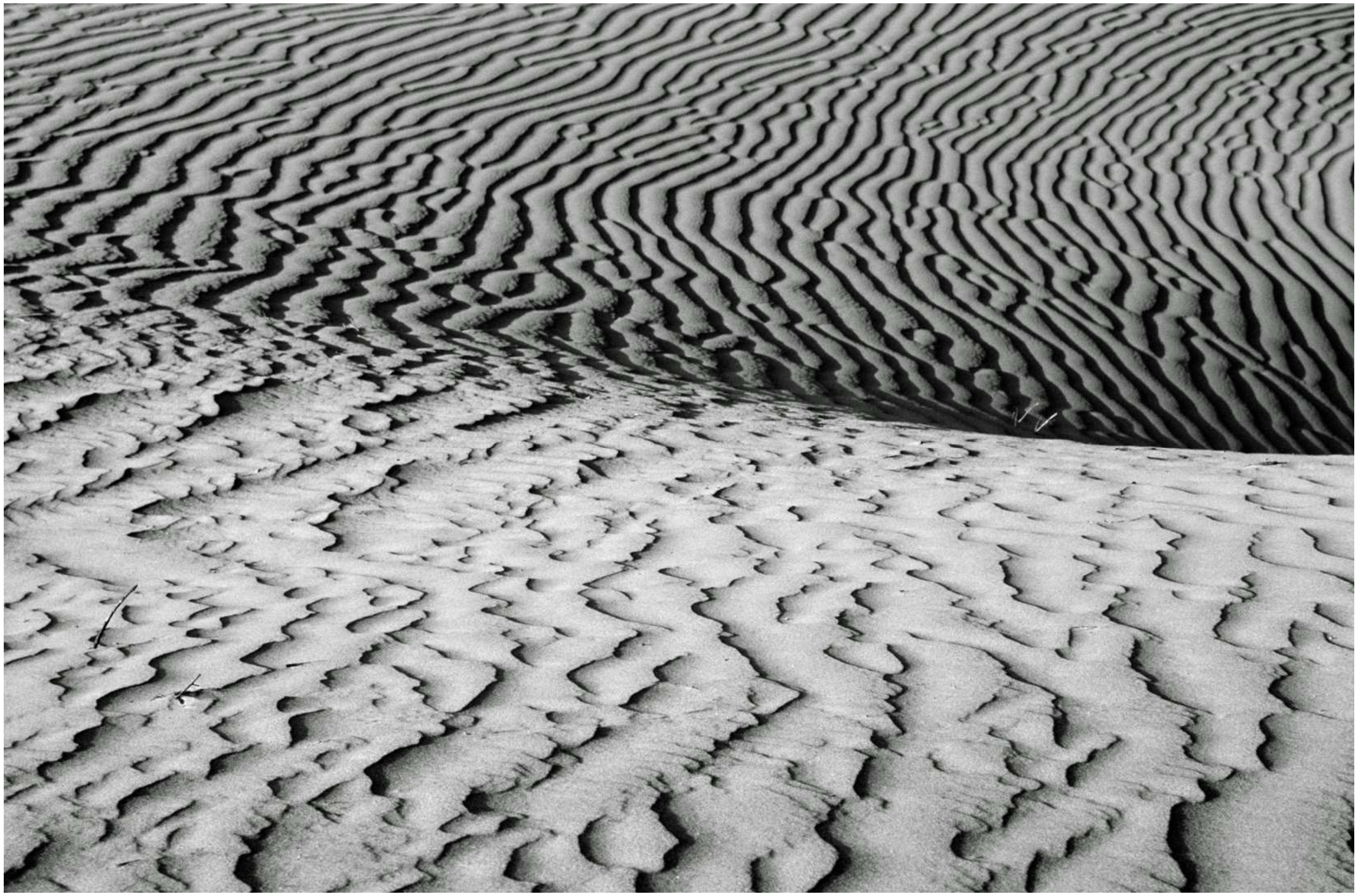
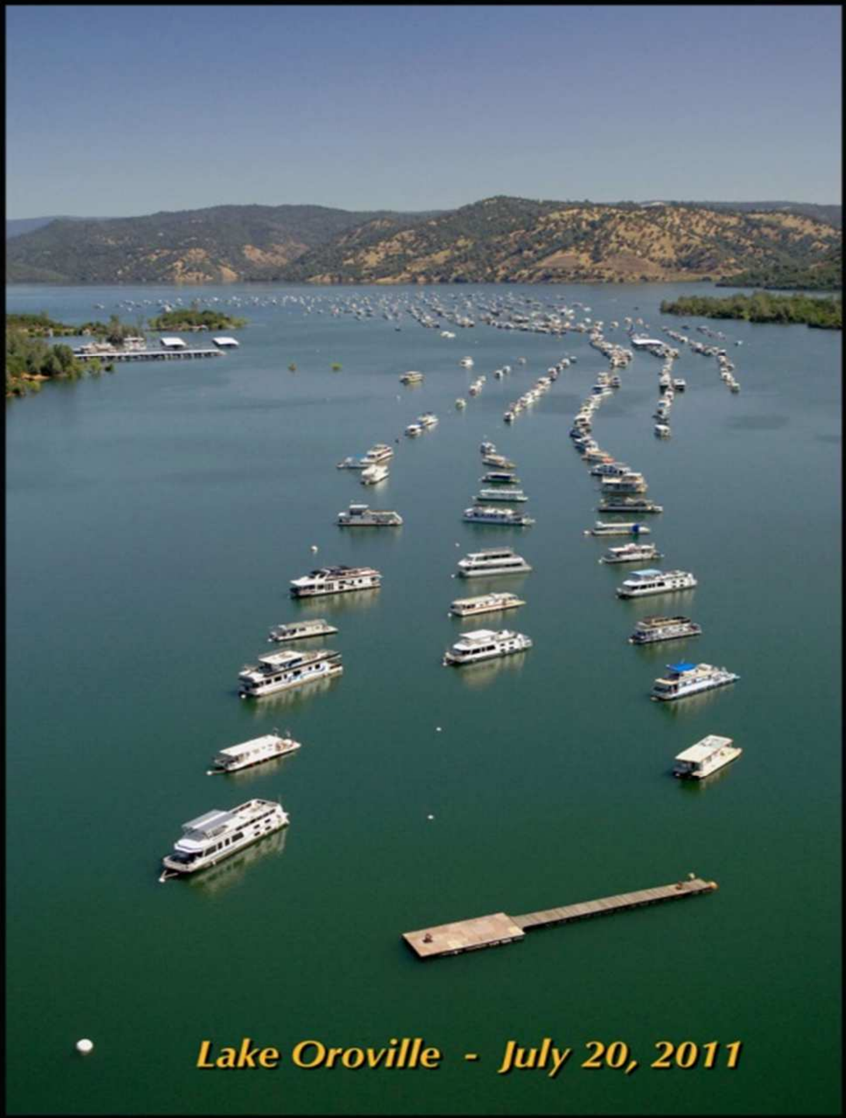


Einar K. Frobom, PE MBA
National Sales Manager
October 13, 2016
einar.frobom@munters.com

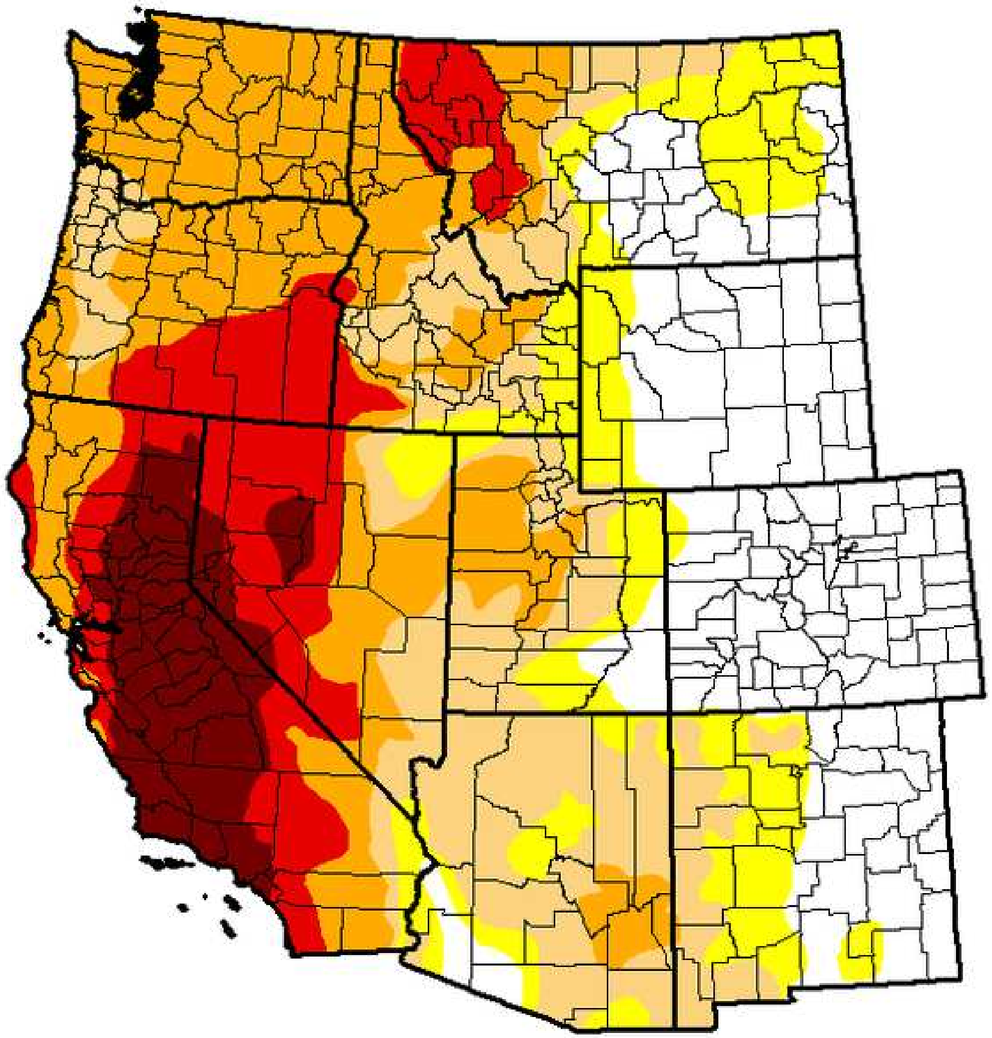
Munters


Lake Oroville - July 20, 2011


Lake Oroville - September 5, 2014

U.S. Drought Monitor

West



July 21, 2015

(Released Thursday, Jul. 23, 2015)

Valid 8 a.m. EDT

Drought Conditions (Percent Area)

	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	25.49	74.51	61.04	41.92	18.87	7.17
Last Week 7/14/2015	25.49	74.51	61.37	43.76	18.87	7.17
3 Months Ago 4/21/2015	28.21	71.79	61.51	37.95	17.19	7.95
Start of Calendar Year 12/30/2014	34.76	65.24	54.48	33.50	18.68	5.40
Start of Water Year 9/30/2014	31.48	68.52	55.57	35.65	19.95	8.90
One Year Ago 7/22/2014	27.30	72.70	60.66	47.17	23.19	6.02

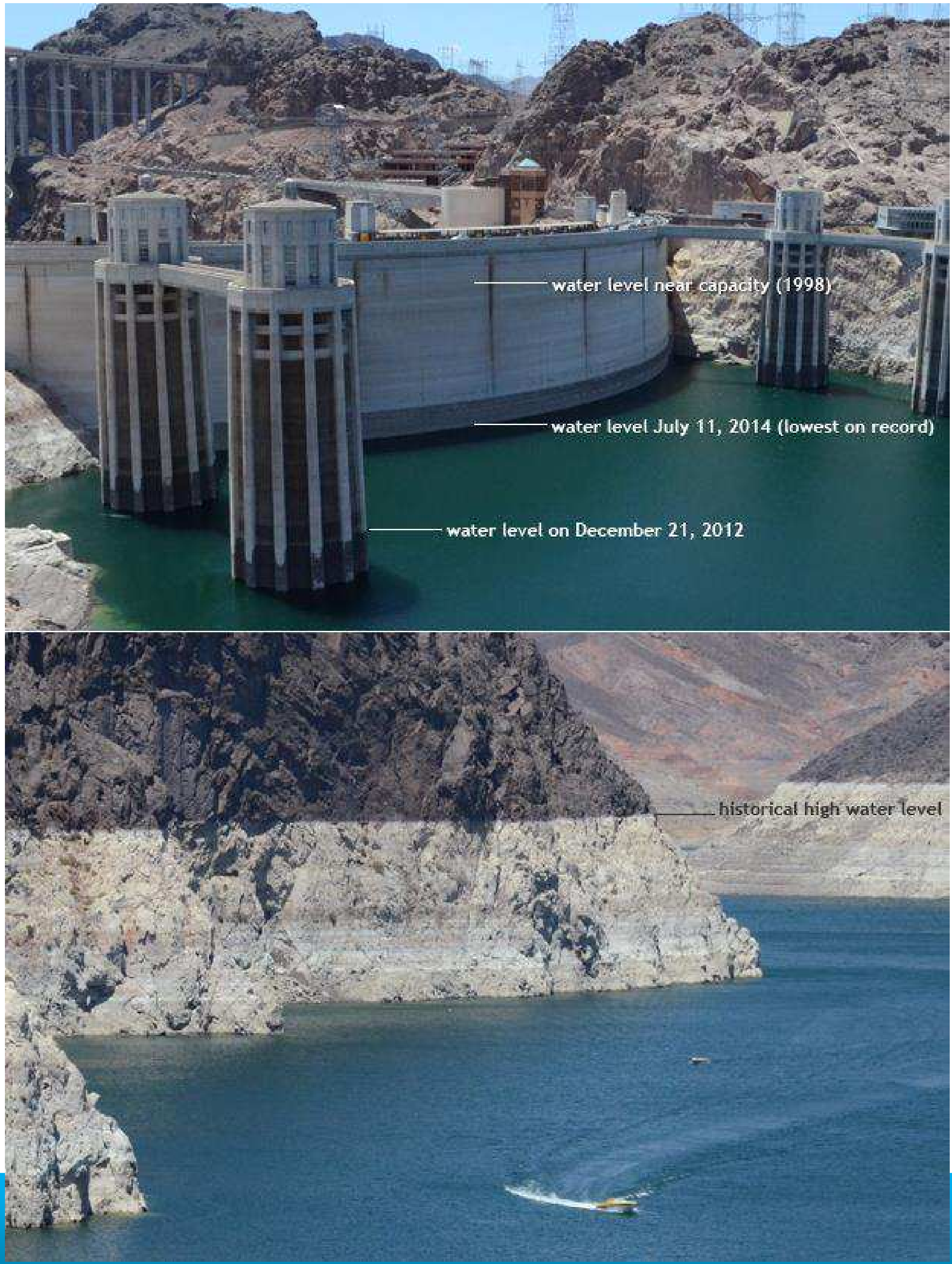
Intensity:

- D0 Abnormally Dry
- D1 Moderate Drought
- D2 Severe Drought
- D3 Extreme Drought
- D4 Exceptional Drought

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

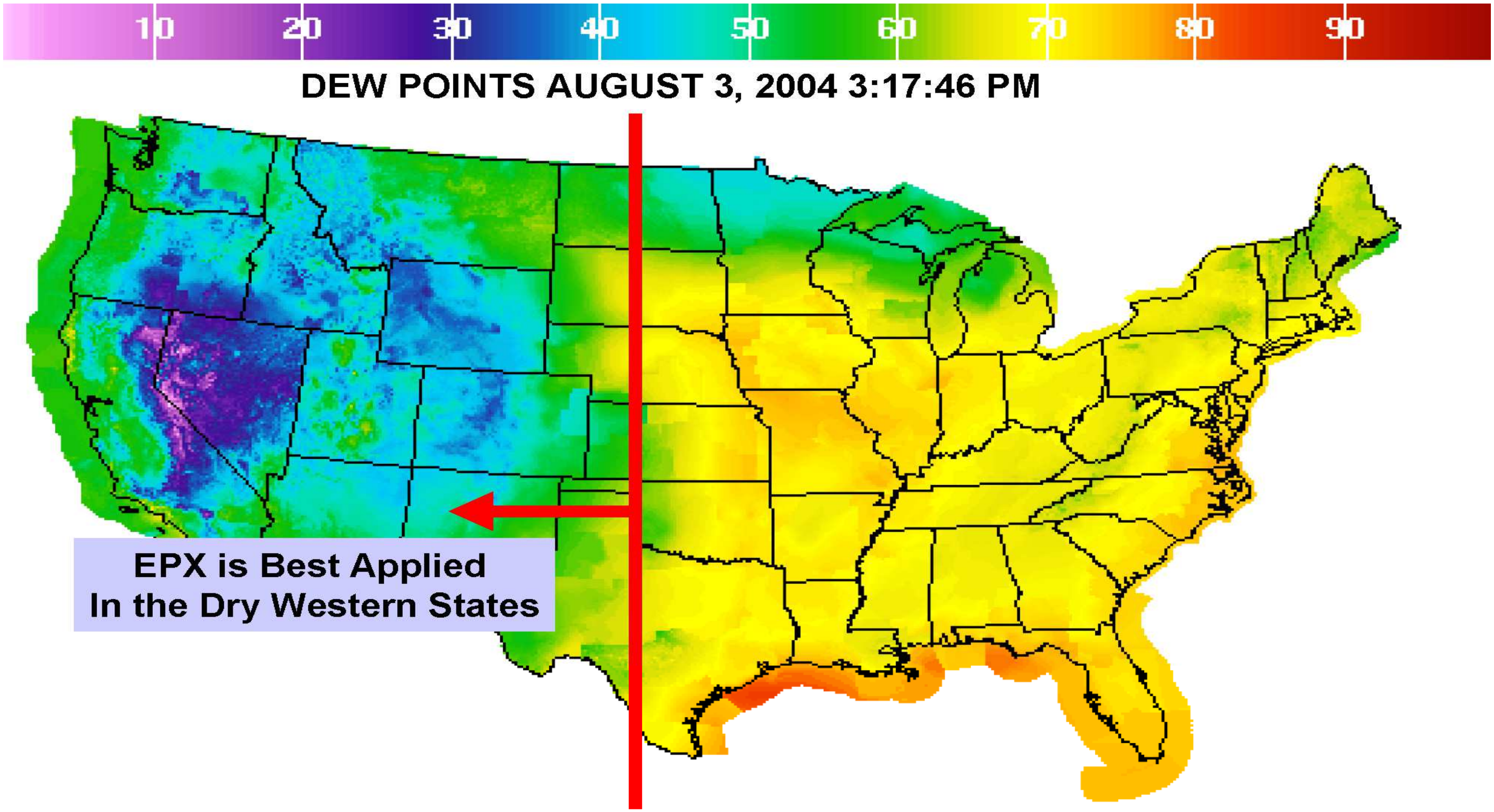
Author:
David Simeral
Western Regional Climate Center

http://droughtmonitor.unl.edu/


water level near capacity (1998)
water level July 11, 2014 (lowest on record)
water level on December 21, 2012
historical high water level

