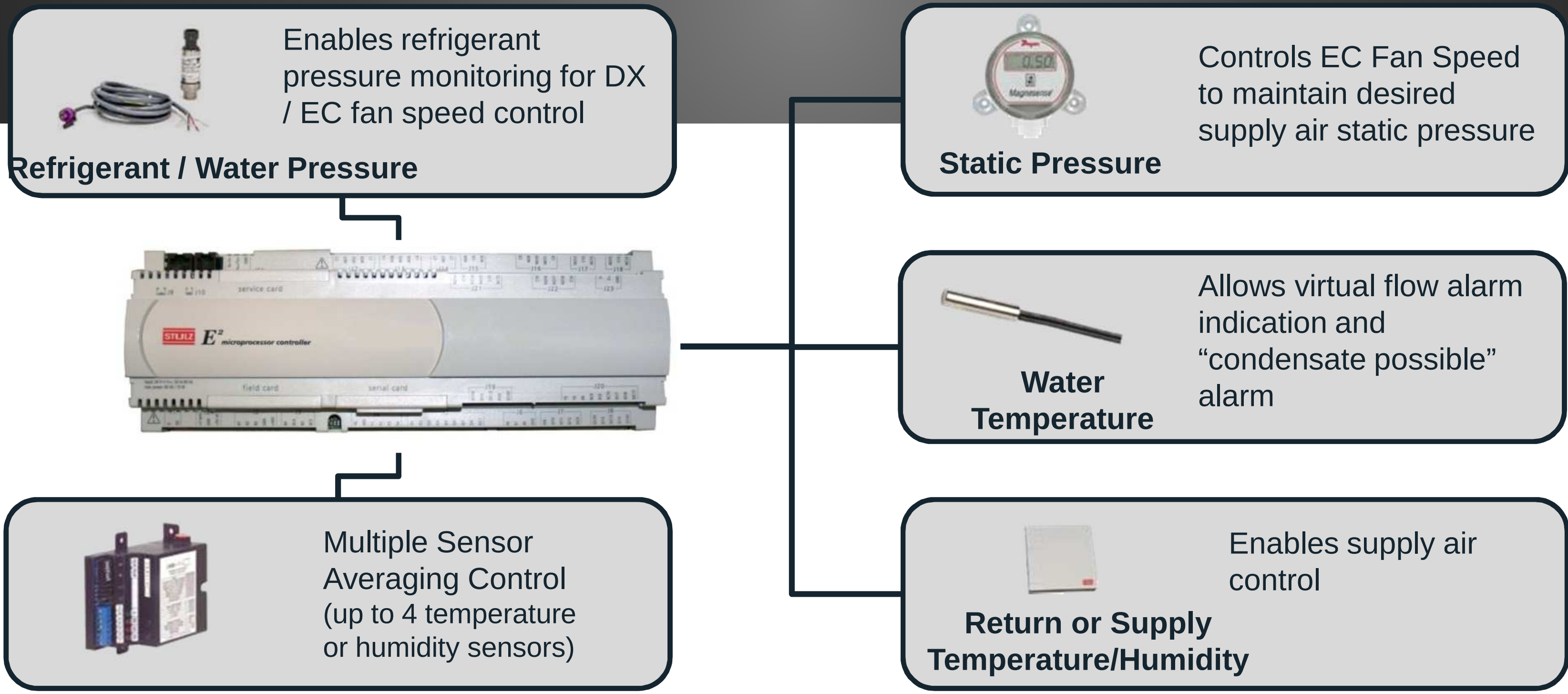
Efficient Operations

- Hot spot prevention
- Up to 50% reduction in equipment cycling
  - Increased equipment life

Energy Savings

- Continuous PUE optimization
- Up to 60% cooling energy savings

Controls Improves Efficiency



Key Control Capabilities	Benefit
Independent Control	Efficiency of EC fans and CW valve (or compressor) can be maximized
Dew Point Control	Temp and RH examined and humidification/dehumidification modes optimized
Static Pressure Control	Provides even airflow on demand at any room position and precise control for containment
Unit Networking	Capable of BMS interface or private local area network (pLAN)
Redundancy	Controller defaults to set points if a sensor fails or if BMS control signal fails; EC fans ramp up if one fails

Ultrasonic Humidification

Ultrasonic

Humidification for mission critical applications and any environment where clean, efficient and tight humidity control is required.

93% energy savings over infrared humidifiers.

Humidification Improves Efficiency

Is Ultrasonic right for your data center?

Key Environmental Criteria:

- Moisture content below the ASHRAE minimum recommendation level will lead to electrostatic discharge (ESD) failures of IT equipment:
    - Compromise equipment reliability
    - Costly system downtime
    - Costly equipment replacement

Key Site Qualification Criteria:

- Review the data center environment conditions
    - Location (dry verses humid environment)
    - Infiltration of outside air (vapor barrier)
    - Design day (worst case dry day < 41.9^{0}F DP)

Humidification Improves Efficiency

Feature	Infrared Humidifier	Ultrasonic
Technology	Infrared	Ultrasonics
Capacity (lbs./hr.)	22	18
Energy Consumption (Watts)	9,600	585
Water Requirements	Non-conditioned city water	Demineralized water using RO and DI
Maintenance Requirements	½ hour to remove mineral buildup in pan	No cleaning of ultrasonic required

Humidification Energy Comparison

Humidification Technology	Number of Humidifiers Required		Watts Consumed		Annual Hours Of Operation		KW/H per year		Cost Per KWH		Annual Cost of Electricity	Annual Savings
Infrared	98	x	9,600	x	3,725	x	3,504,480	x	$0.11	x	$385,493	
Ultrasonic	120	x	585	x	3,725	x	261,495	x	$0.11	x	$28,764	**$356,728**

Free Cooling Energy Savings

	Adiabatic cooling provided (BTU/h)		Total KW/H per year*		Cost Per KWH	Annual Cost of Electricity
Ultrasonic	2,095,200		799,973	x	$0.11	**$87,997**

