DECARBONIZING VENTILATION WITH HEAT RECOVERY, ENTHALPY ECONOMIZER AND SUSTAINABLE TECHNIQUES

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menerga
a systemair company

STATUS QUO

- ASHRAE Standards 62.1 and 62.2 for Ventilation and Indoor Air Quality
- ASHRAE Std 90.1 and 90.2 for Minimum Energy Requirements
- ASHRAE Std 189 for Design of High Performance Green Buildings
- ASHRAE Std 100 : Energy Efficiency in Existing Buildings

ASHRAE STANDARDS

STANDARD

ANSI/ASHRAE Standard 62.1-2019
(Supersedes ANSI/ASHRAE Standard 62.1-2016)
Includes ANSI/ASHRAE addenda listed in Appendix O

Ventilation for Acceptable Indoor Air Quality

See Appendix O for approval dates by ASHRAE and the American National Standards Institute.

This Standard is under continuous maintenance by a Standing Standard Project Committee (SSPC) for which the Standards Committee has established a documented program for regular publication of addenda or revisions, including procedures for timely, documented, consensus action on requests for change to any part of the Standard. Instructions for how to submit a change can be found on the ASHRAE® website (www.ashrae.org/continuous-maintenance).

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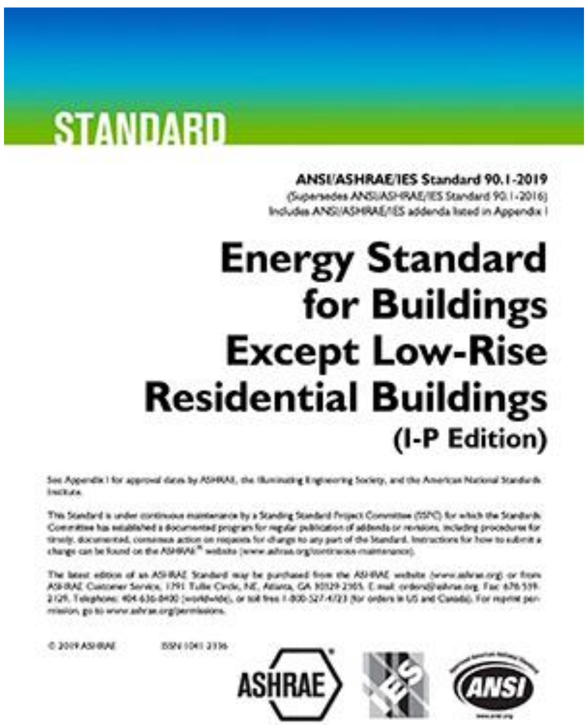

STANDARD

ANSI/ASHRAE/IES Standard 90.1-2019
(Supersedes ANSI/ASHRAE/IES Standard 90.1-2016)
Includes ANSI/ASHRAE/IES addenda listed in Appendix I

Energy Standard for Buildings Except Low-Rise Residential Buildings (I-P Edition)

See Appendix I for approval dates by ASHRAE, the Illuminating Engineering Society, and the American National Standards Institute.

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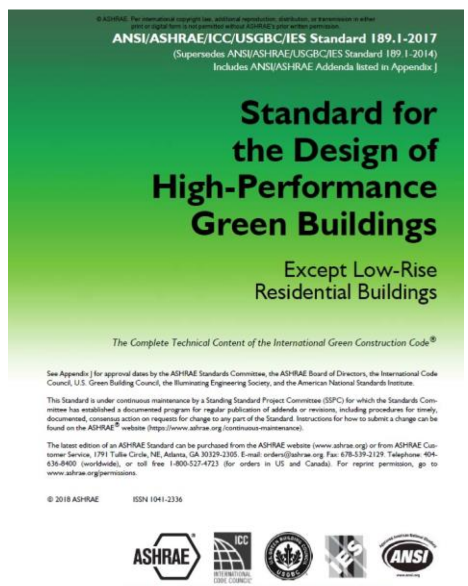

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ANSI/ASHRAE/ICC/USGBC/IES Standard 189.1-2017
(Supersedes ANSI/ASHRAE/USGBC/IES Standard 189.1-2014)
Includes ANSI/ASHRAE Addenda listed in Appendix J

Standard for the Design of High-Performance Green Buildings

Except Low-Rise Residential Buildings

The Complete Technical Content of the International Green Construction Code®

See Appendix J for approval dates by the ASHRAE Standards Committee, the ASHRAE Board of Directors, the International Code Council, U.S. Green Building Council, the Illuminating Engineering Society, and the American National Standards Institute.

This Standard is under continuous maintenance by a Standing Standard Project Committee (SSPC) for which the Standards Committee has established a documented program for regular publication of addenda or revisions, including procedures for timely, documented, consensus action on requests for change to any part of the Standard. Instructions for how to submit a change can be found on the ASHRAE® website (https://www.ashrae.org /continuous-maintenance).

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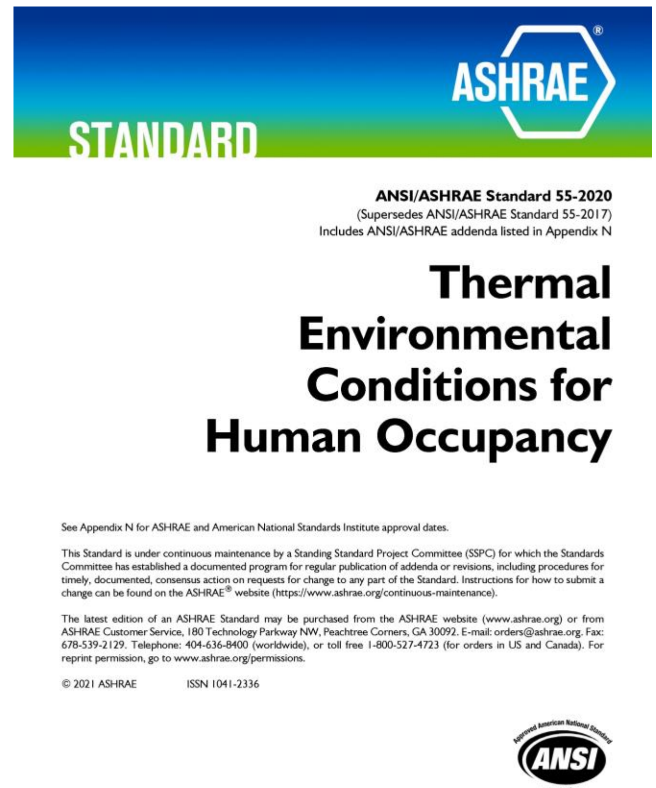

STANDARD

ANSI/ASHRAE Standard 55-2020
(Supersedes ANSI/ASHRAE Standard 55-2017)
Includes ANSI/ASHRAE addenda listed in Appendix N

Thermal Environmental Conditions for Human Occupancy

See Appendix N for ASHRAE and American National Standards Institute approval dates.

This Standard is under continuous maintenance by a Standing Standard Project Committee (SSPC) for which the Standards Committee has established a documented program for regular publication of addenda or revisions, including procedures for timely, documented, consensus action on requests for change to any part of the Standard. Instructions for how to submit a change can be found on the ASHRAE® website (https://www.ashrae.org/continuous-maintenance).

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ASHRAE DECARBONIZATION TASK FORCE

- Std 105: Green House Emissions
- Std 147: Refrigerants
- Std 227 : Passive House Design
- Std 228: Net Zero and Net Carbon Evaluation
- Std 240: Carbon Emissions

ASHRAE TECHNICAL COMMITTEES

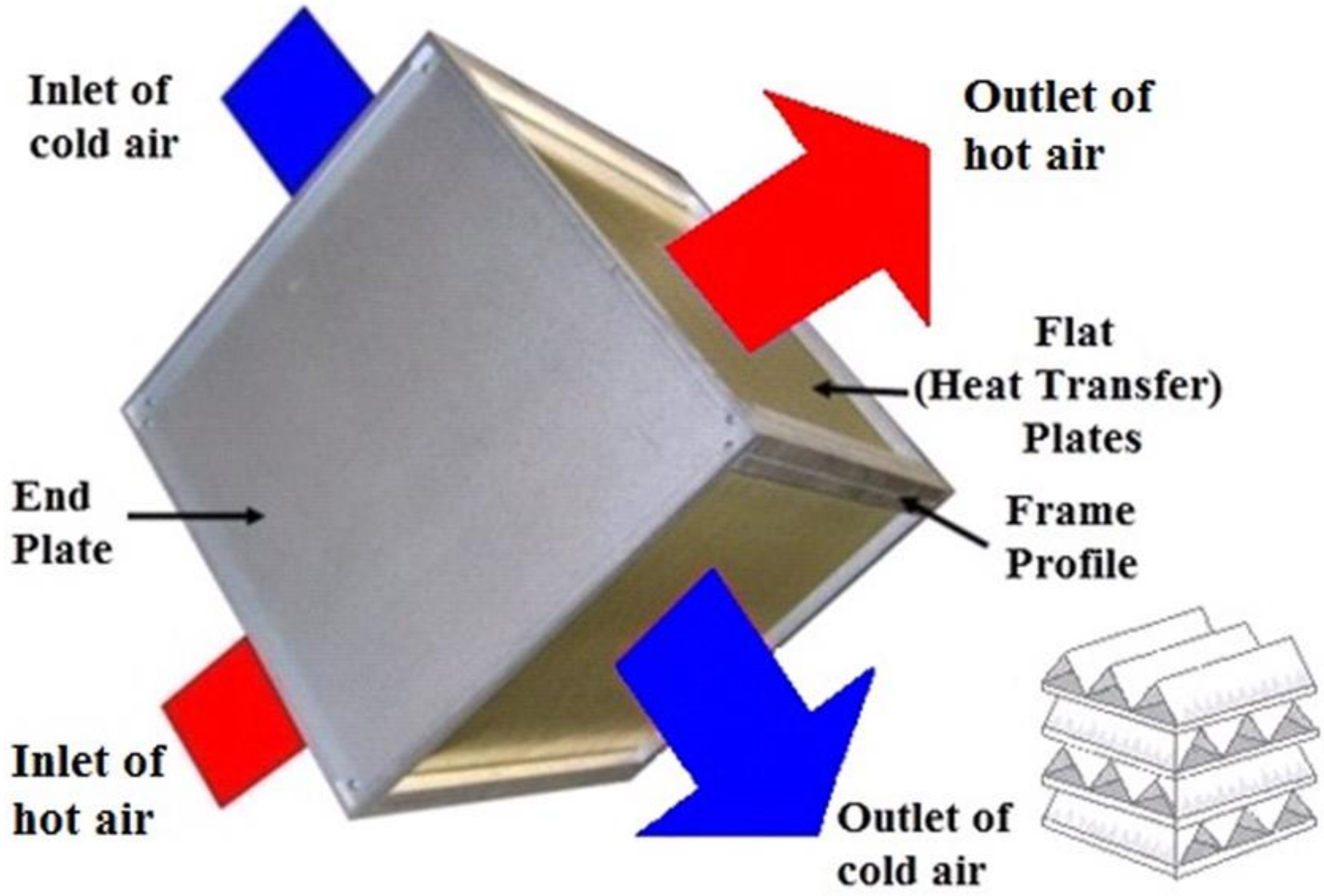
- TC 5.05 : Air-to-Air Energy Recovery
- TC 5.07: Evaporative Cooling
- TC 8.10 : Mechanical and Desiccant Dehumidification Equipment, Heat Pipes and Components

