

**EVAPORATIVE COOLING,
GOING BEYOND "NORMAL"**



konvekta

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AGENDA

- EVAPORATIVE COOLING AND HUMIDIFICATION
 - COOLING EFFICIENCY REVIEW
 - THEORY AND SELECTION
 - ASHRAE 62.1 - 2022
 - IMPACT OF FROSTING ON HEAT RECOVERY
 - CASE STUDIES ON A PHARMACEUTICAL & VET LAB
 - EVAPORATIVE COOLING IN BOSTON?
 - WATER USAGE & TREATMENT
 - LEGIONELLA
 - METHODS

The image features a light gray gradient background with several realistic water droplets of various sizes scattered in the corners. The droplets have highlights and shadows, giving them a three-dimensional appearance. The text is centered in the middle of the page.

**EVAPORATIVE -
THE MOST EFFICIENT COOLING!!**

EVAPORATIVE COOLING ENERGY SAVINGS

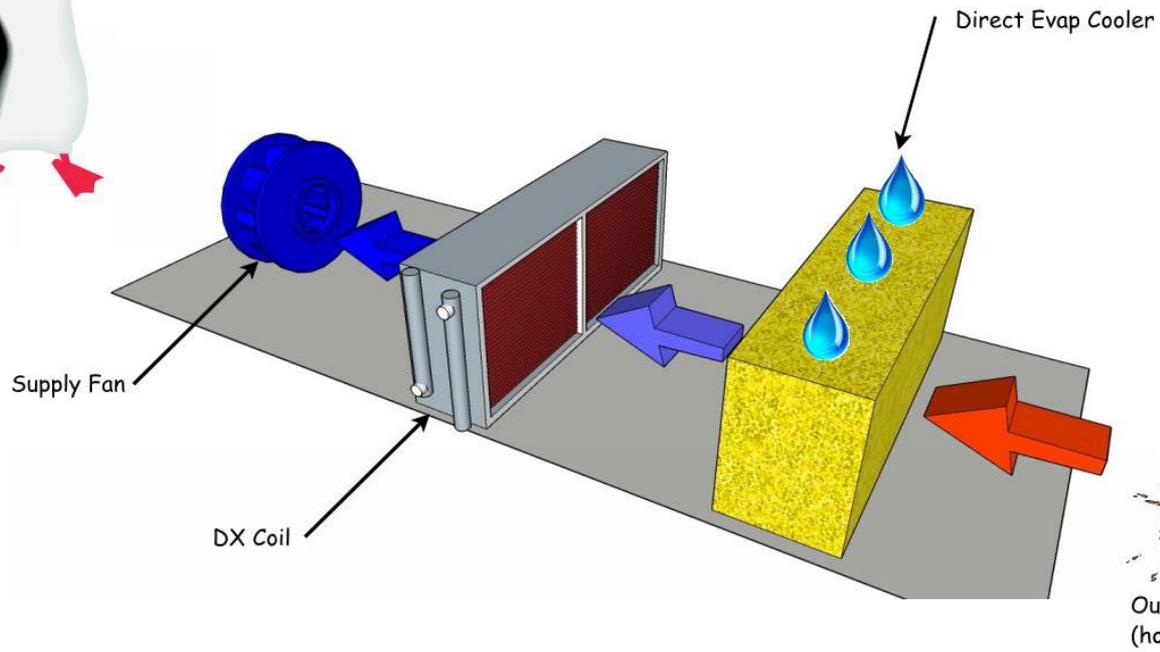
- Compared to Refrigeration equipment:
 - Evaporative cooling saves 90-92% operating costs*
 - Evaporative cooling saves 89-98% energy**
- * Including Water use and Energy
- ** Includes extra pressure drop on fan

BUT WHAT ABOUT THE WATER USE?

- Evaporation provides 1,050 BTU per lb of water
 - Each Gallon = 8.33 lb * 1,050 = 8,746 BTU
 - Each Ton = 11.42 lbs not including bleed (1.37 gal)
- Water Cooled Equipment has to reject the cooling PLUS the motor heat ~ 30%
- Therefore Water Cooled uses at least 30% more water
- Air Cooled uses NO Water?

The background features a light gray gradient with several realistic water droplets of various sizes scattered in the corners. The droplets have highlights and shadows, giving them a three-dimensional appearance. They are located in the top-left, top-right, and bottom-right areas of the frame.

EVAPORATIVE COOLING WITH MECHANICAL BACKUP





Western Mechanical Solutions

SUSTAINABLE HEATING COOLING

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PSYCHROMETRIC CHART

NORMAL TEMPERATURE

I-P Units

5361 FEET

BAROMETRIC PRESSURE : 24.563 INCHES OF MERCURY

8,760 Hours per Year

Weather Data Location:
AULTER, DENVER, COLORADO, USA

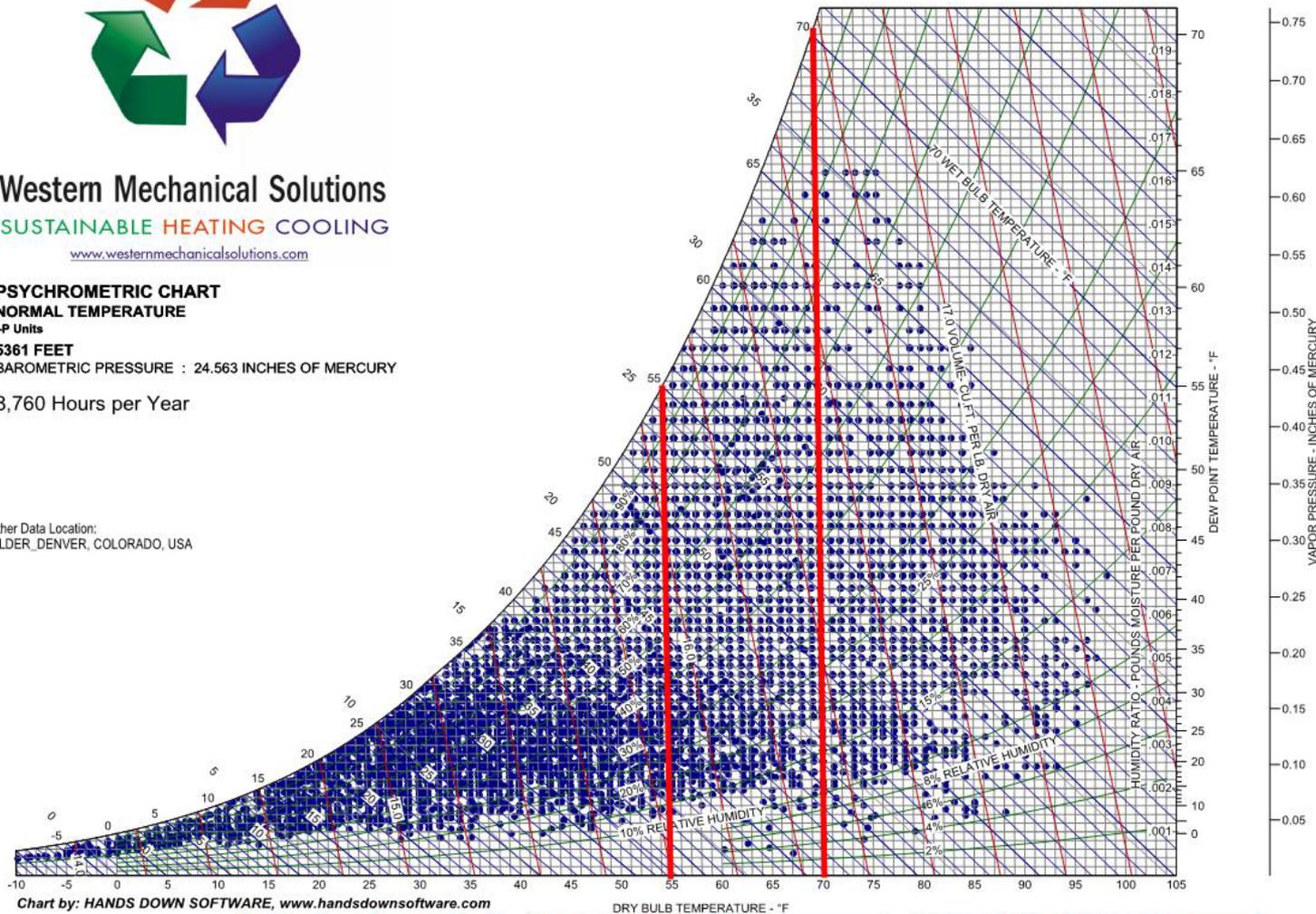
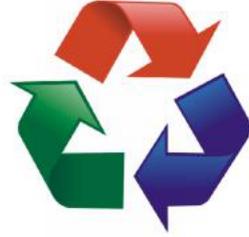


Chart by: HANDS DOWN SOFTWARE, www.handsdownsoftware.com

No Cooling Required,
full Economizer if there
is any building load
5,108 hrs 58%

From 55 deg to 70 deg
integrated economizer lowers
compressor energy 100%
Outside Air 2,108 hours 24%

Above 70 deg Outside Air
Damper closes to minimize
energy use 15 - 20% OA
1,544 hours 18%

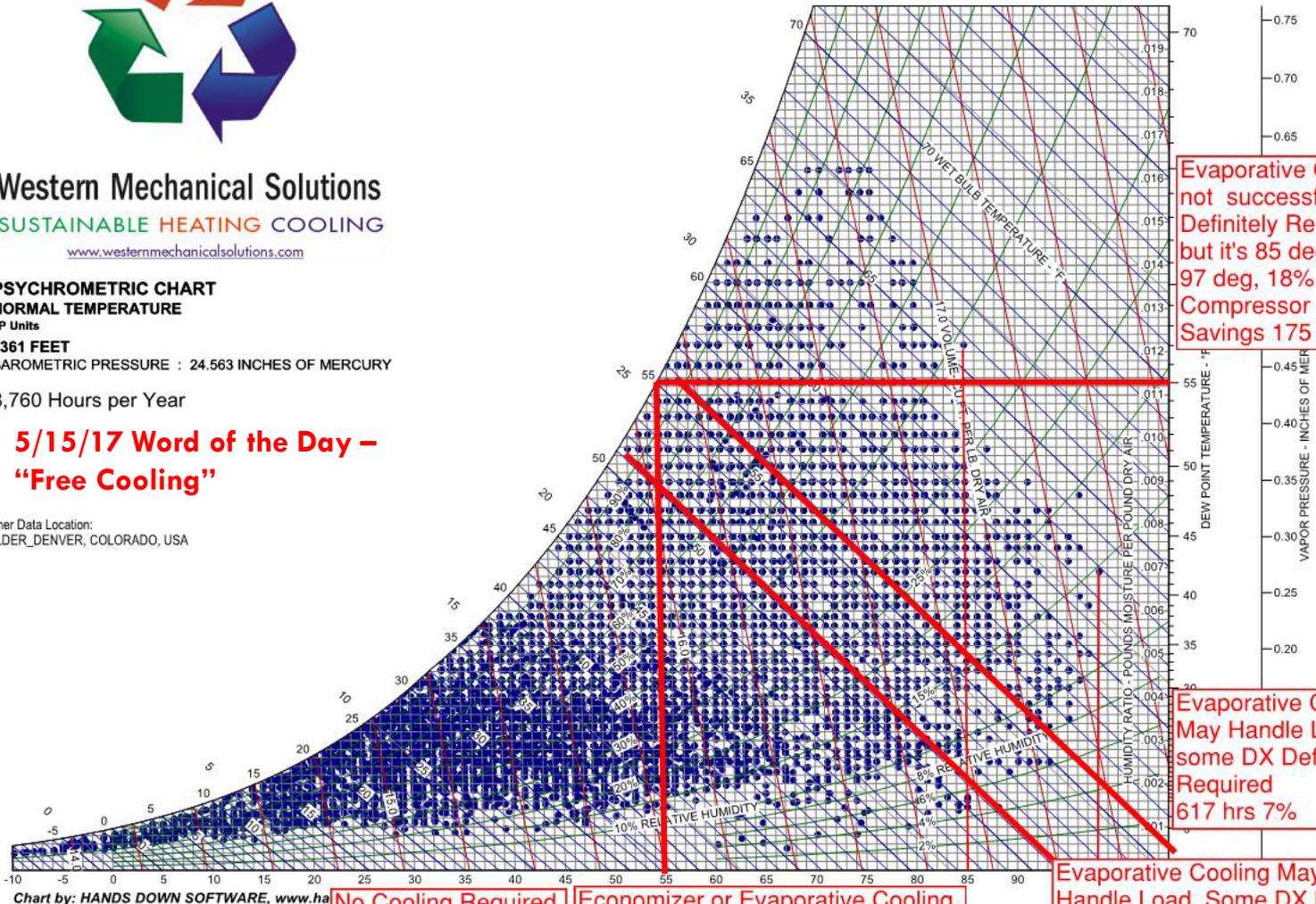


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PSYCHROMETRIC CHART
NORMAL TEMPERATURE
I-P Units
5361 FEET
BAROMETRIC PRESSURE : 24.563 INCHES OF MERCURY
8,760 Hours per Year

5/15/17 Word of the Day –
“Free Cooling”

Weather Data Location:
BOULDER_DENVER, COLORADO, USA



Evaporative Cooling
not successful, DX
Definitely Required,
but it's 85 deg, not
97 deg, 18%
Compressor Energy
Savings 175 hrs 2%

Evaporative Cooling
May Handle Load,
some DX Definitely
Required
617 hrs 7%

Evaporative Cooling May
Handle Load, Some DX May
Be Required 1,311 hrs 15%

No Cooling Required
5,108 hrs 58%

Economizer or Evaporative Cooling
Can Handle Load 6,657 hrs 76%

Chart by: HANDS DOWN SOFTWARE, www.handsdownsoftware.com

Initial Struggles

With no humidity control there was a requirement for dehumidification of the air requiring refrigeration and then heating

We figured out how to evaporatively cool to the plotted point “Target Humidity Ratio Limit”.