*KWH based on 1.23 KW/Ton for air cooled chiller

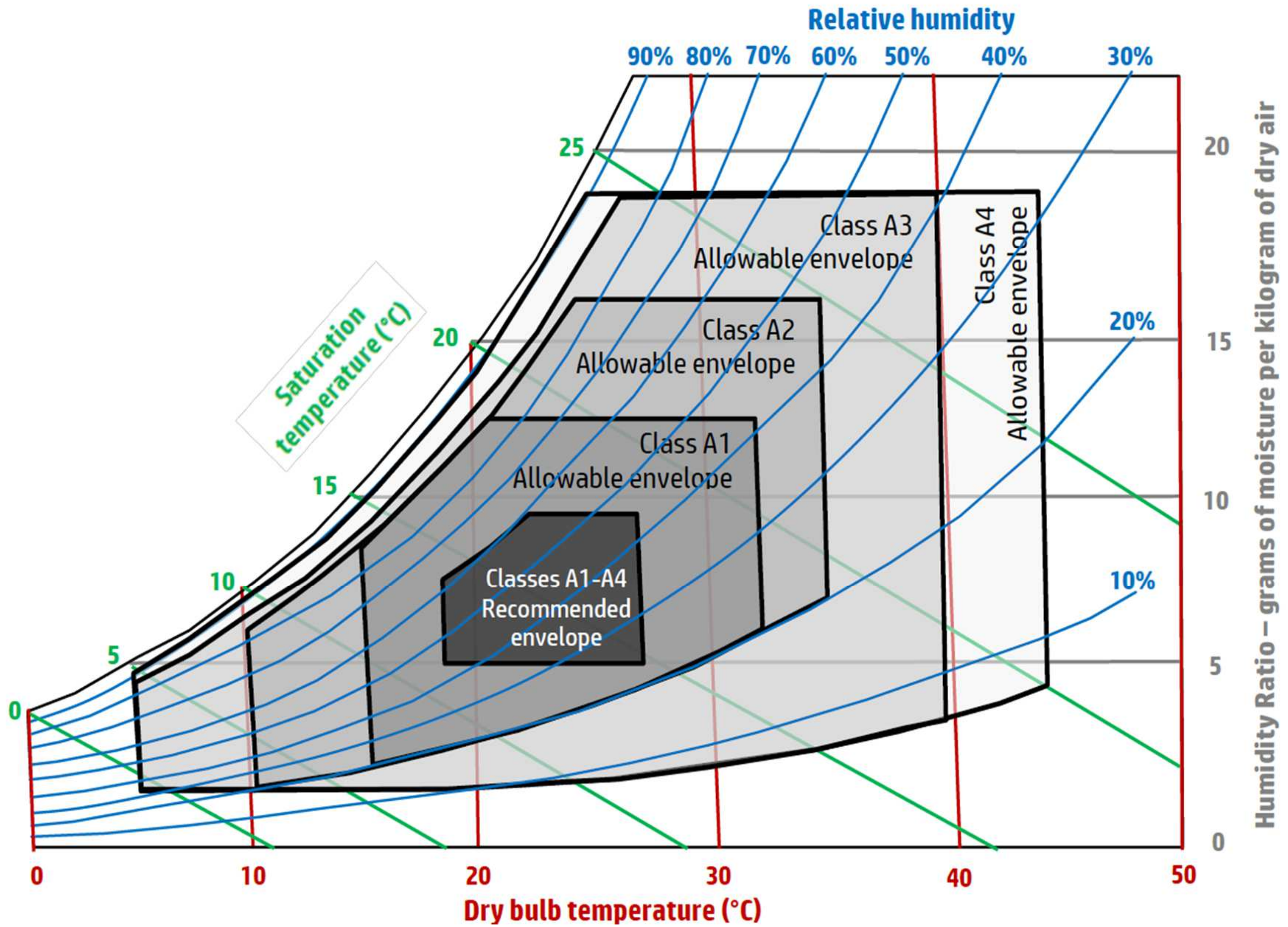
Combined

Humidification and Free Cooling Energy Savings
$444,725

Ultrasonic Humidifier in Space

Economizers Control

Figure 2. This illustration shows the data center recommended and allowed operating envelopes for ASHRAE classes A1 thru A4.



Outdoor Cooling: Modular Container

Outdoor modular container system is designed for conditioning the air in a containerized computer room (POD).

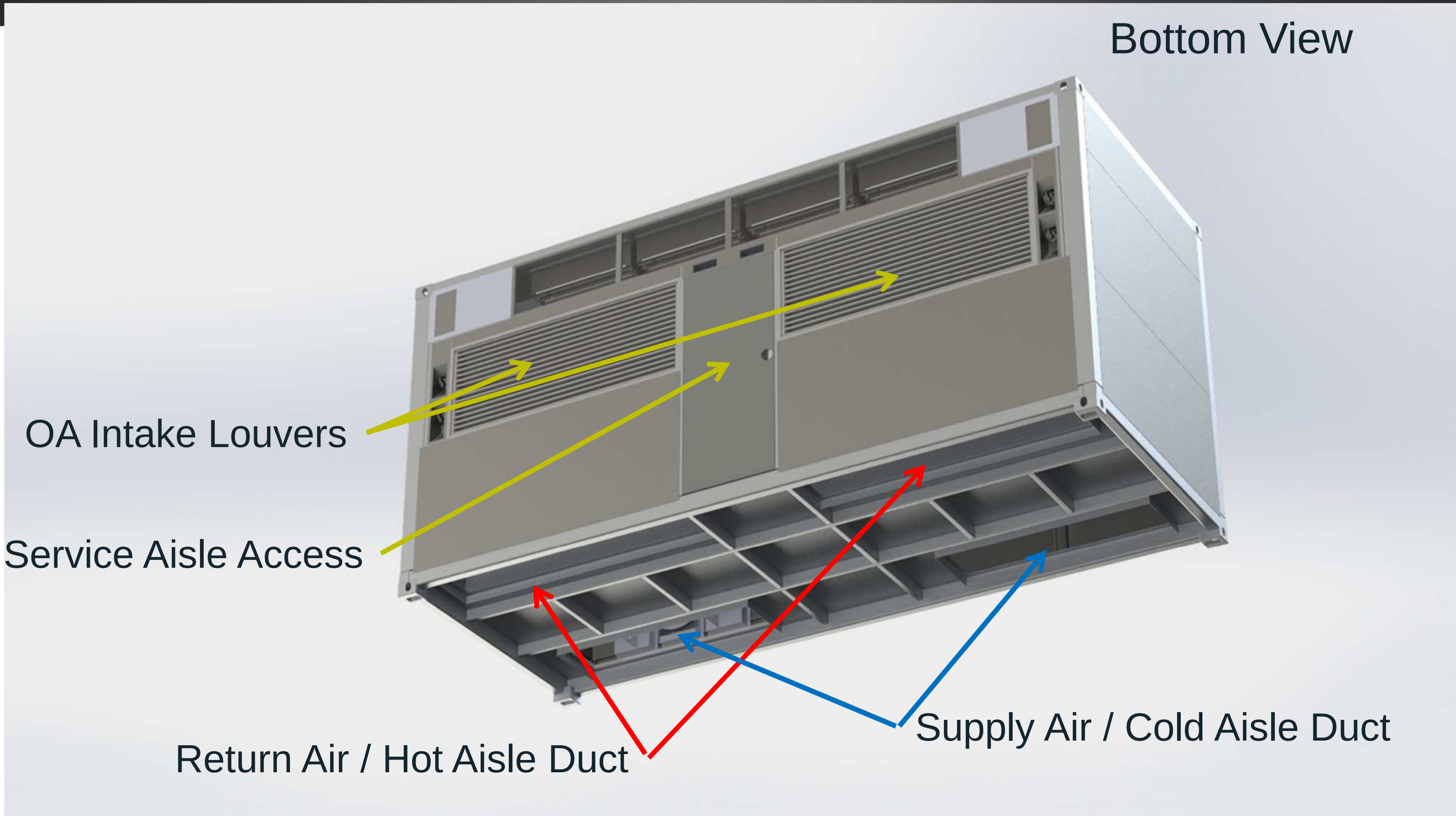
Features and Benefits

- Controller ensures precise operation
    - ✓ Separate control cabinet per integral cooling unit