2 METHODS OF ENERGY RECOVERY

- RECUPERATIVE
- REGENERATIVE

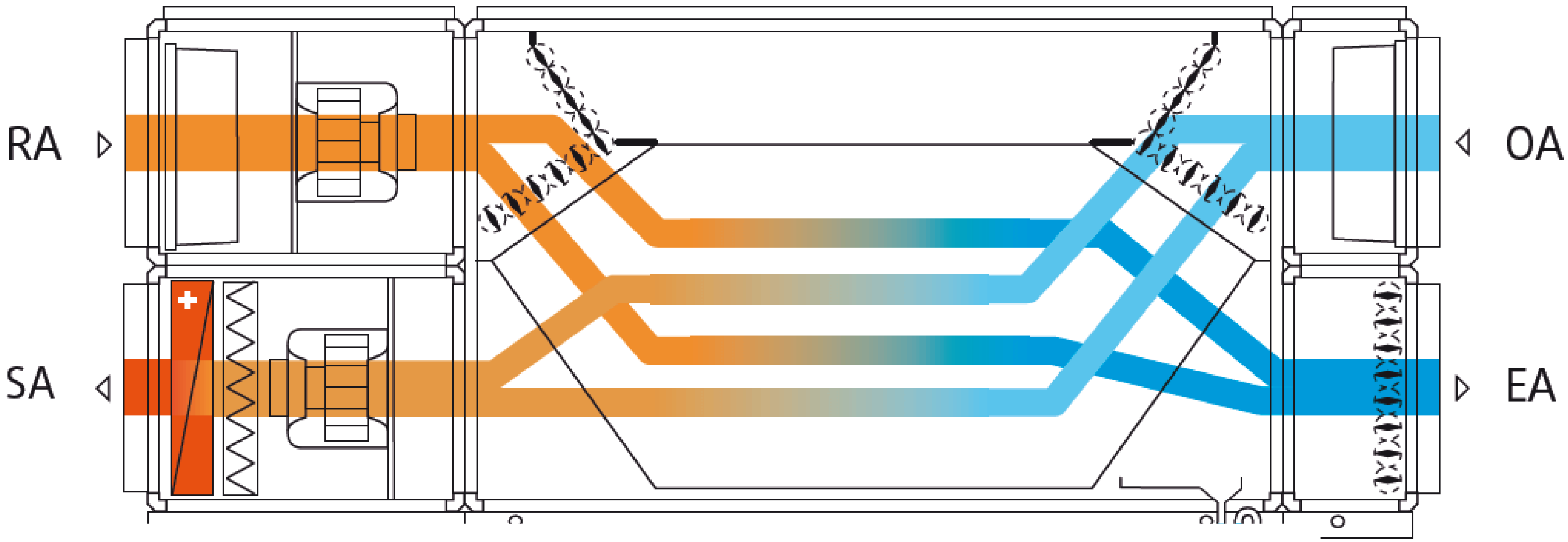
Heat Exchangers

- Cross Flow

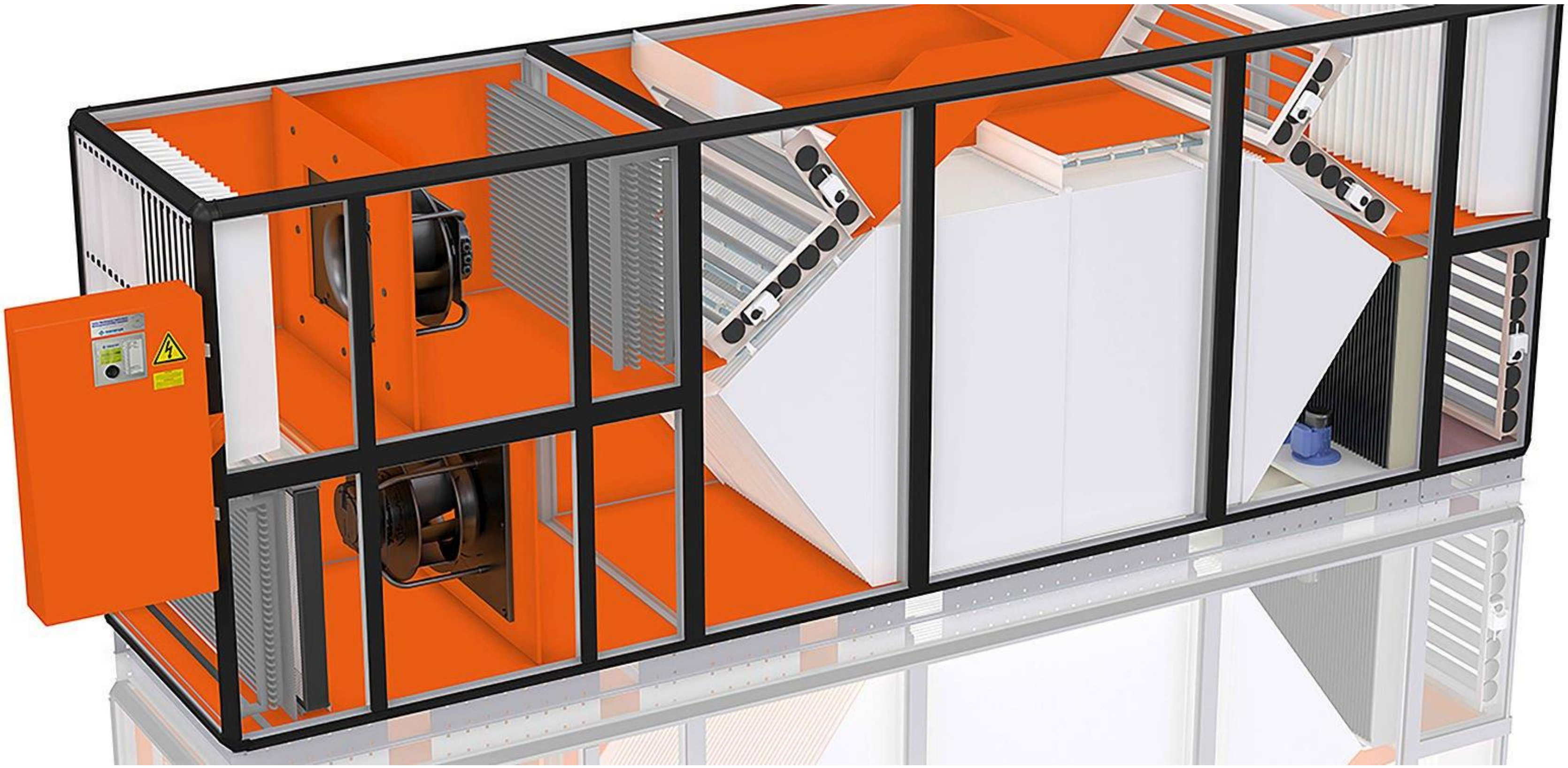

Inlet of
cold air
Outlet of
hot air
Flat
(Heat Transfer)
Plates
End
Plate
Frame
Profile
Inlet of
hot air
Outlet of
cold air

- Less efficient (max 65-70%) even when a very large exchange surface area
- Reaches its maximum even with small surface areas
- Compact size

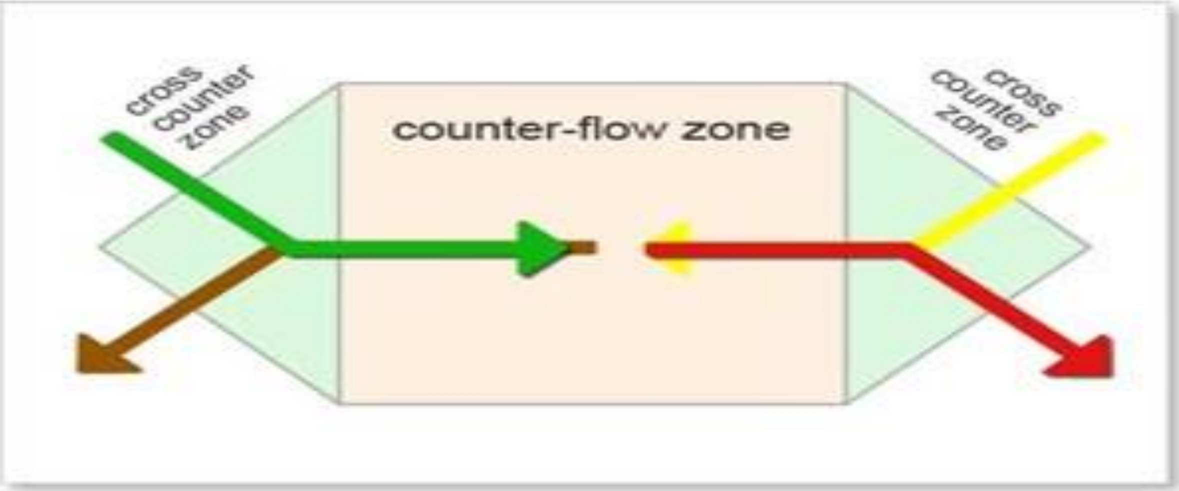
COUNTER FLOW



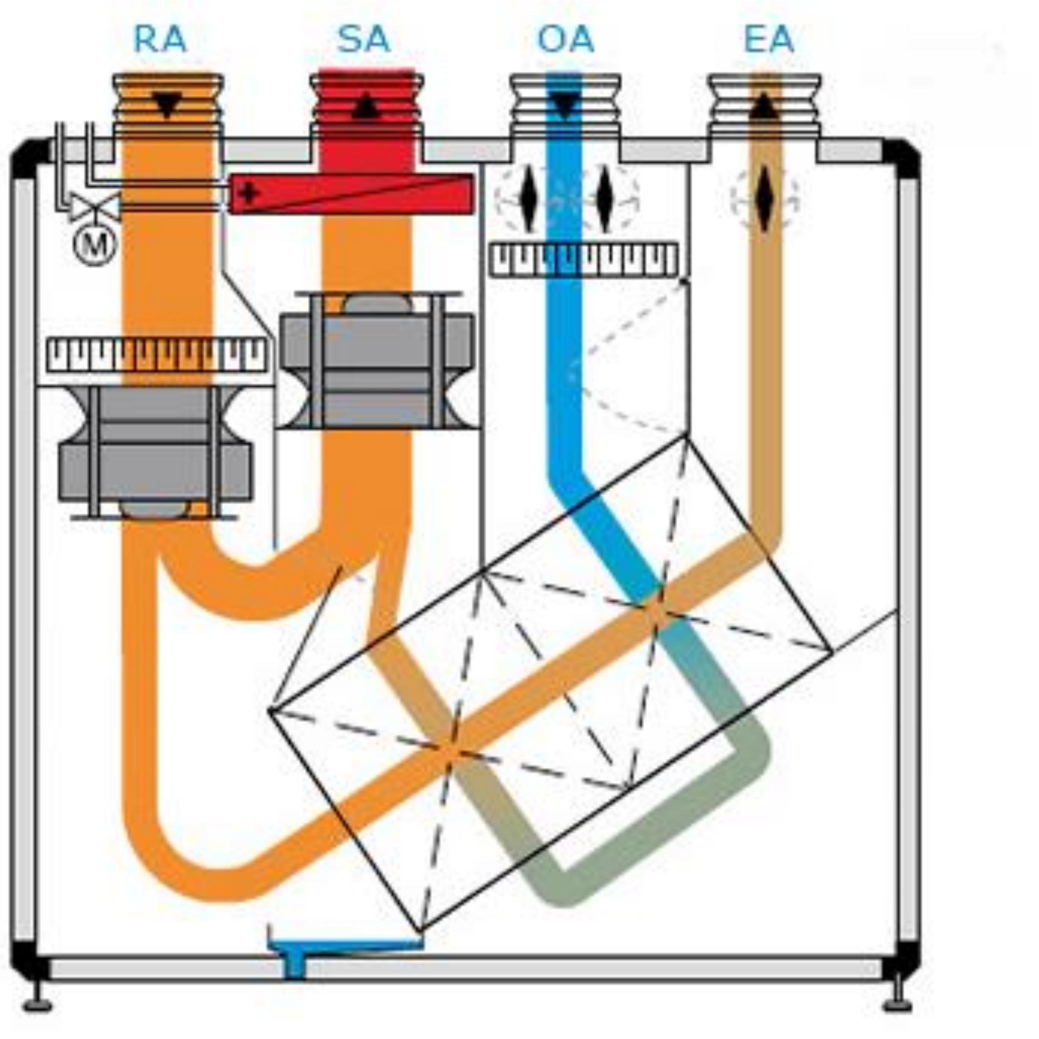
Recuperative



- Very High efficiency (up to 95%)
- Very Large dimensions
- Small cross counter zones