Take aways – Three points

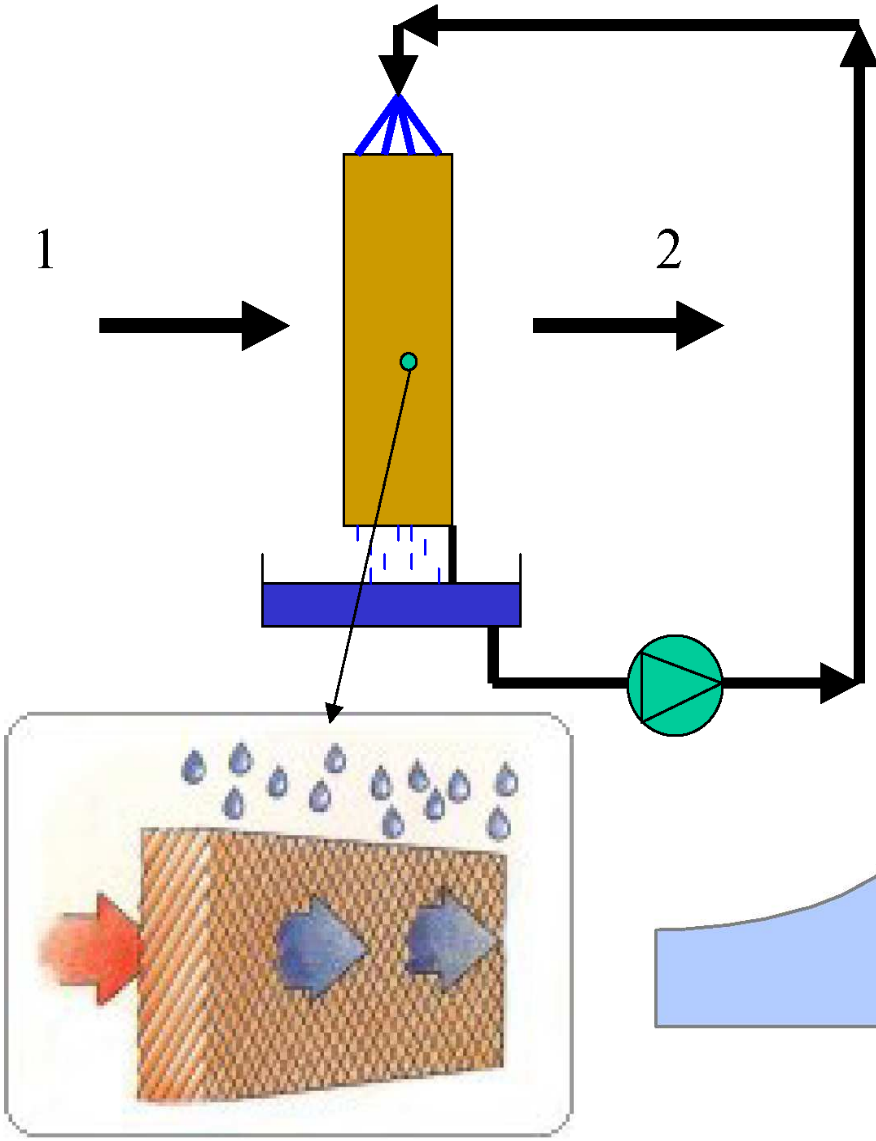
- Use and application of, IEC/DEC + DX – even in some applications not necessarily of typical acceptance
- Efficiency of using IDEC
- H_2O use vs drought



Dewpoint Temperature(F) For Tue Aug 03 2004 5PM EDT
(Tue Aug 03 2004 21Z)

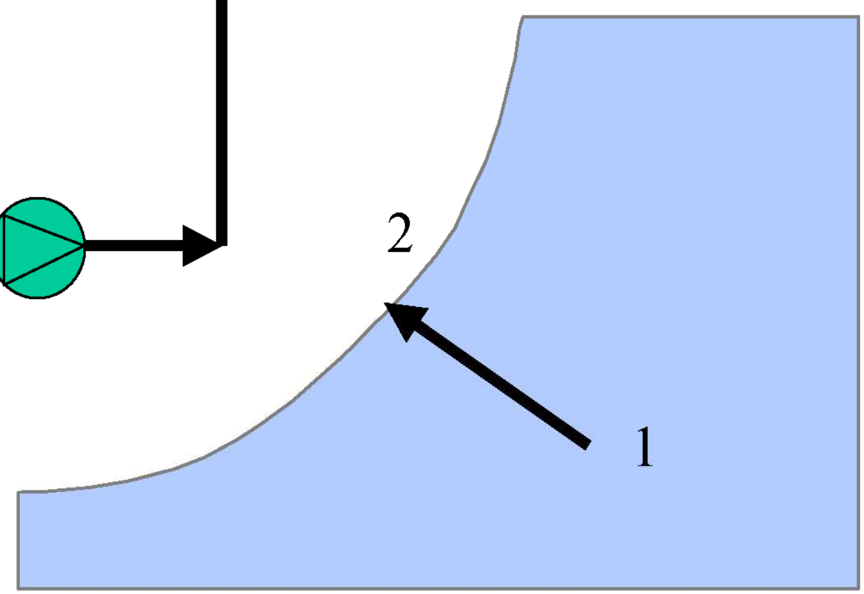
National Digital Forecast Database

Experimental graphic created 08/03/2004 11:26AM EDT



DIRECT EVAPORATIVE COOLING … A CONSTANT WET BULB PROCESS

HUMIDIFIES AND COOLS



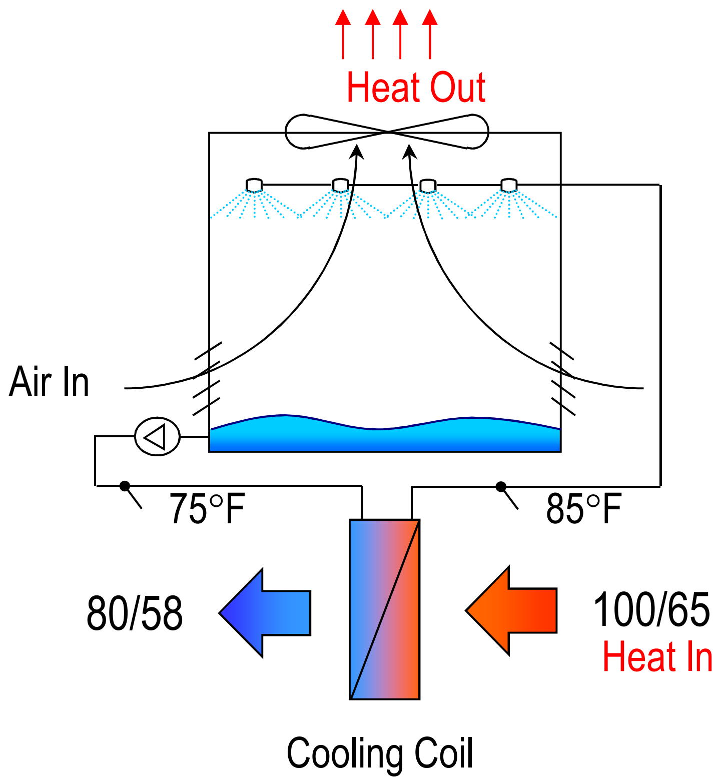
Additional Benefits of Evap Cooling with Media

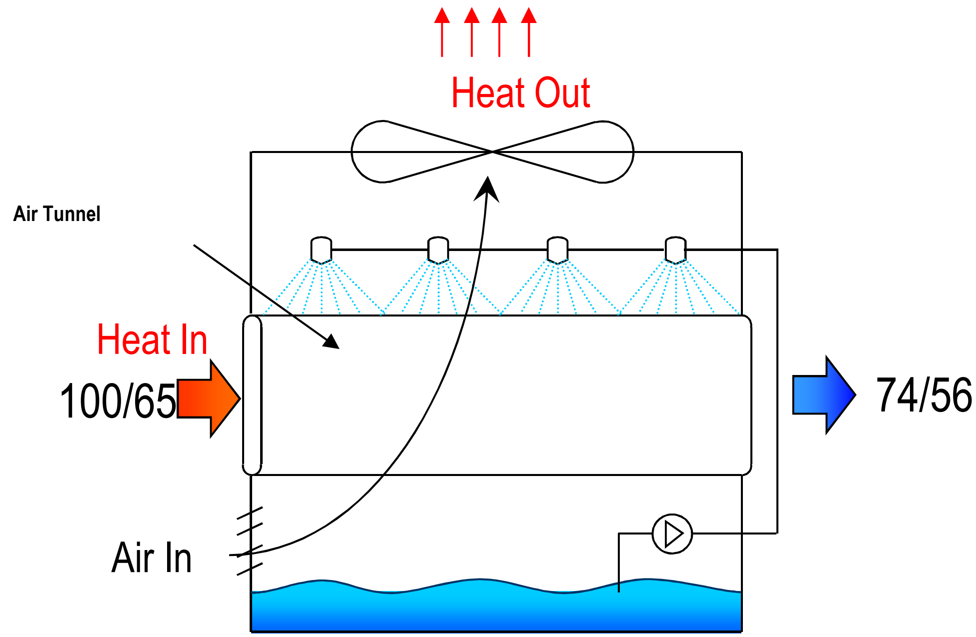
- Sound Attenuation – Notable noise level reduction even in lower frequencies.
- Particulate Removal – “Dust spot efficiency” of 16. Higher efficiencies possible for particle sizes 5-10 microns.
- Humidity control in arid regions

Indirect Evaporative Cooling = IEC or IDEC

- Not a new technology
- First recorded use was in the thirties and used cooling tower and coils
- First use with the Integral Heat Exchanger/Cooling Tower was in 1975 and it was then that the term “Indirect Evaporative Cooling” was coined
- From 1975 to 1985 IEC was used but a lot of projects failed because of poor designs

Indirect Evaporative Cooler (IEC)
Cooling Tower Analogy





Cooling Tower to Cooling Coil IEC

Heat Load enters water loop and is rejected at CT

EPX Indirect Evaporative Cooler

Heat Load enters water and air directly within CT

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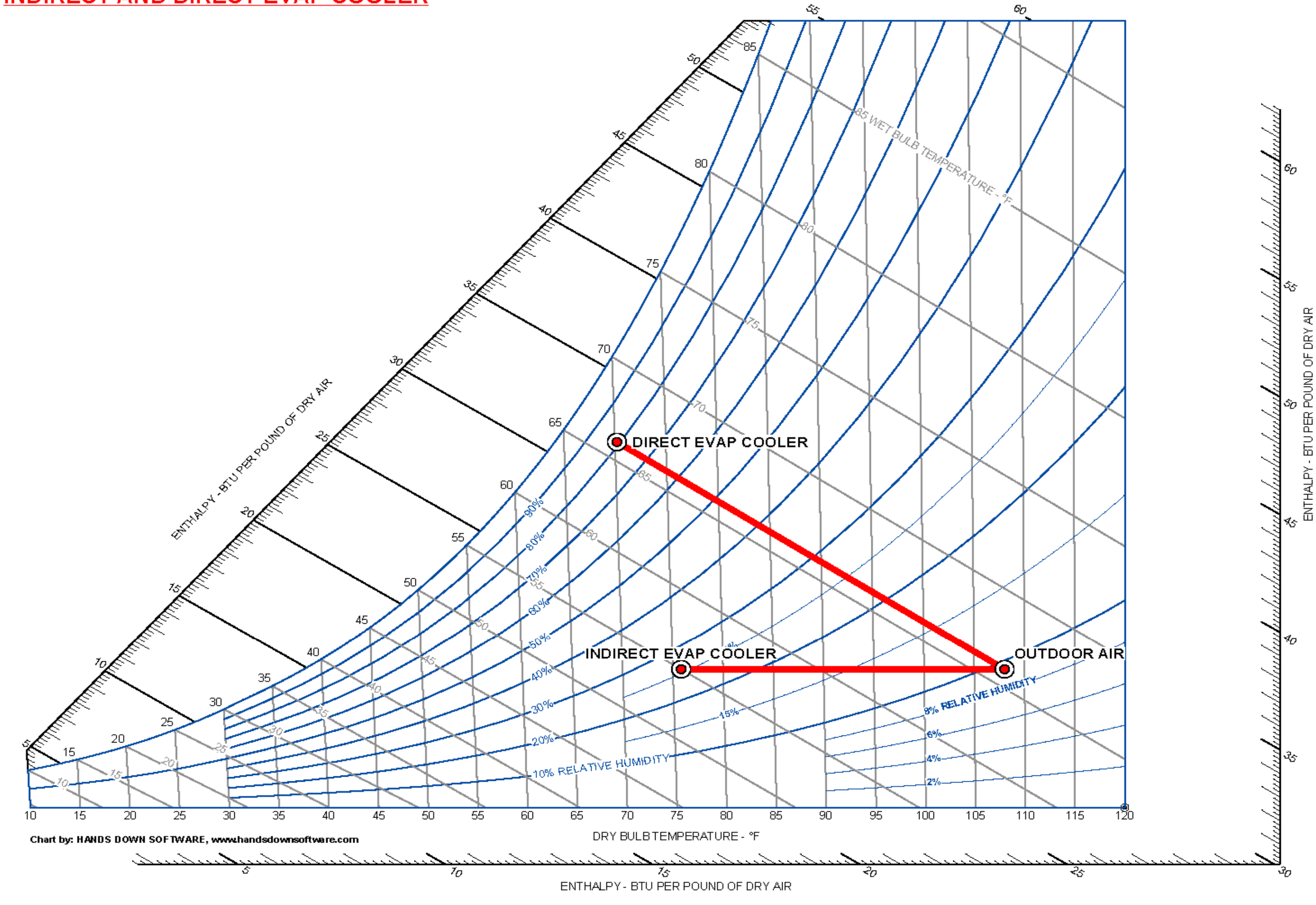
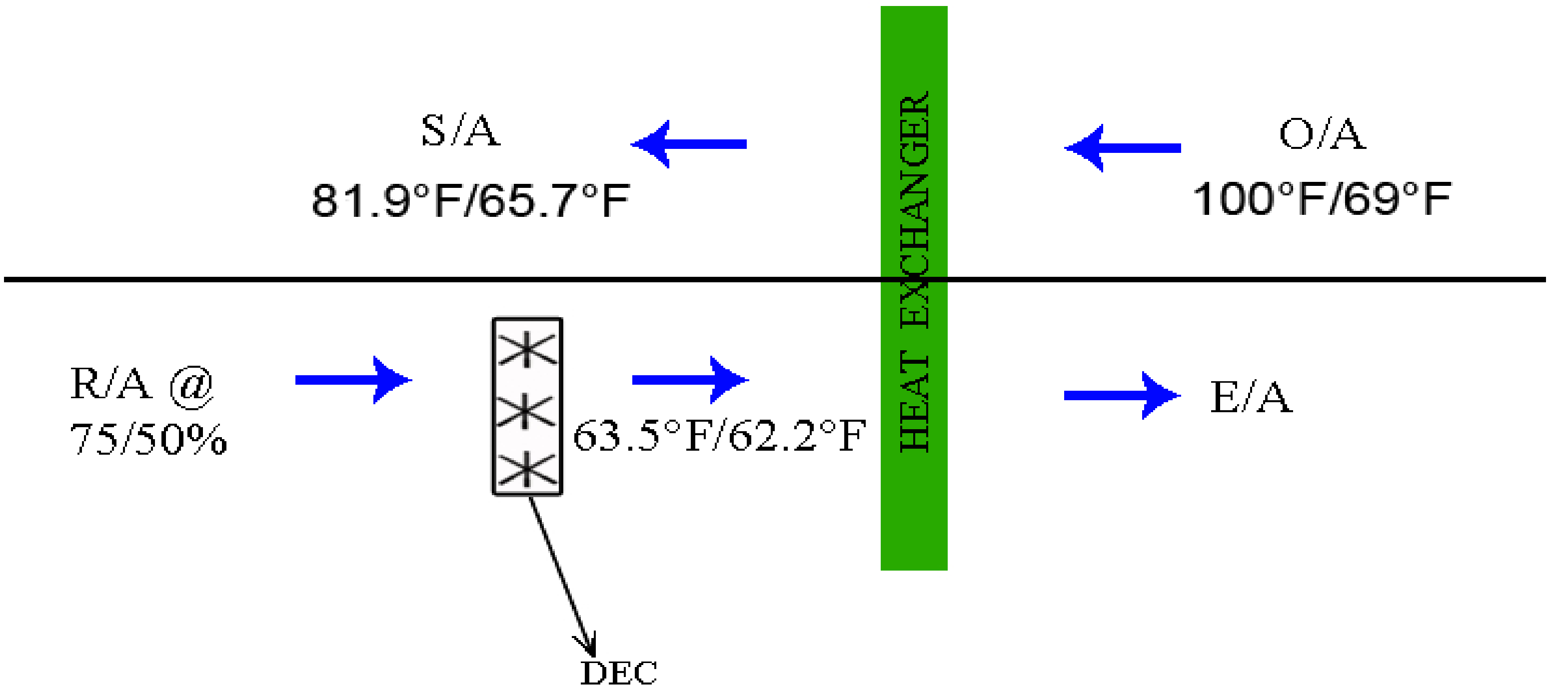
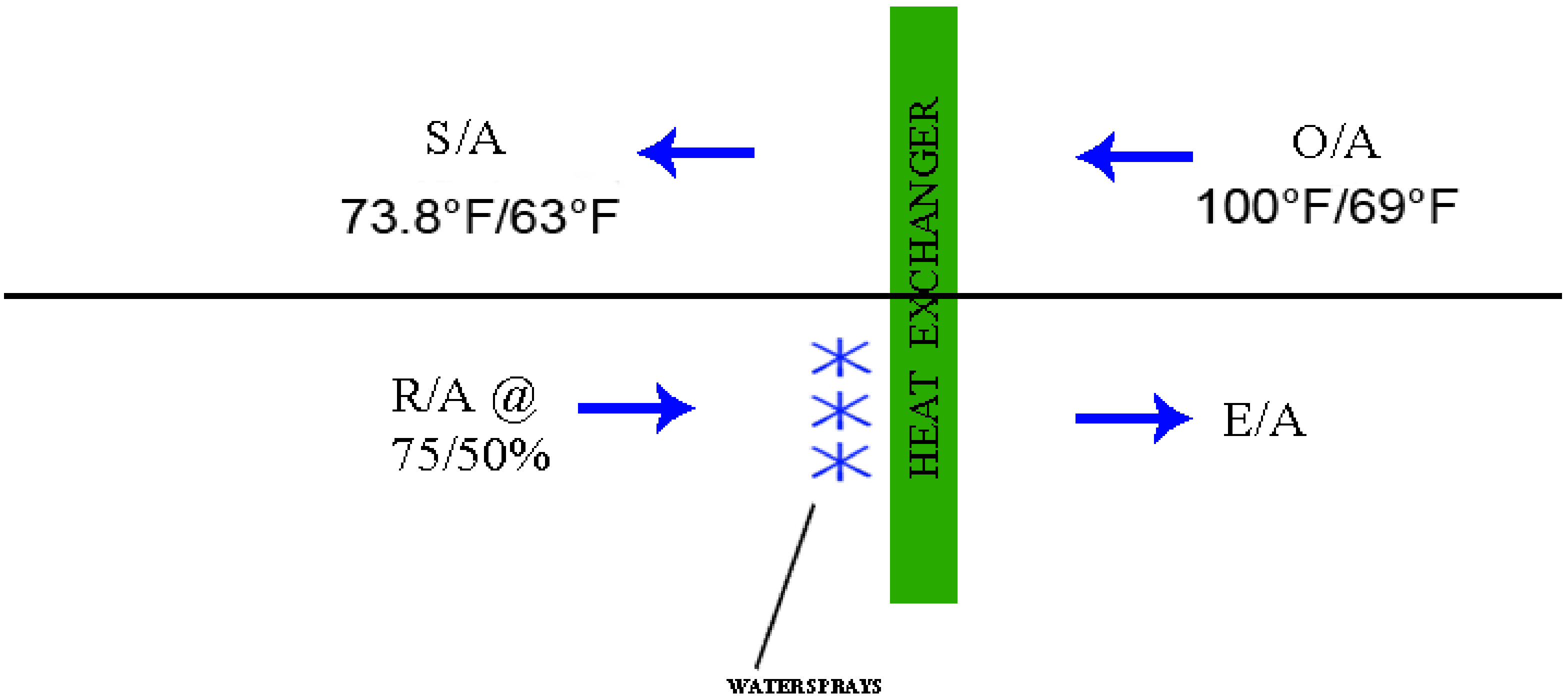
INDIRECT AND DIRECT EVAP COOLER