The mechanical cooling required is a reduction of 29.7% energy in cooling, and 46% total heating and cooling energy.

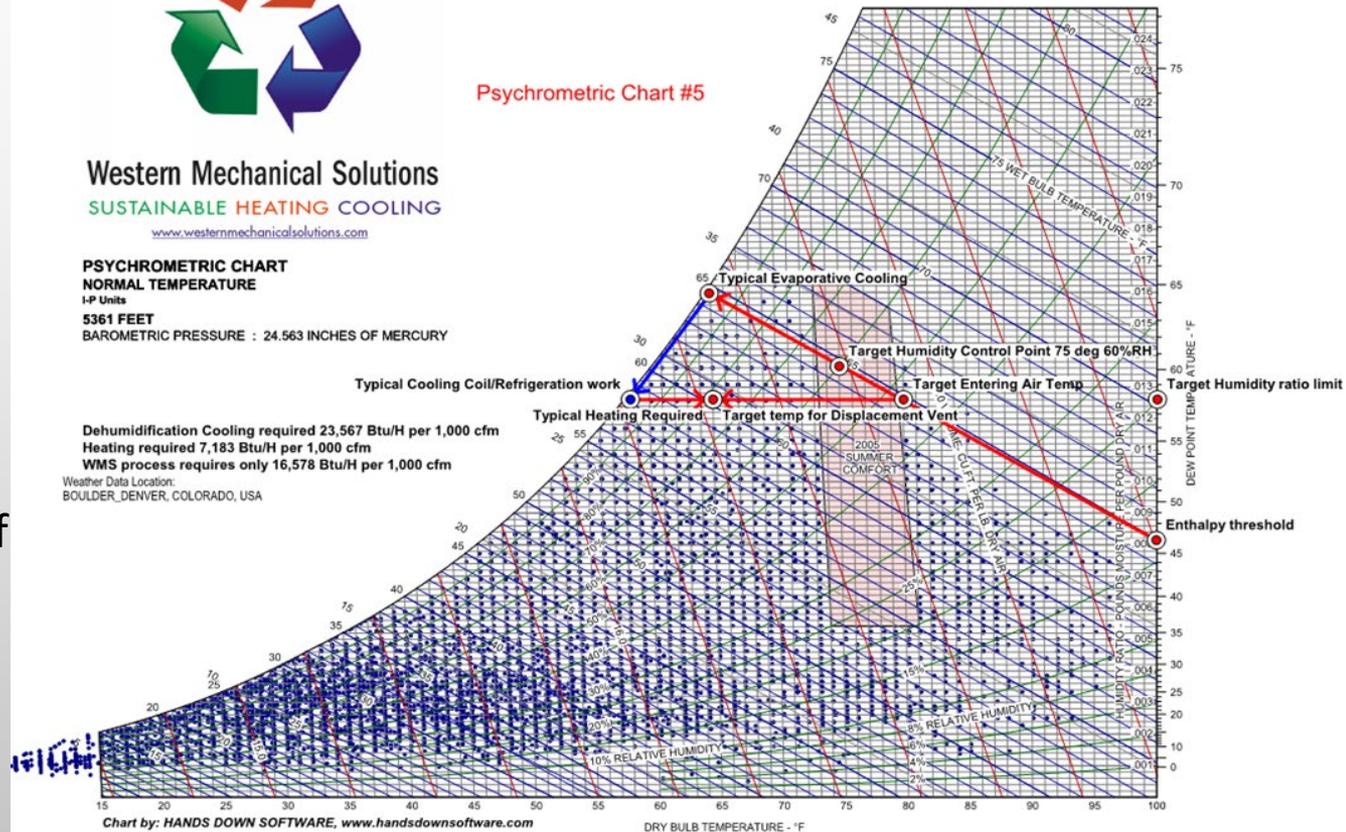


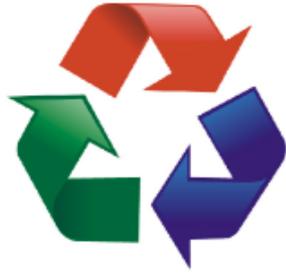
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PSYCHROMETRIC CHART
NORMAL TEMPERATURE
I-P Units
5361 FEET
BAROMETRIC PRESSURE : 24.563 INCHES OF MERCURY

Dehumidification Cooling required 23,567 Btu/H per 1,000 cfm
Heating required 7,183 Btu/H per 1,000 cfm
WMS process requires only 16,578 Btu/H per 1,000 cfm

Weather Data Location:
BOULDER, DENVER, COLORADO, USA





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PSYCHROMETRIC CHART

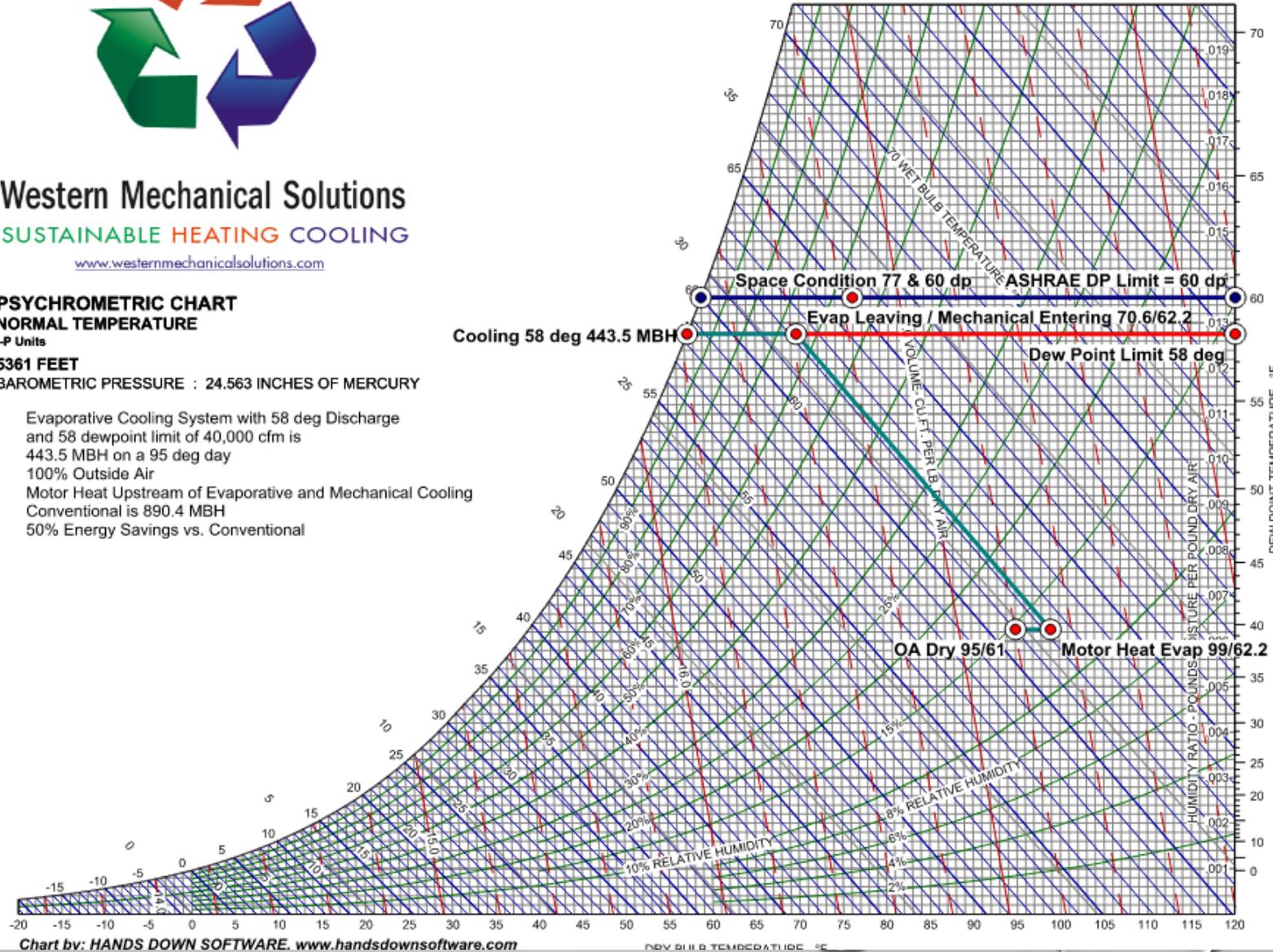
NORMAL TEMPERATURE

I-P Units

5361 FEET

BAROMETRIC PRESSURE : 24.563 INCHES OF MERCURY

Evaporative Cooling System with 58 deg Discharge
and 58 dewpoint limit of 40,000 cfm is
443.5 MBH on a 95 deg day
100% Outside Air
Motor Heat Upstream of Evaporative and Mechanical Cooling
Conventional is 890.4 MBH
50% Energy Savings vs. Conventional



With careful design, tonnage can be decreased
Evaporative with Mech 40,000 cfm
EAT 70.6!!
LAT 58
Dp - 58
37 Tons
50% Energy Savings
70% for Labs!

TRADITIONAL VS. INTEGRATED EVAP DX

TRADITIONAL HOURS

• ECONOMIZER	5,108
• INTEGRATED ECONOMIZER	2,108
• ALL DX	1,544
• POTENTIAL COMPRESSOR OPERATION	3,652

NEW APPROACH HOURS

• ECONOMIZER OR COOLER	6,657
• ECONOMIZER OR COOLER MAY WORK	1,311
• ECONOMIZER OR COOLER WITH DX	617
• ALL DX	175
• POTENTIAL COMPRESSOR OPERATION	2,103

% REDUCTION IN COMPRESSOR OPERATION 42 %

ASHRAE 2022 62.1

5.12 Mechanically or Indirectly Evaporatively Cooled Buildings. Systems that cool by mechanical means or indirect evaporation shall be designed to limit the indoor humidity to a maximum dew point of 60° F (15° C) during both occupied and unoccupied hours whenever the outdoor air dew point is above 60° F (15° C). The dew-point limit shall not be exceeded when system performance is analyzed with outdoor air at the dehumidification design condition (that is, design dew point and mean coincident dry-bulb temperatures) and with the space interior loads (both sensible and latent) at cooling design values and space solar loads at zero.

Exceptions to 5.12:

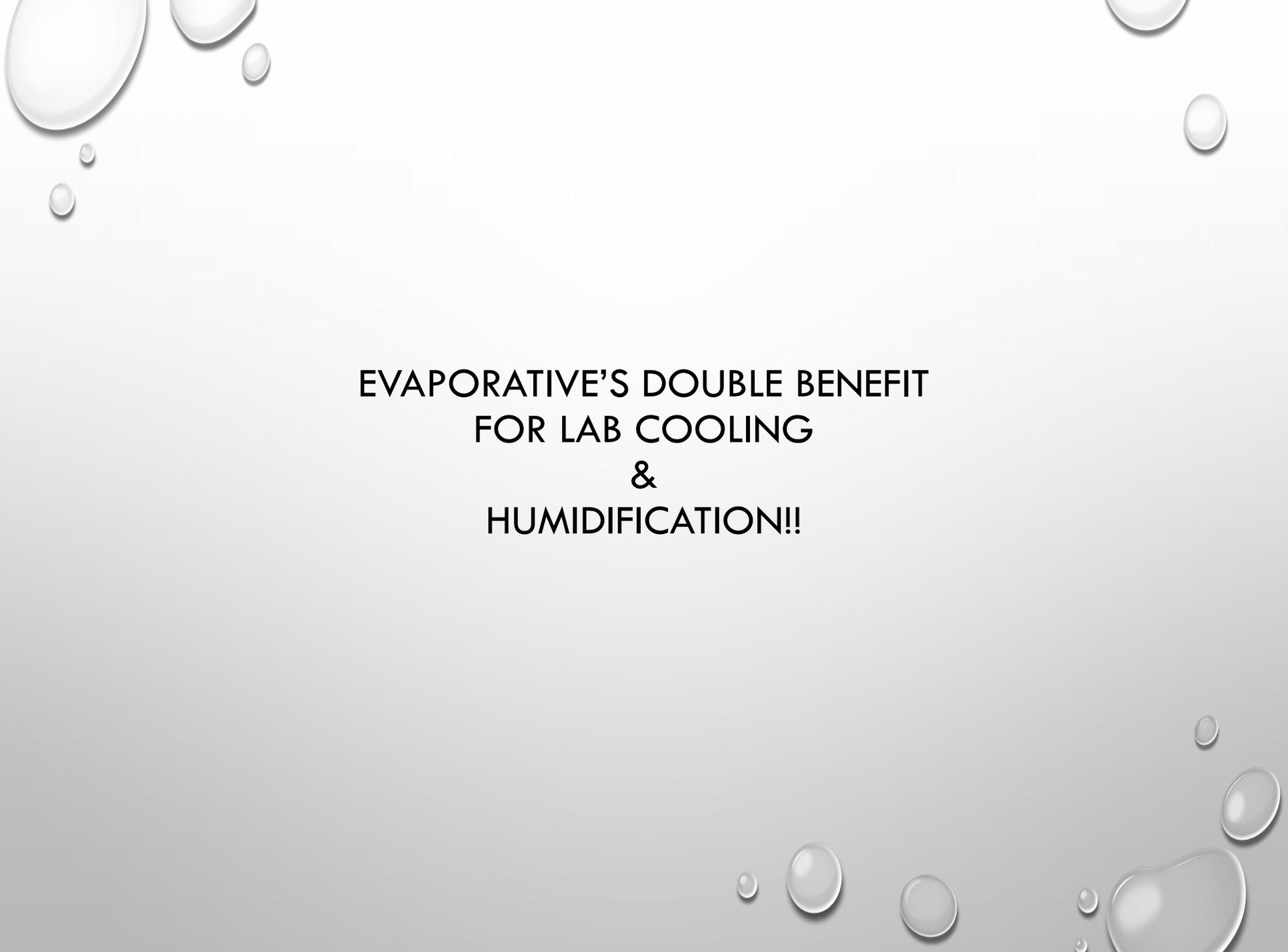
1. Spaces equipped with materials, assemblies, coatings, and furnishings that resist microbial growth and that are not damaged by continuously high indoor air humidity.
2. **During overnight unoccupied periods not exceeding 12 hours, the 60° F (15° C) dew-point limit shall not apply, provided that indoor relative humidity does not exceed 65% at any time during those hours.**