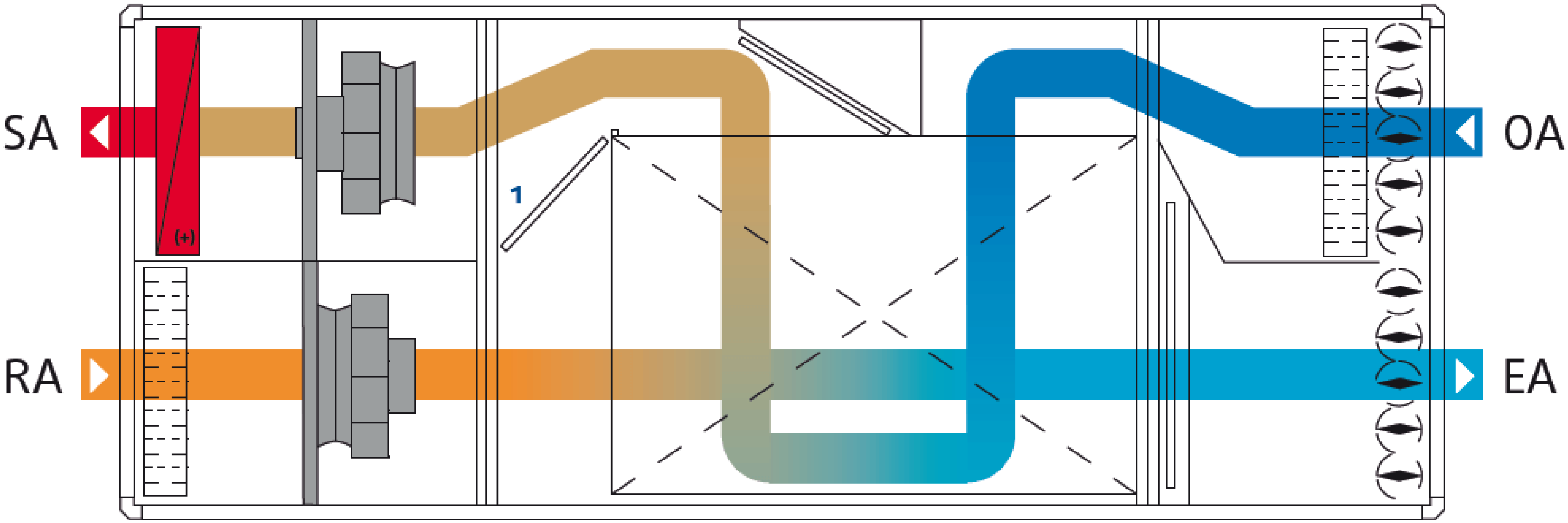


DOUBLE PLATE HEAT EXCHANGER



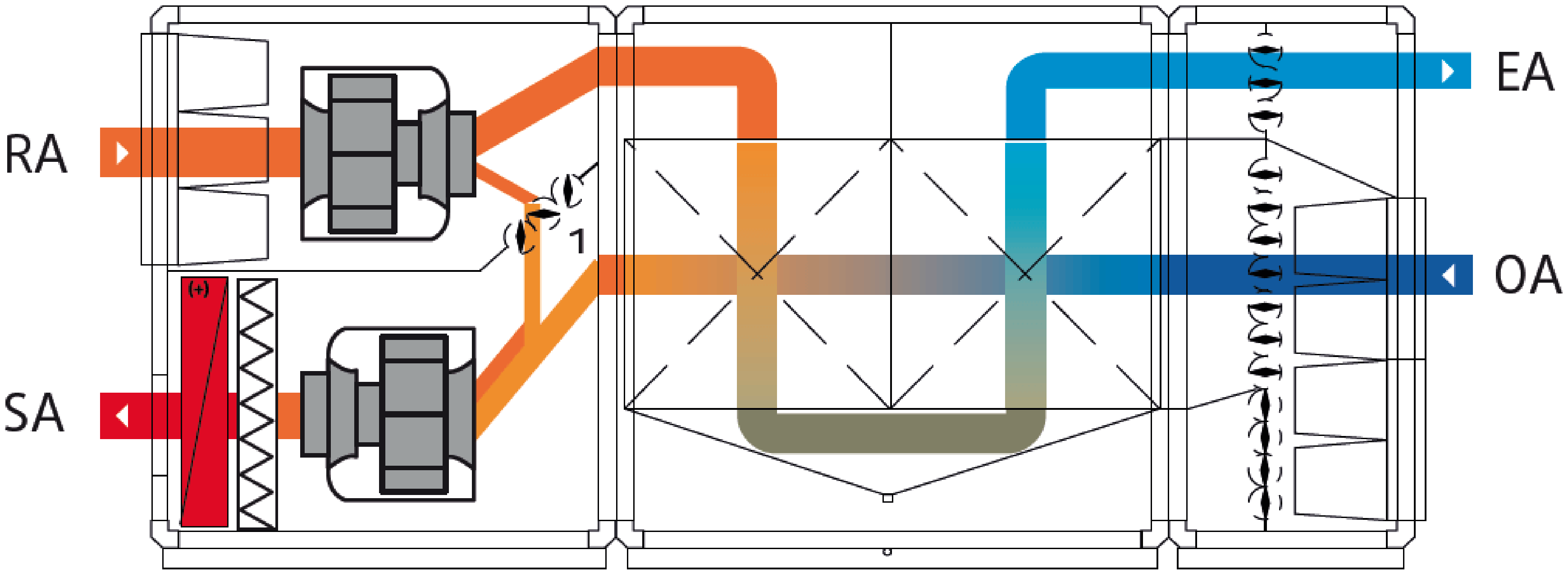
- Efficiency around 75-80%
- Compact size

THREE-STAGE RECUPERATROS (A)



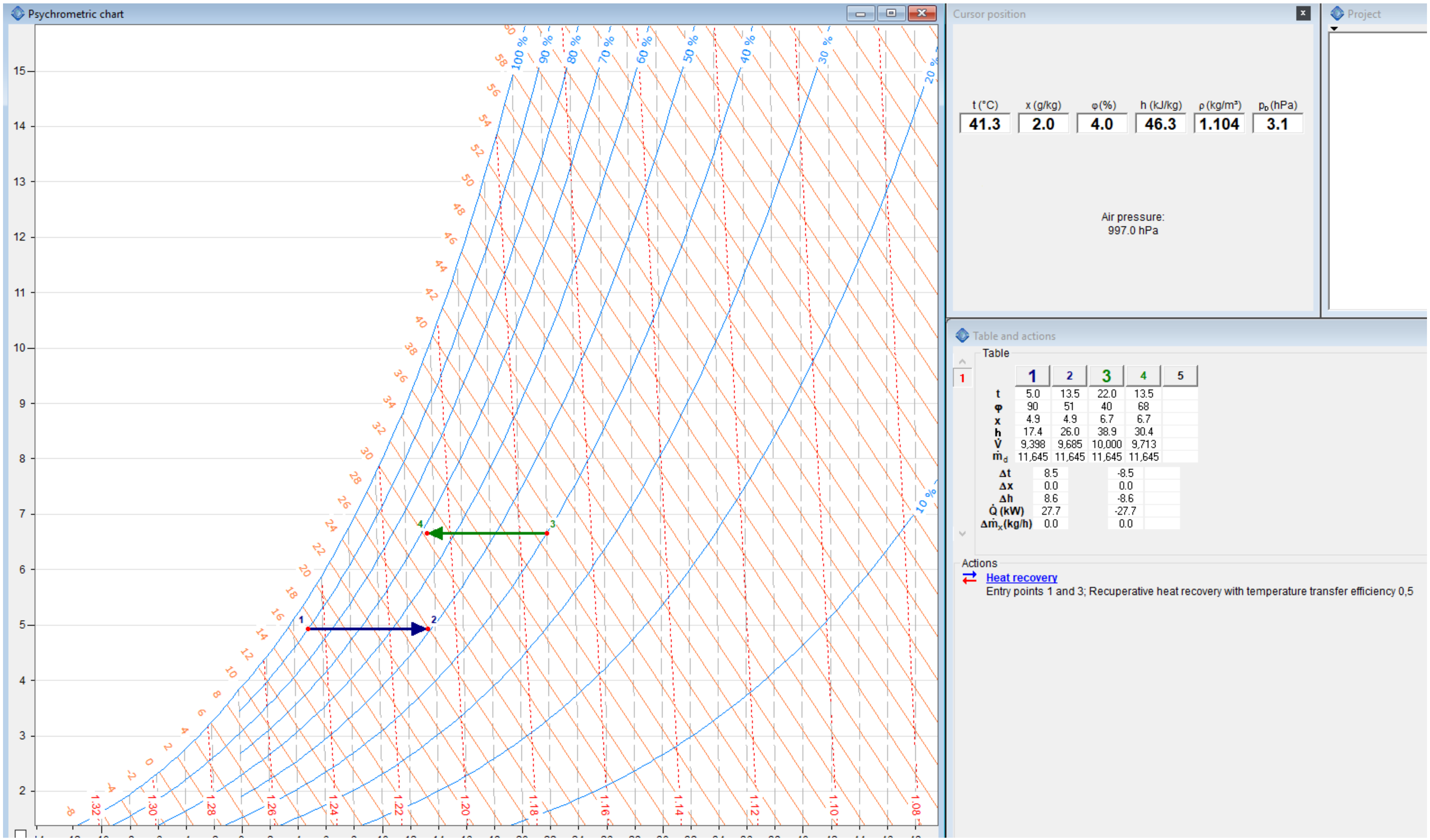
- Efficiency around 75-85%
- Medium to large size

THREE-STAGE RECUPERATROS (B)

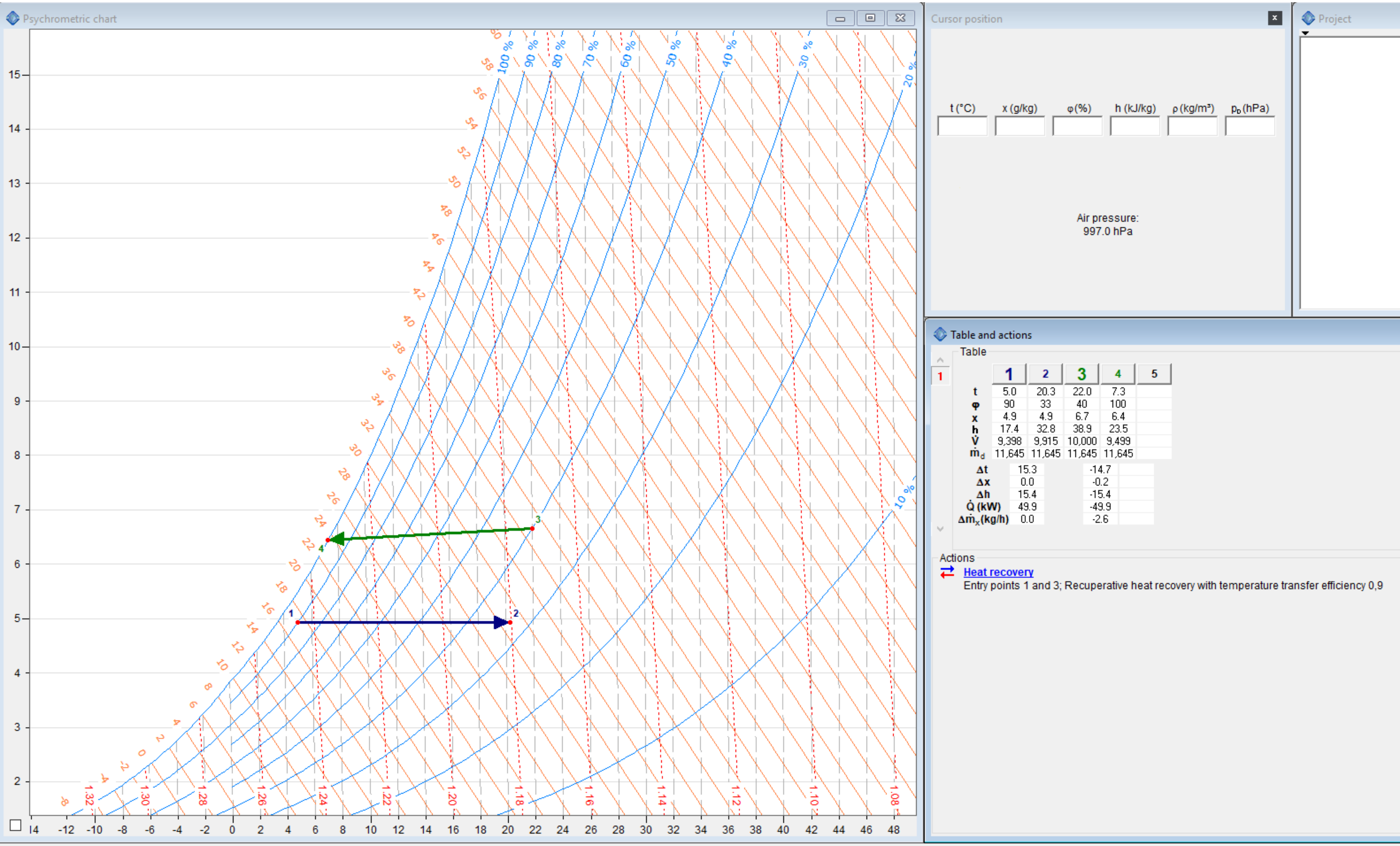


- Efficiency around 75-85%
- Large size

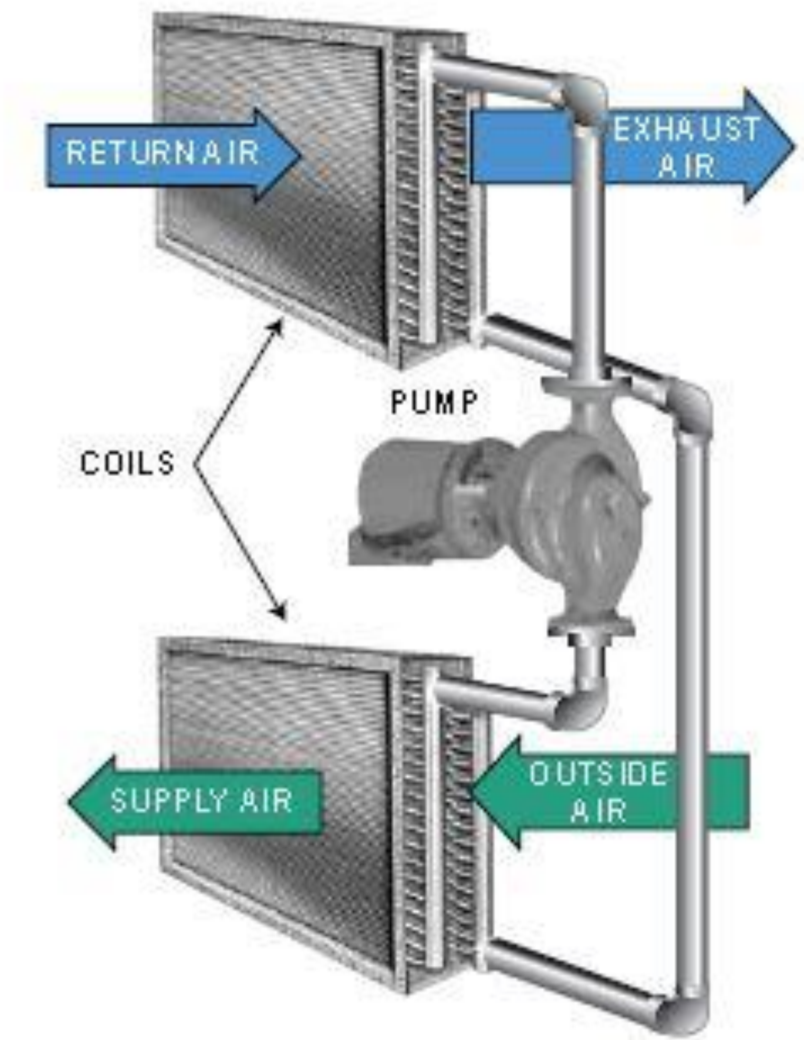
50%

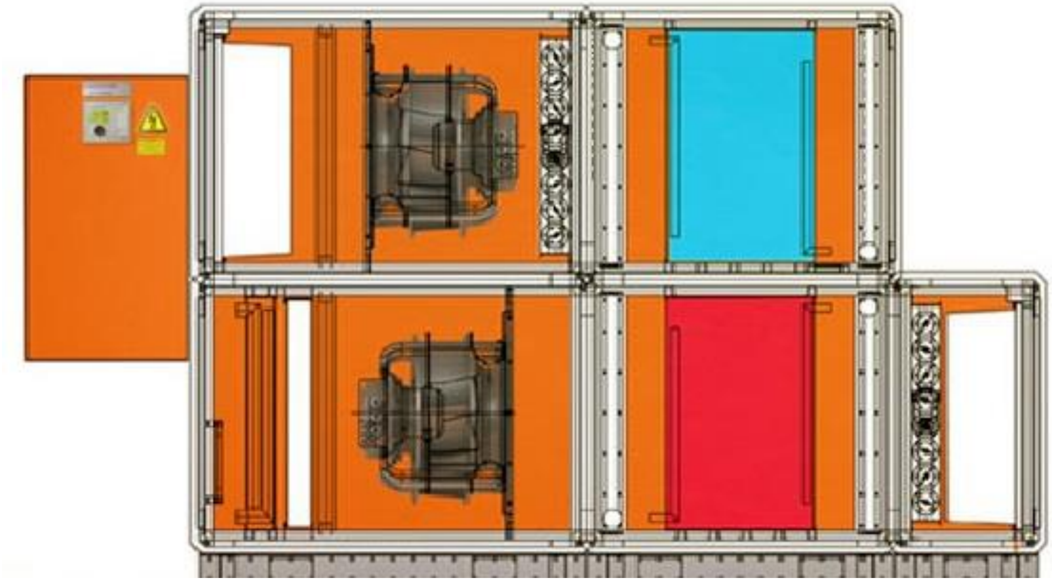

Psychrometric chart
Cursor position
t (°C) 41.3
x (g/kg) 2.0
φ (%) 4.0
h (kJ/kg) 46.3
ρ (kg/m³) 1.104
pD (hPa) 3.1
Air pressure:
997.0 hPa
Project
Table and actions
Table
1 2 3 4 5
t 5.0 13.5 22.0 13.5
φ 90 51 40 68
x 4.9 4.9 6.7 6.7
h 17.4 26.0 38.9 30.4
V̇ 9,398 9,685 10,000 9,713
ṁd 11,645 11,645 11,645 11,645
Δt 8.5 -8.5
Δx 0.0 0.0
Δh 8.6 -8.6
Q̇ (kW) 27.7 -27.7
Δṁx (kg/h) 0.0 0.0
Actions
Heat recovery
Entry points 1 and 3; Recuperative heat recovery with temperature transfer efficiency 0,5