- ETL & cETL Listed
    - ✓ Compliance with UL 1995 Standards

Outdoor Cooling: Modular Container

Design Principle and Operation

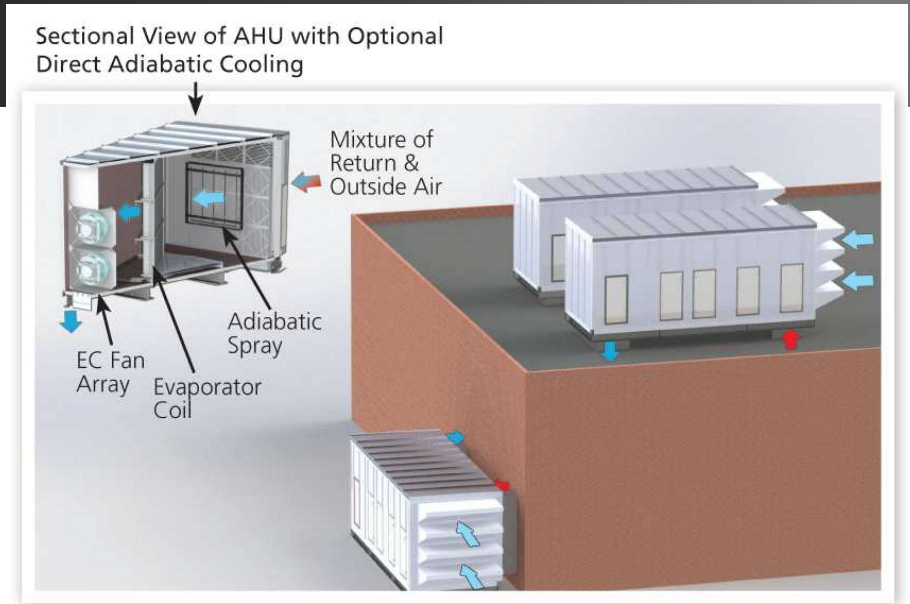


Modular Container Solution: Air-Side Economizers

Allows modular build out of containerized data centers

Owners can increase data center capacity as their demand increases

Air Side Economizers

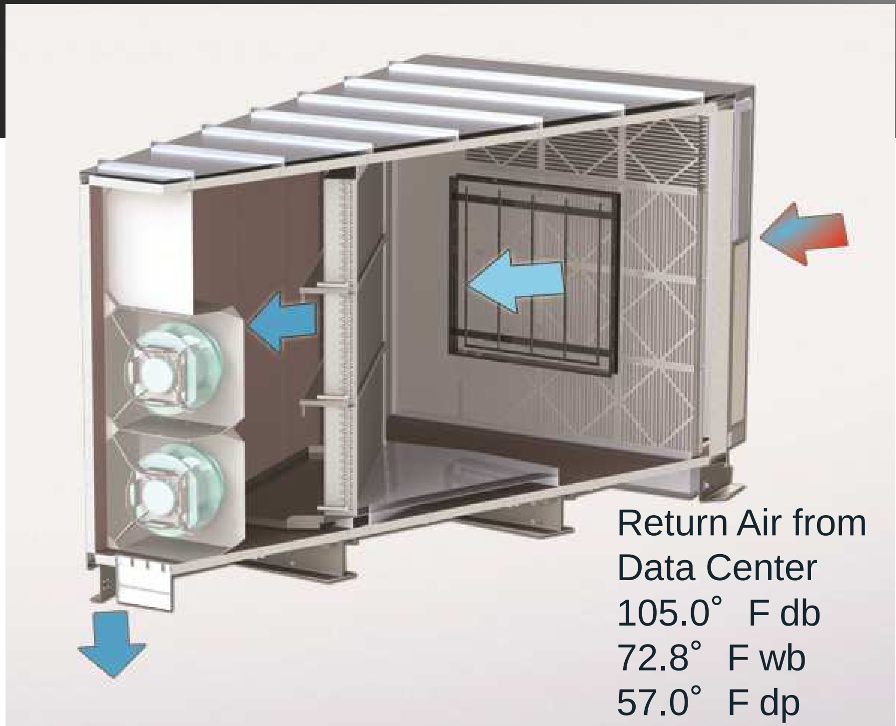


Air Side Economizers - Integrated into Air Handler Unit

Air Handler with an integrated mixing box and damper controls provides free cooling. Can be mounted on top of a building or ducted to the side of a building.

Outside Air & Moisture	Operation
Warmer / High Humidity	Dampers close & the CRAC/CRAH revert to traditional operation
Within Proper Range	Outside air is directly introduced through the dampers in the mixing box
Colder than Desired	Dampers mix outside air & return air to achieve desired temperature

Air Side Economizers



Outside Air
to Air Handler
68.0˚ F db
61.1˚ F wb
57.0˚ F dp

Return Air from
Data Center
105.0˚ F db
72.8˚ F wb
57.0˚ F dp

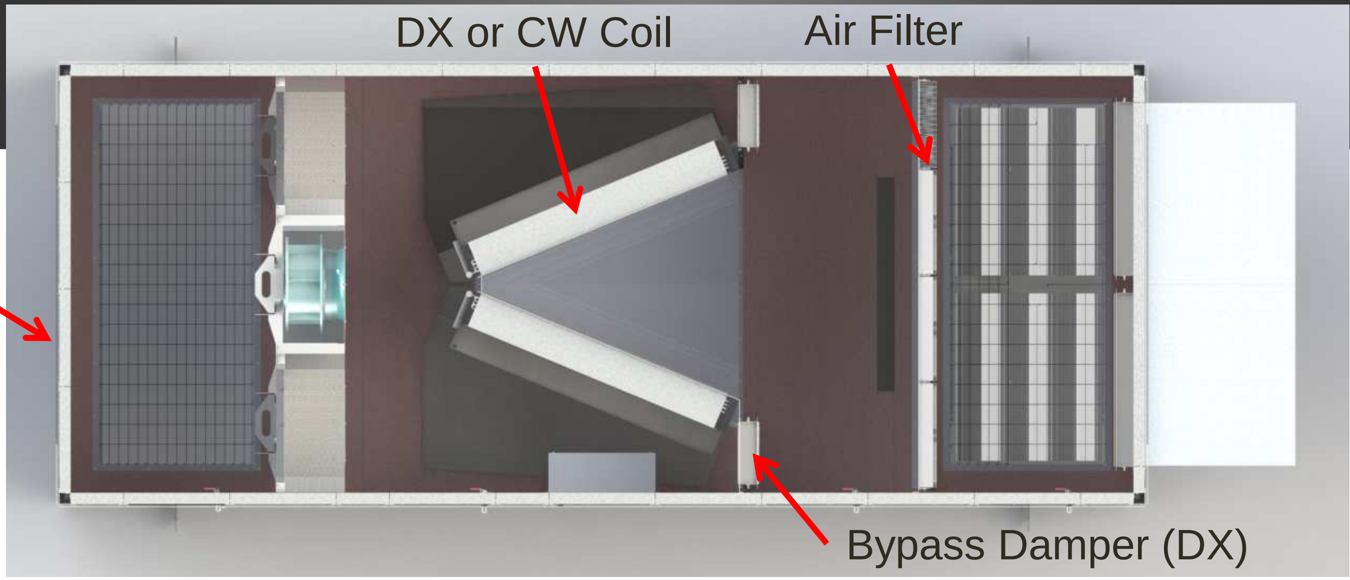
Supply Air to
Data Center
69.1˚ F db
61.5˚ F wb
57.0˚ F dp