CONTROLS

- Integrating Mechanical and Evaporative Cooling is very difficult
- Evaporative cooling is difficult to control
 - Takes 10 minutes to fully wet the media
 - Takes 30 minutes to 1 hour to dry the media
 - The more humid the air, the slower the dryout process
 - So any change in temperature reacts very slowly
- Overshoot Humidity, have to dehumidify

OPERATIONAL MAINTENANCE BENEFITS

- **Mixed air units:**
- The Unit is 100% Outside Air in the Summer
 - Summer Reheat may be Eliminated
 - VAV box minimum can most be drastically reduced
 - Reheat can probably be eliminated
 - Boilers can be turned off
- Evaporative Cooling has lower maintenance than compressors

The background features a light gray gradient with several realistic water droplets of various sizes scattered in the corners. The droplets have highlights and shadows, giving them a three-dimensional appearance. The text is centered in the middle of the page.

**EVAPORATIVE'S DOUBLE BENEFIT
FOR LAB COOLING
&
HUMIDIFICATION!!**



CASE STUDIES

- Winter Humification with Evaporative Cooling
 - Pharmaceutical Lab
 - Vet Hospital



PHARMACEUTICAL LAB IN DENVER

- Low Carbon was important
- Energy Recovery was imperative
- Supply Evaporative cooling to minimize cooling hours
- Humidify with evaporative cooling?
- Eliminate steam humidifier!
- Integrate – Evap controller drives heating DAT
- Exhaust evaporative cooling
- Konvekta system with one coil design
 - Heat recovery
 - 32% Heating Energy Savings! (38% design day savings)
 - 37% Cooling Energy Savings w/o Supply Evap Considerations! (39% design day savings)
 - Heating
 - Mechanical Cooling

Get rid of Steam with Evap & Predictive Controls!



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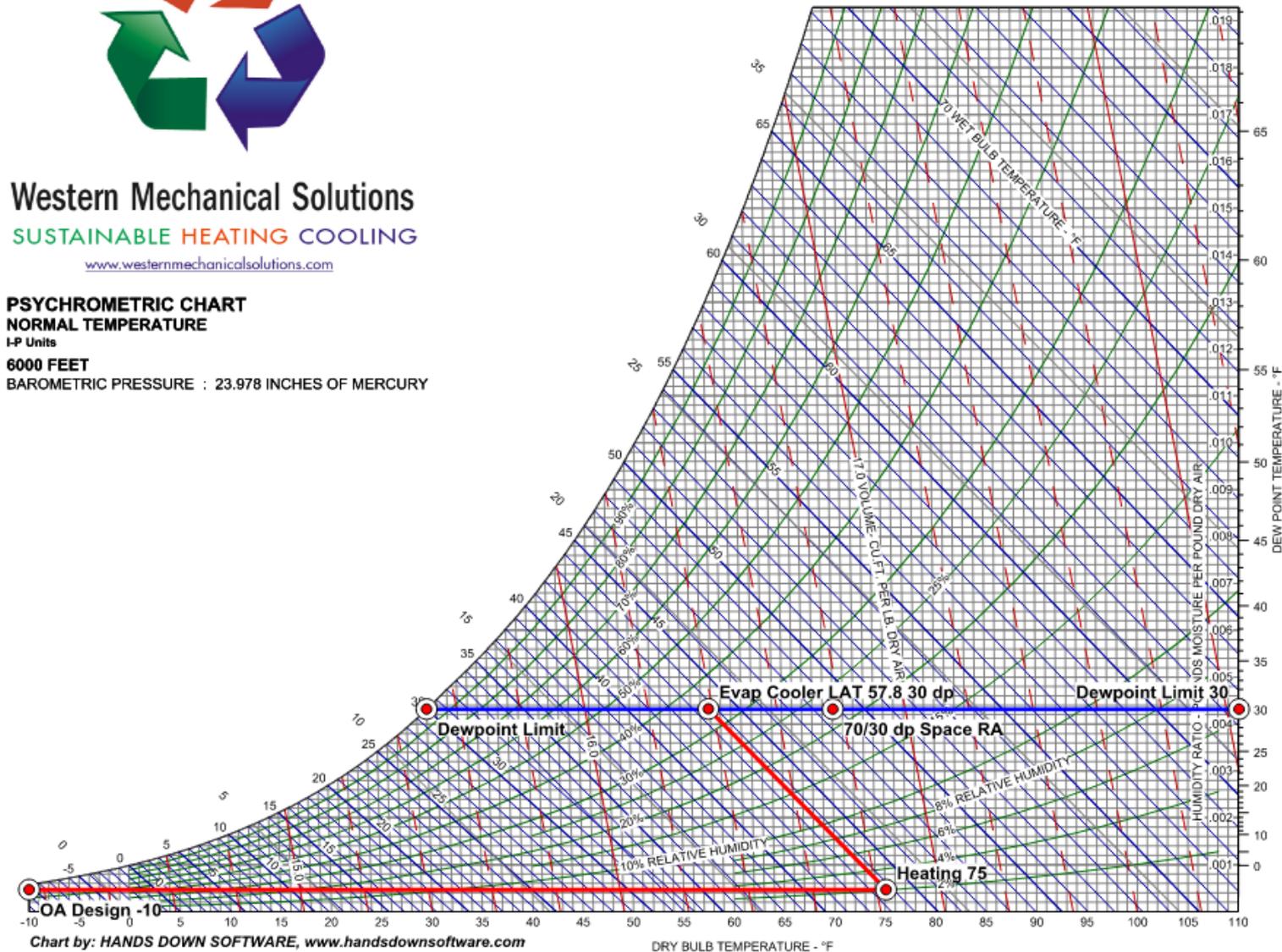
PSYCHROMETRIC CHART

NORMAL TEMPERATURE

I-P Units

6000 FEET

BAROMETRIC PRESSURE : 23.978 INCHES OF MERCURY



Predictive allows
Control to
humidity
threshold

Can heat air to
then
evaporatively
cool and
maintain a
space humidity
+ or - 5% RH

Reduce
installation and
maintenance
costs

DON'T FROST UP!!



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PSYCHROMETRIC CHART
NORMAL TEMPERATURE
IP Units
6000 FEET
BAROMETRIC PRESSURE : 23.978 INCHES OF MERCURY

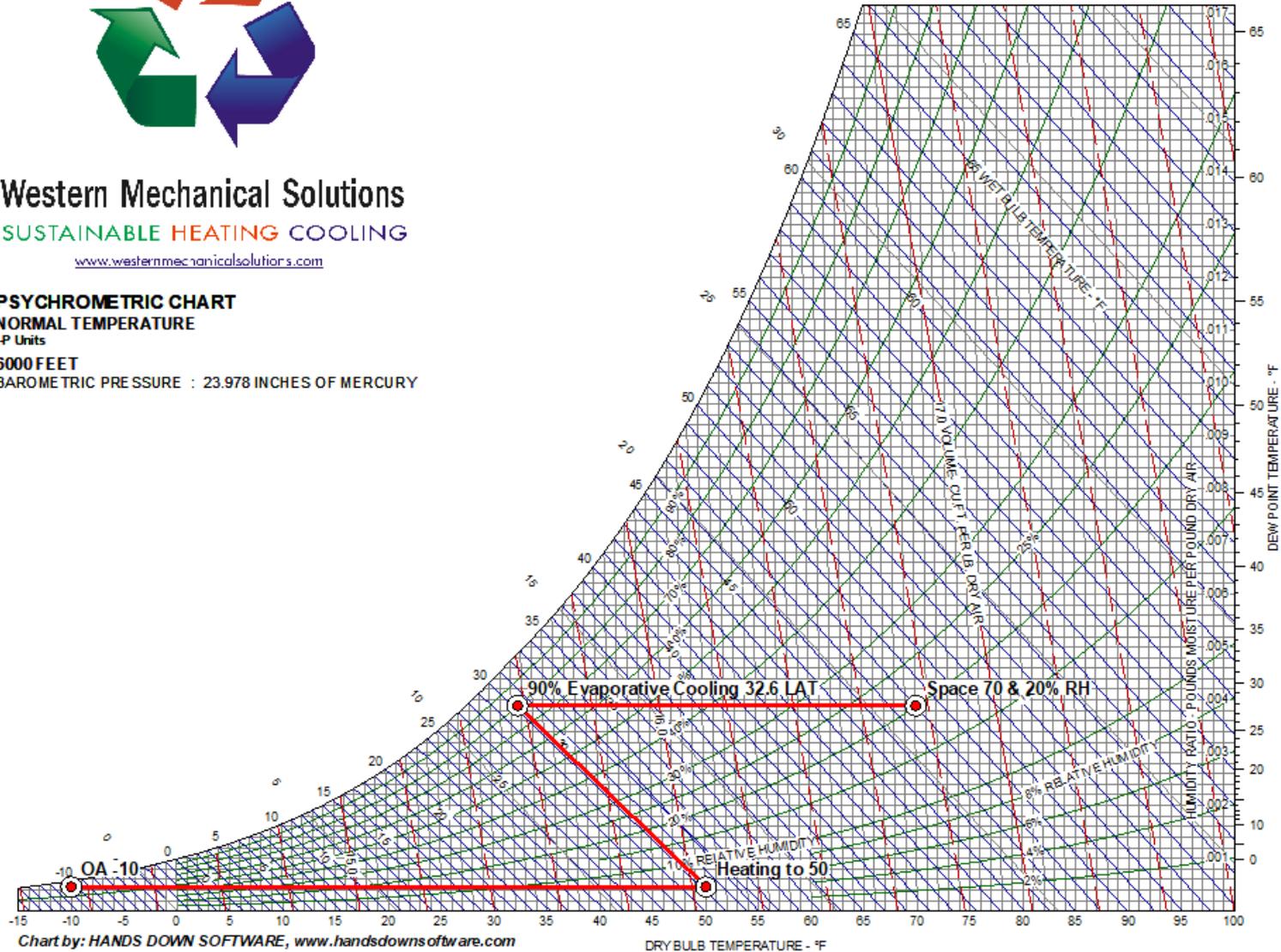


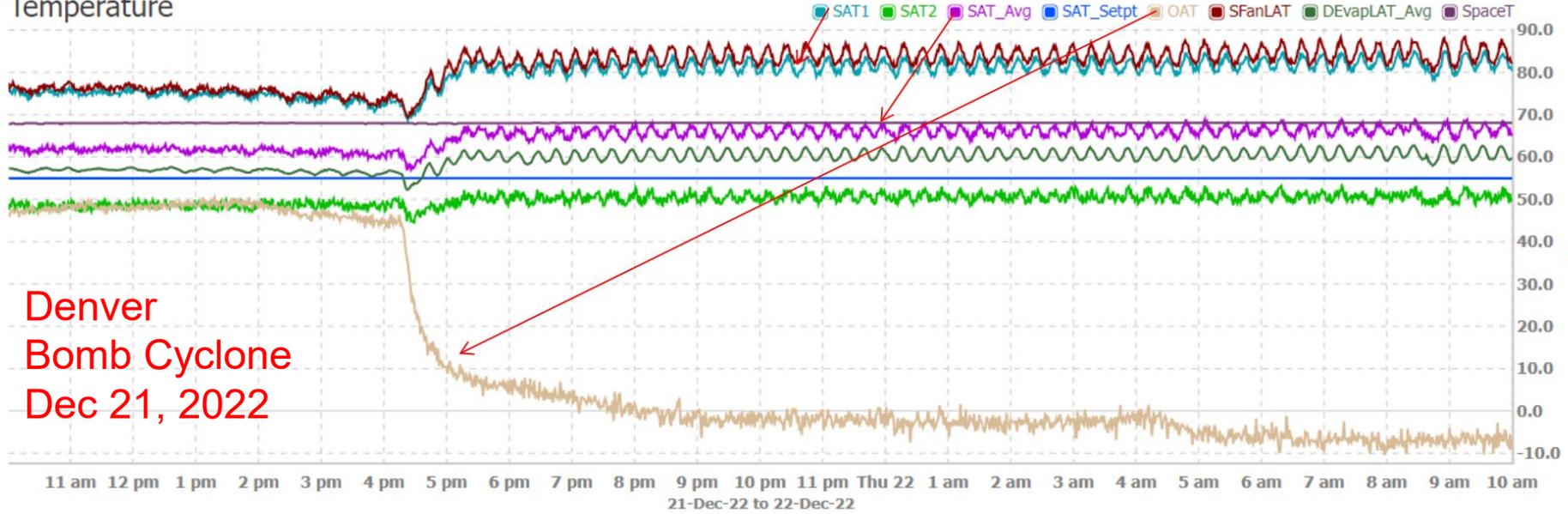
Chart by: HANDS DOWN SOFTWARE, www.handsdownsoftware.com