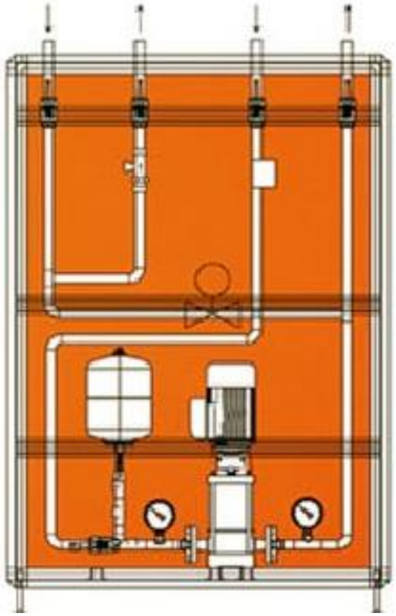
90%


Psychrometric chart
100 %
90 %
80 %
70 %
60 %
50 %
40 %
30 %
20 %
10 %
Cursor position
t (°C)
x (g/kg)
φ(%)
h (kJ/kg)
ρ (kg/m³)
p_b (hPa)
Air pressure:
997.0 hPa
Project
Table and actions
Table
1 2 3 4 5
t 5.0 20.3 22.0 7.3
φ 90 33 40 100
x 4.9 4.9 6.7 6.4
h 17.4 32.8 38.9 23.5
V̇ 9,398 9,915 10,000 9,499
$\dot{m}_d$ 11,645 11,645 11,645 11,645
Δt 15.3 -14.7
Δx 0.0 -0.2
Δh 15.4 -15.4
Q̇ (kW) 49.9 -49.9
$\Delta\dot{m}_x$(kg/h) 0.0 -2.6
Actions
Heat recovery
Entry points 1 and 3; Recuperative heat recovery with temperature transfer efficiency 0,9

RUN AROUND COILS

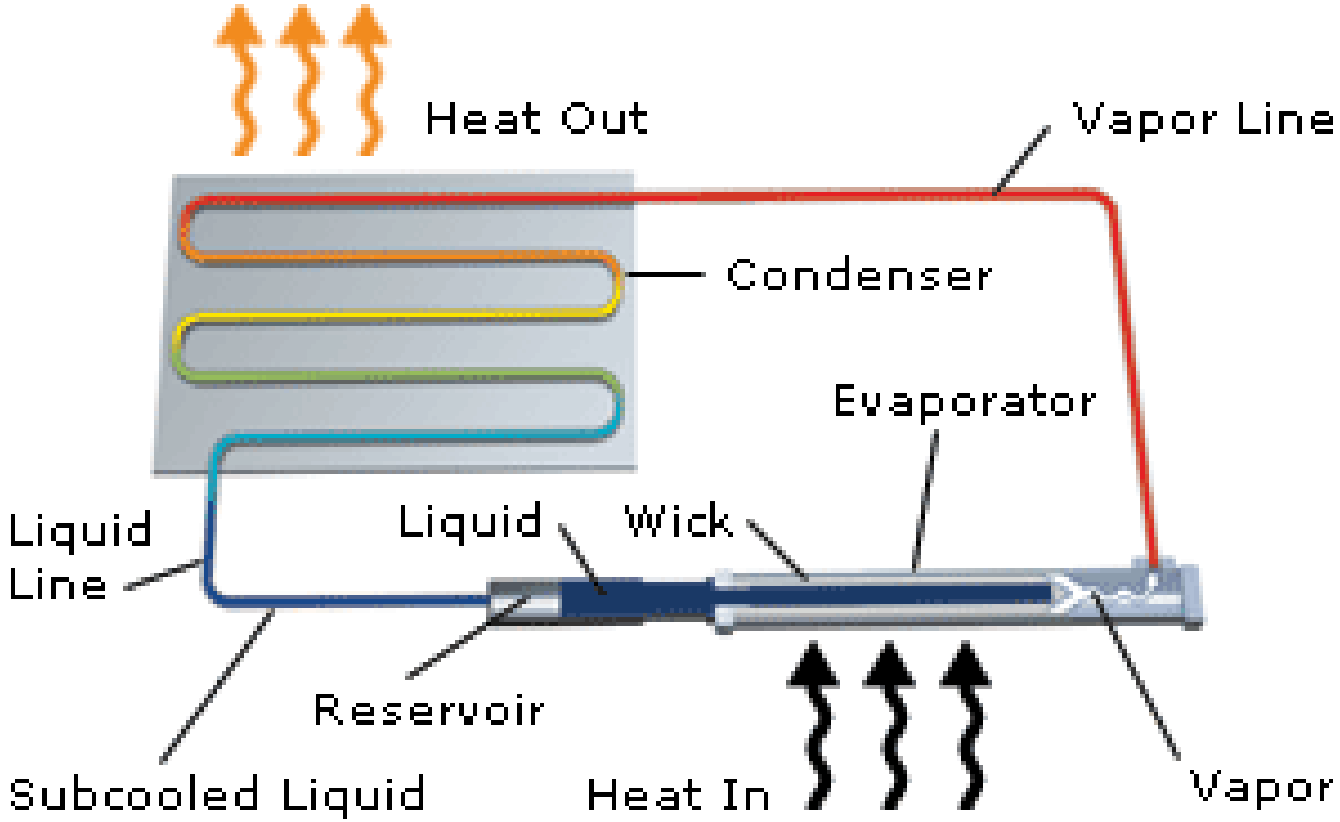


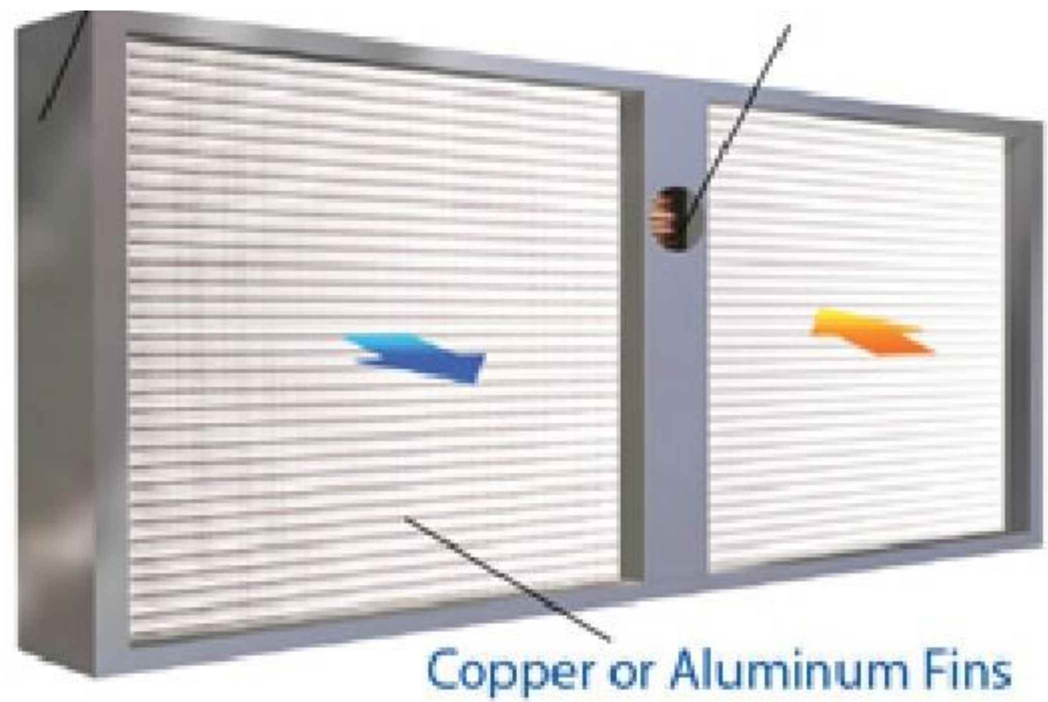




- Efficiency around 50-65%
- Compact size
- Suitable for “clean rooms” too

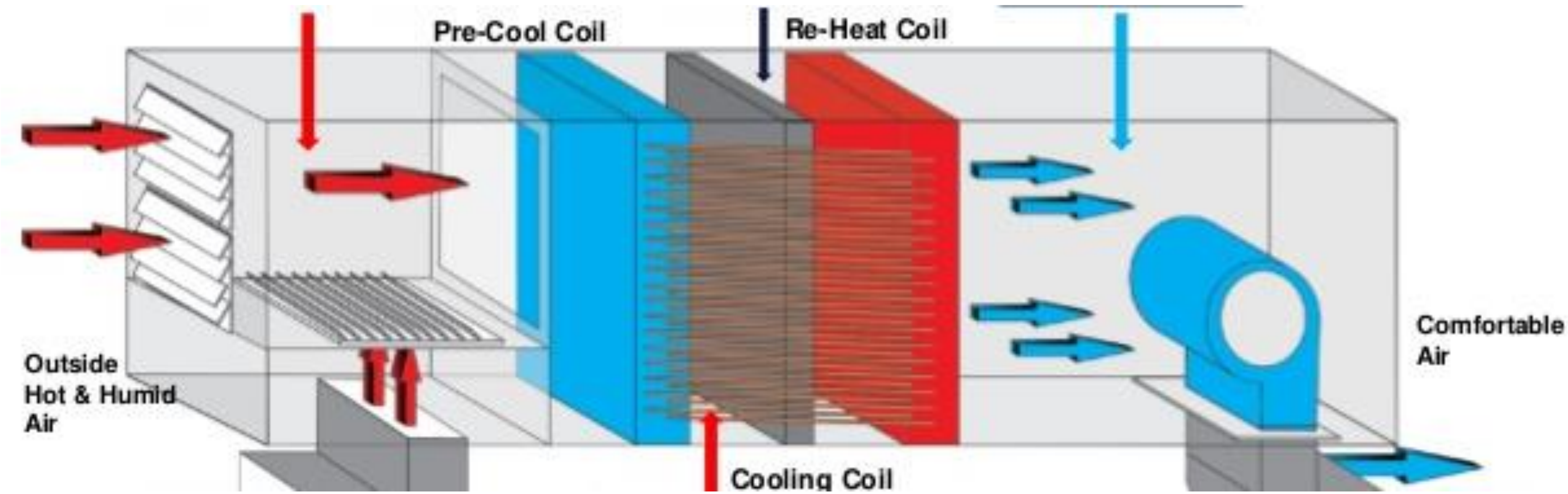
HEAT PIPES


Heat Out
Vapor Line
Condenser
Evaporator
Liquid
Line
Liquid
Wick
Reservoir
Subcooled Liquid
Heat In
Vapor


Copper or Aluminum Fins

- Low Maintenance
- Compact design
- Clean Room suitable
- Horizontal Arrays max 50%
- Vertical arrays max 75%