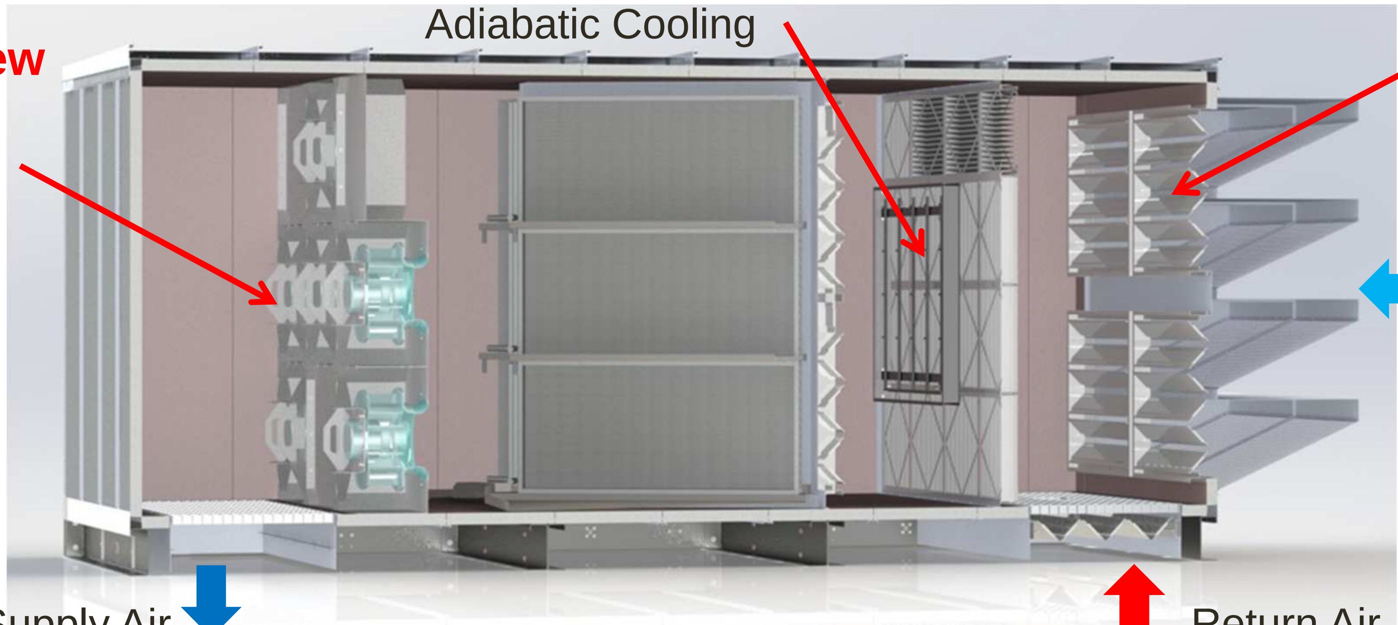
Air Side Economizer
- Integrated into Container or Air Handler

Air side economizer with direct adiabatic cooling provides the lowest possible energy consumption

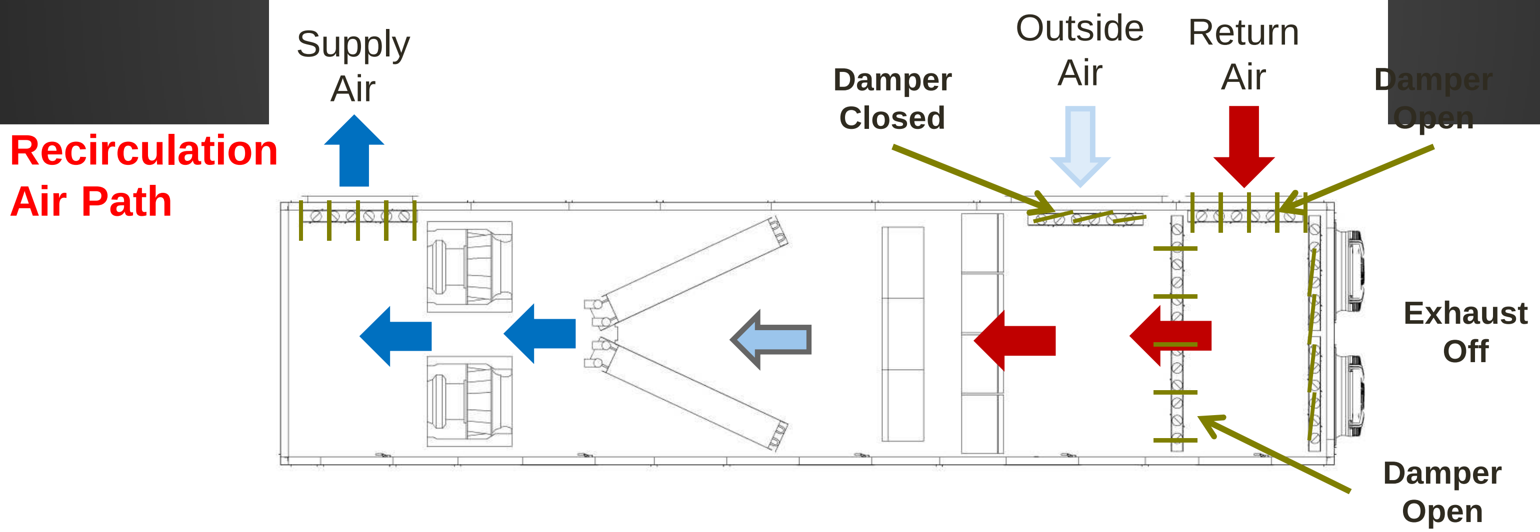
68℉ Outside Air 105℉ Return Air 69.1℉ Supply Air	DX Cooling Only	Air-Side Economizer and DX for Trim	Air-Side Economizer, Direct Adiabatic Cooling, and DX for Trim
Power Required	123.5 kW	83.4 kW	67.7 kW
Energy Savings	0 kW	40.1 kW (32%)	55.8 kW (45%)