IEC WITH GLASDEK MEDIA IN THE R/A STREAM BEFORE THE HEAT EXCHANGER



IEC WITH DIRECT SPRAYS IN THE R/A STREAM



Wet Bulb Depression Efficiency (WBDE)

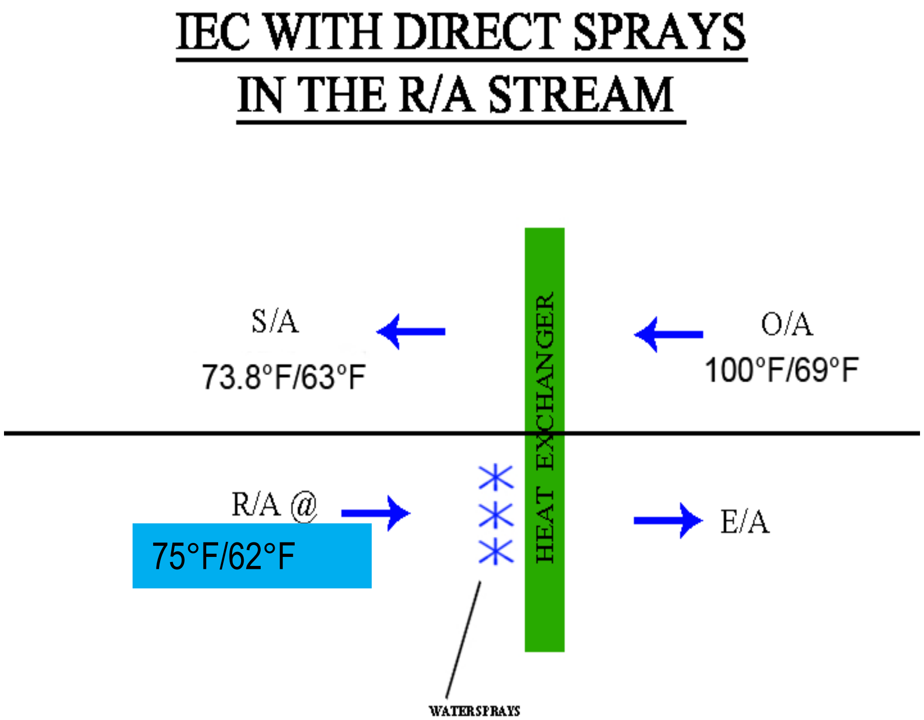
Effectiveness = 100% x $\frac{(EDBT-LDBT)}{(EDBT-WBT)}$

EDBT = Entering dry bulb temperature of primary air

LDBT = Leaving dry bulb temperature of primary air

WBT = Entering wet bulb temperature of secondary air

This example: (100-73.8)/(100-62) = 69%



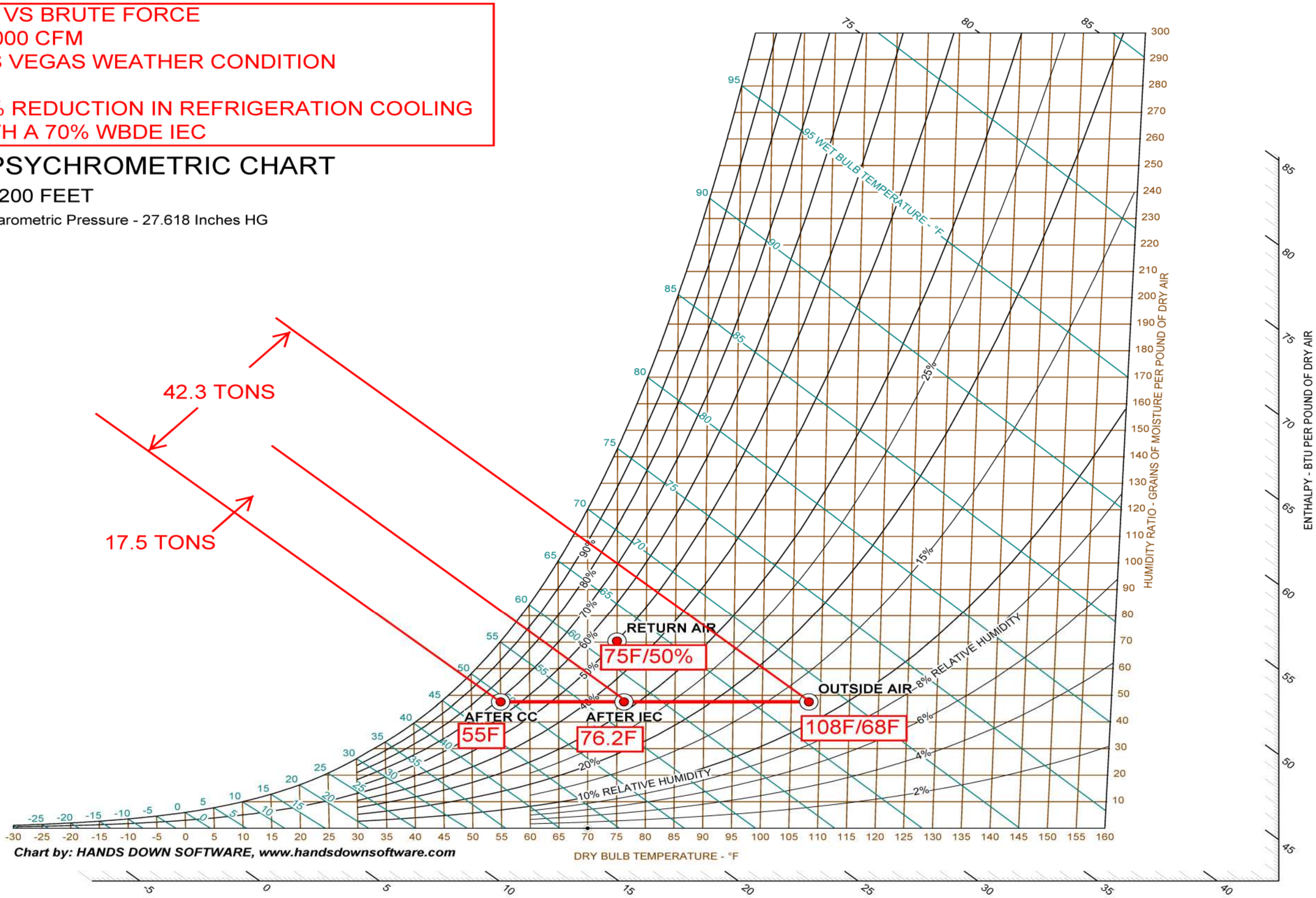
IEC VS BRUTE FORCE
10,000 CFM
LAS VEGAS WEATHER CONDITION

59% REDUCTION IN REFRIGERATION COOLING
WITH A 70% WBDE IEC

PSYCHROMETRIC CHART

2200 FEET

Barometric Pressure - 27.618 Inches HG



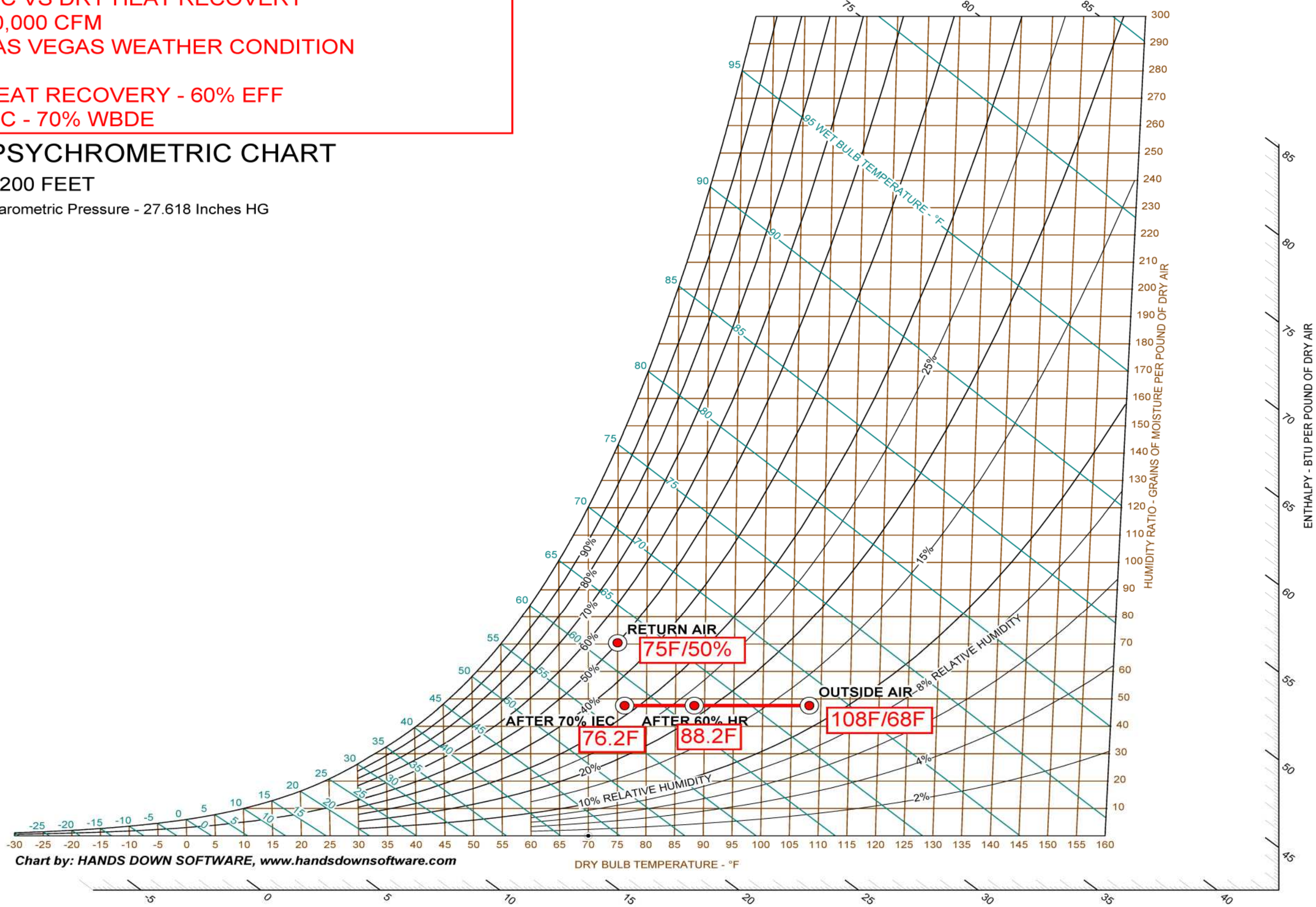
IEC VS DRY HEAT RECOVERY
10,000 CFM
LAS VEGAS WEATHER CONDITION

HEAT RECOVERY - 60% EFF
IEC - 70% WBDE

PSYCHROMETRIC CHART

2200 FEET

Barometric Pressure - 27.618 Inches HG



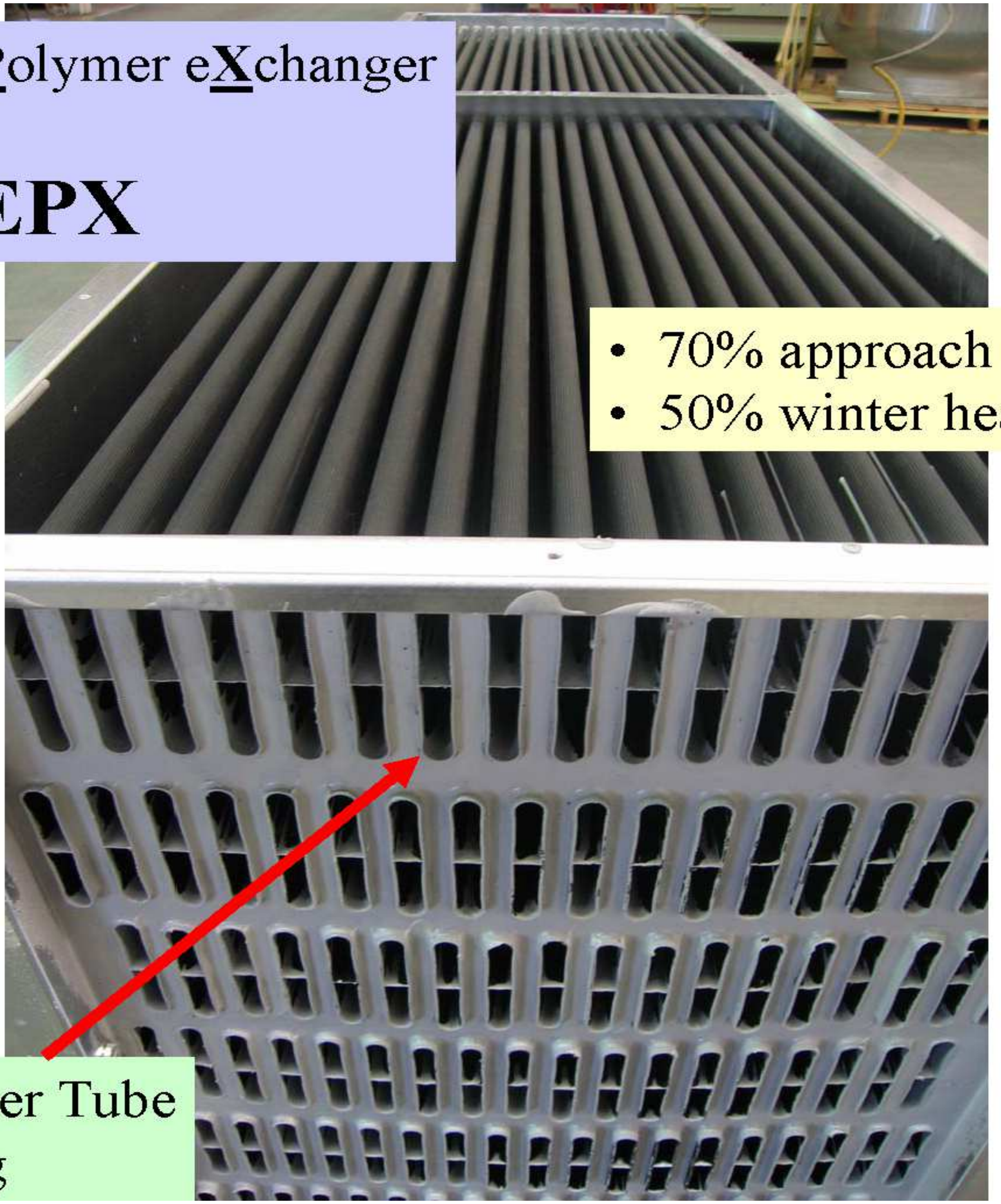
Sample EER Calculation

CFM	10000
Mass flow rate (lb/min)	638.56
IEC EAT	108
R/A WB	62.5
WBDE	0.7
HP LAT (deg F)	76.15
dt	31.85
IEC cooling (btu/hr) =	**297750.3**
Net Total Cooling Capacity (btu/hr)	**297,750**
IEC Pump HP	1
IEC Pump KW	0.7457
Supply air pressure drop from IEC	0.6
Supply fan BHP contribution from IEC	1.31
Supply fan motor eff	0.9
Supply fan KW contribution	1.09
Exhaust air pressure drop from IEC (wet side)	0.5
Exhaust fan BHP contribution from IEC	1.21
Exhaust fan motor eff	0.9
Exhaust fan KW contribution from IEC+Condenser	1.00
Total Electric input to achieve cooling effect (KW)	**2.83**
EER	**105.0**