DRY BULB TEMPERATURE - °F

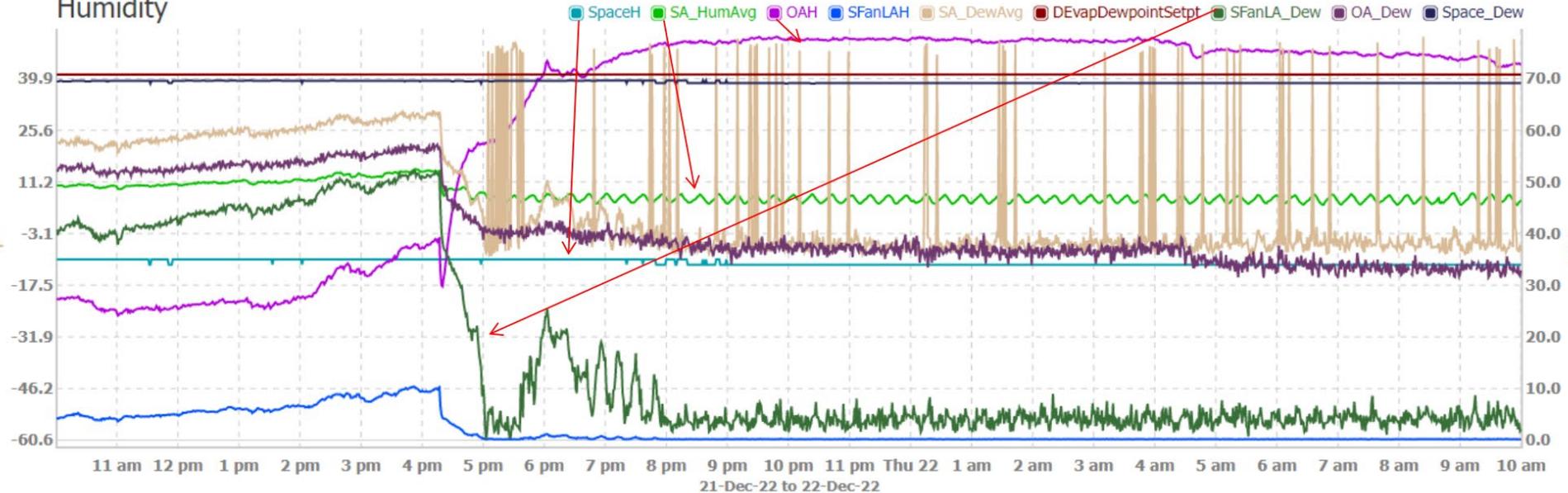
The resultant evaporative cooling temperature must be above 32 deg!
Target 65 with low limit of 55 min?

Pharma Lab – The Real Test!!

Temperature



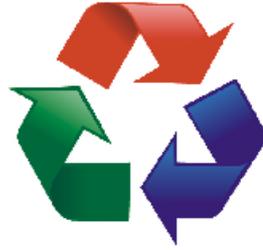
Humidity



The background features a light gray gradient with several realistic water droplets of various sizes scattered in the corners. The droplets have highlights and shadows, giving them a three-dimensional appearance. They are located in the top-left, top-right, and bottom-right areas of the page.

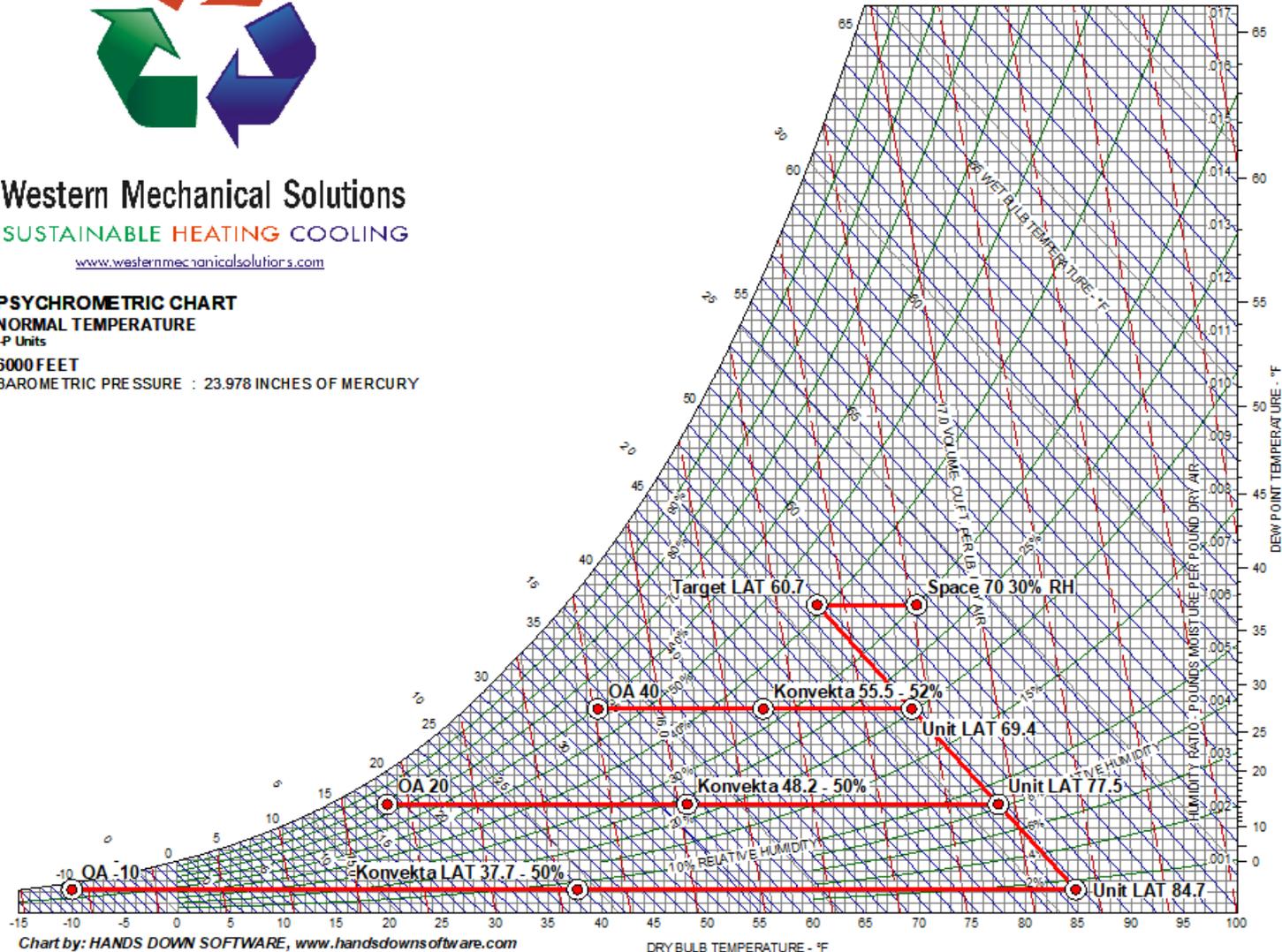
**KONVEKTA'S ONE COIL COMBINES HEAT RECOVERY
AND HEATING IN ONE SYSTEM**

Preheat to Evaporatively Cool



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PSYCHROMETRIC CHART
NORMAL TEMPERATURE
IP Units
6000 FEET
BAROMETRIC PRESSURE : 23.978 INCHES OF MERCURY



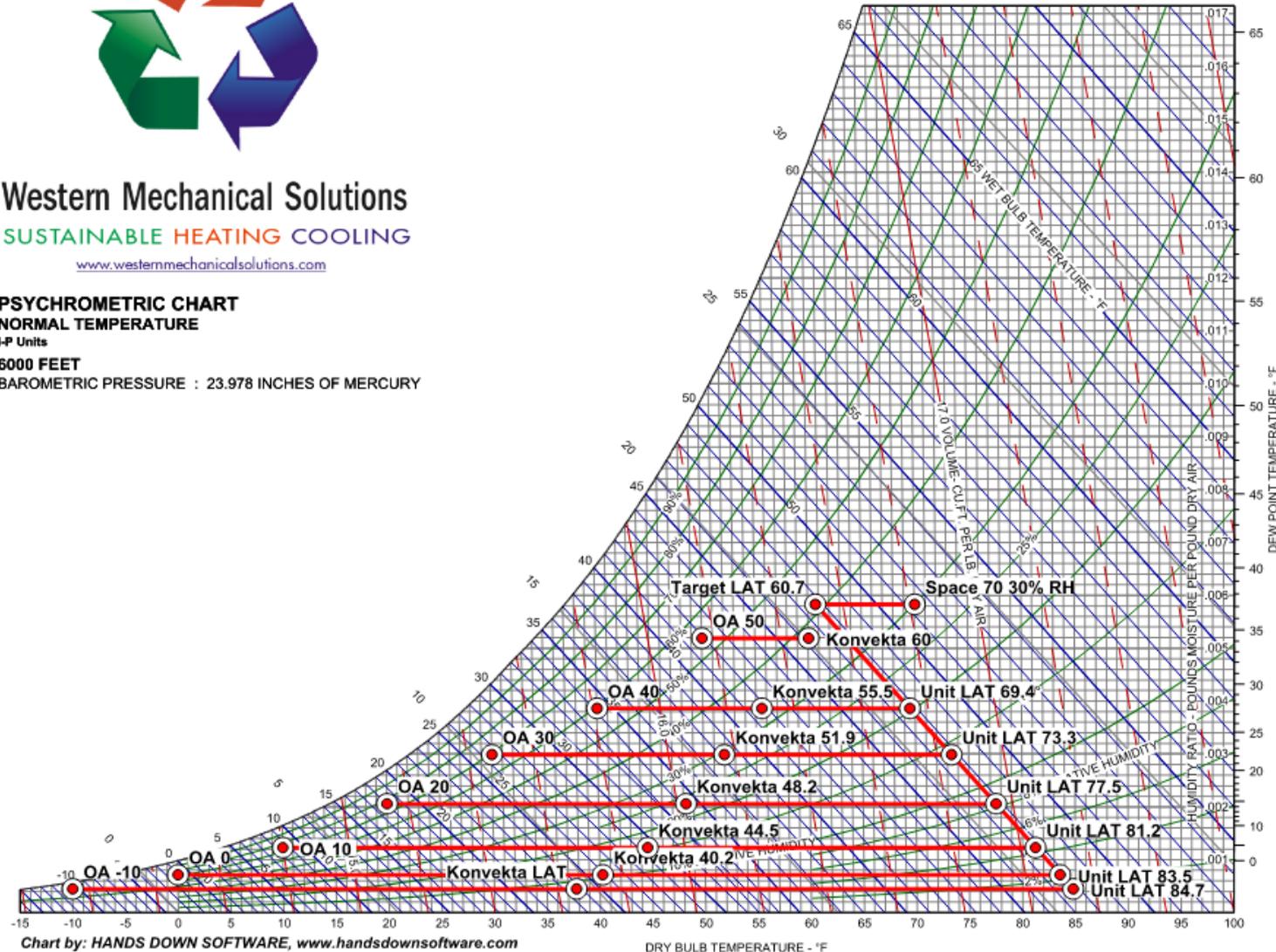
Typical bin
temperature
analysis for
30% RH
Condition
37.1 dewpoint
exhaust

Preheat to Evaporatively Cool



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PSYCHROMETRIC CHART
NORMAL TEMPERATURE
I-P Units
6000 FEET
BAROMETRIC PRESSURE : 23.978 INCHES OF MERCURY



Typical bin
temperature
analysis for
30% RH
Condition
37.1 dewpoint
exhaust
Note 45 deg
bin
Normally limit
heat
recovery....