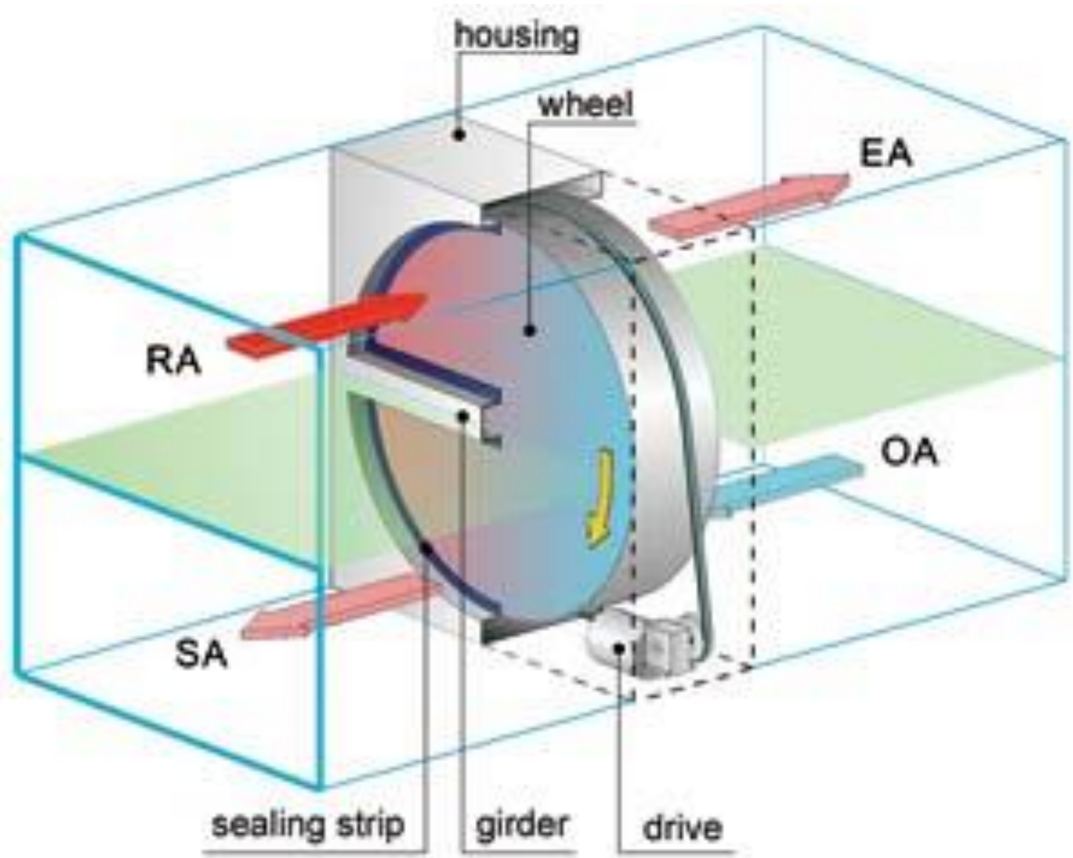
WRAP AROUND COILS-DEHUMIDIFICATION



- Pre-cooling and reheating of air
- Suitable for dehumidification
- Lower DT at coils
- Passive (free) reheating
- Equipment Savings Through Downsizing

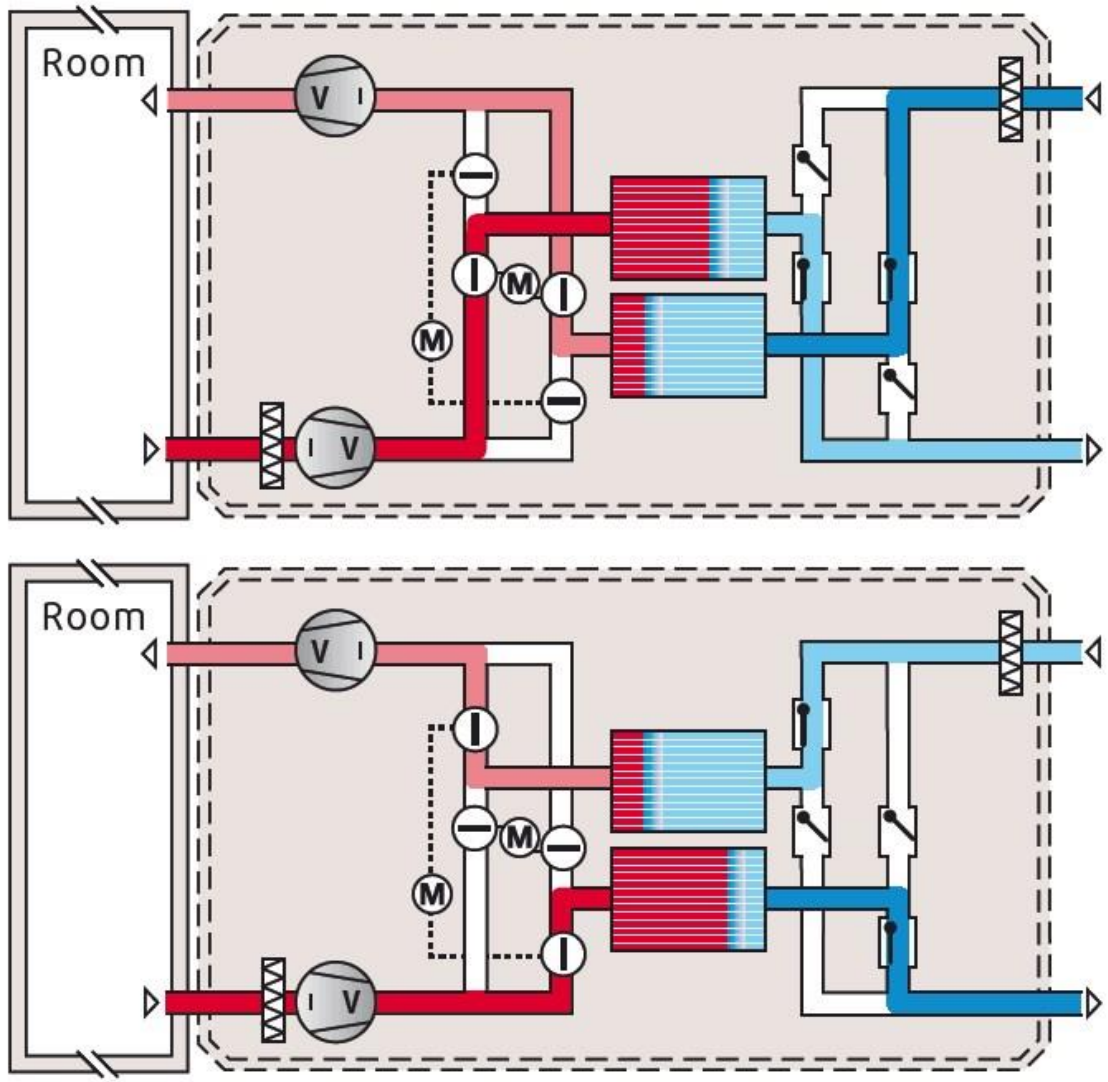
- REGENERATIVE

ROTARY-ENTHALPY ECONOMIZERS

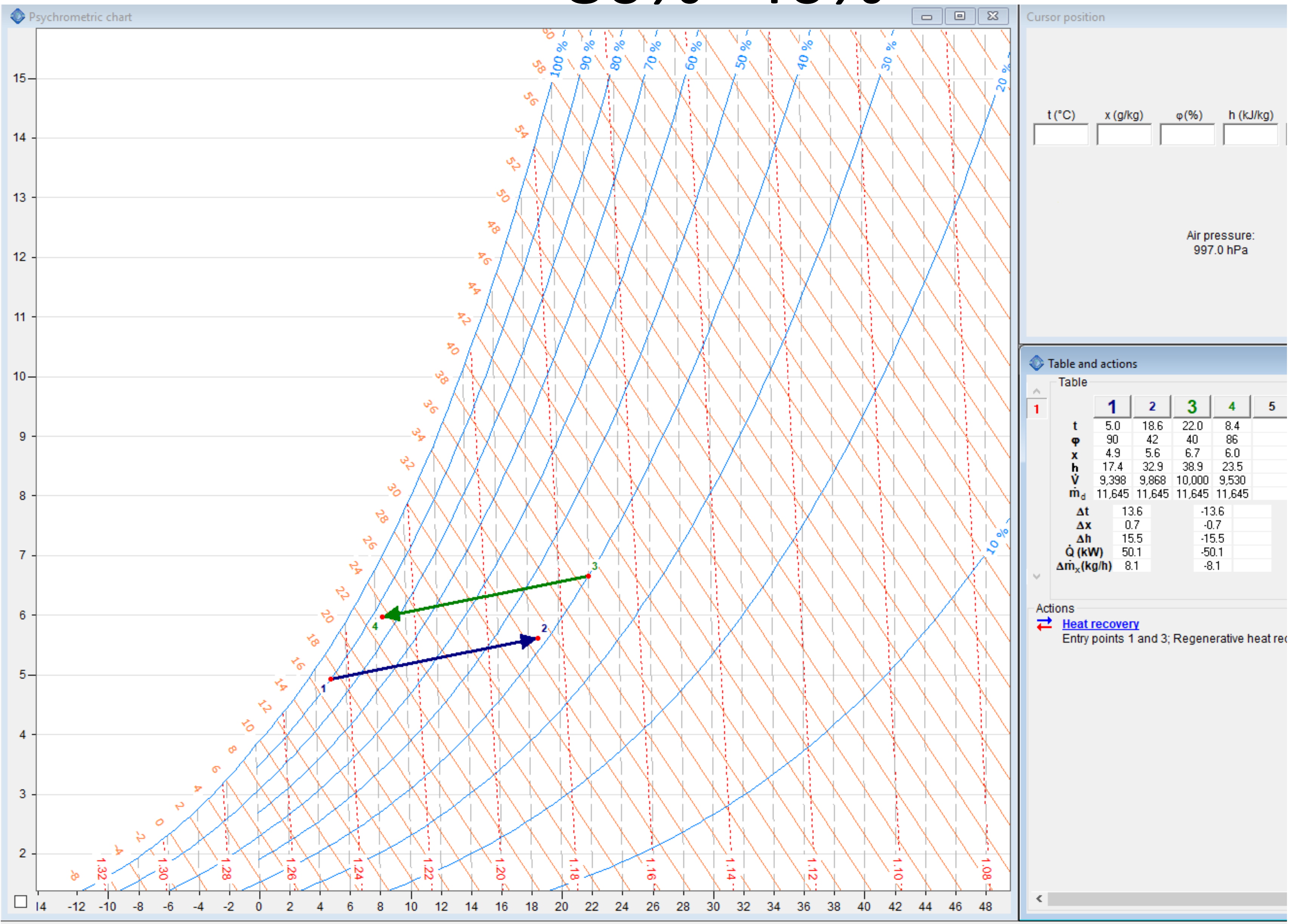

housing
wheel
EA
RA
OA
SA
sealing strip
girder
drive

- High Maintenance
- High pressure drop
- Moving parts, motors etc
- VERY Compact design
- Thermal efficiency 80%
- Latent Efficiency 40-50%