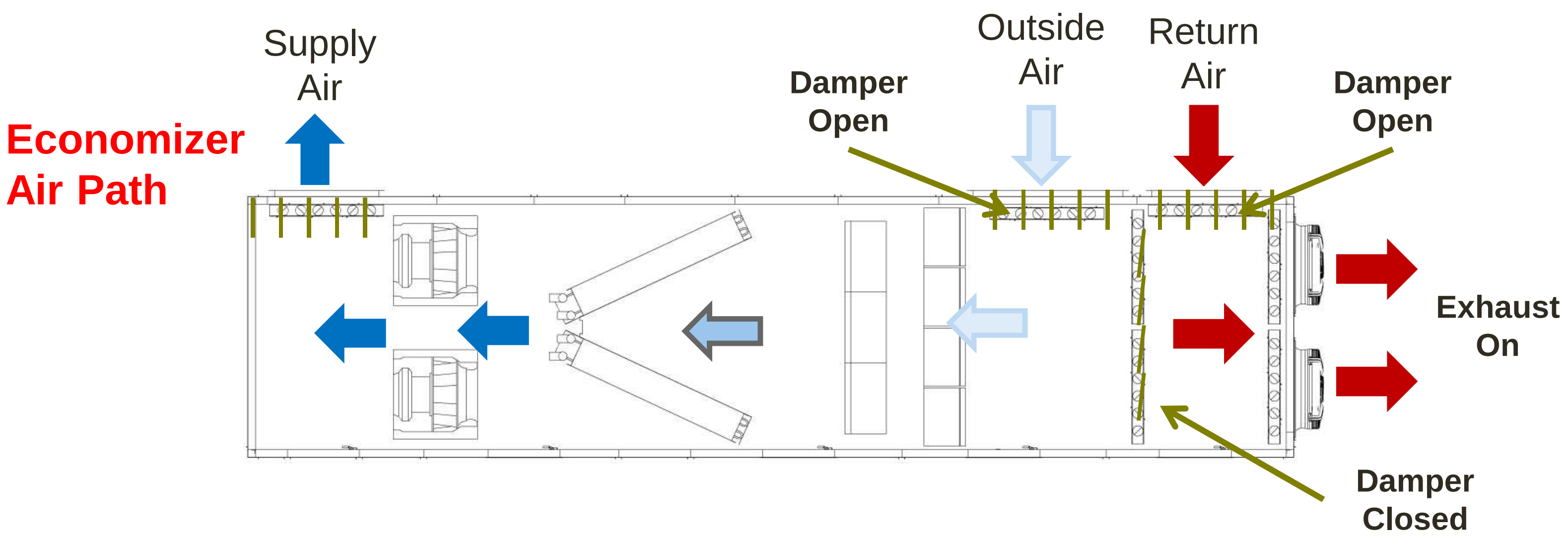
Air Handler Solution



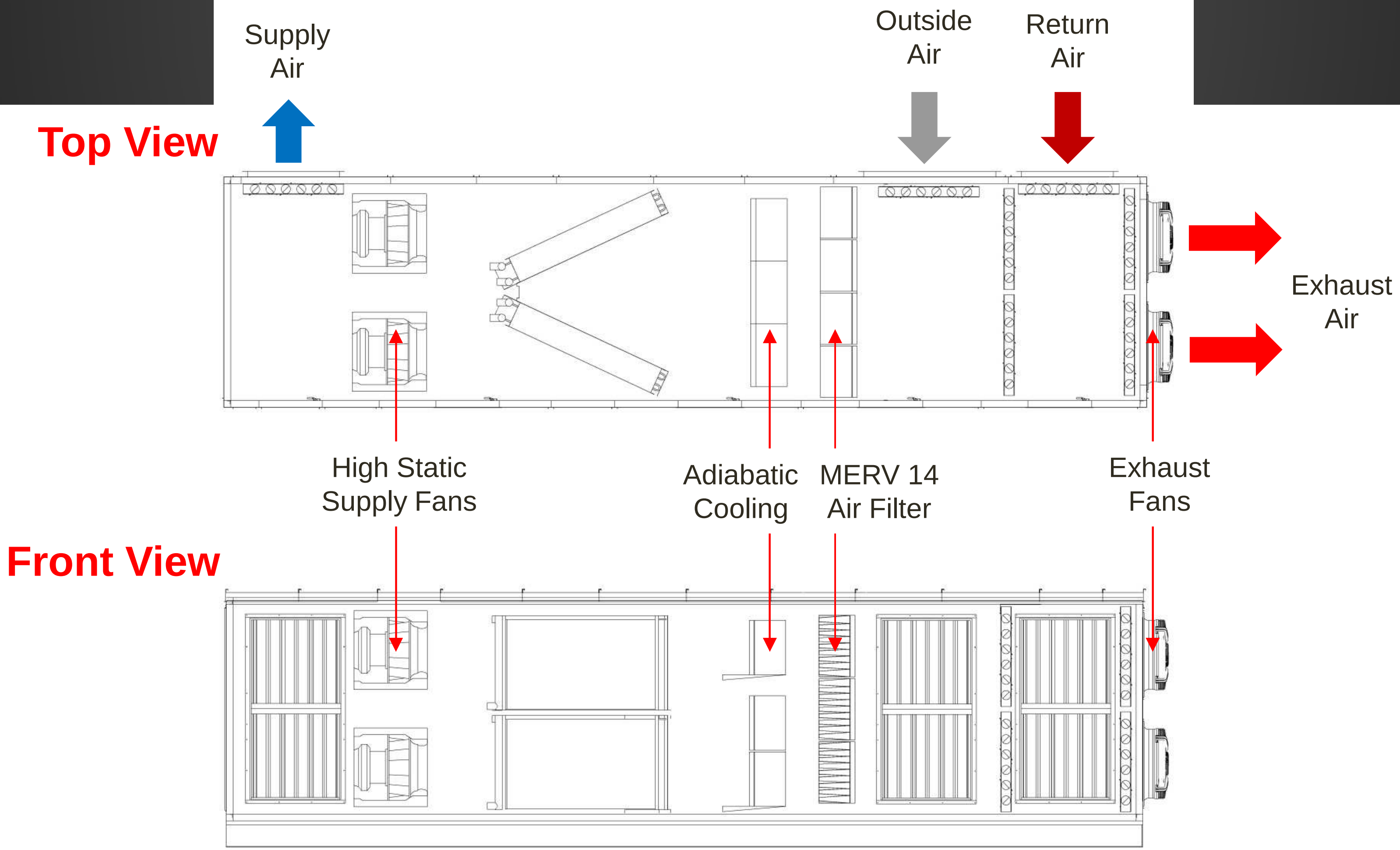


Air Handler Solution – Air Paths





Air Handler Solution



Direct Adiabatic Cooling - Operation

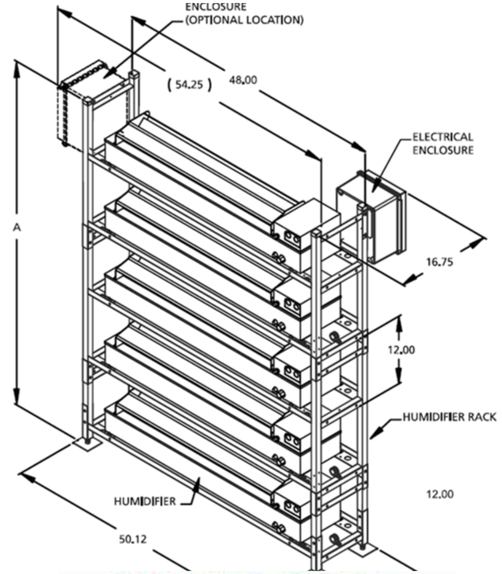
- Direct adiabatic cooling systems introduce water for evaporation directly into the supply airstream

- Direct adiabatic cooling options:
  1. Using Ultrasonic Humidifier
  2. Using an adiabatic pad
  3. Using a high pressure spray system

- Integrated controls monitor conditions to prevent over-humidifying

- Direct adiabatic cooling utilized with an air-side economizer provides the lowest possible energy consumption.