Preheat to Evaporatively Cool

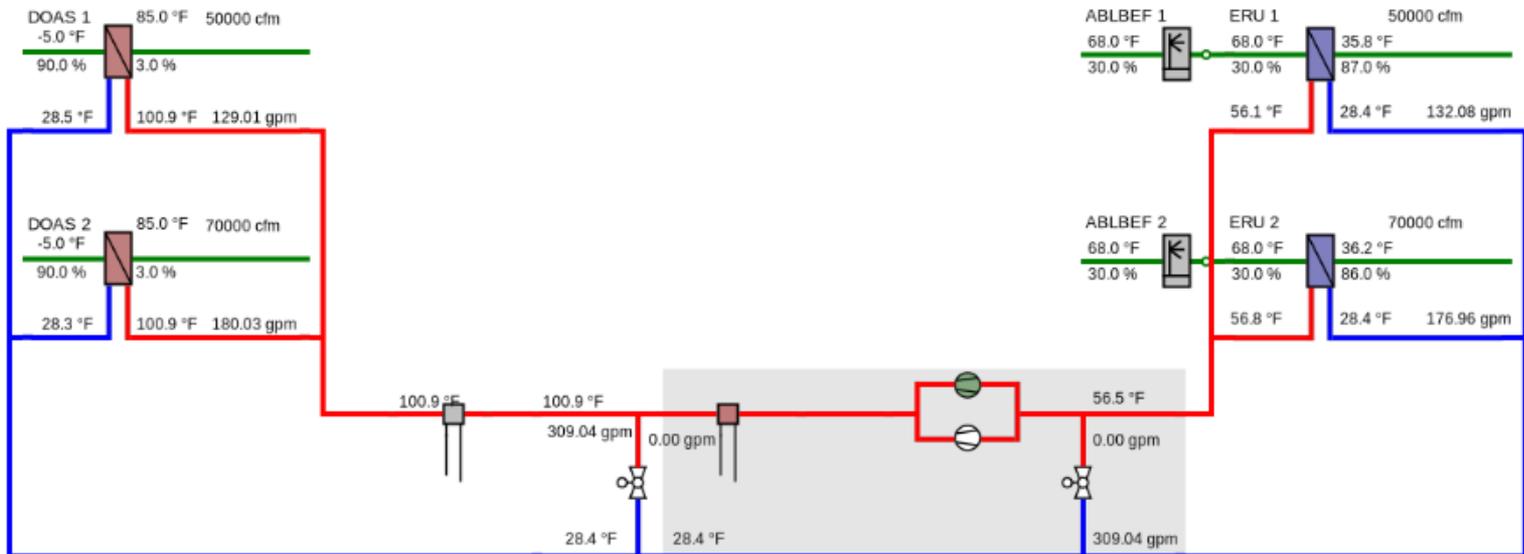
sys▼kon_4.0

kon▼vekta

Project: // system 1

Reference: 84200820-a1-v8, January 25., 2021 / V4.2.4

Operating Point: Winter



- Preheat to 85 to be able to evaporatively cool air
- -5 to 85 F and 38% of that is energy recovery on a design day!!
- Low heating temps work well with Heat Pumps!

The image features a light gray background with a subtle gradient. In the top-left and bottom-right corners, there are several realistic-looking water droplets of various sizes, some overlapping. The text is centered in the middle of the page.

KONVEKTA ADDS FROSTING!!

Design Considerations - Exhaust Coil Frost/Defrost

Exhaust Coil – Design Considerations:

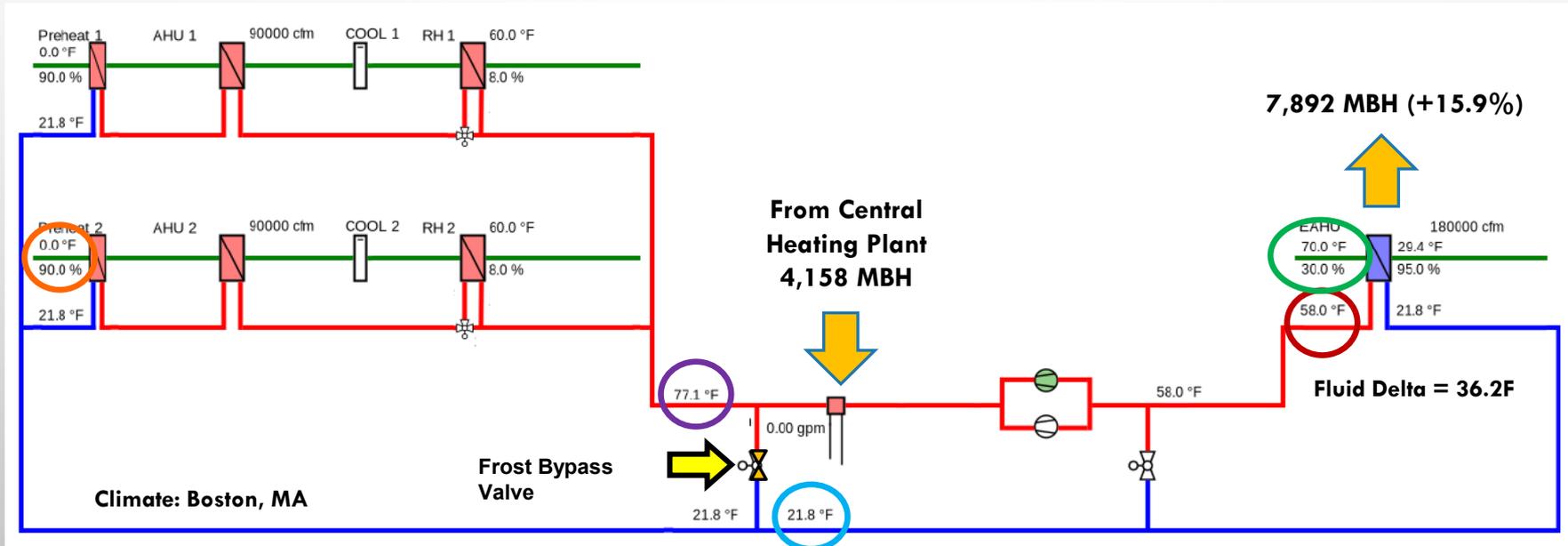
Accumulation of frost will occur at conditions near winter design.

- Coil fins must be designed and manufactured to withstand frost/defrost cycles
 - 0.4 mm fins
 - 4mm fin spacing (6 fpi)
 - KO32 epoxy coating
- Controls design and sequence of operation, must account for a defrost cycle
 - 6 to 8 independently controlled exhaust coil zones
 - 1 to 2 zones deactivated on rotating basis, during defrost cycle



Design Options – Winter with Frosting

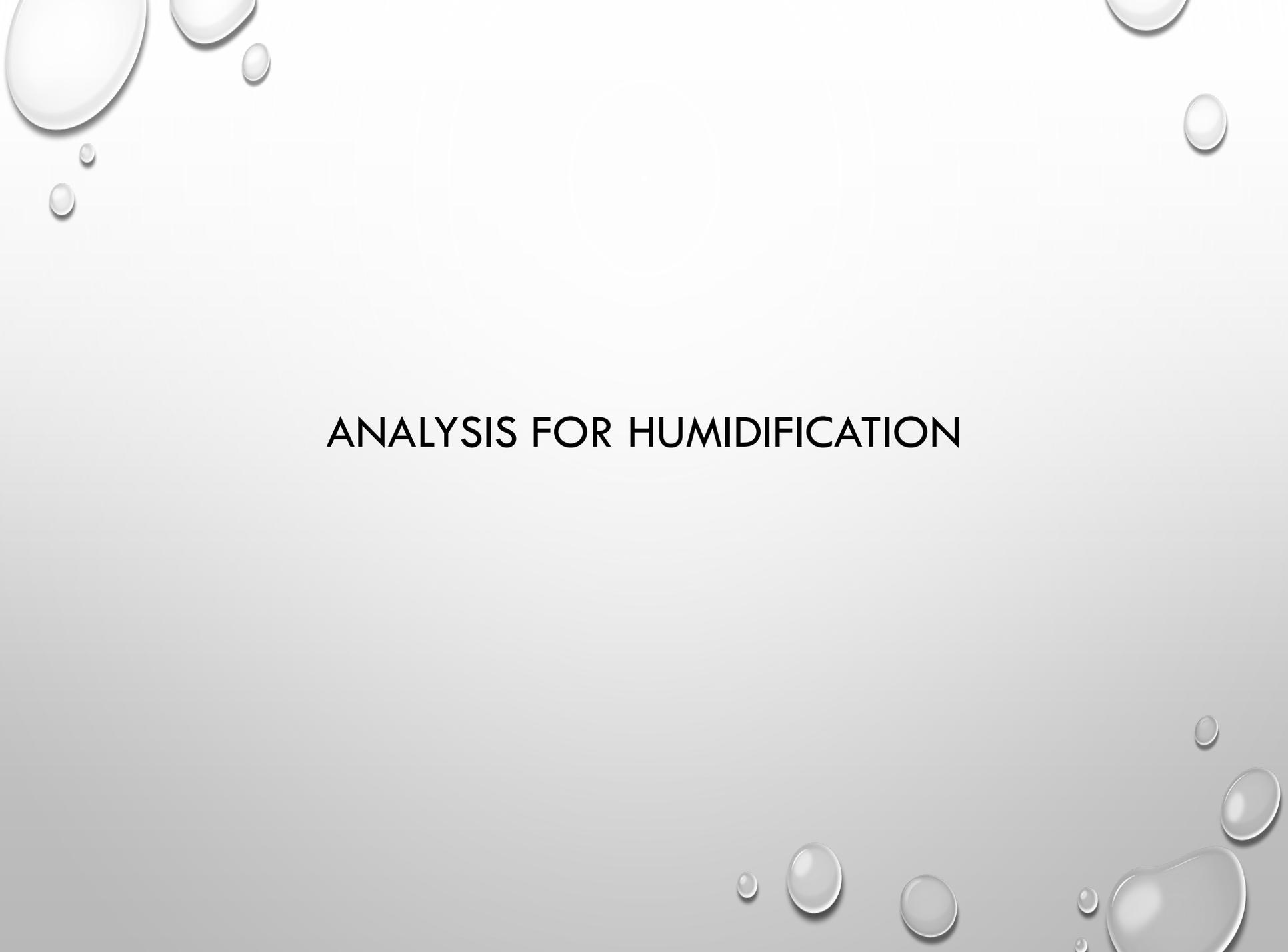
Winter Operation: Frosting



Colder Exhaust Air = More Heat Recovery

Condensing and Freezing of the Exhaust Air Moisture

Increases heat recovery 15 – 20%!!

The background features a light gray gradient with several realistic water droplets of various sizes scattered in the corners. The droplets have highlights and shadows, giving them a three-dimensional appearance. The text is centered in the middle of the page.

ANALYSIS FOR HUMIDIFICATION

VET LAB HUMIDIFICATION HEATING & COOLING ANALYSIS

Typical bin temperature analysis for 20 & 30% RH

Steam humidification would require boiler operation in the summer. Evap provides free humidification.



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PSYCHROMETRIC CHART
NORMAL TEMPERATURE
I-P Units
5016 FEET
BAROMETRIC PRESSURE : 24.881 INCHES OF MERCURY

Weather Data Location:
FORT COLLINS_AWOS, COLORADO, USA

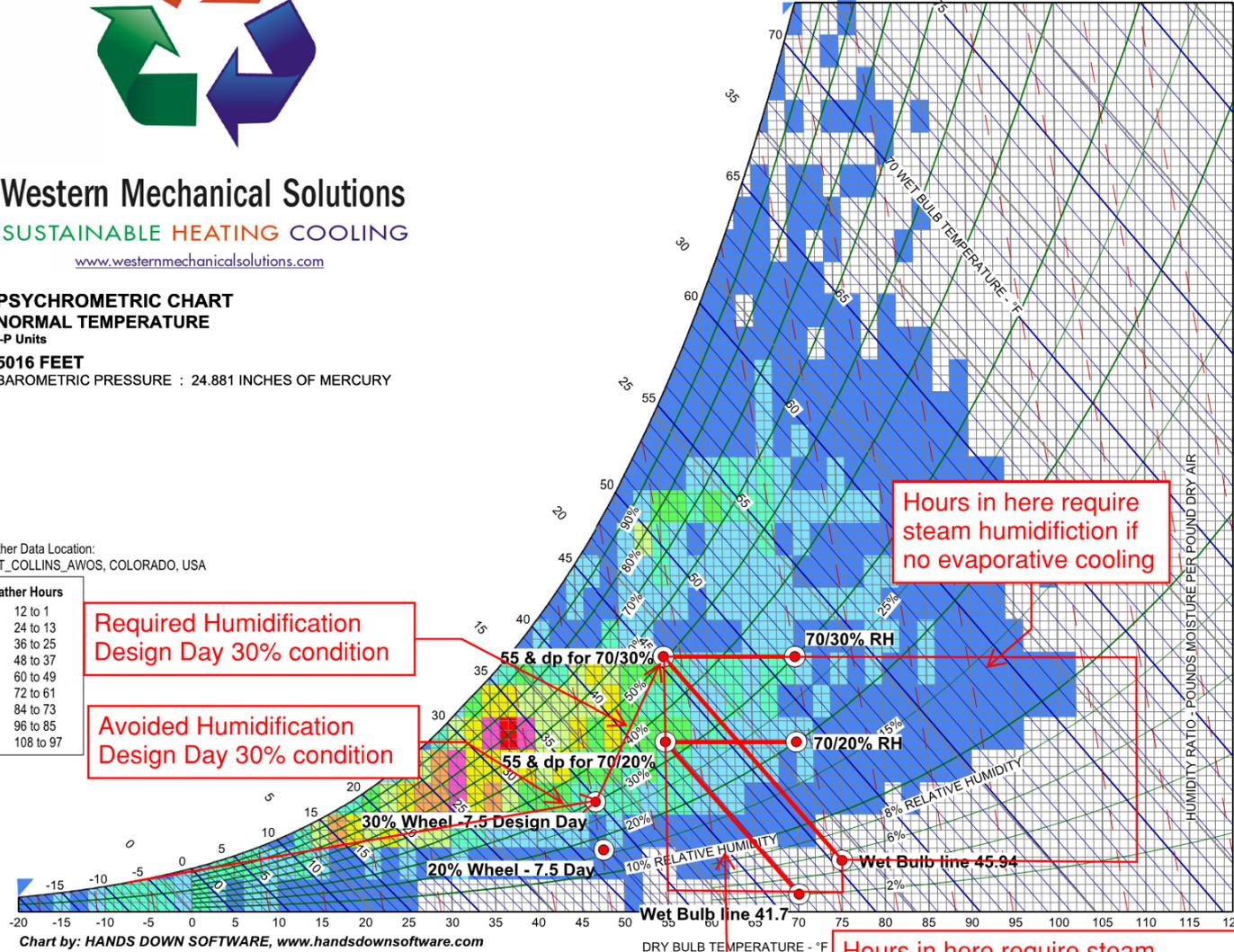
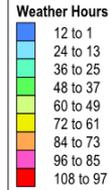


Chart by: HANDS DOWN SOFTWARE, www.handsdownsoftware.com

VET LAB HUMIDIFICATION HEATING ANALYSIS

	Total Airflow CFM	Outside Air Percentage	Humidity Setpoint RH%	Hours Above 55 Needing Heat for Humidification	Winter Heating MBH Input	Humidification Heating MBH Input	Total Boiler MBH Input	Notes
AHU-4 w/Steam	42,000	30%	30% RH	1,109	1182	414	1,596	Steam is 80% eff, water treatment,
AHU-4 w/Heat Wheel & Evap	42,000	30%	30% RH	0	353	360	713	Heat is 92% eff, no water treatment
Savings							883	

- Steam – 80%
- Hot Water Boiler – 92? % Efficient
- 55% Savings with Heat Recovery and Evaporative Humidification!!