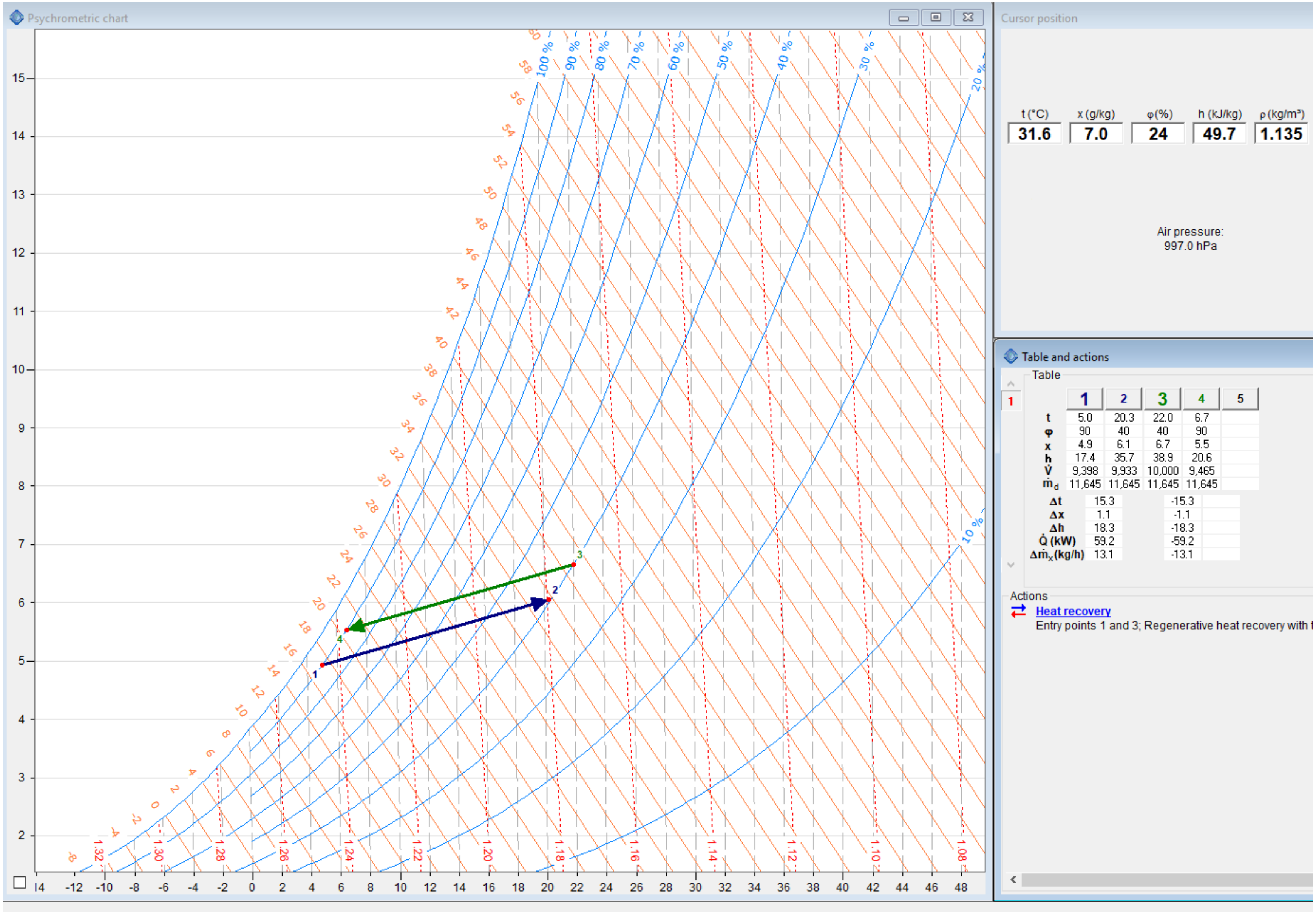
HEAT ACCUMULATORS



80%- 40%

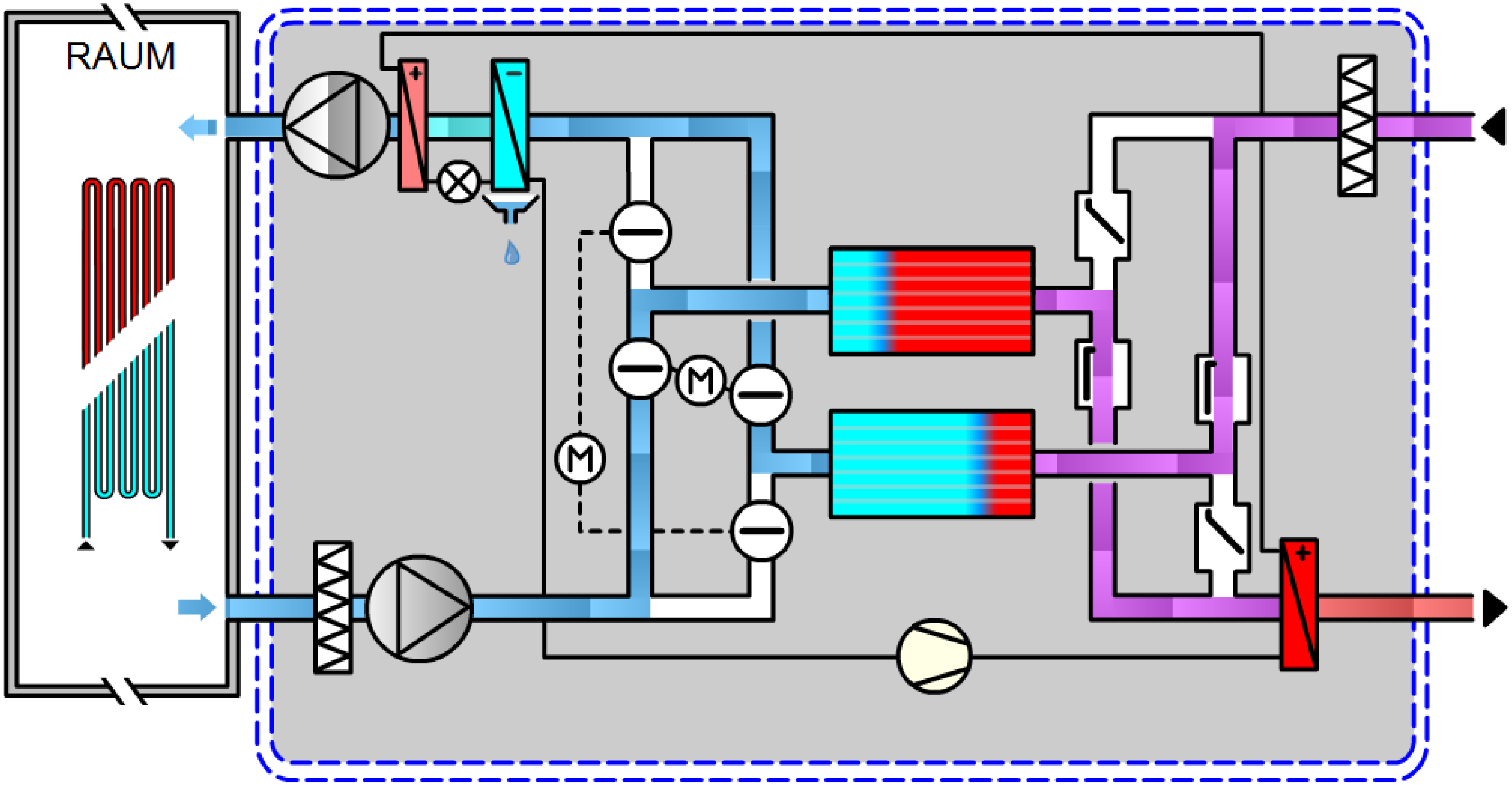

Psychrometric chart
Cursor position
t (°C) x (g/kg) φ(%) h (kJ/kg)
Air pressure:
997.0 hPa
Table and actions
Table
1 2 3 4 5
t 5.0 18.6 22.0 8.4
φ 90 42 40 86
x 4.9 5.6 6.7 6.0
h 17.4 32.9 38.9 23.5
V̇ 9,398 9,868 10,000 9,530
ṁd 11,645 11,645 11,645 11,645
Δt 13.6 -13.6
Δx 0.7 -0.7
Δh 15.5 -15.5
Q̇ (kW) 50.1 -50.1
Δṁx(kg/h) 8.1 -8.1
Actions
Heat recovery
Entry points 1 and 3; Regenerative heat re
100 % 90 % 80 % 70 % 60 % 50 % 40 % 30 % 20 % 10 %

90%-65%


Psychrometric chart
Cursor position
t (°C) 31.6
x (g/kg) 7.0
φ(%) 24
h (kJ/kg) 49.7
ρ (kg/m³) 1.135
Air pressure: 997.0 hPa
Table and actions
Table
1 2 3 4 5
t 5.0 20.3 22.0 6.7
φ 90 40 40 90
x 4.9 6.1 6.7 5.5
h 17.4 35.7 38.9 20.6
V̇ 9,398 9,933 10,000 9,465
ṁd 11,645 11,645 11,645 11,645
Δt 15.3 -15.3
Δx 1.1 -1.1
Δh 18.3 -18.3
Q̇ (kW) 59.2 -59.2
Δṁx(kg/h) 13.1 -13.1
Actions
Heat recovery
Entry points 1 and 3; Regenerative heat recovery with t

- Low Maintenance
- Large Design
- Thermal efficiency 90-95%
- Latent Efficiency 65%
- Low pressure Drop
- No moving part, motors etc

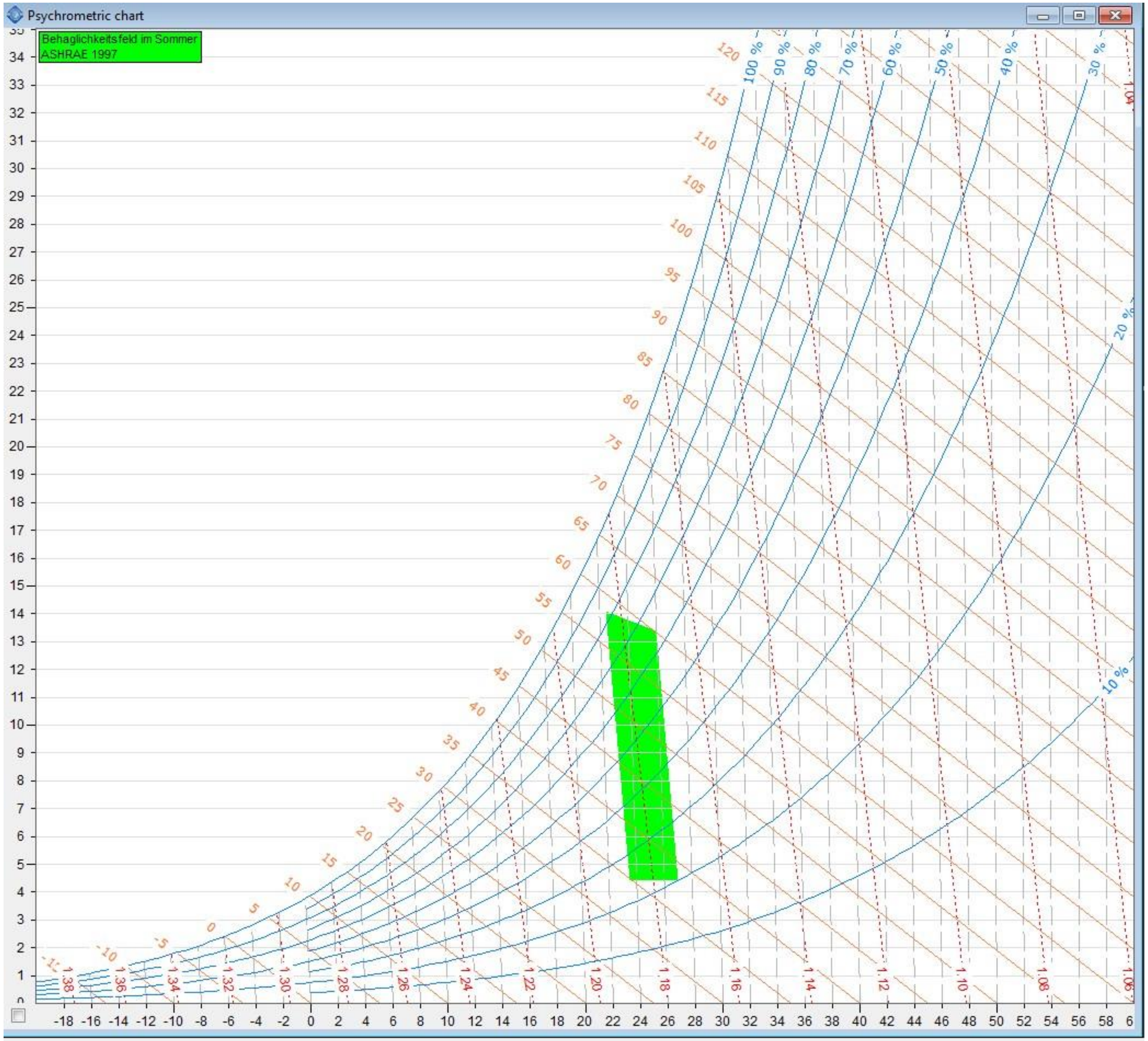
CONDENSER
HEAT RECOVERY-DEHUMIDIFICATION



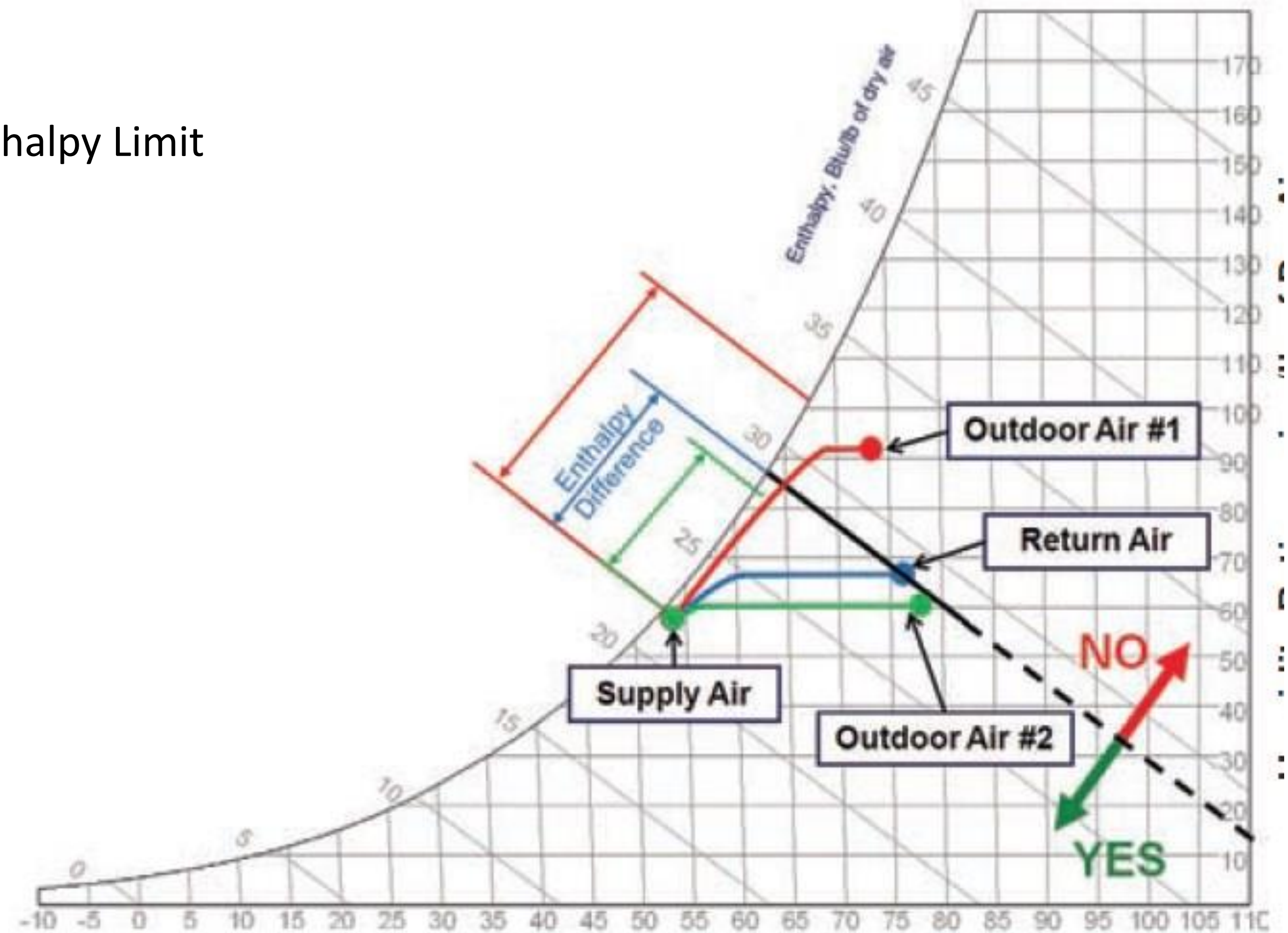
ENTHALPY ECONIMIZERS / BYPASS DAMPER

- (published in ASHRAE Journal, November 2010)
- when cooling return air will use less mechanical cooling energy than cooling outdoor air.
- Determining when the changeover condition occurs is complicated by the fact that cooling coils both cool and dehumidify supply air.