Indirect Evaporative Cooling with Direct Spray Polymer Tubes (EPX)

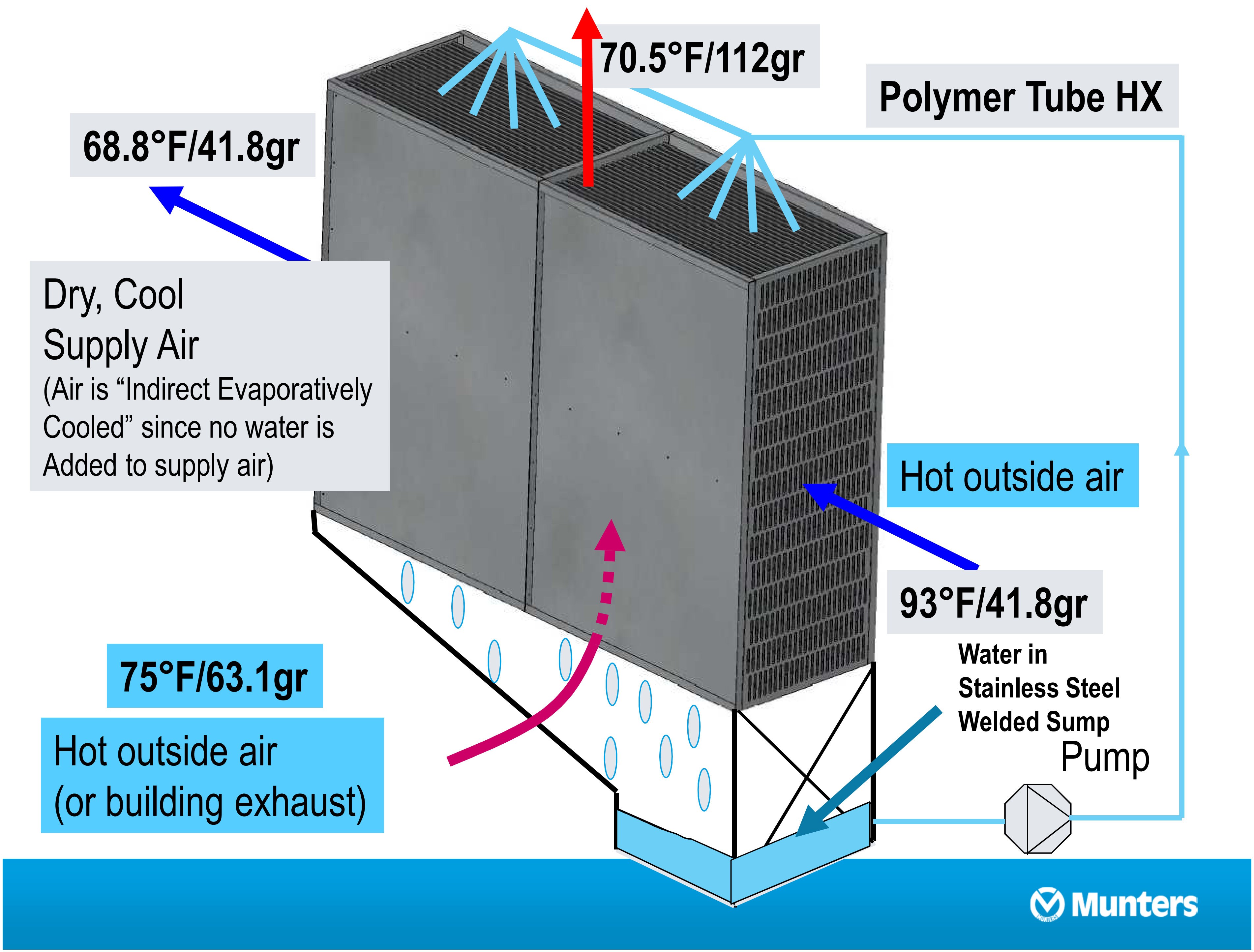
Evaporative Polymer eXchanger

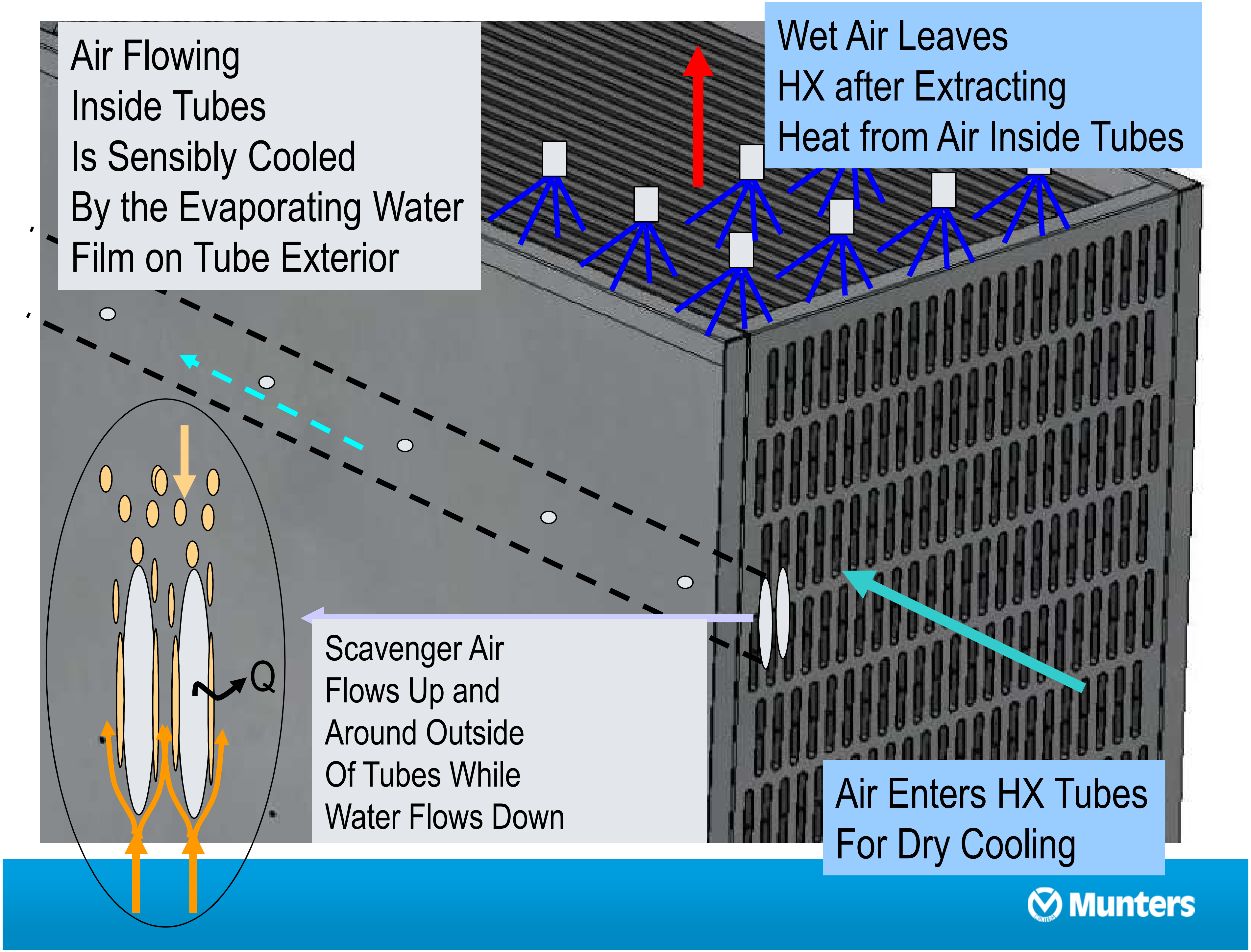
EPX

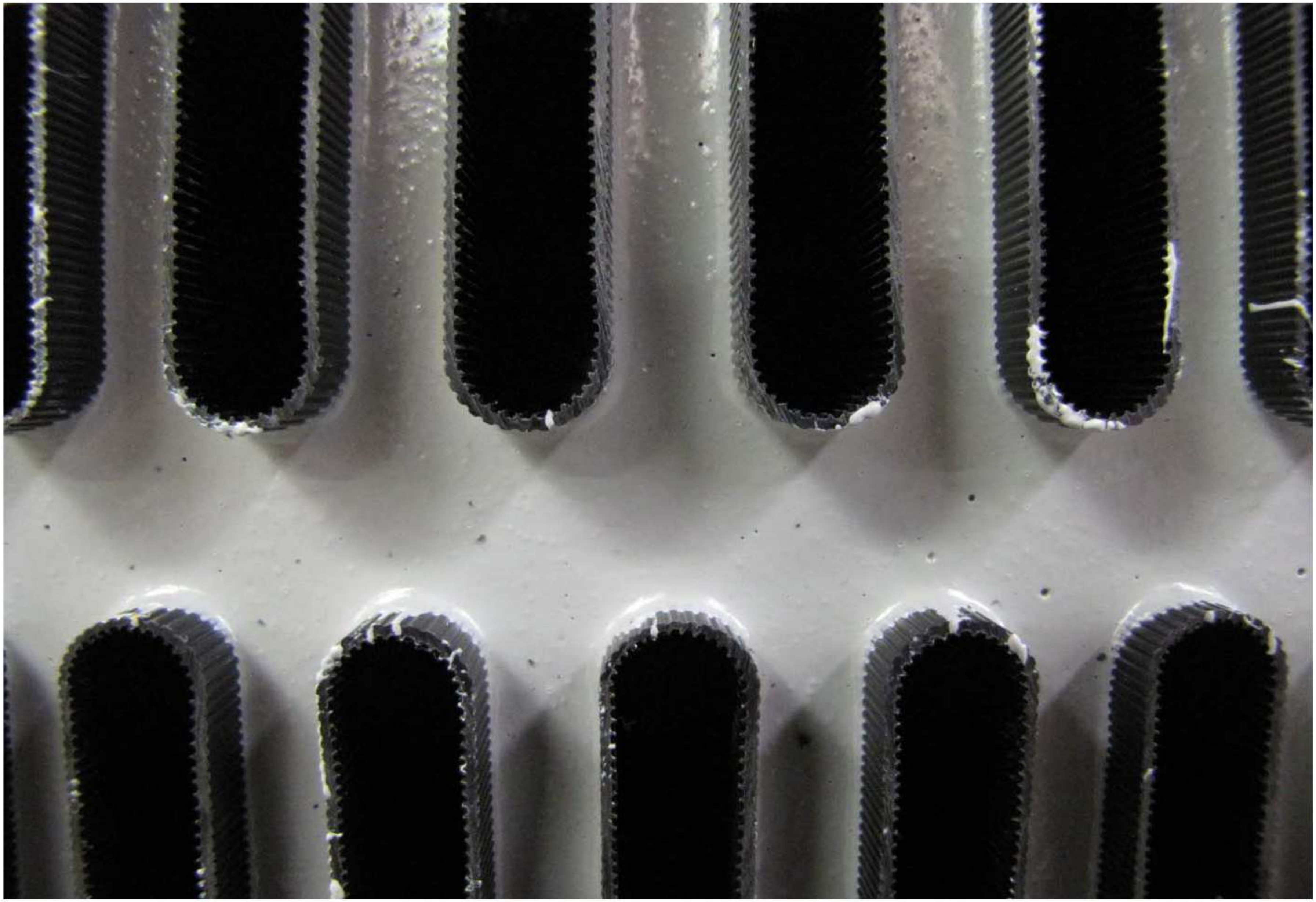


- 70% approach to exhaust WB
- 50% winter heat recovery

Flexible Polymer Tube
6 ft long


70.5°F/112gr
Polymer Tube HX
68.8°F/41.8gr
Dry, Cool
Supply Air
(Air is "Indirect Evaporatively
Cooled" since no water is
Added to supply air)
Hot outside air
93°F/41.8gr
Water in
Stainless Steel
Welded Sump
Pump
75°F/63.1gr
Hot outside air
(or building exhaust)
Munters


Air Flowing
Inside Tubes
Is Sensibly Cooled
By the Evaporating Water
Film on Tube Exterior
Wet Air Leaves
HX after Extracting
Heat from Air Inside Tubes
Q
Scavenger Air
Flows Up and
Around Outside
Of Tubes While
Water Flows Down
Air Enters HX Tubes
For Dry Cooling
Munters

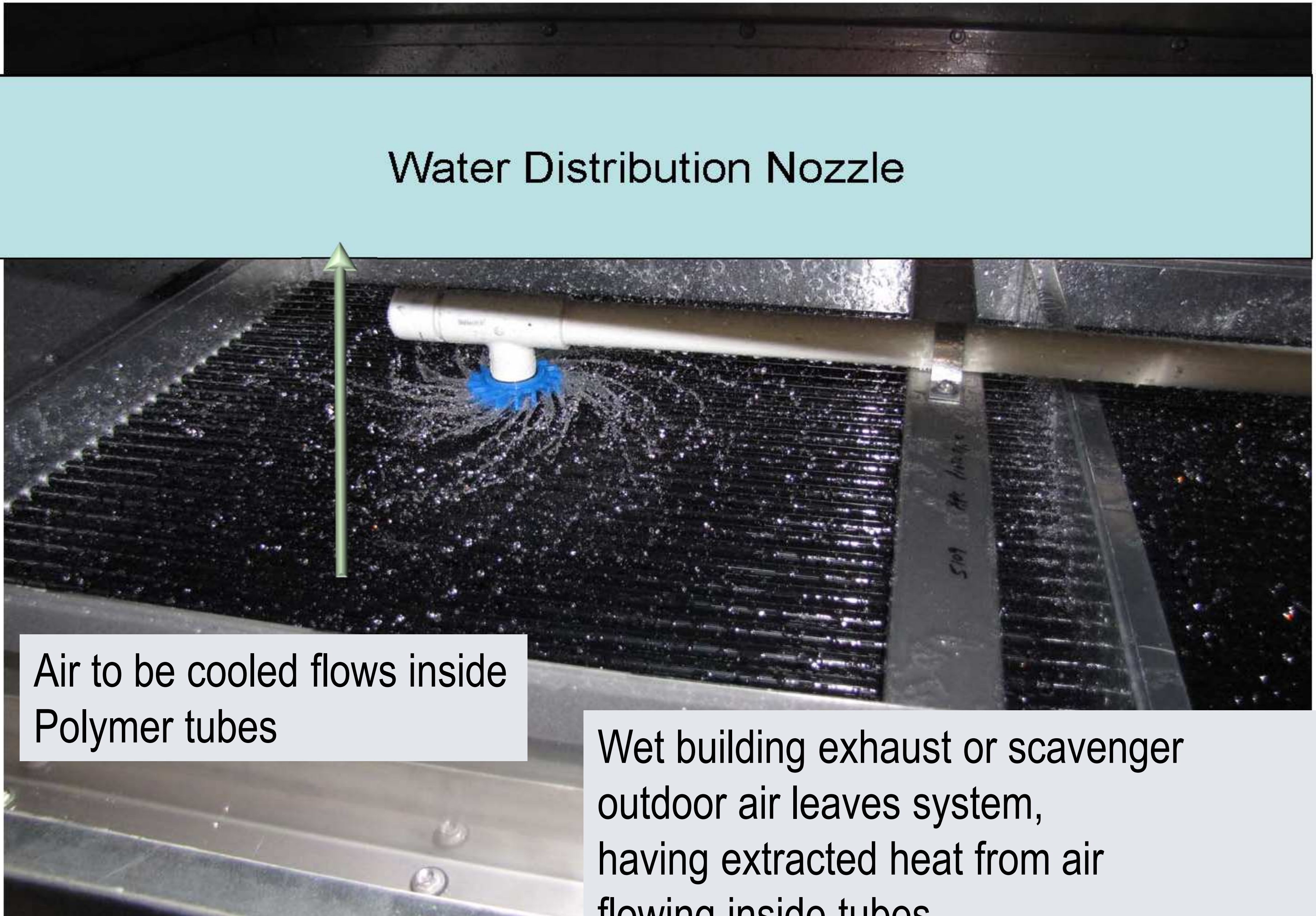


Munters EPX® Indirect Evaporative Heat Exchanger

Intertek/ETL Certified

The performance tests were conducted in accordance with the following standards:

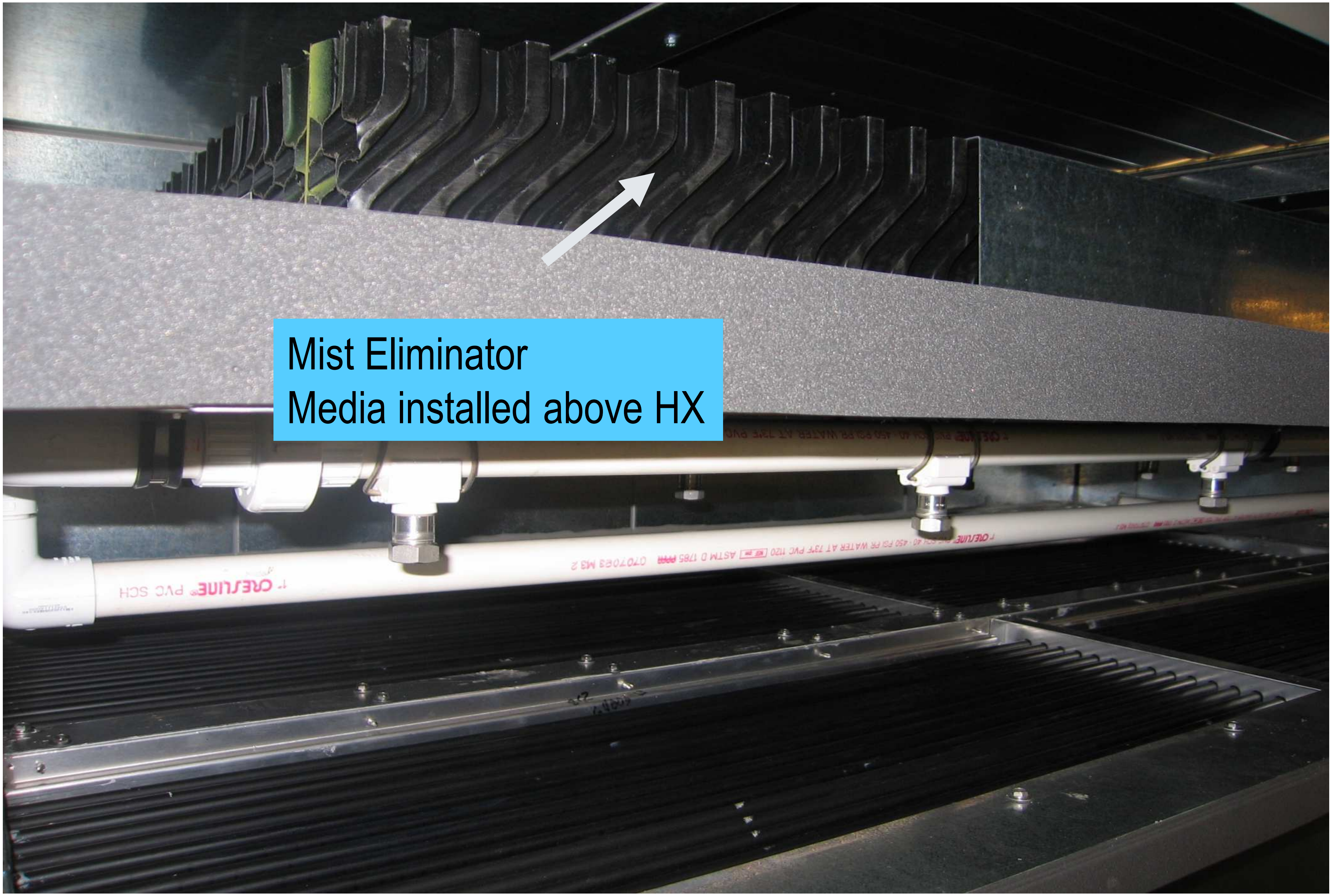
- ASHRAE Standard ANSI/ASHRAE 143-2007, "Methods of Testing for Rating Indirect Evaporative Coolers," published by the American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc.