VET LAB EVAPORATIVE COOLING ANALYSIS

A	B	C	D	E	F	G	H	I	J	K	L
Country	USA	Evap Configuration				Total hours analyzed		8,760			
State	COLORADO	Media Depth	12Inch		Traditional cooling		3,887				
City	FORT_COLLINS_AWOS	Velocity	500 FPM		Evap cooling only		1,602	41%			
Altitude	5016 Ft	Fan Type	Downstream		Partial Evap cooling		2,171	56%			
barometric Pres	24.896 In Hg	Motor Heat	4°F		Total Evap cooling		3,773	97%			
		Discharge Temp Setpt	55°F		Mechanical cooling only		114	3%			
		Final Evap Temp Setpt	51°F								

- Cooling – Traditional 3,887 hours required
- With Evaporative
 - 1,600 hours No Mechanical Cooling
 - 2,171 hours reduced Mech Cooling Load
 - 114 hours full Mechanical - no benefit

NOT THE WHOLE PICTURE - DENVER

Denver

Typical bin temperature analysis for 30% RH

Evap provides free cooling between the horizontal lines!



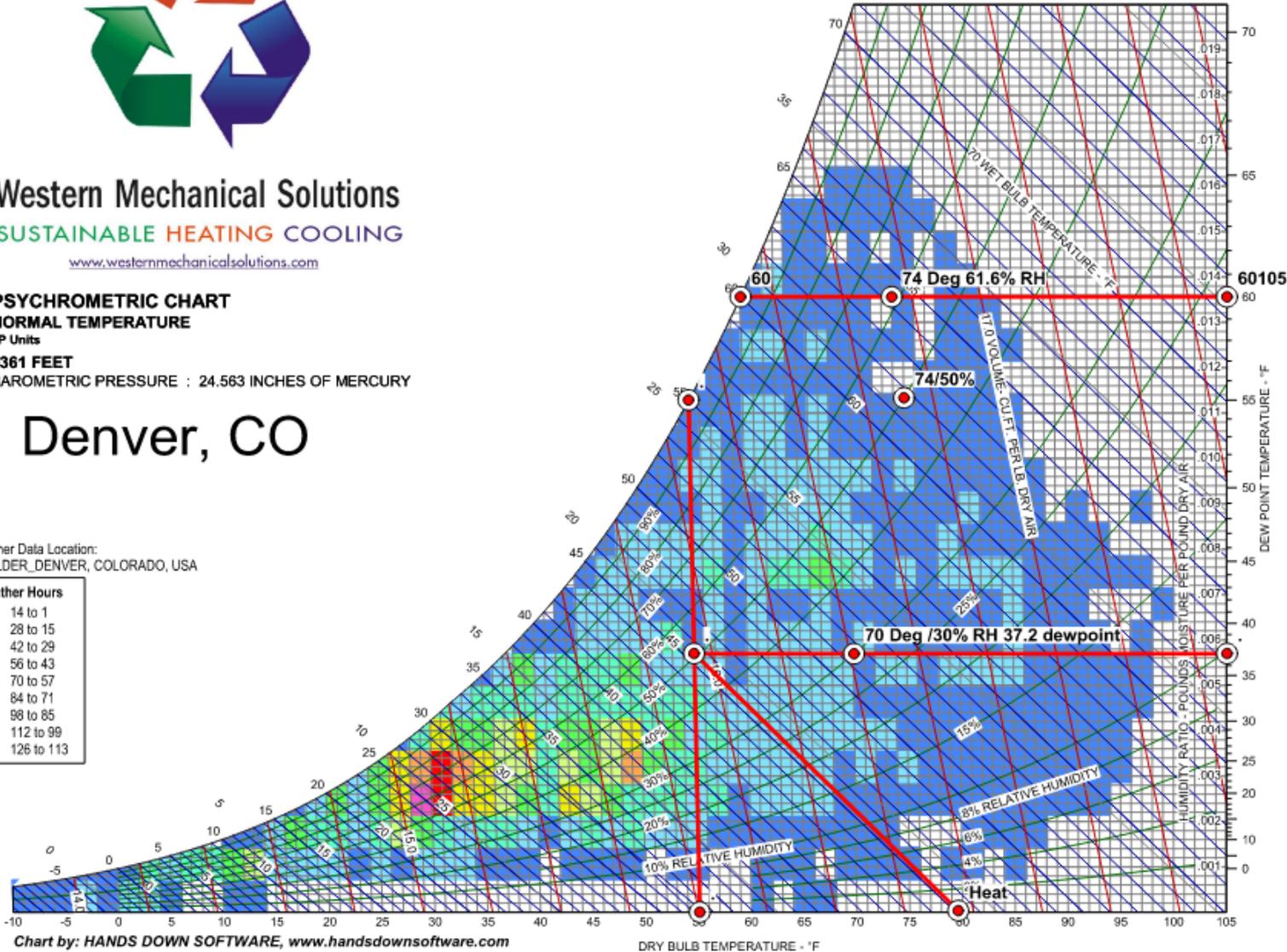
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PSYCHROMETRIC CHART
NORMAL TEMPERATURE
IP Units
361 FEET
BAROMETRIC PRESSURE : 24.563 INCHES OF MERCURY

Denver, CO

Weather Data Location:
_DER_DENVER, COLORADO, USA

Weather Hours
14 to 1
28 to 15
42 to 29
56 to 43
70 to 57
84 to 71
98 to 85
112 to 99
126 to 113



OTHER AREAS OF THE COUNTRY



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PSYCHROMETRIC CHART

NORMAL TEMPERATURE

I-P Units

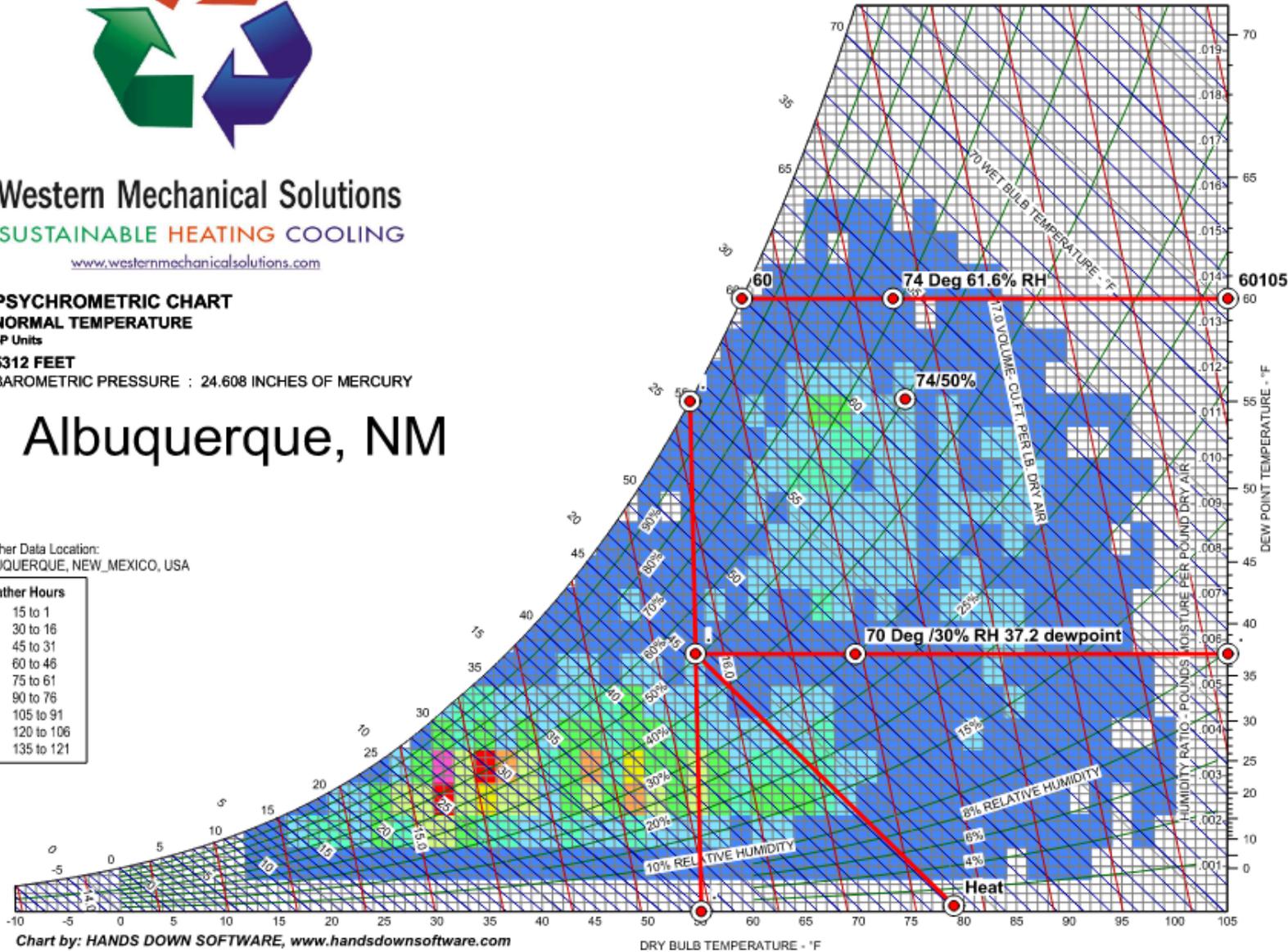
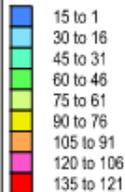
5312 FEET

BAROMETRIC PRESSURE : 24.608 INCHES OF MERCURY

Albuquerque, NM

Weather Data Location:
ALBUQUERQUE, NEW_MEXICO, USA

Weather Hours



OTHER AREAS OF THE COUNTRY



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PSYCHROMETRIC CHART

NORMAL TEMPERATURE

I-P Units

1112 FEET

BAROMETRIC PRESSURE : 28.738 INCHES OF MERCURY

Phoenix, AZ

Weather Data Location:
PHOENIX, ARIZONA, USA

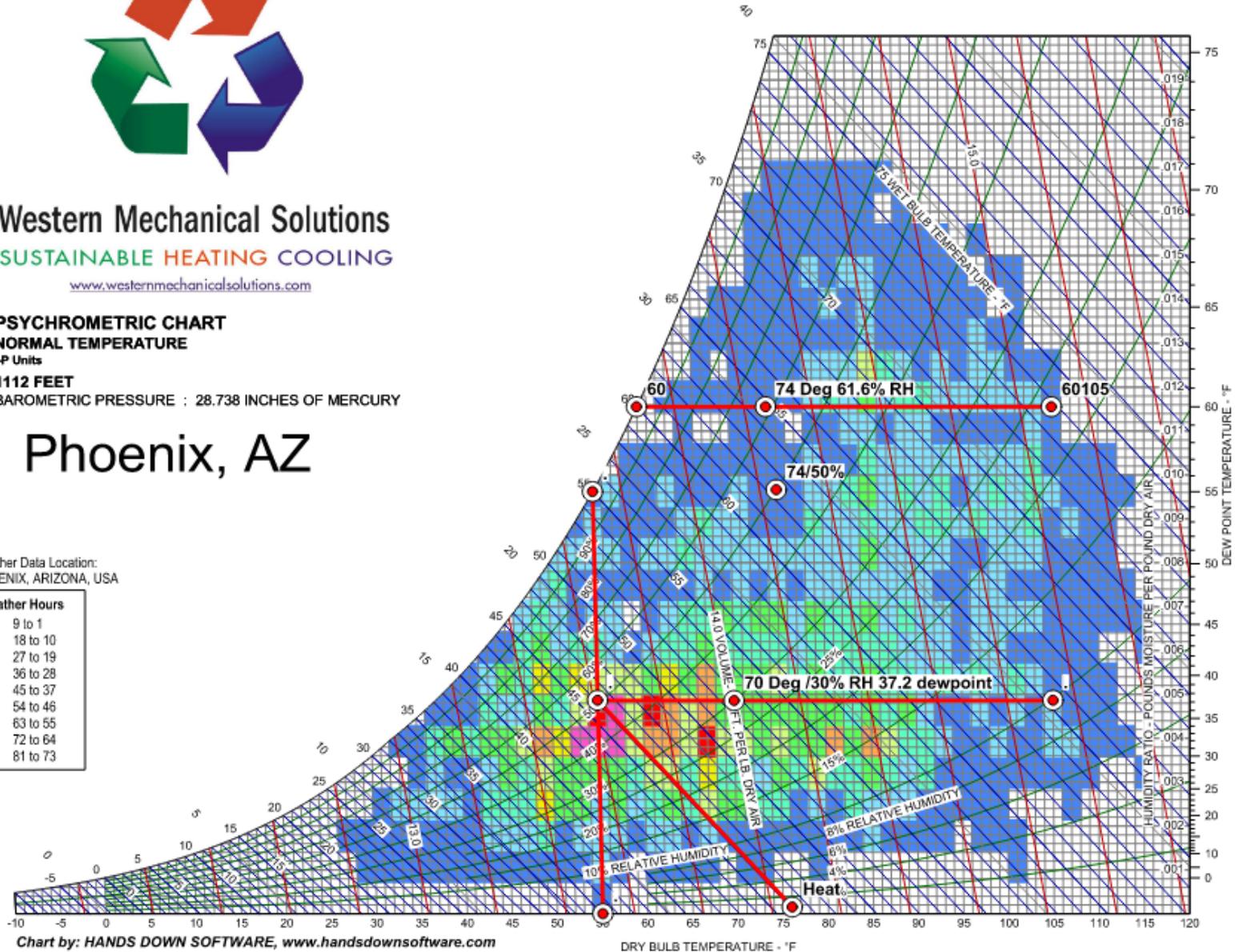
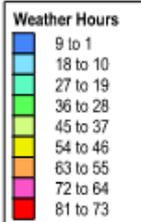