Ultrasonic Humidifier on Mounting Racks

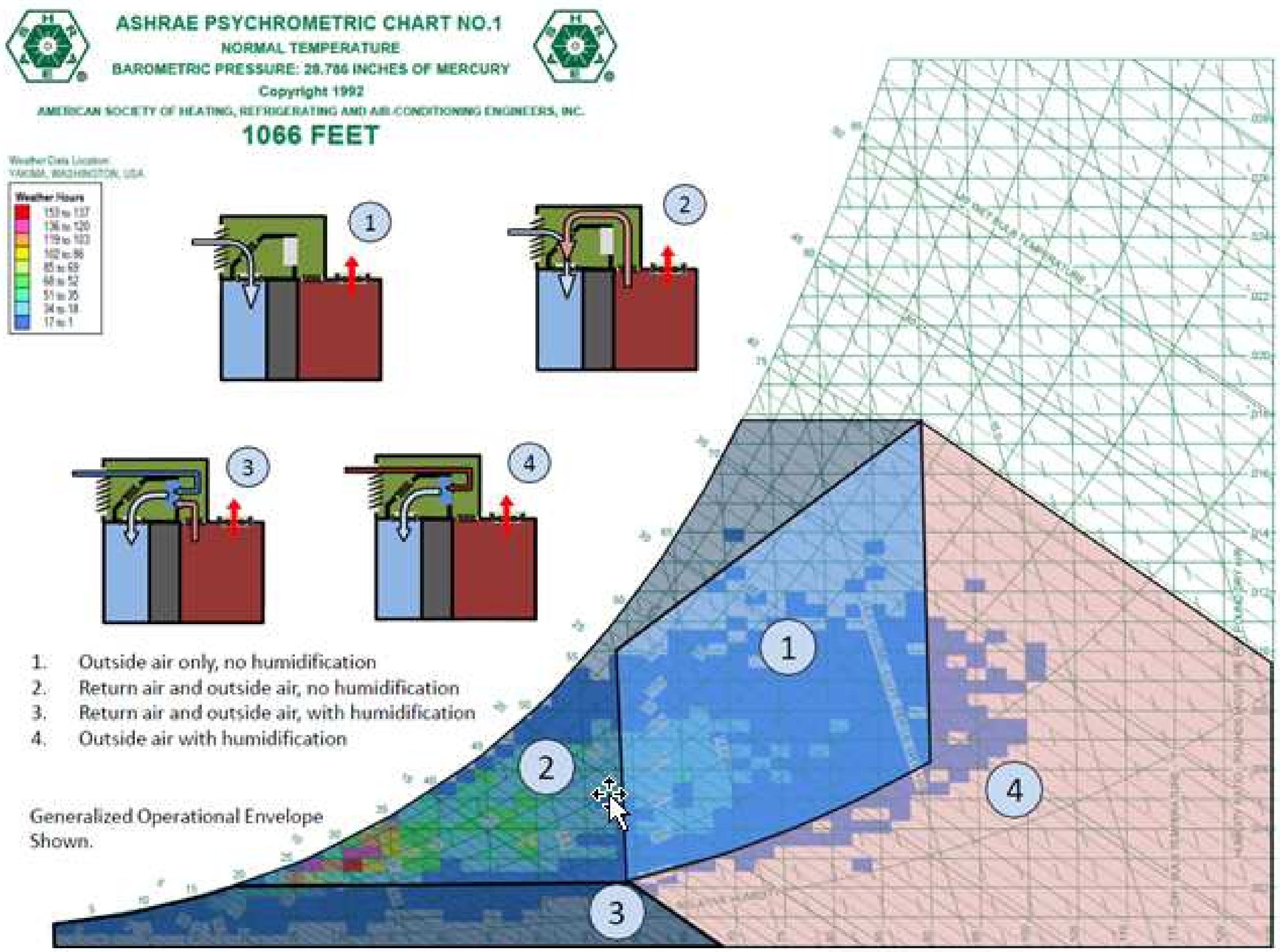


Non-Mechanical Cooling Solution

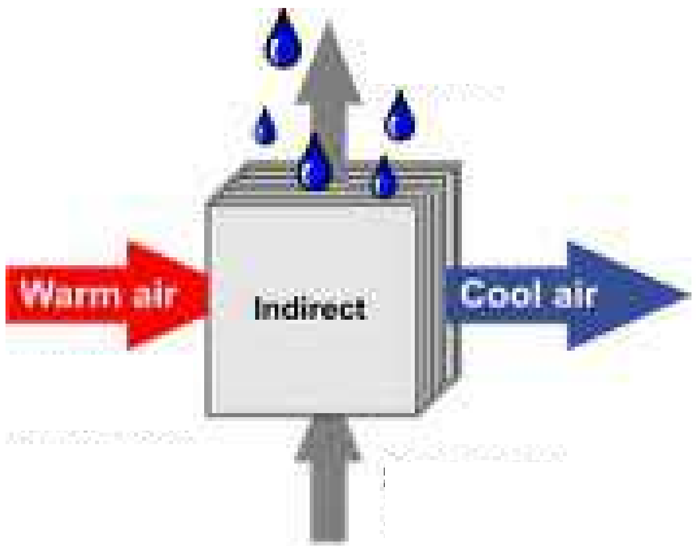
Outdoor Direct Adiabatic Cooling Unit

- Evaporative Pad
    - non-recirculating water (no pump, no filter)
    - minimal water waste (precise absorption control)
- Air-Side Economizer with mixing dampers