ASHRAE SUMMER COMFORT RANGE



Enthalpy Limit



- enthalpy difference across the coil would be less than that required to cool return air to the supply air temperature despite the fact that the dry-bulb temperature is higher than the return air dry-bulb temperature.
- Because the outdoor air results in a lower latent cooling load

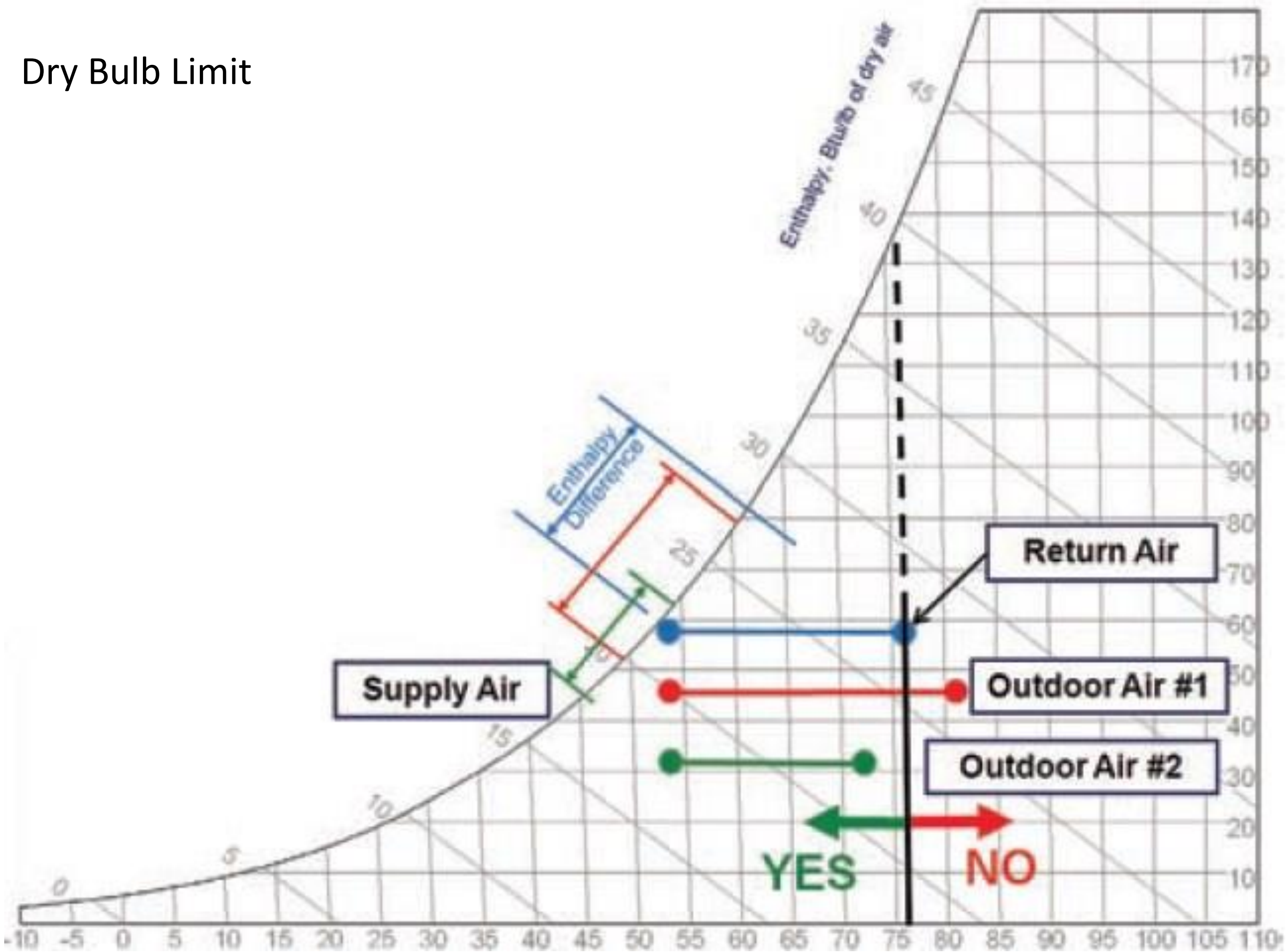
WET COIL

- if the return air has a higher dew-point temperature than the supply air temperature setpoint, assuming near saturated conditions leaving the coil

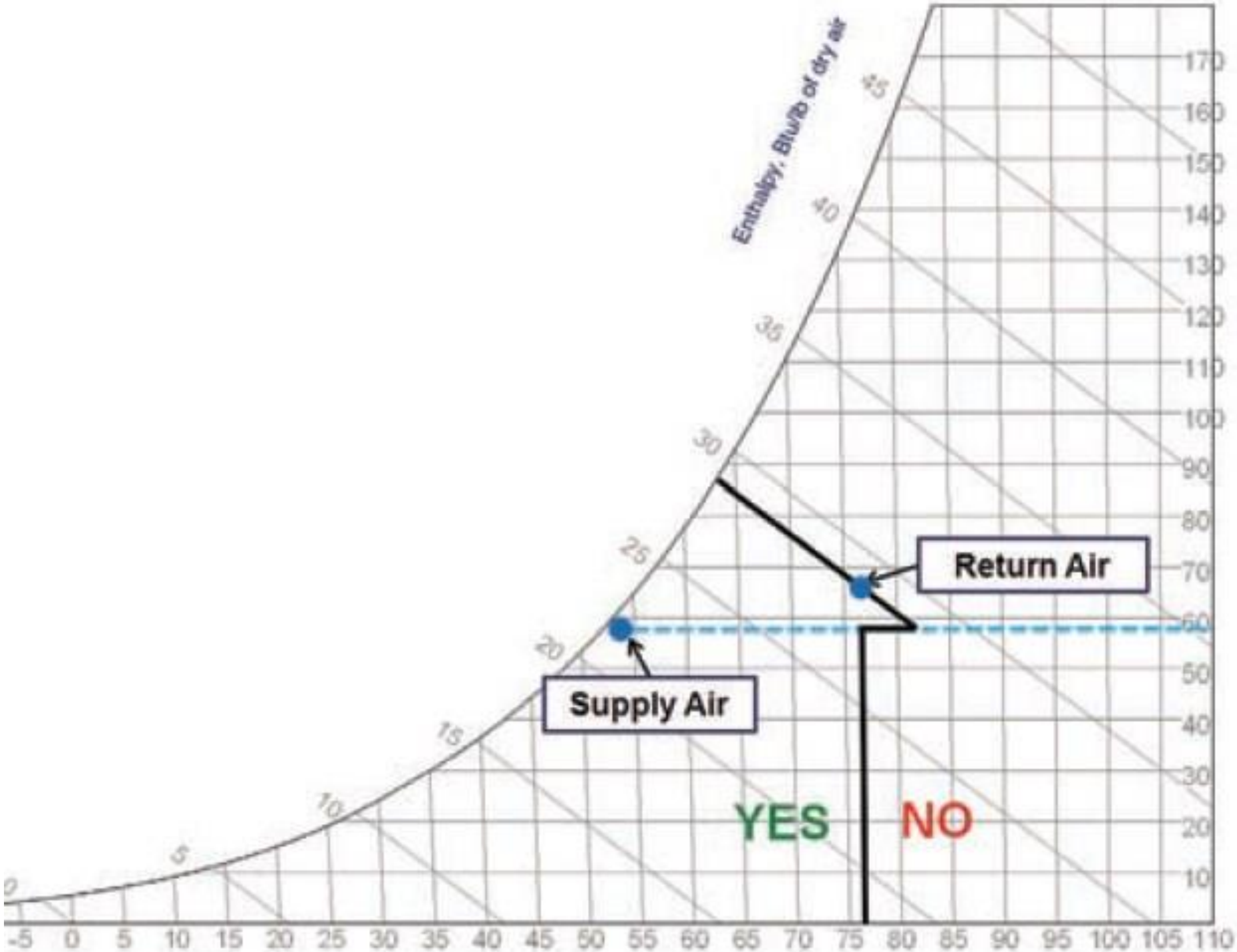
DRY COIL

- entering coil dew-point temperatures are below the supply air temperature dew point, so no dehumidification occurs