Chart by: HANDS DOWN SOFTWARE, www.handsdownsoftware.com

DRY BULB TEMPERATURE - °F

OTHER AREAS OF THE COUNTRY

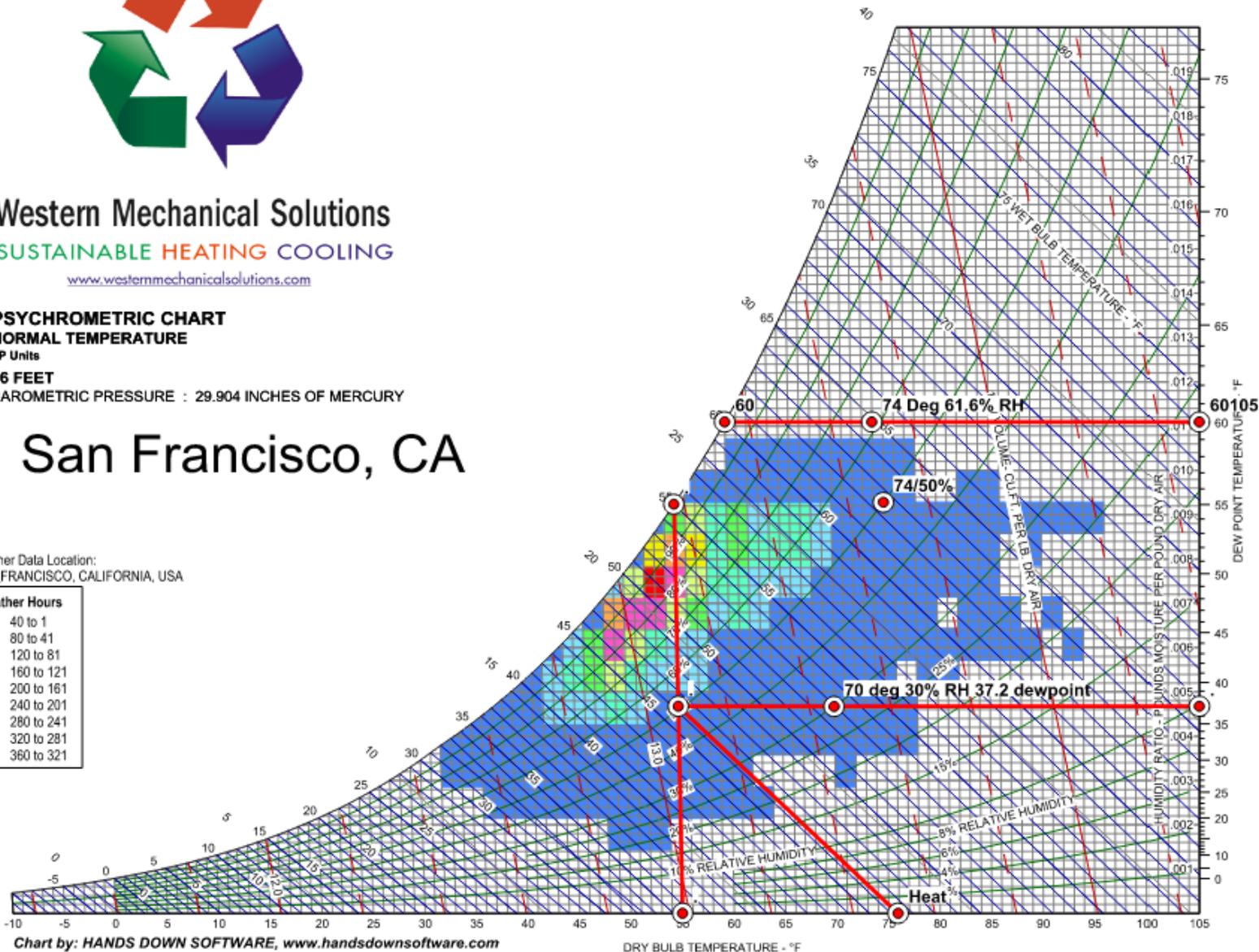
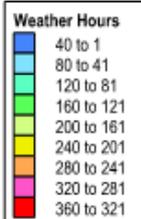


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PSYCHROMETRIC CHART
NORMAL TEMPERATURE
I-P Units
16 FEET
BAROMETRIC PRESSURE : 29.904 INCHES OF MERCURY

San Francisco, CA

Weather Data Location:
SAN FRANCISCO, CALIFORNIA, USA



OTHER AREAS OF THE COUNTRY



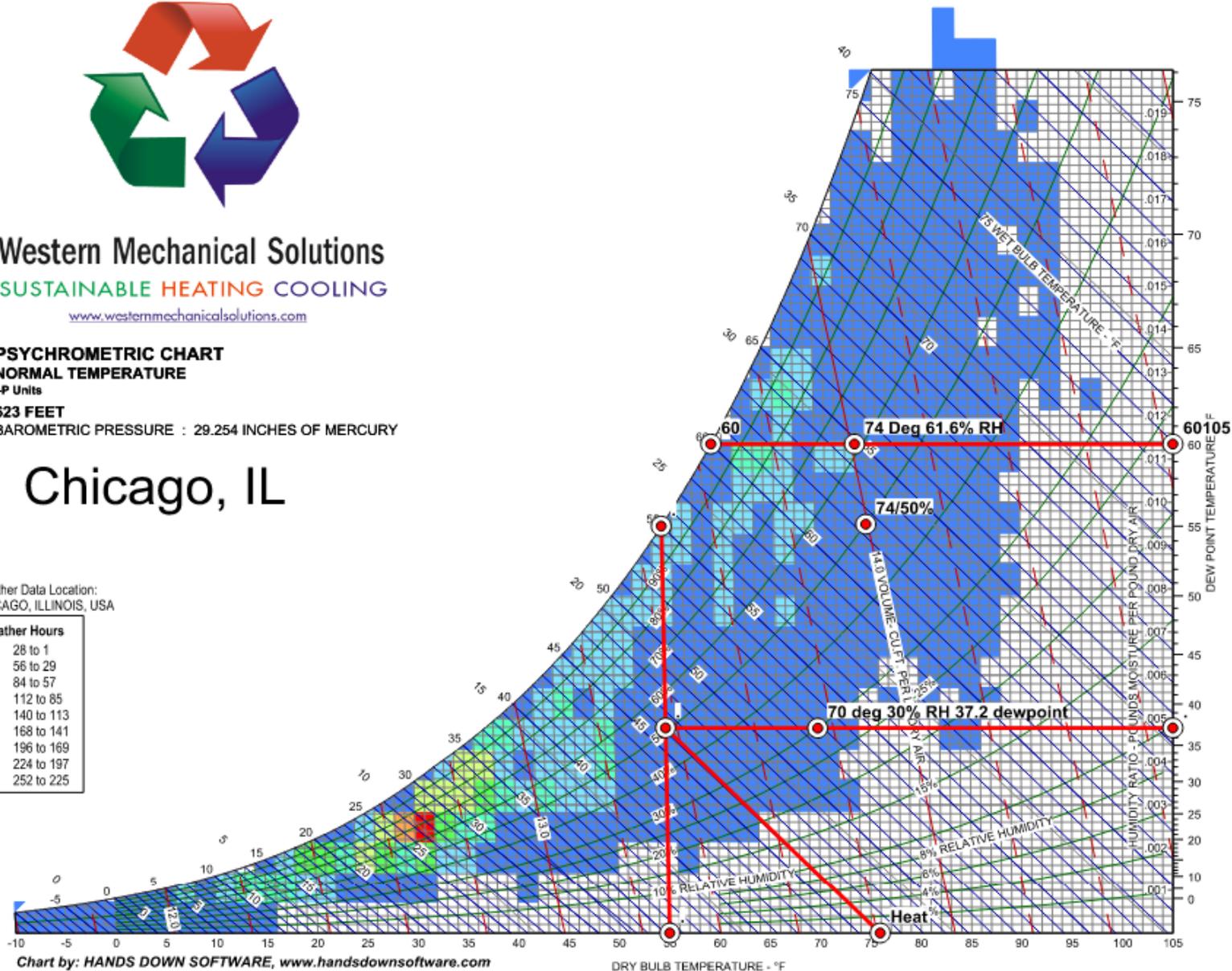
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PSYCHROMETRIC CHART
NORMAL TEMPERATURE
I-P Units
623 FEET
BAROMETRIC PRESSURE : 29.254 INCHES OF MERCURY

Chicago, IL

Weather Data Location:
CHICAGO, ILLINOIS, USA

Weather Hours	
Blue	28 to 1
Light Blue	56 to 29
Light Green	84 to 57
Green	112 to 85
Yellow-Green	140 to 113
Yellow	168 to 141
Orange	196 to 169
Red-Orange	224 to 197
Red	252 to 225



Chicago

If you
have to
humidify
Consider
Evap

OTHER AREAS OF THE COUNTRY

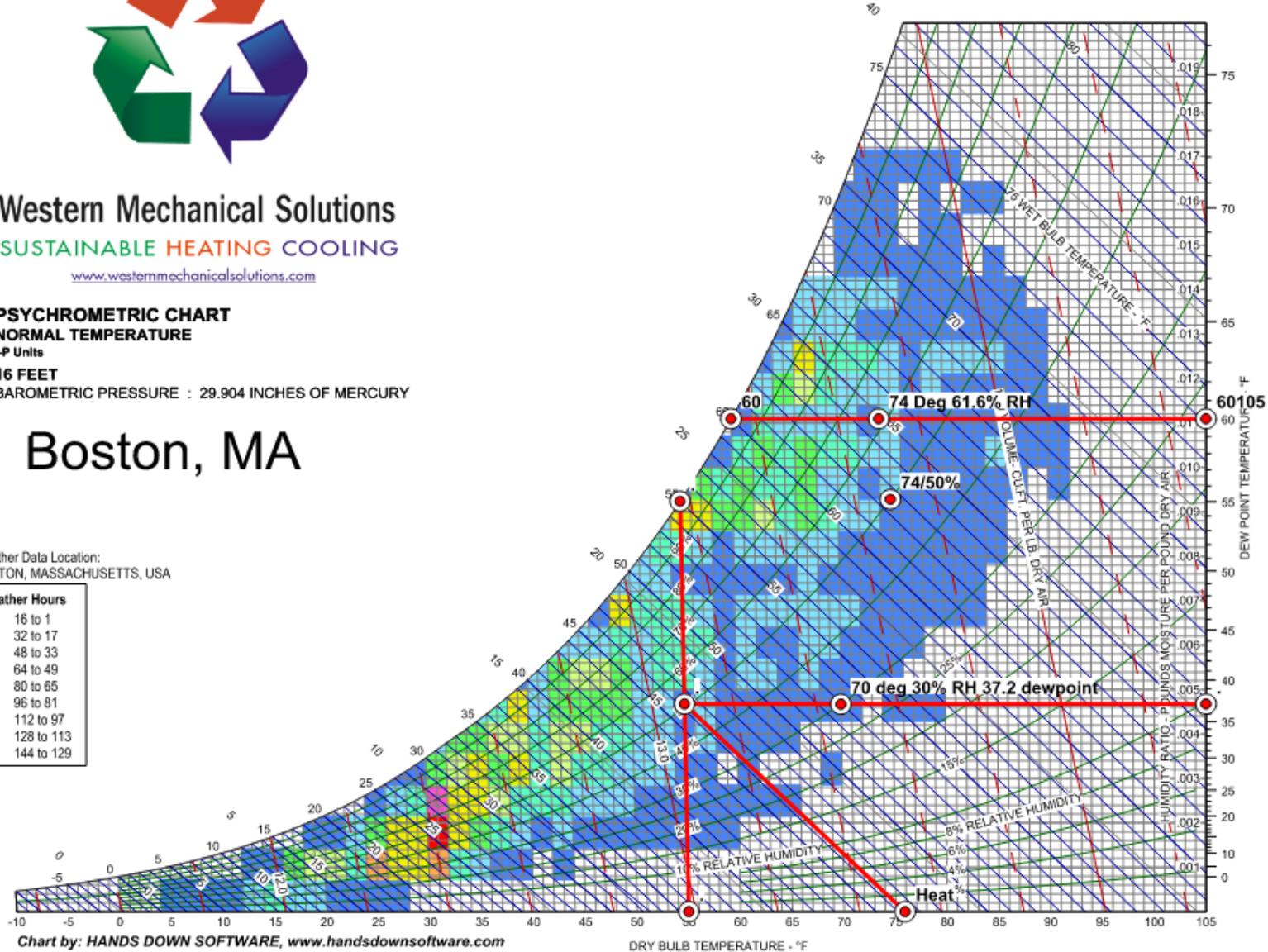
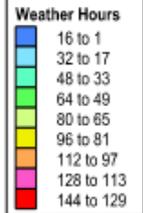