Cooling Solutions



Indirect Adiabatic Cooling



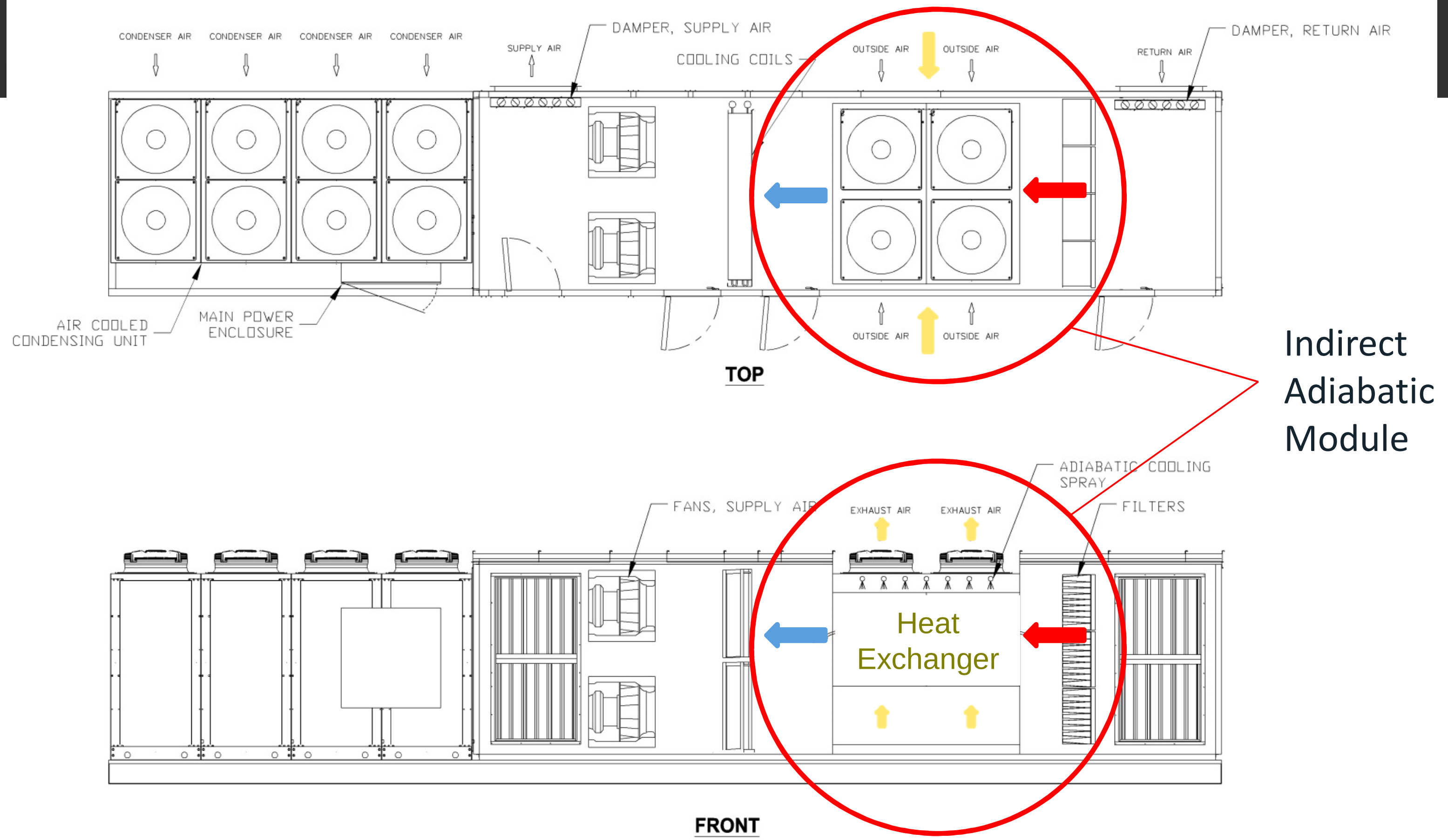
Indirect Adiabatic Module

1. Return air flows through the heat exchanger
2. Outside air flows through the heat exchanger
3. Liquid water is introduced to the heat exchanger to reduce the temperature of the outside air
    1. Evaporation takes place on the heat exchanger
    2. Water evaporates into the outside air stream
4. Return air is cooled through the heat exchanger
    1. No mixing of outside air and return air

Energy Efficiency Example

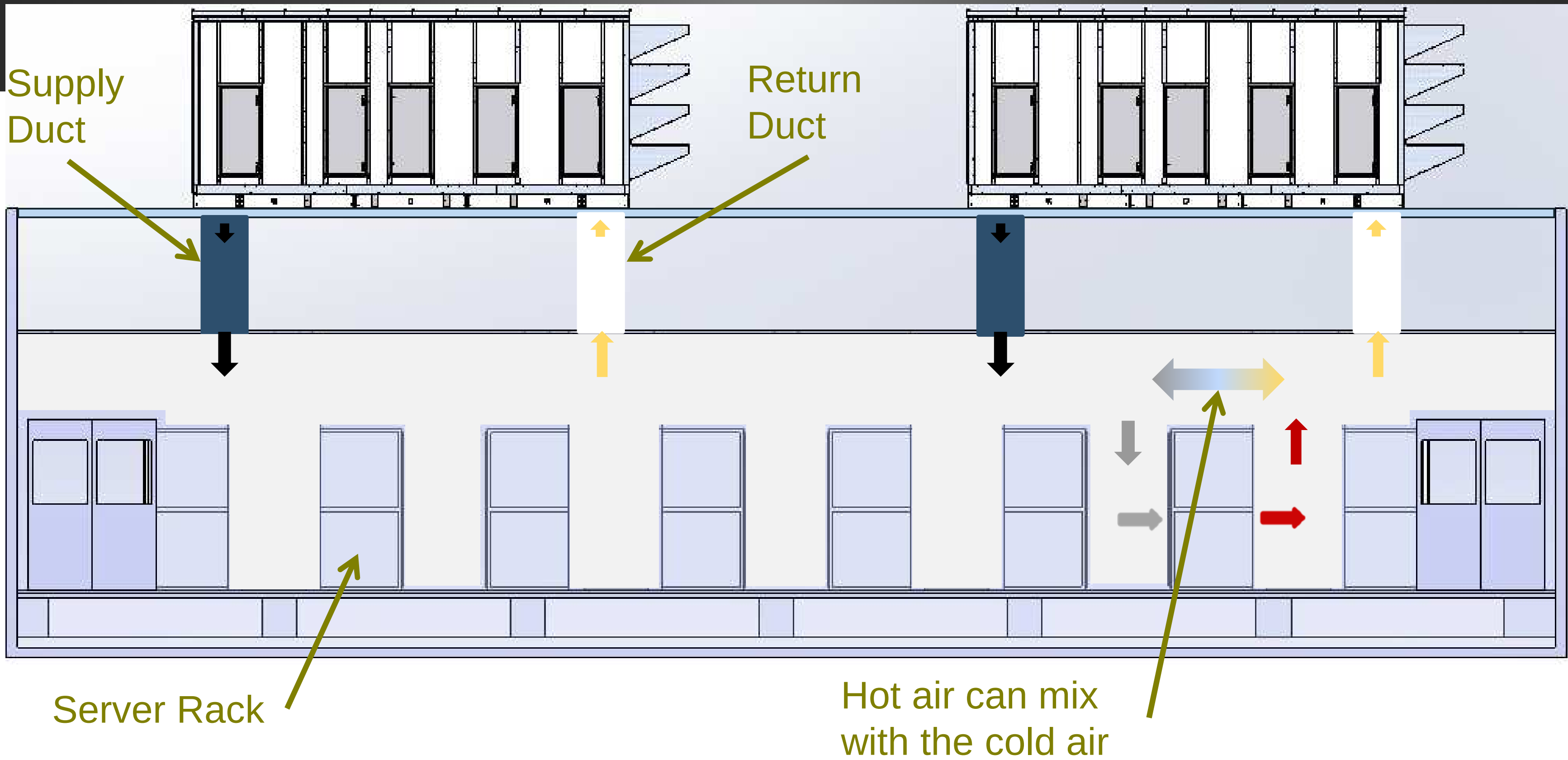
- Starting DP temp 86° F and WB temp 66° F (20° F delta)
- Possible temperature drop of 14° F
- The > the difference between the WB and DB temp's, the > the achievable temperature reduction