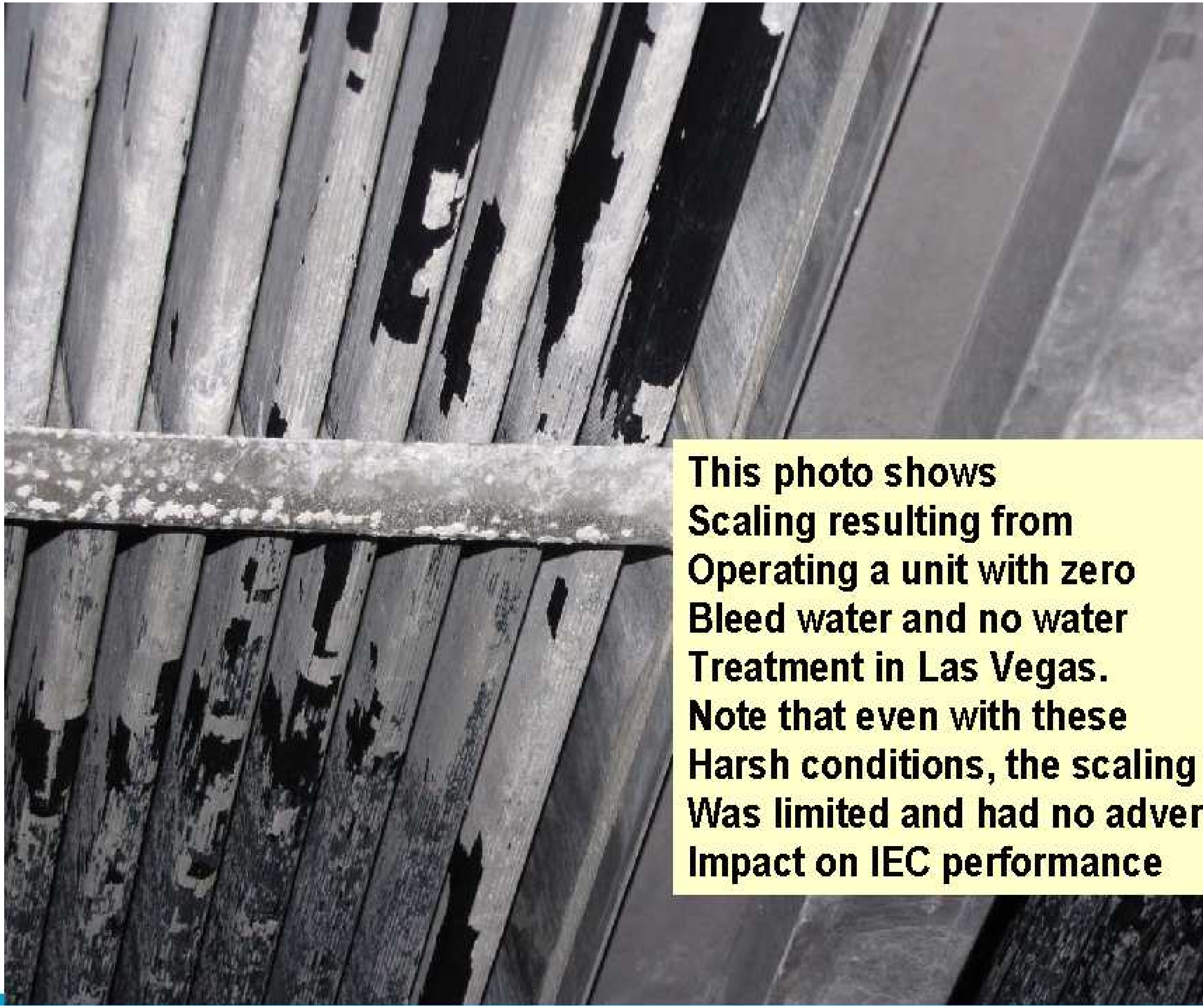


Water Distribution Nozzle

Air to be cooled flows inside Polymer tubes

Wet building exhaust or scavenger outdoor air leaves system, having extracted heat from air flowing inside tubes

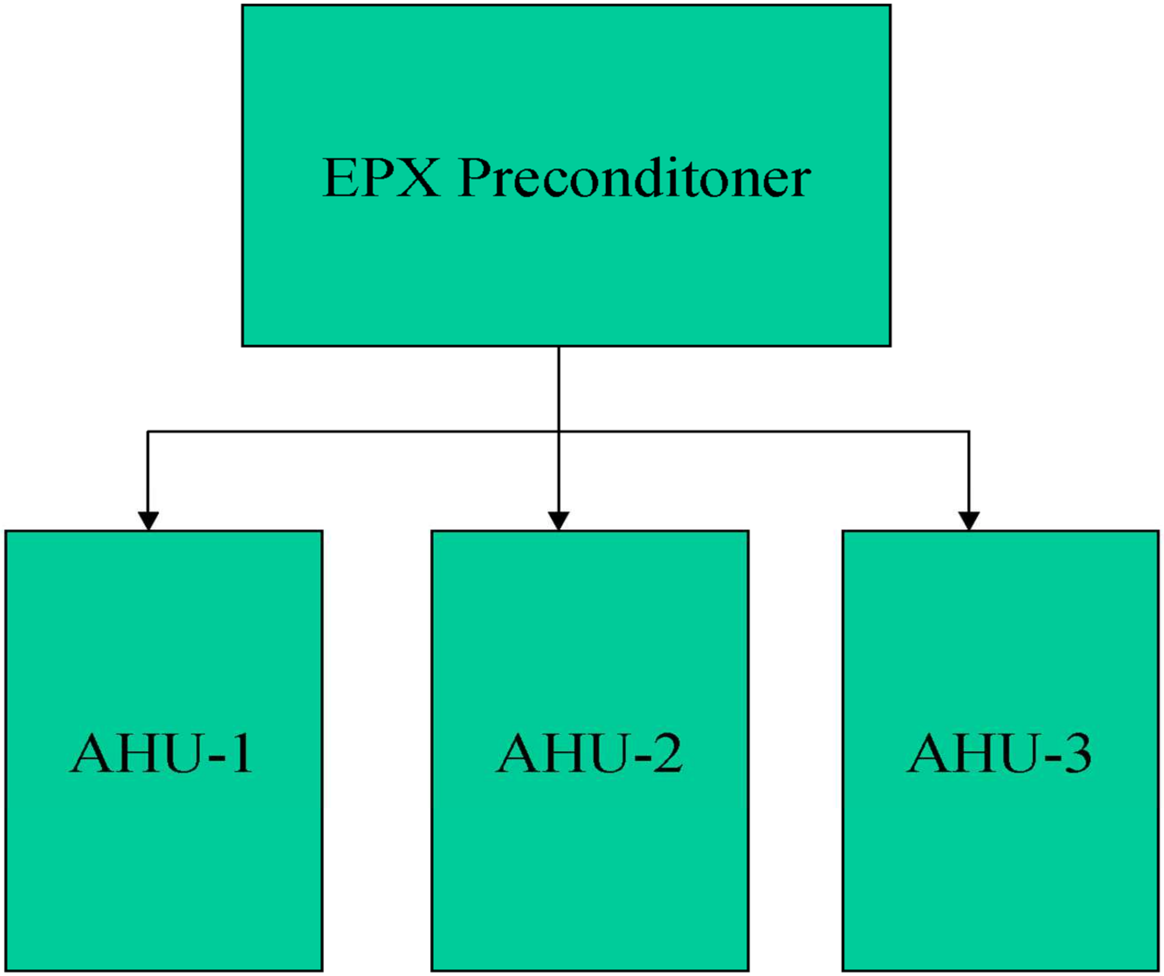

Mist Eliminator
Media installed above HX



This photo shows
Scaling resulting from
Operating a unit with zero
Bleed water and no water
Treatment in Las Vegas.
Note that even with these
Harsh conditions, the scaling
Was limited and had no adverse
Impact on IEC performance

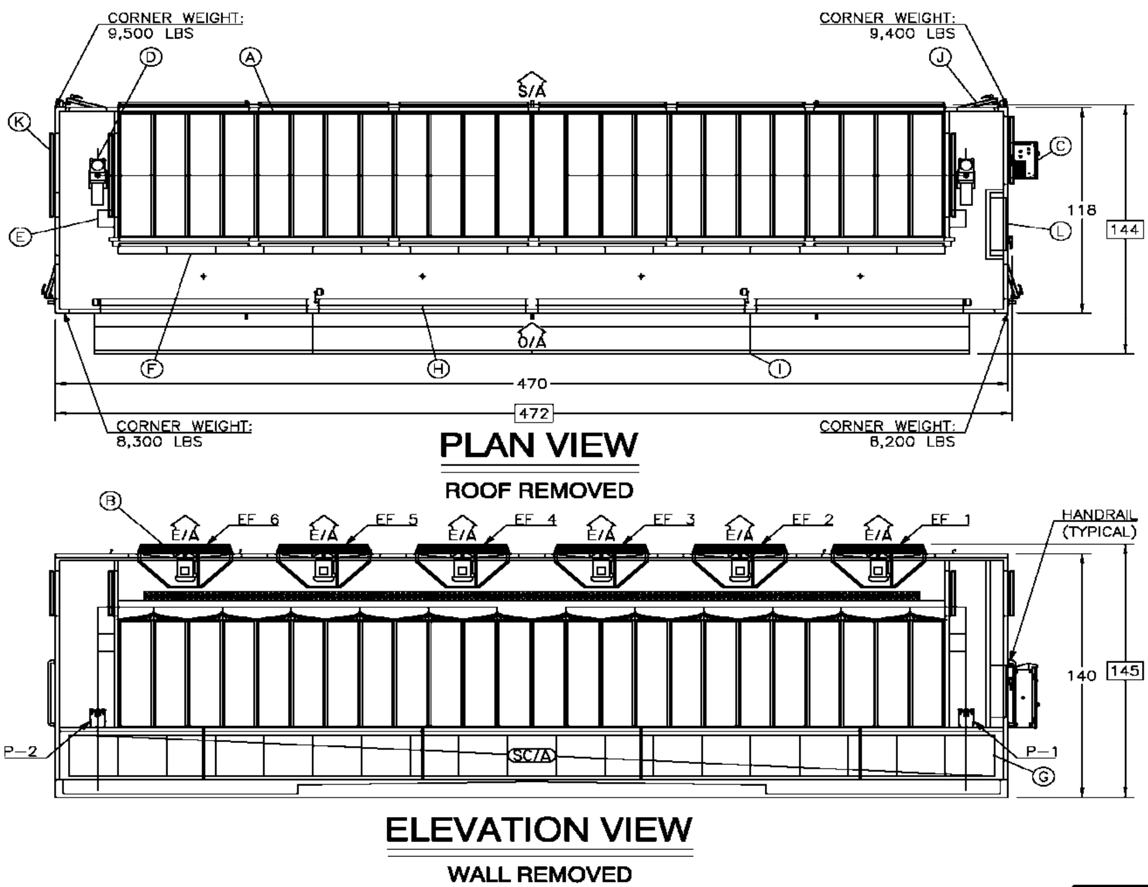
Ways to Apply Indirect Evaporative Cooling

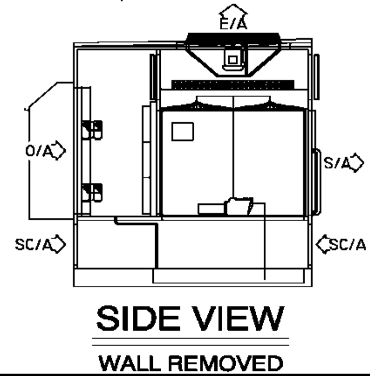
- Outdoor Air Pre-cooler (Pre-cool air feeding other AHUs)
- Outdoor Air Pre-cool + Pre-heat (Uses building exhaust to provide summer indirect evaporative cooling + winter heat recovery)
- Total AC with or without building Exhaust (indirect evaporative with options for direct evaporative and/or DX cooling



EPX Preconditoner
AHU-1
AHU-2
AHU-3


Munters





MAJOR COMPONENTS:

A. DCP EPX CROSSFLOW HEAT EXCHANGER (TYPICAL)
B. E/A FAN WITH MOTOR AND DRIVES (TYPICAL)
C. E/A FAN VARIABLE FREQUENCY DRIVE
D. WATER RECIRCULATION PUMP (TYPICAL)
E. WATER TREATMENT CONTROL PANEL (TYPICAL)
F. O/A FILTER BANK (30% PLEATED)
G. SC/A FILTER BANK (PERMANENT METALLIC)
H. O/A SHUT-OFF DAMPER (TYPICAL)
I. O/A HOOD WITH BIRDSCREEN
J. UNIT ACCESS DOOR (TYPICAL)
K. UNIT ACCESS PANEL (TYPICAL)
L. UNIT ELECTRICAL PANEL

NOTES:

1. MINIMUM 3'-0" CLEARANCE REQUIRED FOR SERVICE ACCESS (COILS MAY REQUIRE MORE ACCESS FOR REMOVAL).
2. FOR DRAIN AND CONNECTION LOCATIONS, SIZES, AND QUANTITIES SEE M-AB02.
3. FOR BASE FRAME DWG SEE M-AB03.
4. FOR INDIRECT EVAPORATIVE COOLING PIPING SEE M-AB04.
5. UNIT OVERALL ENVELOPE DIMENSIONS ARE SHOWN IN BOXED DIMENSIONS.
6. WEATHER HOODS MAY BE SHIPPED IN PIECES FOR ASSEMBLY AND INSTALLATION BY OTHERS.
7. ATTENUATION OF FAN SOUND POWER LEVELS, IF REQUIRED, IS BY OTHERS.

AIR FLOW KEY:
O/A: OUTSIDE AIR
S/A: SUPPLY AIR
SC/A: SCAVENGER AIR
E/A: EXHAUST AIR

UNIT TAG: IEC-2
ITEM #: -02
S/O NUMBER: -02
UNIT QUANTITY: 1 TOTAL
EST. UNIT WEIGHT: 35,400 LBS
EST. SHIPPING WEIGHT: 31,600 LBS.