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PSYCHROMETRIC CHART
NORMAL TEMPERATURE
I-P Units
16 FEET
BAROMETRIC PRESSURE : 29.904 INCHES OF MERCURY

Boston, MA

Weather Data Location:
BOSTON, MASSACHUSETTS, USA



Boston
If you
have to
humidify
Consider
Evap

OTHER AREAS OF THE COUNTRY



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PSYCHROMETRIC CHART
NORMAL TEMPERATURE
I-P Units
187 FEET
BAROMETRIC PRESSURE : 29.720 INCHES OF MERCURY

New York City, NY

Weather Data Location:
NEW_YORK_CITY, NEW_YORK, USA

Weather Hours	
25 to 1	Blue
50 to 26	Light Blue
75 to 51	Light Green
100 to 76	Green
125 to 101	Yellow-Green
150 to 126	Yellow
175 to 151	Orange
200 to 176	Red-Orange
225 to 201	Red

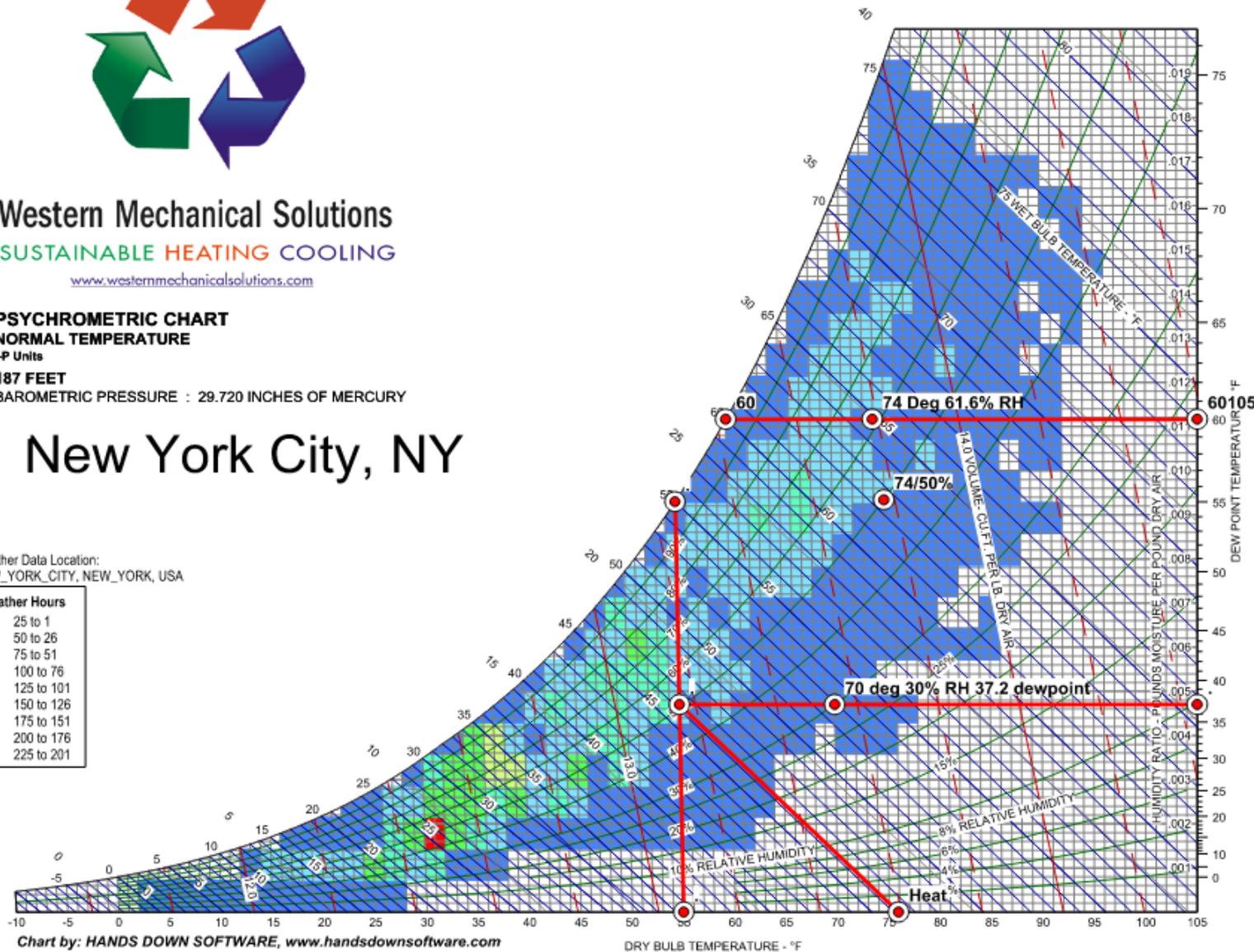


Chart by: HANDS DOWN SOFTWARE, www.handsdownsoftware.com

DRY BULB TEMPERATURE - °F

60105

DEW POINT TEMPERATURE - °F

HUMIDITY RATIO - POUNDS MOISTURE PER POUND DRY AIR

NYC

If you
have to
humidify
Consider
Evap

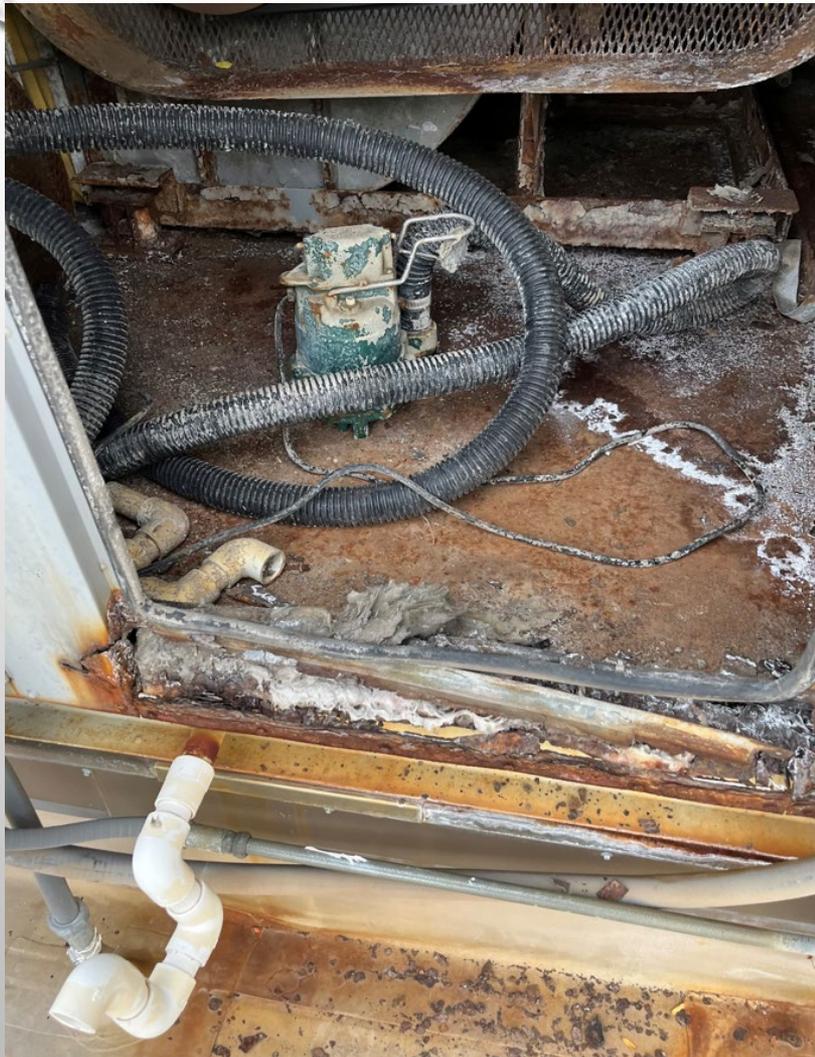
The image features a light gray background with a subtle gradient. In the top-left and bottom-right corners, there are several realistic water droplets of various sizes, rendered with soft shadows and highlights to give them a three-dimensional appearance. The text is centered in the middle of the page.

EVAPORATIVE COOLING IS NOT EQUAL

ATOMIZING EVAPORATIVE COOLING

- Have to use expensive RO water
- RO water softener often not being maintained
- Problems with:
 - Water leaking into pipe chase
 - Dis-similar metals
 - Water creepage
 - Use to FRP
 - Need larger exhaust distance for absorption

BUT I HATE EVAP!!



G-35 Steel



EVAP DONE CORRECTLY 11 YEARS LATER

1. Media has not been replaced!
2. All Stainless components to prevent rusting.



SPECIFY MAINTENANCE FRIENDLY!!

- CU Boulder's was the industry leader in Denver for specifying maintenance friendly options.
- Standards to minimize maintenance issues!!
 - 1. Header blow down to clear any debris from the header
 - 2. Cleanout Tee to brush the header
 - 3. Easily removable header access
 - 4. Hose connection to clean and flush the sump
 - 5. All Stainless components to prevent rusting.
 - 6. Tuff-Edge on the inlet of the cooler to protect the media
 - 7. Glass Dek Media (Fire Proof)
 - 8. Drain Pan under the Cooler to catch any Carryover and prevent floor corrosion
 - 9. Go Blow through to prevent rusty units – it's more expensive, but more efficient

CAUTIONS

- Direct evaporative cooling – exceeding ASHRAE 62.1 dewpoint limits
- Over humidify then dehumidify & waste water
- Indirect evaporative cooling – Running exhaust evap if it won't provide beneficial cooling and actually heating the air!!

BUT WHAT ABOUT THE WATER USE?

- Evaporation provides 1,050 BTU per lb of water
 - Each Gallon = 8.33 lb * 1,050 = 8,746 BTU
 - Each Ton = 11.42 lbs not including bleed
- Water Cooled Equipment has to reject the cooling PLUS the motor heat ~ 30%
- Therefore uses at least 30% more water
- Air Cooled uses NO Water?

BUT WHAT ABOUT THE WATER USE?

- Currently using Evaporative Cooling is more water efficient than Air Cooled or Evaporative Condensing
- Coal fired and Gas fired Power Plants are not very efficient (~40%), they reject a LOT of heat
- That heat is typically cooled with cooling towers, using water to reject heat
- As less power is required by the air conditioning, less water is required to reject the inefficient heat
- And as power plants transition to more Wind and Solar, more water will be available from the power plants that are decommissioned

WATER TREATMENT AND MAINTENANCE?

- City Water is treated
 - Not required or suggested
- Watch Total Dissolved Solids and Scaling
- Drain sump accordingly
 - Denver is weekly
 - Days below freezing (if not humidifying)
- Dry media daily to extend media life

LEGIONELLA PNEUMOPHILIA (LEGIONNAIRES' DISEASE) AND STORAGE TANKS

- From the 2003 ASHRAE Applications Handbook 49.8.
- “Legionnaires’ disease (a form of severe pneumonia) is caused by inhaling the bacteria Legionella pneumophila.
- It has been discovered in the service water systems of various buildings through-out the world.
- Infection has often been traced to Legionella pneumophila colonies in shower heads.
- Ciesielki et al. (1984) determined that Legionella pneumophila can colonize in hot water maintained at 115 F or lower.
- Segments of service water systems in which the water stagnates (e.g., shower heads, faucet aerators, and certain sections of storage-type water heaters) provide ideal breeding locations.

LEGIONELLA PNEUMOPHILIA (LEGIONNAIRES' DISEASE) AND EVAPORATIVE COOLING

- 2023 ASHRAE Applications Handbook Chapter 53, section 10.
- There have been **no** known cases of Legionnaires' disease with air washers or wetted-media evaporative air coolers.
- This is can be attributed to the low temperature of the recirculated water, which is not conducive to Legionella bacteria growth, as well as the absence of aerosolized water carryover that could transmit the bacteria to a host (ASHRAE Guideline 12-2000).

CONTROLS CONSIDERATIONS

- Low limit sump level for pump start
- Inputs
 - Occ/unocc
 - DAT Setpoint Cooling
 - Humidity setpoint cooling
 - Dat setpoint heating (If Winter Humidification)
 - Humidity setpoint heating (If winter humidification)
 - Initiate evap Drying sequence daily to extend life, end of day
- Outputs
 - Turn off ahu/close vav boxes delay after unocc
 - Heating setpoint (if winter humidification)
- Fill & Drain to prevent freezing.
- Ball Valves full size, non characterized
- 3 valves for outdoor unit
- 2 valves for indoor unit?
- Drain water weekly, more often with higher scaling

QUESTIONS?