Air Handler with Indirect Adiabatic



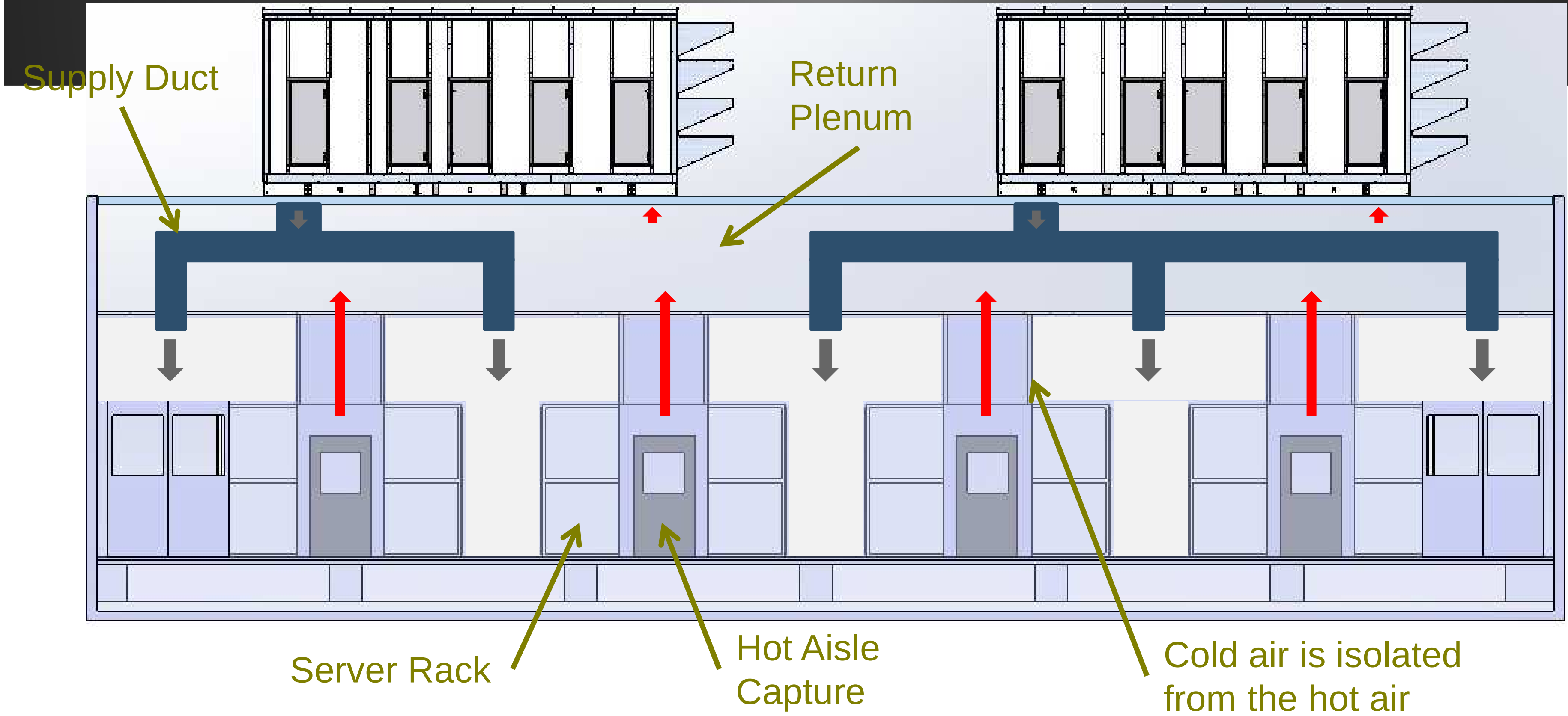
- When outside air conditions are favorable, the indirect evaporative system is active
- On cooler days, the system can be used without evaporation as an air-to-air heat exchanger
- When outside air temperature or humidity level are not favorable for free cooling, then
  - Turn off water to heat exchanger
  - Turn off heat exchanger exhaust fans - to prevent heating of the return air

Air Handler Solution - Traditional



- Open data center designs allow hot return air to mix with cold supply air
- This mixed air surrounds the server racks, and is then used as the control point
- This results in lower return air temperature and requires lower supply air temperatures
- Latent cooling is often a result of lower supply/return temperatures

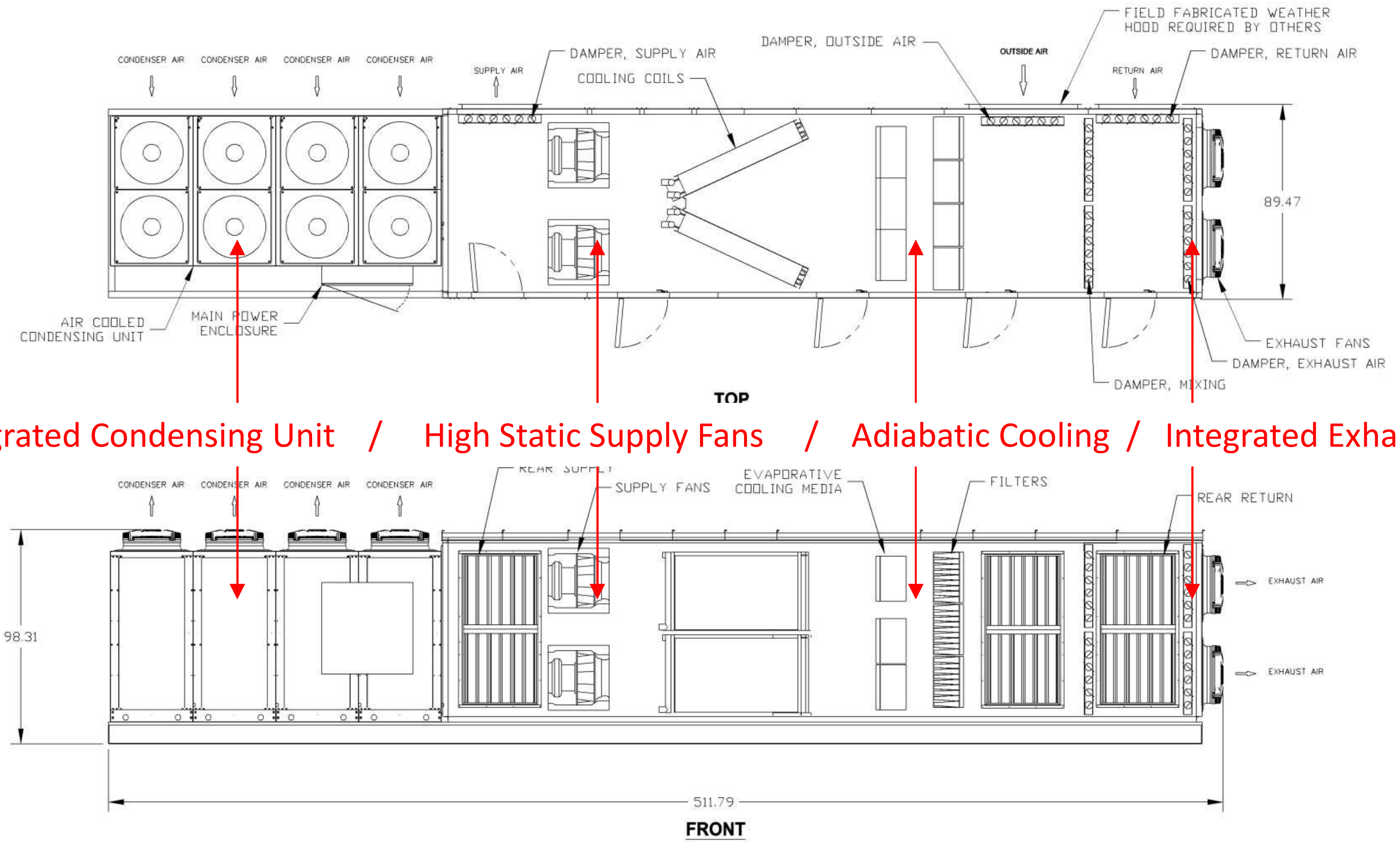
Air Handler Solution



- Isolating cold supply air from hot return air prevents mixing of the air streams and short-cycling
- All cold supply air is used for cooling; all hot air goes back to the AHU return (or is exhausted)
- Supply air temperature can be used as the control point (no mixing of hot and cold air)
- Higher supply temperatures and higher return temperatures can be utilized
- The cooling equipment operates at higher efficiency with greater capacity

Pre-Engineered AHU's

Design to optimize to be shorter and narrower
Allows for international shipping inside a shipping container



Air Handler Development

has over 20 years of experience designing and building air handling equipment
has the ability to meet customer application-specific requirements

Utility Rebates Further Improve ROI

Utility Rebates Further Improve ROI

- Many utility companies are running out of capacity
- Most utility companies are offering incentive programs for:
  - Retrofitting existing cooling equipment
  - Replacing cooling equipment
  - Installing new energy efficient cooling equipment

Key Takeaways

Optimizes the Reliability and Efficiency of POD Cooling

1. State-of-the-art row and perimeter cooling equipment for POD applications
2. Enhances reliability & efficiency of cooling equipment
    1. ASHRAE TC9.9: hotter return air increases efficiency
    2. ASHRAE 90.1: water side economizers increase efficiency
    3. Controls: matching cooling to IT load increases efficiency

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