ORDER NO. 21018266		Munters		
		ORDER NAME: STATE PRINTING PLANT		
APPROVALS	DATE	UNIT TYPE: PVT - 900		
DRAWN: JFH	11/22/10	TITLE: MECHANICAL LAYOUT		
CHKD:		SIZE: A	DWG NO. M-AB01	
APPD:				
SHEET 1 OF 1		SCALE: NTS	MODEL: PV-MZP-8790-PVT	

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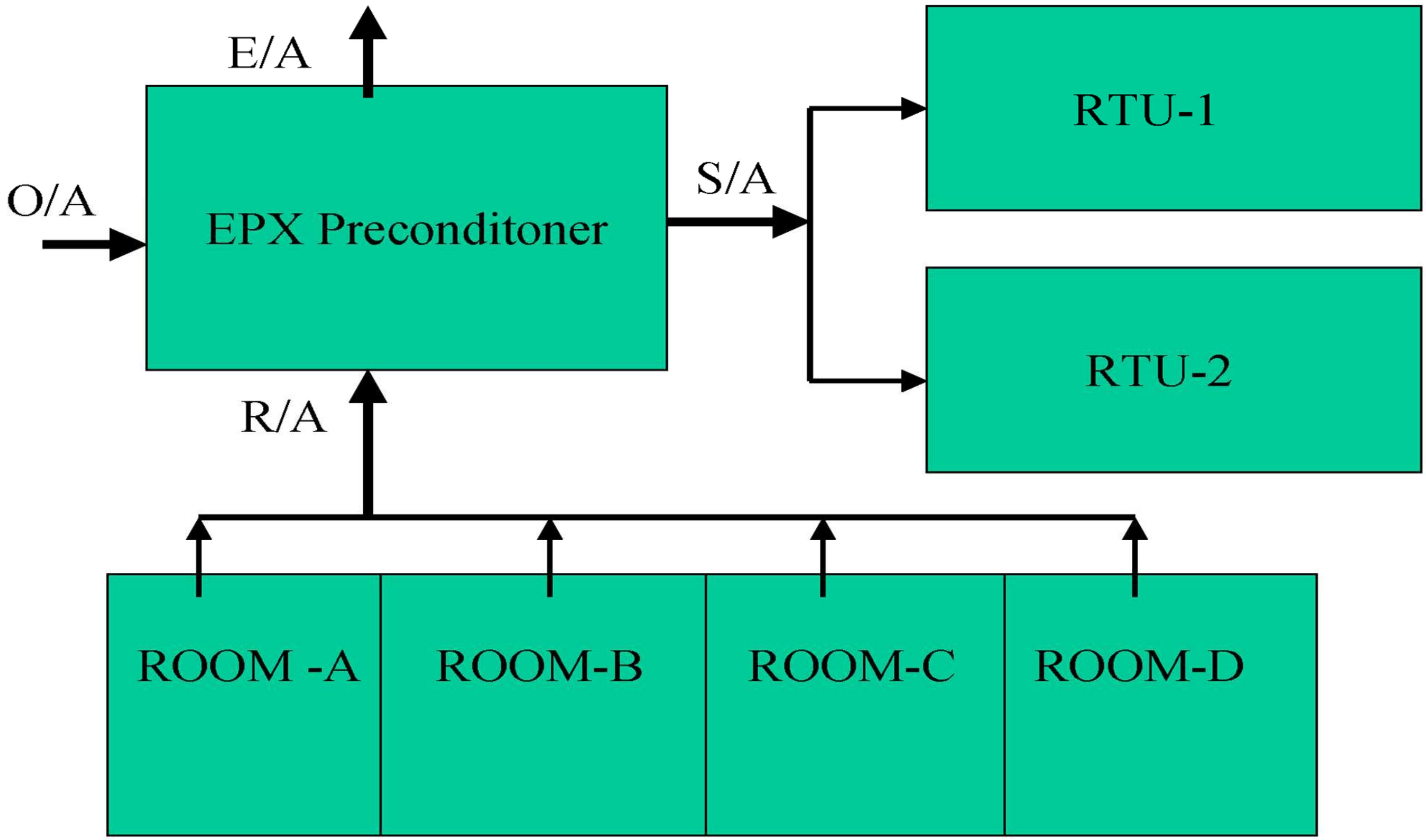
Cooling System Comparison

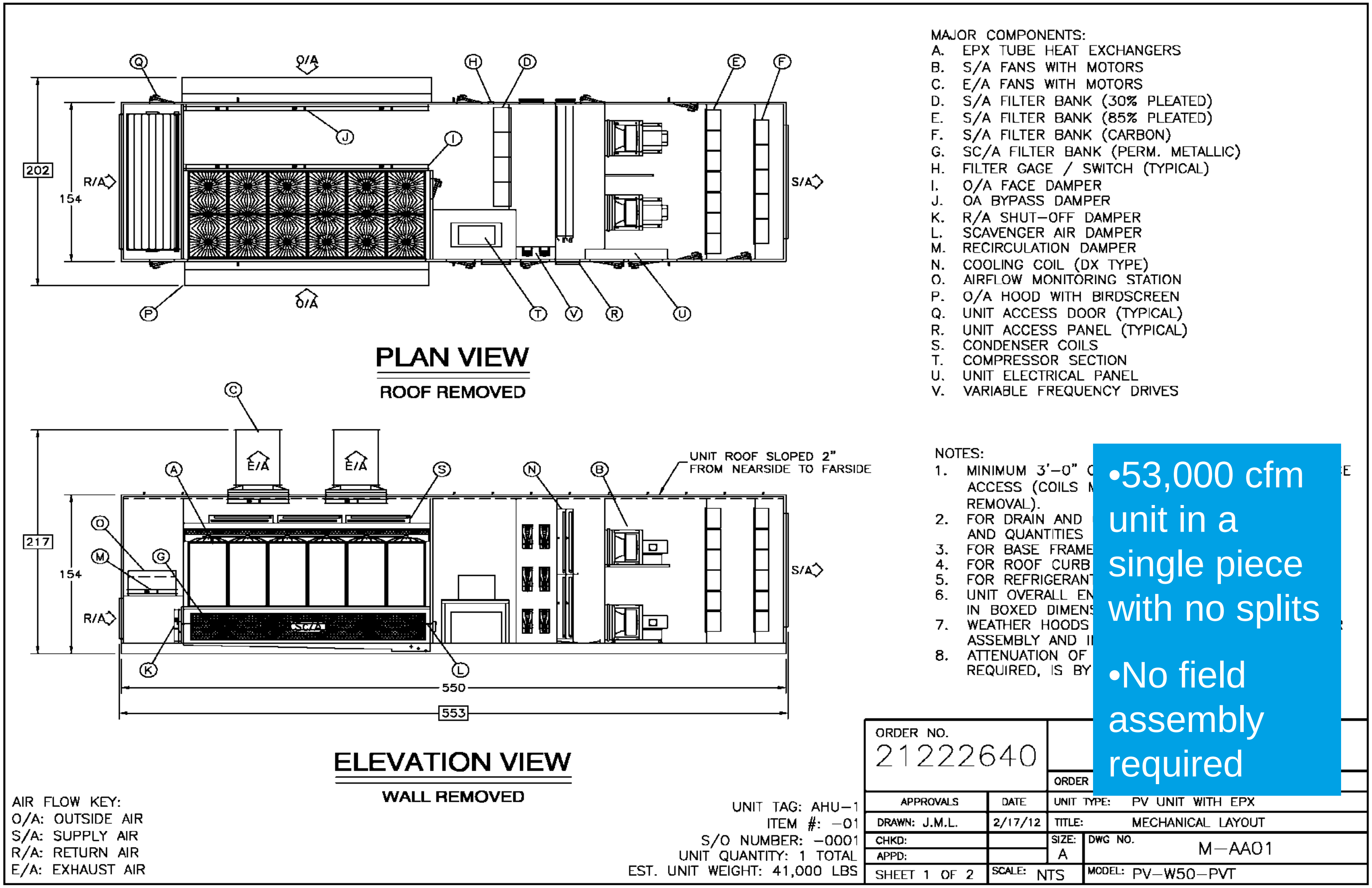
- 353,600 cfm at 105 º F/ 74 º F WB to 83.3 º F/67.7 º F
- IEC Total Tons of Cooling = (353,600 cfm)(105-83.3)(1.1)/12,000 = 703.37 Tons (sensible)
- Total KW IEC at 0.2 KW/ton = 140.67 KW
- Total KW Aircooled Chiller at 1.2 KW/ton = 843.6 KW
- Total KW peak day demand reduction = 702.93 KW
- Total KW peak day demand reduction using IEC and DEC = 1107.9 KW
- Additional savings achieved from lower capital first cost from distribution piping, refrigerant, electrical feeds, maintenance.

In August 2011, a test was run on the IEC-3 module at the California Office of State Publishing. Ambient temperatures at 2:00 p.m. were 95.5°F DB and 68.5°F WB. The IEC unit was cooling the outdoor air, leaving the dry-side polymer tubes down to 74.1°DB and 61.5°F WB. This represents an approach to the ambient WB condition of 79.26%, 11% above the specified performance requirements with full flow through both sides of the air-to-air heat exchanger.

The dry side flow through the heat exchanger was 98,200 cfm constant volume. The sensible cooling produced was calculated to be 192.6 tons. Assuming an 80% saturation efficiency for the air washers located downstream of the IEC module, the supply air to the building would be in the range 64°F DB, ignoring fan heat.


E/A
O/A
EPX Preconditoner
S/A
RTU-1
RTU-2
R/A
ROOM -A
ROOM-B
ROOM-C
ROOM-D

Unit Tag: AHU-1 (S/O# -0001)



- 53,000 cfm unit in a single piece with no splits
- No field assembly required

Example layout, RA energy recovery & scavenger OA option


Munters
www.HATTONS.com
HATTON

EX: Whole Building Comfort Cooling w IDEC

IDEC Highlights with Polymer HX

- Up to 70%+ WBDE and Winter Heat Recovery with 50% Effectiveness
- EER in excess of 100 possible
- Corrosion resistant: works great for labs, pools and other corrosive airstreams
- The polymer heat exchanger self cleans. Proven performance for operational concerns related to hard water, arid conditions.

Why do we need
Direct Evaporative Cooling?

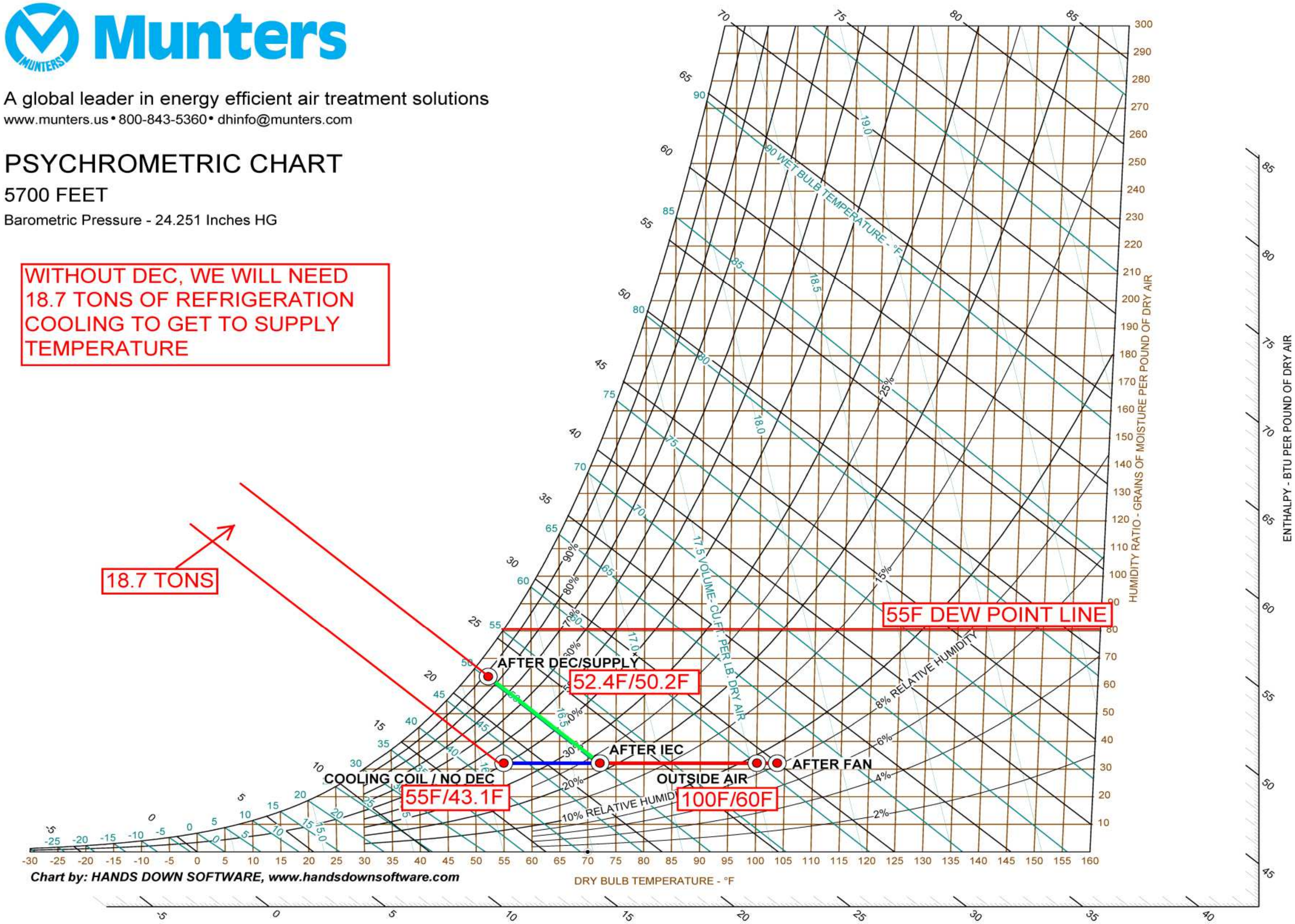
A global leader in energy efficient air treatment solutions

www.munters.us • 800-843-5360 • dhinfo@munters.com

PSYCHROMETRIC CHART

5700 FEET

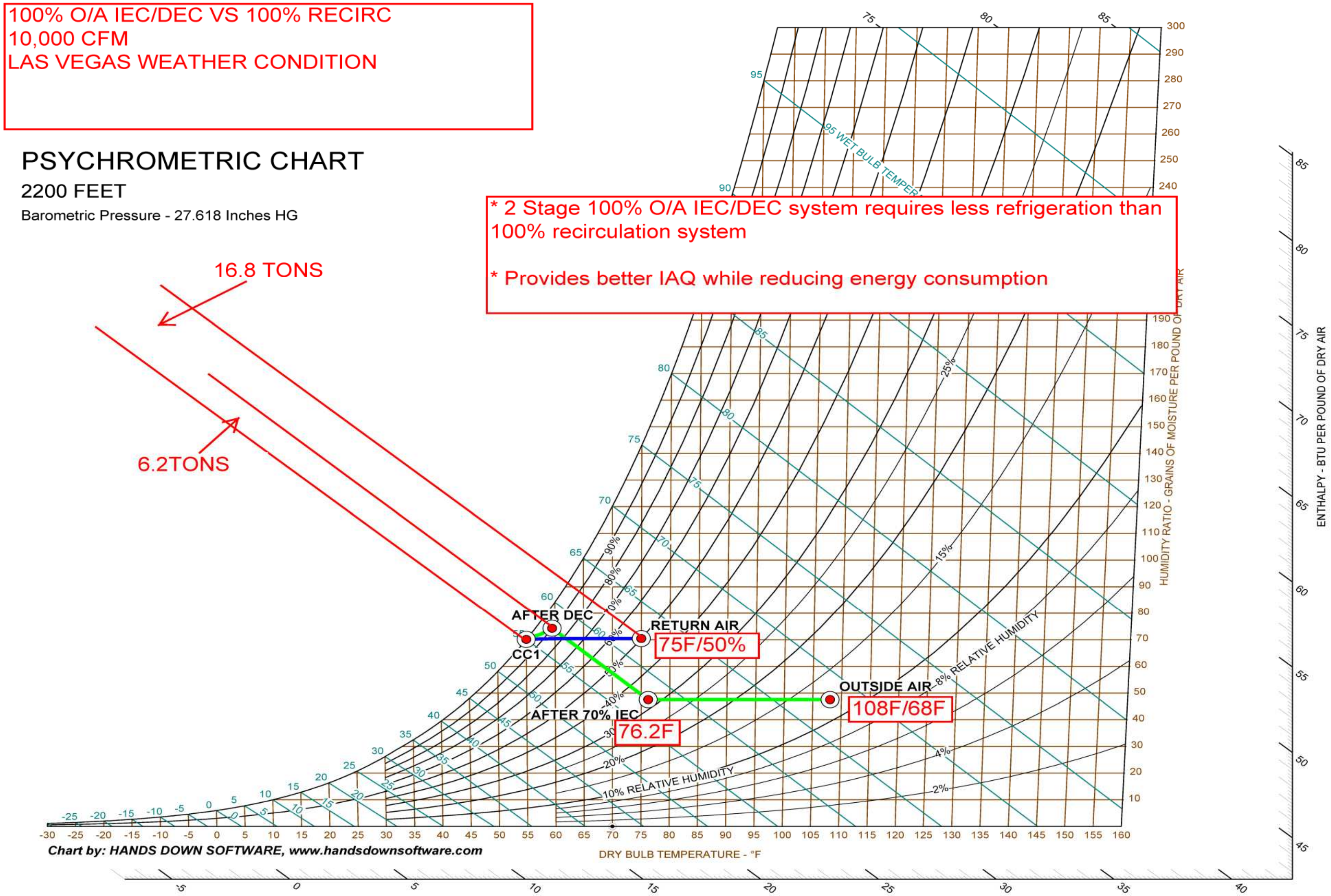
Barometric Pressure - 24.251 Inches HG



Combining IEC and DEC- IDEC Systems

- DEC downstream of the IEC
- IEC provides a new lower wet bulb for DEC allowing for further cooling without too much penalty of humidity addition

100% O/A IEC/DEC VS 100% RECIRC
10,000 CFM
LAS VEGAS WEATHER CONDITION



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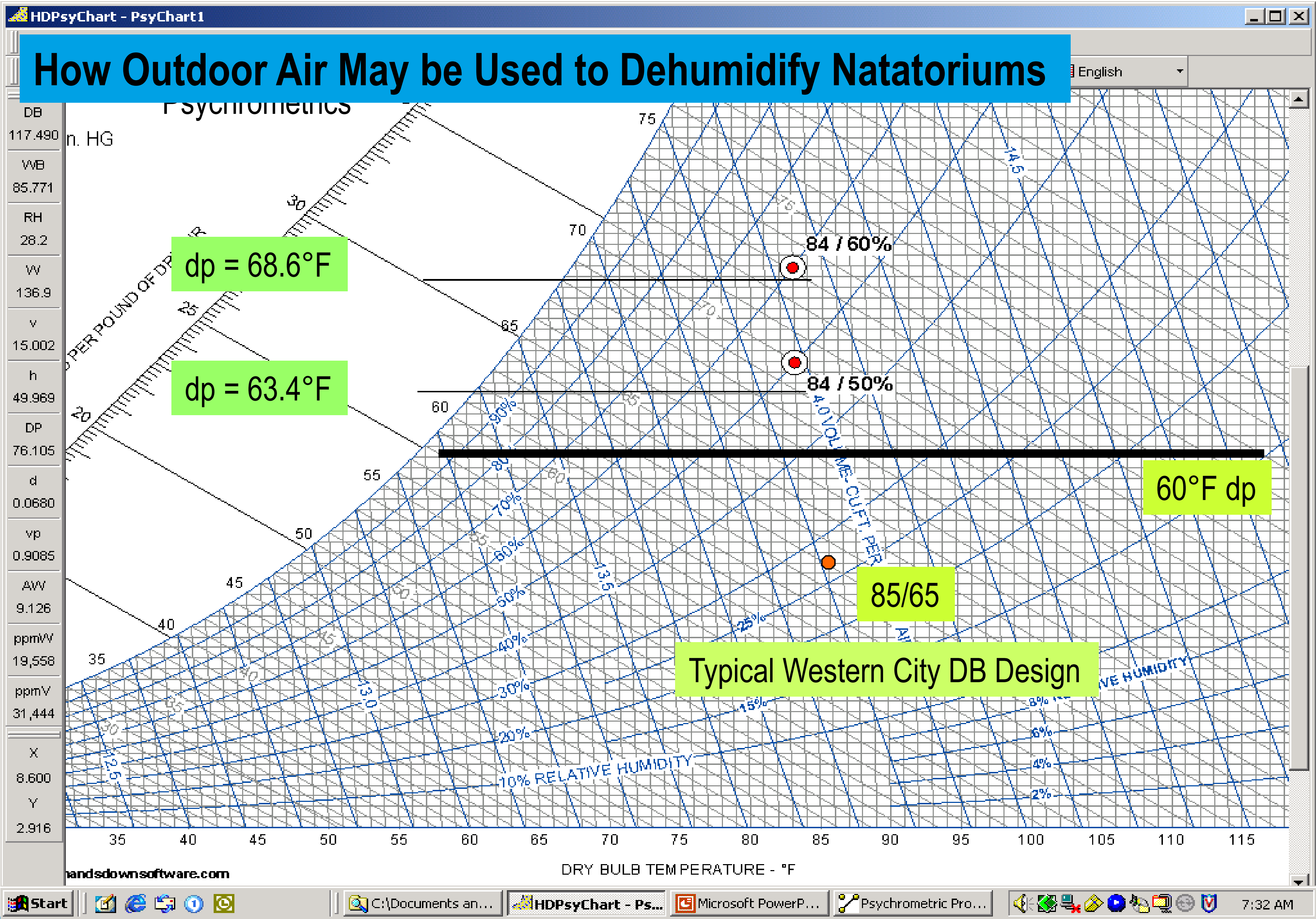
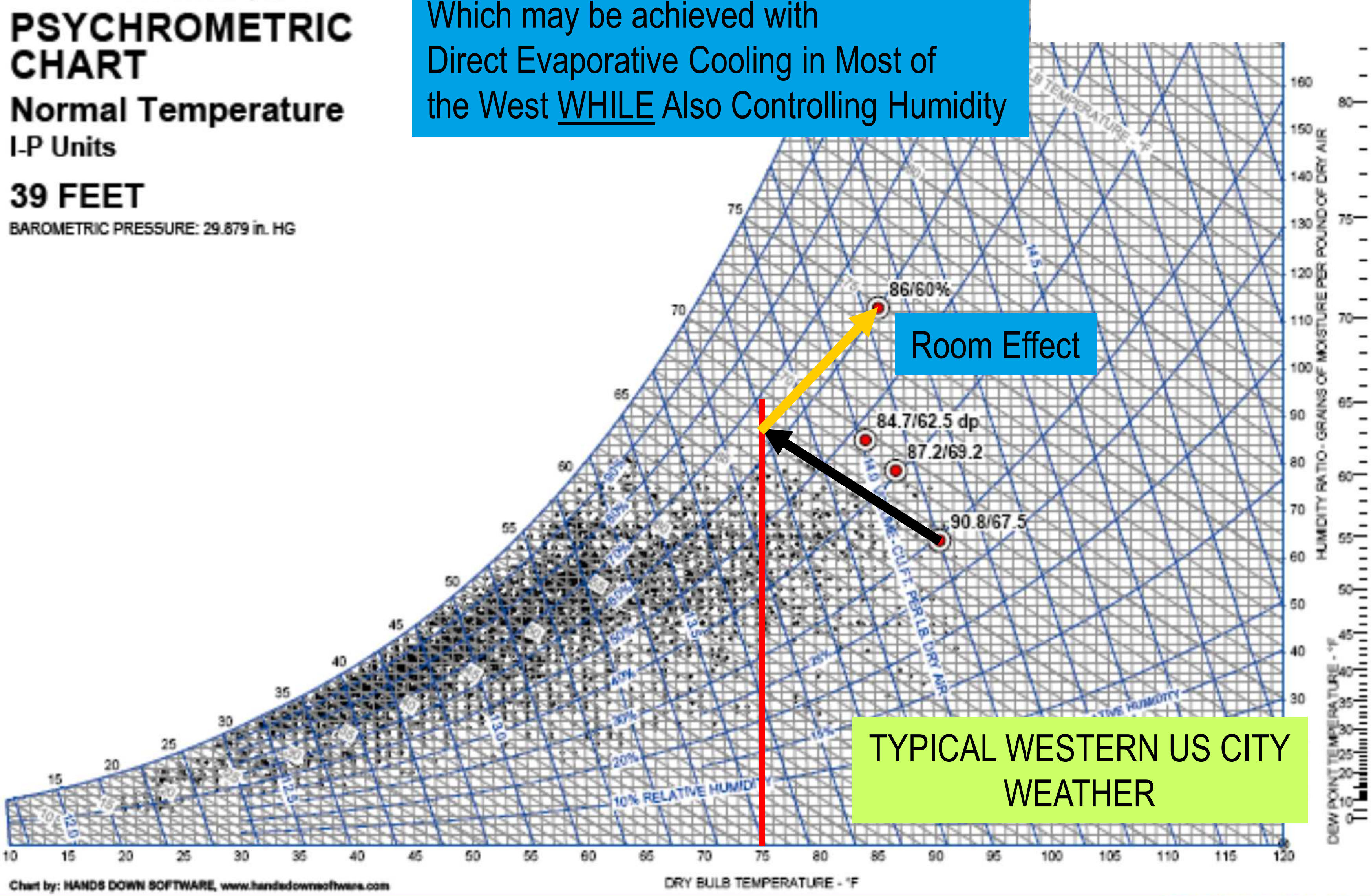
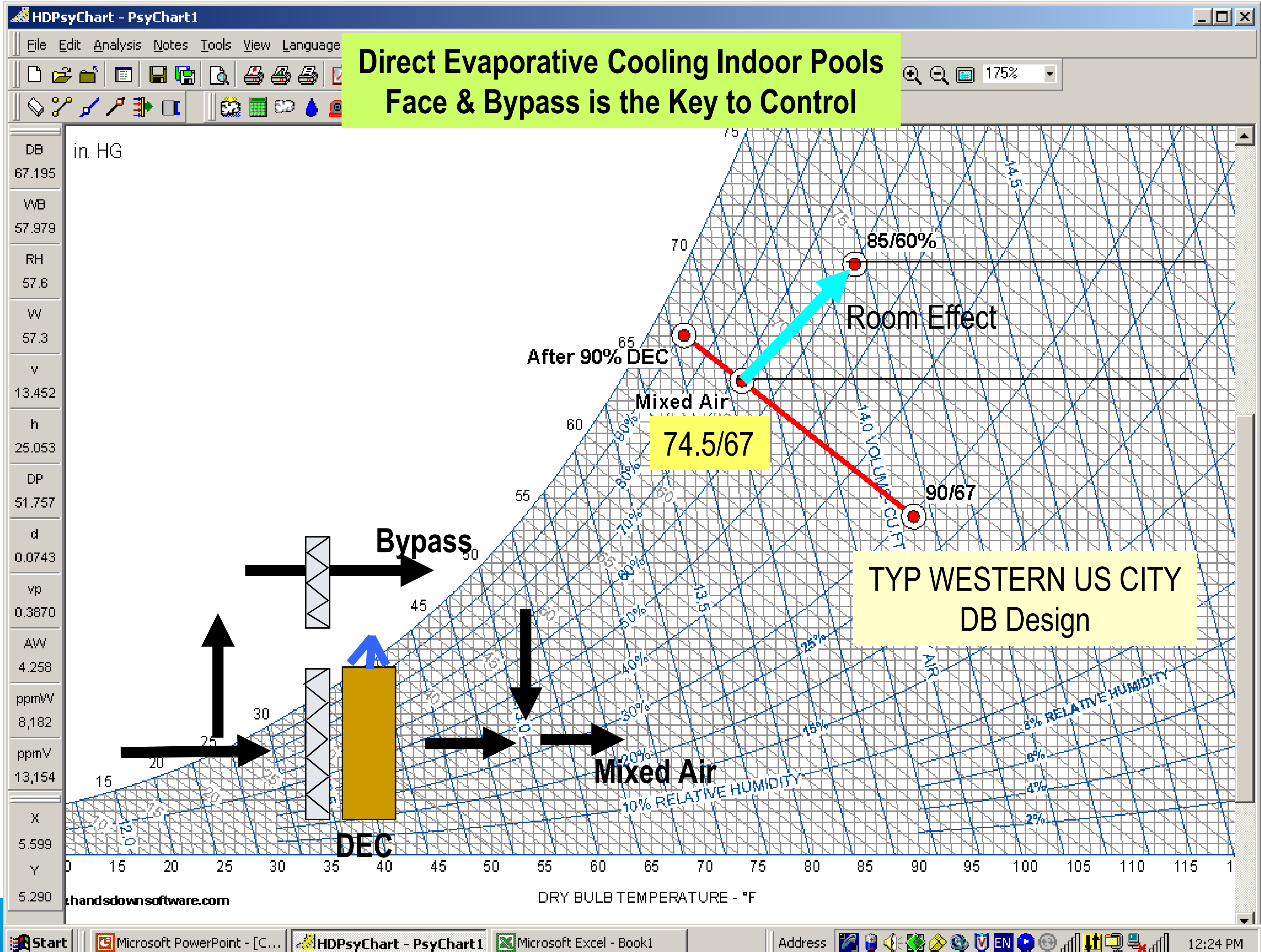
How Outdoor Air May be Used to Dehumidify Natatoriums



In Summer, Most Indoor Pools
May be Cooled With
70°F to 75°F Supply Air ….
Which may be achieved with
Direct Evaporative Cooling in Most of
the West WHILE Also Controlling Humidity



Direct Evaporative Cooling Indoor Pools
Face & Bypass is the Key to Control



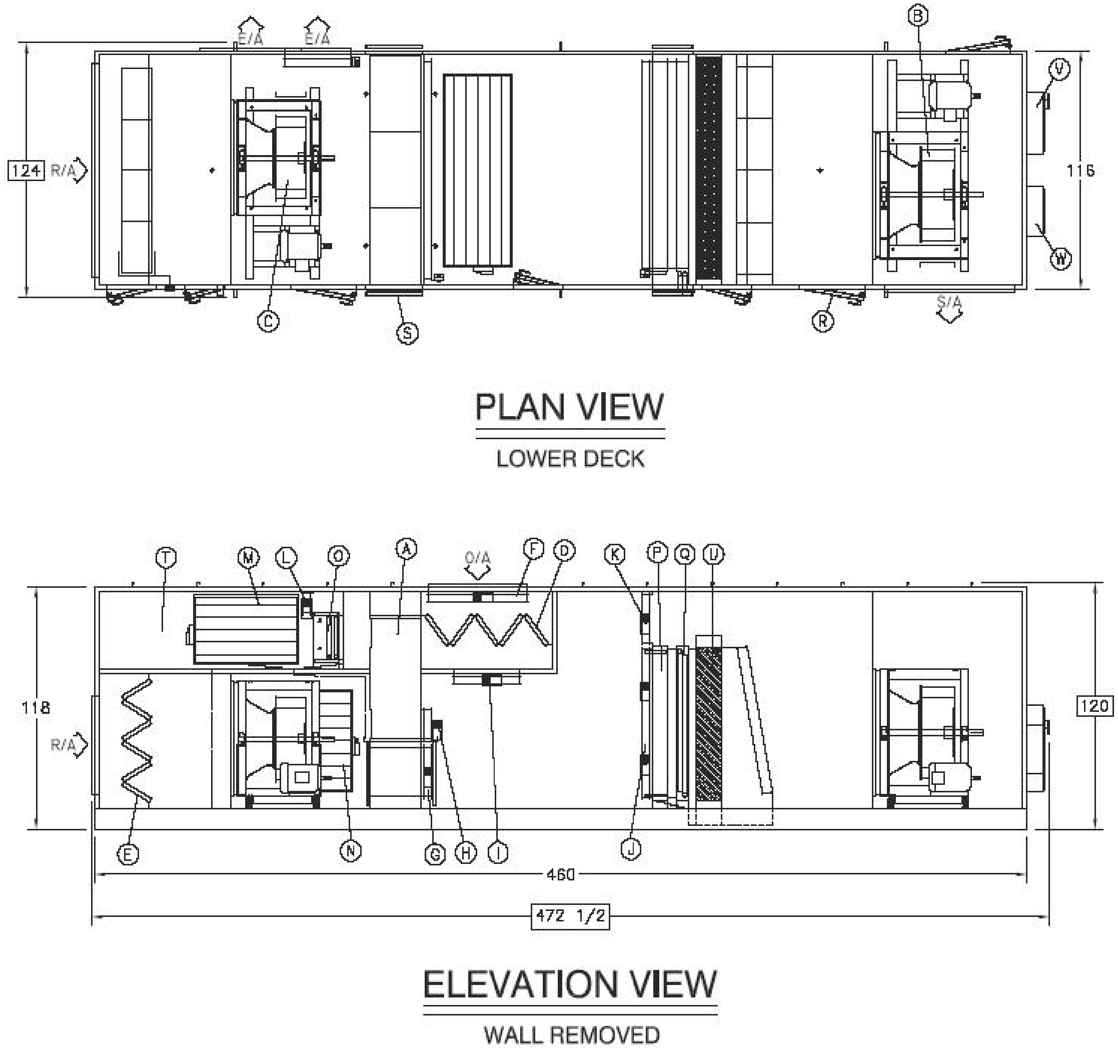
Benefits of Applying Direct Evaporative Cooling To The Design of Natatorium Air Handling Systems:

1. Energy Savings: No compressors PLUS better humidity control results in lower pool water evaporation and resulting costs of water heating (DX cooling systems with min OSA in dry climates can result in over drying of the space)

2. Improved IAQ, resulting from higher ventilation rates when cooling is required

3. Direct evaporative cooling provides air washing that removes some pollen and other particulate

Direct Evap Cooling in Pool Application



Rio Rancho Aquatic

Rio Rancho, NM

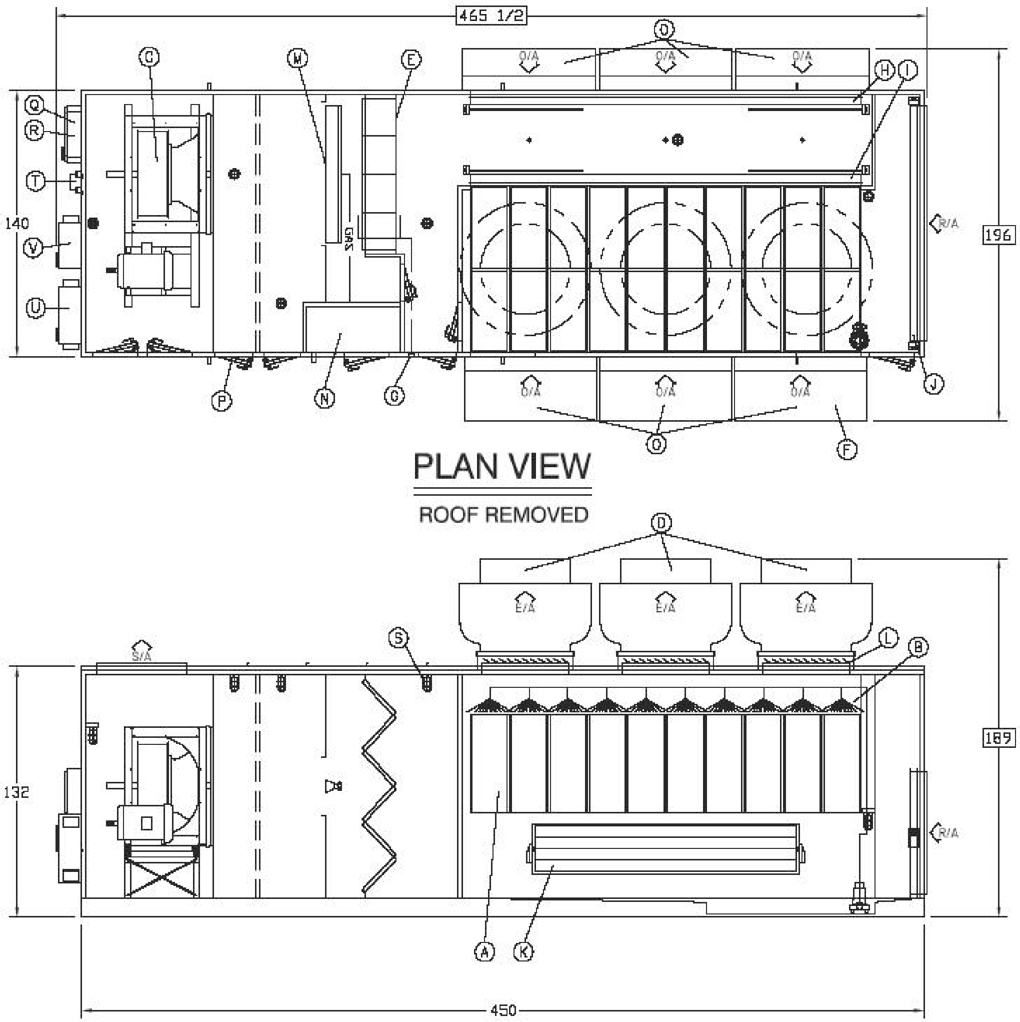
30,000 CFM

100% O/A capable

Direct evap. cooling

E/A energy recovery

Indirect Evap Cooling in Pool Application



Radisson Water Park

Albuquerque, NM

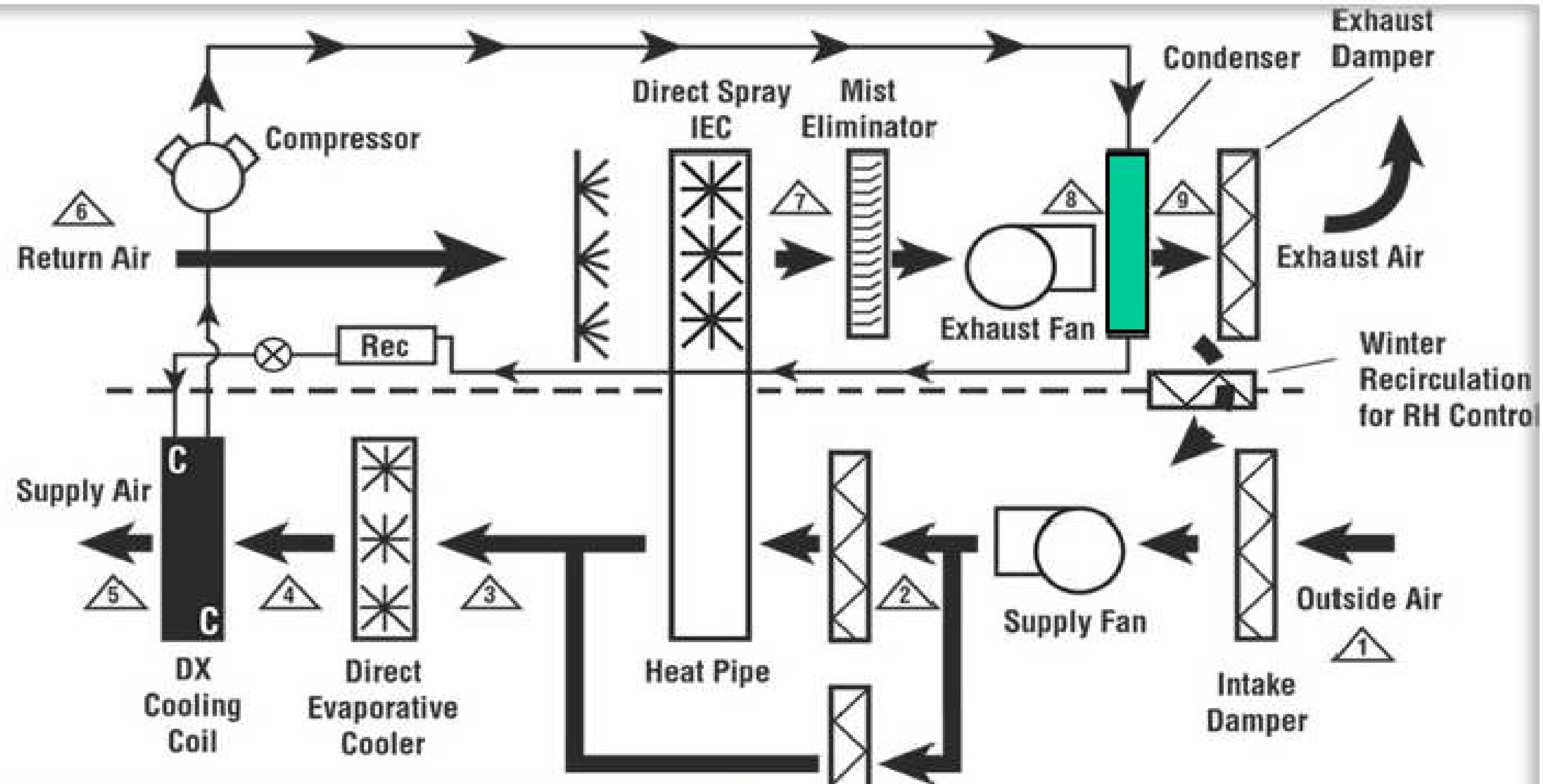
42,000 CFM

100% O/A capable

Indirect evap. cooling

E/A energy recovery

Triple Dip System



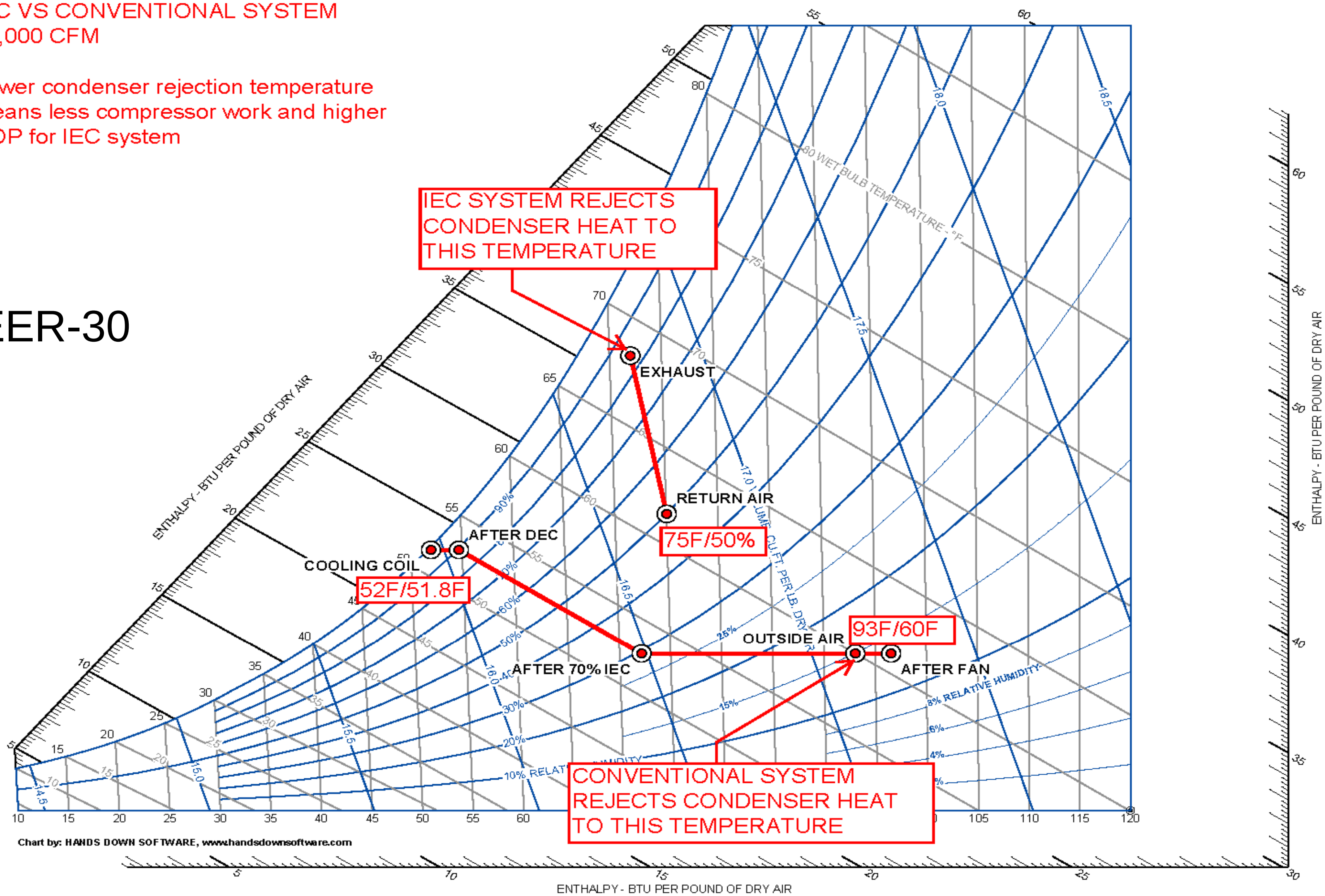
THE TRIPLE DIP SYSTEM …
IEC, DEC, & EVAP COOLED CONDENSER

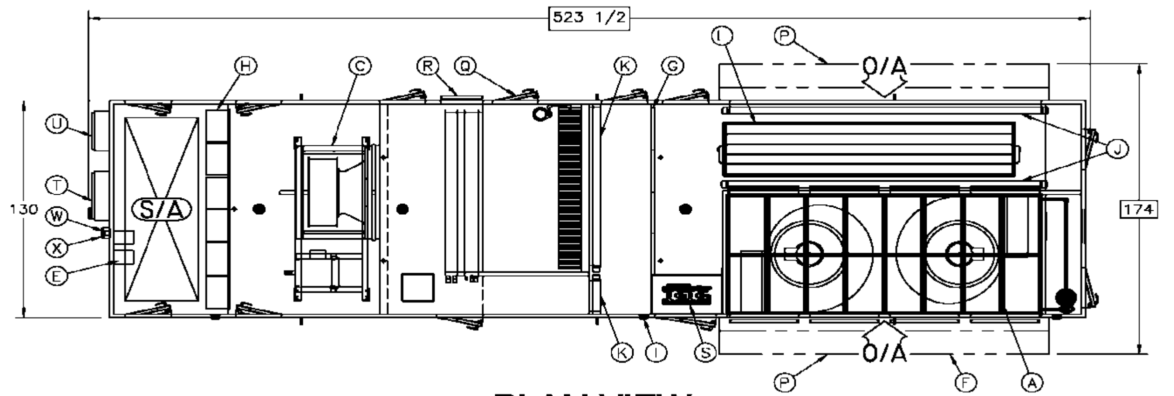
Figure 1

IEC VS CONVENTIONAL SYSTEM
10,000 CFM

Lower condenser rejection temperature means less compressor work and higher COP for IEC system

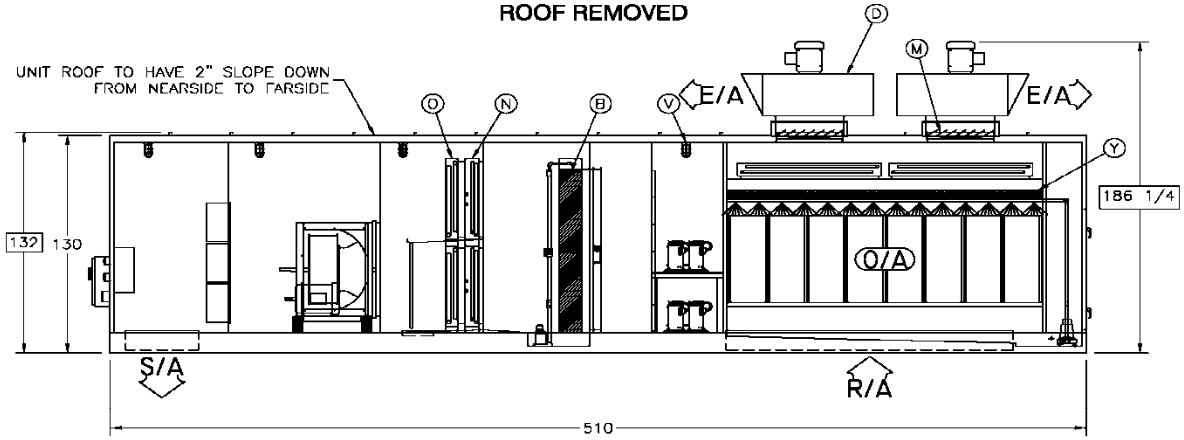
EER-30





PLAN VIEW

ROOF REMOVED



ELEVATION VIEW

WALL REMOVED

MAJOR COMPONENTS:

A. DCT HORIZONTAL TUBE HEAT EXCHANGER
B. DEC MEDIA
C. S/A FAN WITH MOTOR AND DRIVES
D. E/A FAN WITH MOTOR (DIRECT DRIVE)
E. FAN MOTOR VARIABLE FREQUENCY DRIVE
F. O/A HOOD FILTER BANK (METALLIC)
G. S/A FILTER BANK (30% PLEATED)
H. S/A FILTER BANK (85% PLEATED)
I. FILTER GAGE / SWITCH (TYPICAL)
J. O/A FACE AND BYPASS AIR DAMPER
K. DEC FACE AND BYPASS AIR DAMPER
L. RECIRCULATION AIR DAMPER
M. E/A BACKDRAFT DAMPER
N. COOLING COIL (DIRECT EXPANSION)
O. HEATING COIL (HOT WATER)
P. O/A HOOD WITH BIRDSCREEN
Q. UNIT ACCESS DOOR (TYPICAL)
R. UNIT ACCESS PANEL (TYPICAL)
S. CONDENSING SECTION (AIR COOLED)
T. UNIT ELECTRICAL PANEL
U. DDC CONTROL PANEL
V. VAPOR PROF LIGHT (TYPICAL)
W. GFCI RECEPTACLE
X. LIGHT SWITCH
Y. DRIFDEK MIST ELIMINATOR

NOTES:

1. MINIMUM 3'-0" CLEARANCE REQUIRED FOR SERVICE ACCESS (COILS MAY REQUIRED MORE ACCESS FOR REMOVAL).
2. FOR DRAINS AND CONNECTIONS LOCATIONS, SIZE, AND QUANTITY SEE 57868-M-AA02.
3. FOR BASE FRAME DWG SEE 57868-M-AA03.
4. FOR ROOF CURB DWG SEE 57868-M-AA04.
5. FOR REFRIGERANT PIPING SEE 57868-M-AA05.
6. FOR DEC PIPING SEE 57868-M-AA06.
7. FOR IEC PIPING SEE 57868-M-AA07.
8. UNIT OVERALL ENVELOPE DIMENSIONS ARE SHOWN IN BOXED DIMENSIONS.
9. WEATHER HOODS MAY BE SHIPPED IN PIECES FOR ASSEMBLY AND INSTALLATION BY OTHERS.
10. E/A FANS TO BE SHIPPED LOOSE FOR ASSEMBLY AND INSTALLATION BY OTHERS.
11. ATTENUATION OF FAN SOUND POWER LEVELS, IF REQUIRED, IS BY OTHERS.

AIR FLOW KEY:
O/A: OUTSIDE AIR
S/A: SUPPLY AIR
R/A: RETURN AIR
E/A: EXHAUST AIR

UNIT TAG: EC-1
ITEM #: PVT28C-0008
S/O NUMBER: 66878
UNIT QUANTITY: 1 TOTAL
EST. UNIT WEIGHT: 32800 LBS
(INCLUDES 900 LB ROOF CURB)

ORDER NO. 57868		Munters	
		ORDER NAME: WEST COLLEGE UTILITIES FACILITY	
APPROVALS	DATE	UNIT TYPE: PV UNIT WITH PLASTIC TUBE HX	
DRAWN: JCP	12/01/09	TITLE: MECHANICAL LAYOUT	
CHKD:		SIZE: A	DWG NO. 57868-M-AA01
APPD:			
SHEET 1 OF 1	SCALE: NTS	MODEL: PV-MZP-8730-PVT	

HIGH WATER CONSUMPTION WITH IDEC SYSTEMS???

IEC VS CHILLER WITH COOLING TOWER

- Evaporation of 1 pound of water requires 1,000 BTU of heat
- To provide one ton of cooling, we need to remove 12,000btu/hr
- 1 ton of cooling requires 12lbs/hr of water consumption

Indirect Evaporative Cooler

Water Evaporation = 12 Lbs/hr =1.44 gallons/hr per ton of cooling

Cooling Tower

Chiller adds about 3,000 btu/hr of parasitic load for every 12,000 btu/hr of cooling (approx 25%)

Water Evaporation = 15 Lbs/hr =1.8 gallons/hr per ton of cooling

- Additional water is wasted in CT due to drift.
- Bleed rate is higher due to higher evaporation rate and low cycles of concentration

Water consumed at the power plant

- 2 gallons of water is required for every kWh of electrical power consumed

Chiller

- Efficiency of chiller is 0.8kW/ton
- 1 ton of cooling provided by chiller requires **1.6 gallons/hr** at the power plant

IEC

- Efficiency of IEC is 0.2kW/ton
- 1 ton of cooling provided by IEC requires **0.4 gallons/hr** at the power plant

IEC = 1.44 gal/hr through evaporation + 0.4 gal/hr at power plant

1.84 GALLONS/HR per ton

CHILLER/CT = 1.8gal/hr through evaporation + 1.6 gal/hr at power plant

3.4 GALLONS/HR per ton

Water-use efficiency for alternative cooling technologies in arid climates

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Arid climates

A B S T R A C T

In arid climates, evaporative cooling technologies are generally valued for their reduced energy consumption in comparison to compressor-based air conditioning systems. However, two concerns that are often raised with respect to evaporative cooling equipment are their on-site water use and the impact of poor water quality on their performance. While compressor-based systems do not use water on-site, they do consume water through their use of electricity, which consumes water through evaporation at hydroelectric power plants and cooling at thermal power plants. This paper defines a water-use efficiency metric and a methodology for assessing the water use of various cooling technologies. The water-use efficiencies of several example cooling technologies are compared, including direct evaporative, indirect evaporative in two different configurations, compressor-based systems, compressor-based systems with evaporative pre-cooling of condenser inlet air, and hybrid systems that consist of an indirect evaporative module combined with a compressor-based module. Designing cooling systems for arid climates is entwined in the close relationship between water and energy and the scarcity of both resources. The analyses presented in this paper suggest that evaporative systems that significantly reduce peak electricity demand and annual energy consumption need not consume any more water than conventional systems.

Water use for evaporative cooling

- Technical efforts should continue to improve water use efficiency for evaporative solutions; however:

- Onsite consumption partially offset by water savings for reduced generation:
  - Recent evaluations of various technologies show water use of 5-10 gal/kWh savings
  - California average water use for electricity generation is ~1.4 gal/kWh
    - Thermal generation estimated at <1 gal/kWh
    - Hydro electric generation estimated >10 gal/kWh
    - Water use intensity for generation varies widely by region

- Estimate of water costs amount to 1-10% of the value of energy savings (not counting demand charges), depending on region, technology, and application.

Water use for evaporative cooling

- If all commercial buildings in California used indirect evaporative cooling
  - o Annual electricity savings = 6,511 GWh
  - o GHG emissions reduced = 4.5 MTonCO_2e
    - Equivalent to 950,000 automobiles
  - o Annual water use = 0.18 Million Acre Feet
    - 0.5% of all (non environmental) applied water use in California
    - Equivalent to 5% of all urban landscape uses

The research reported herein directly supports California Energy Efficiency Strategic Plan goals to accelerate marketplace penetration of climate appropriate air conditioning technologies. The report presents results from a field assessment of a dedicated outdoor air supply (DOAS) air hander that uses both indirect evaporative cooling and vapor compression to cool ventilation air for commercial buildings. This hybrid system was installed for an existing food store in San Ramon, California in combination with a whole building systems controls revision, and a closed door medium temperature refrigerated case lineup. In the year since installation, the project has demonstrated 20% whole building peak demand reduction, and 20% annual energy savings.

BENEFITS OF USING IDEC SYSTEM

- Energy Efficiency: Evaporative Cooling EERs in excess of 100 may be achieved.
- Can provide free cooling even if there is no building return air.
- Customers can achieve LEED points and can get utility rebates. Payback typically in less than 5 years.
- In arid climates, IDEC systems provide 100% O/A, leading to better IAQ while using less energy than typical recirculation air cooling systems.
- IDEC system helps reduce peak demand charges. They are most effective on the hottest days when most cooling is required.
- Positive impact on a regional basis for water use due to lowered kW use

Three Take Aways

- Use, and application of, IDEC + DEC has a proven track record.

- When applied correctly, highly efficient and effective versus traditional mechanical cooling

- Don’t let water consumption be the sole deterrent – 3rd party verification supports the benefits of its use.

Questions

We’ve covered a LOT