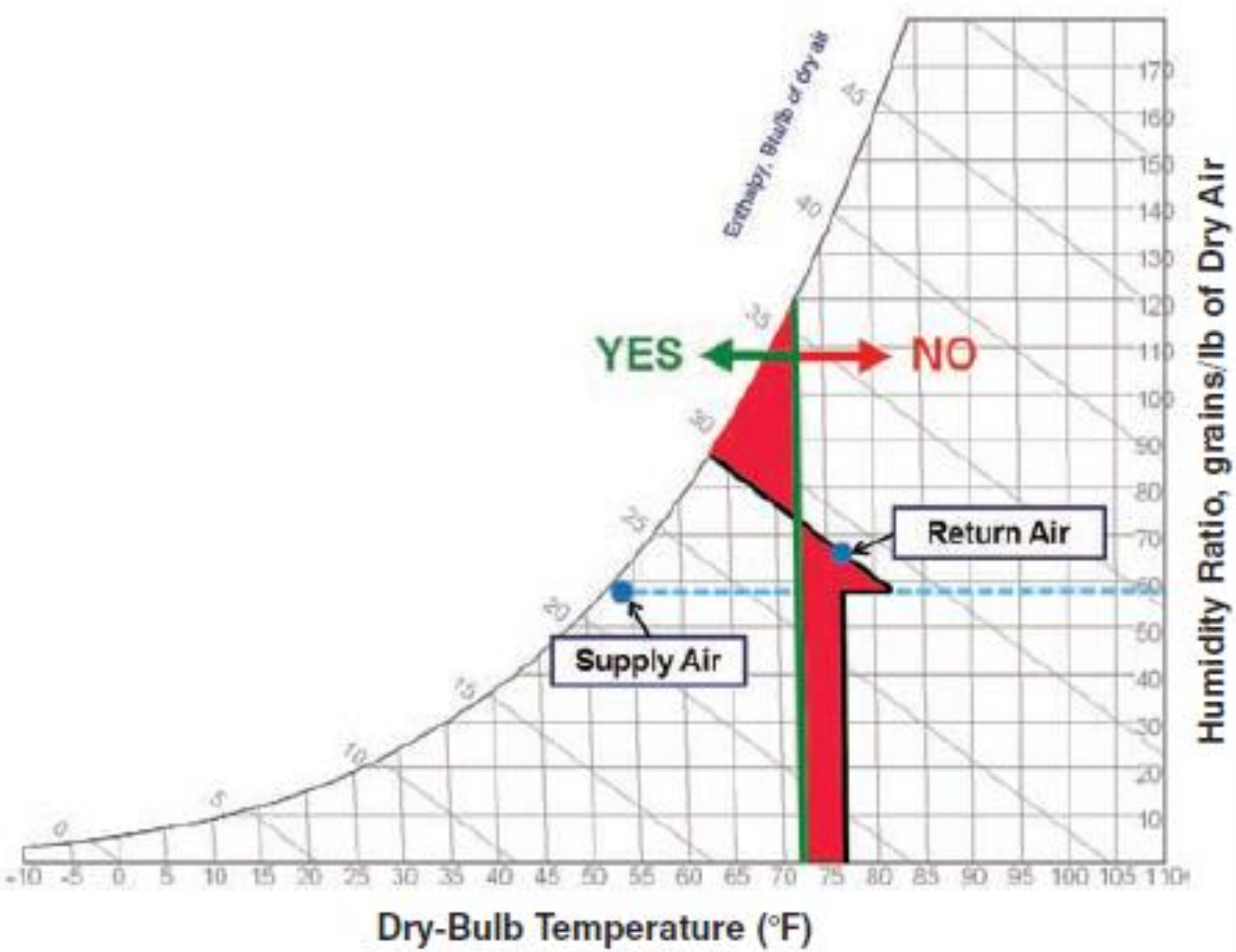
Dry Bulb Limit

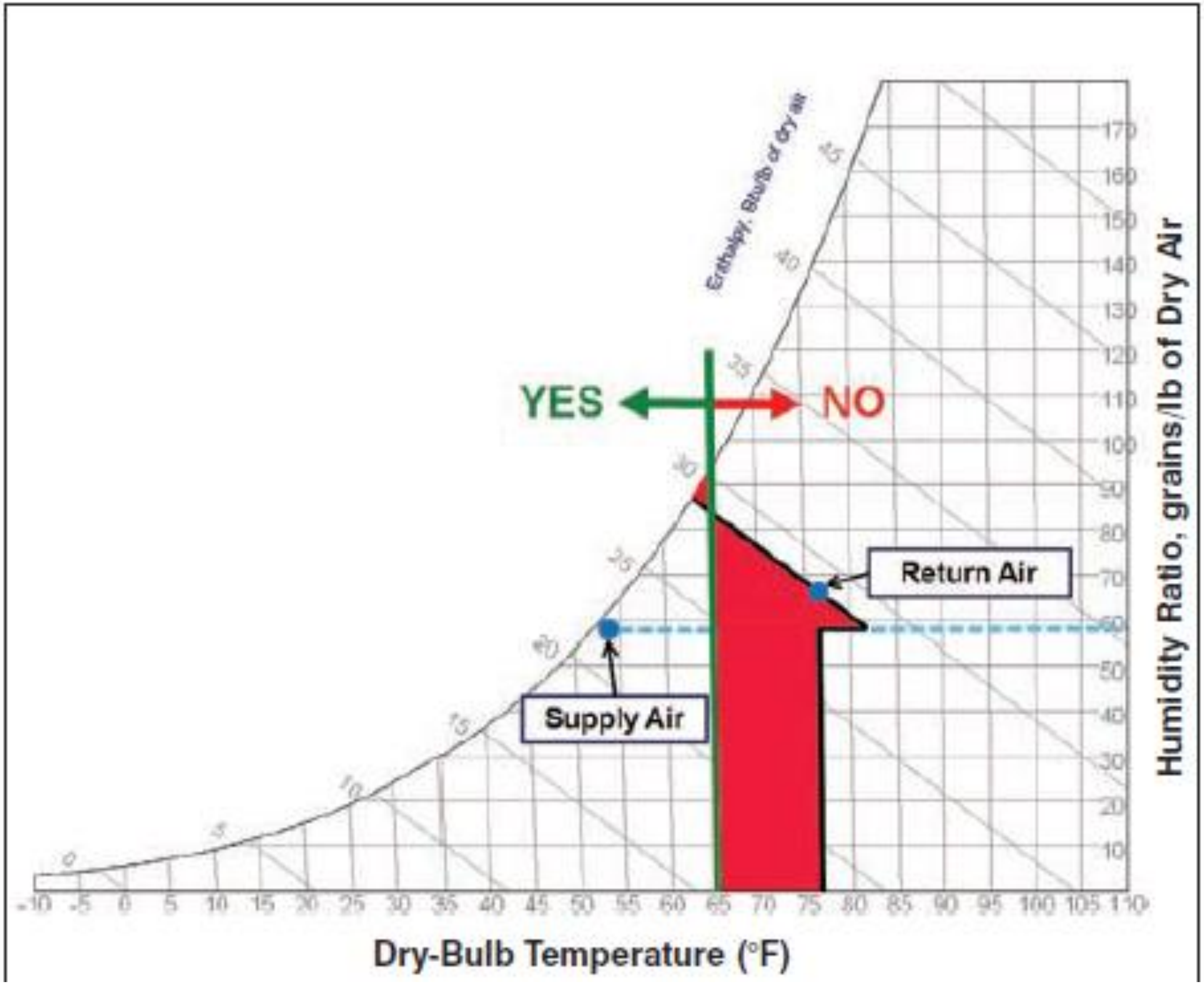


COMBINED GRAPHS

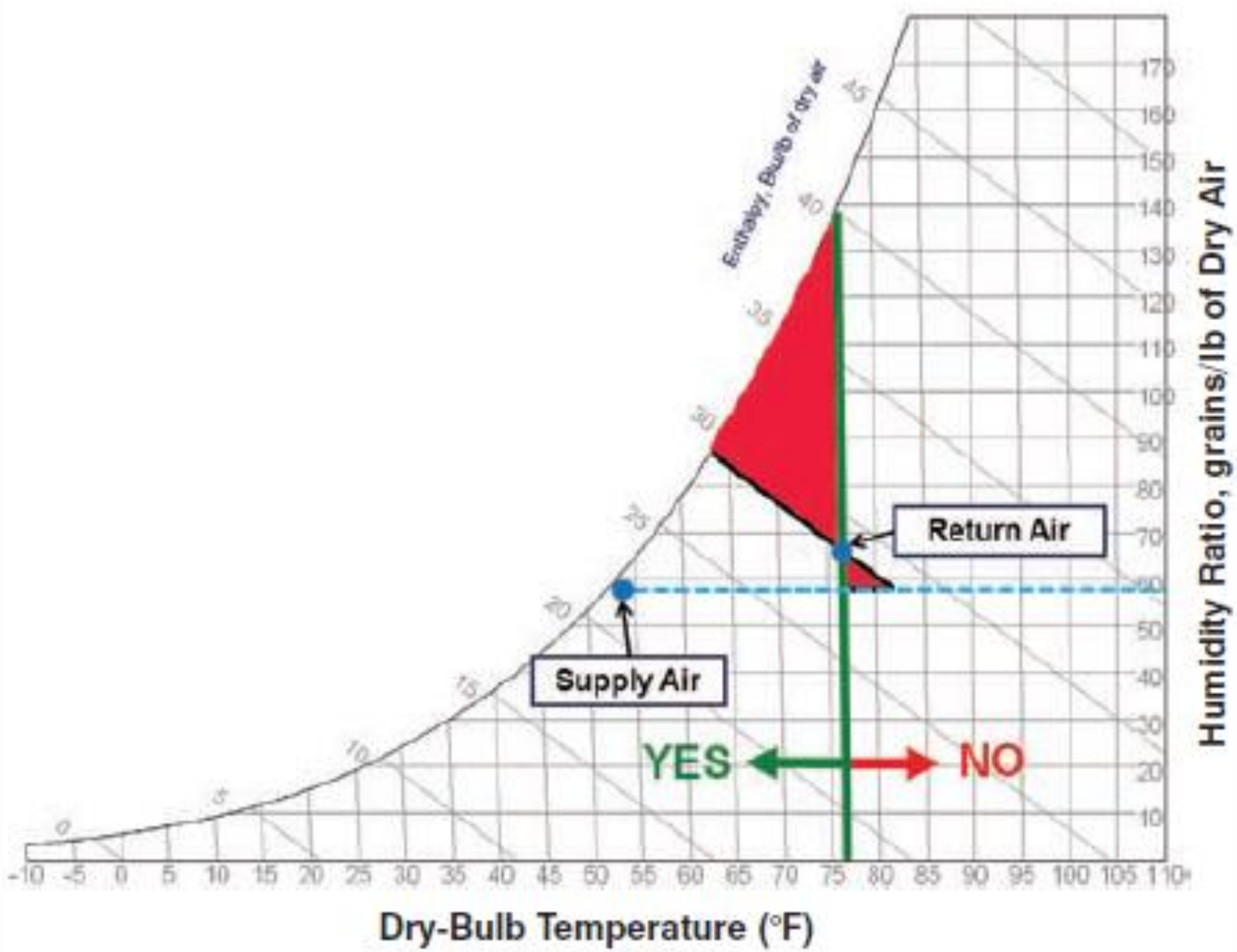


FIXED-DRY BULB ERRORS

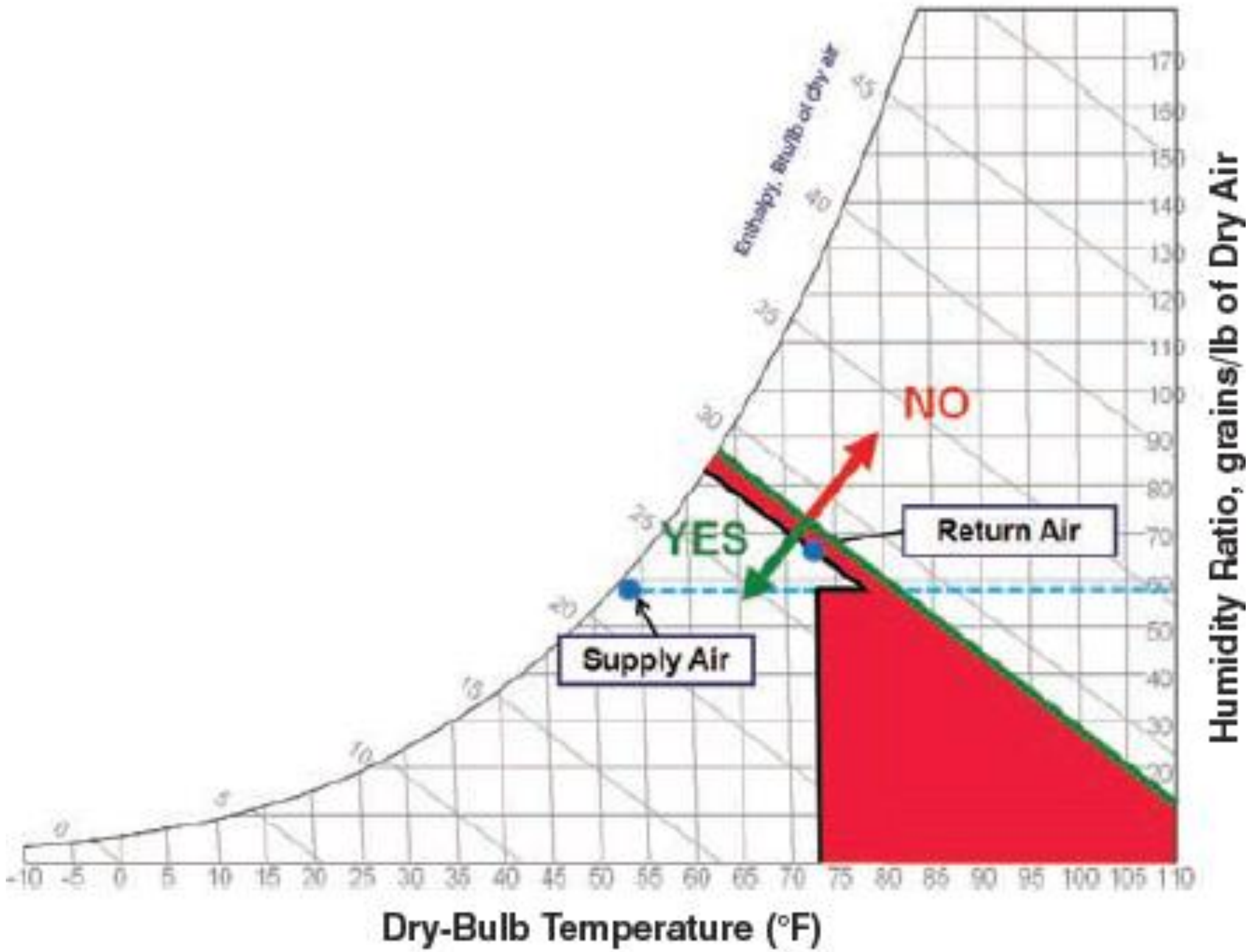



Enthalpy, Btu/lb of dry air
YES
NO
Return Air
Supply Air
Humidity Ratio, grains/lb of Dry Air
Dry-Bulb Temperature (°F)

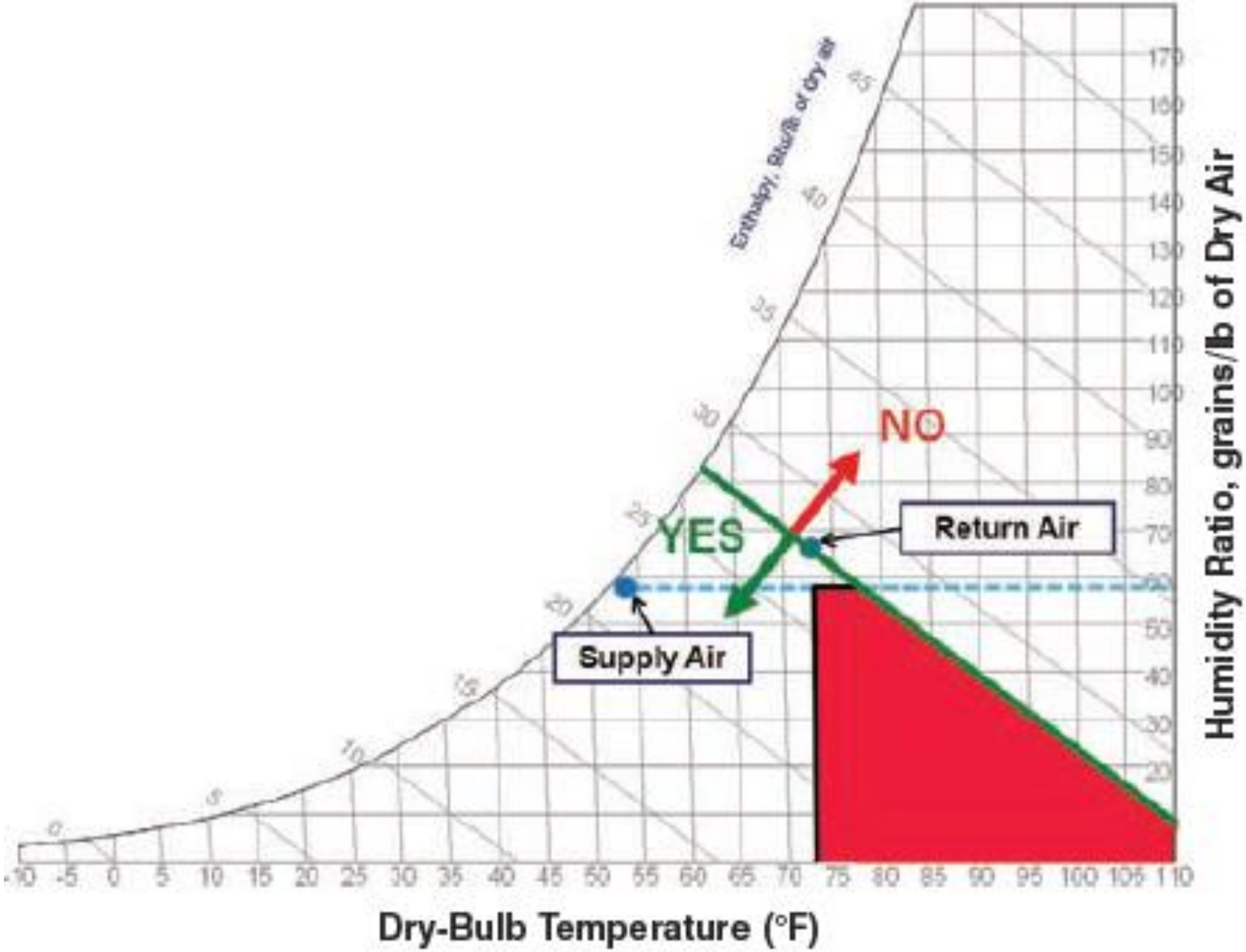
DIFFERENTIAL-DRY BULB ERRORS



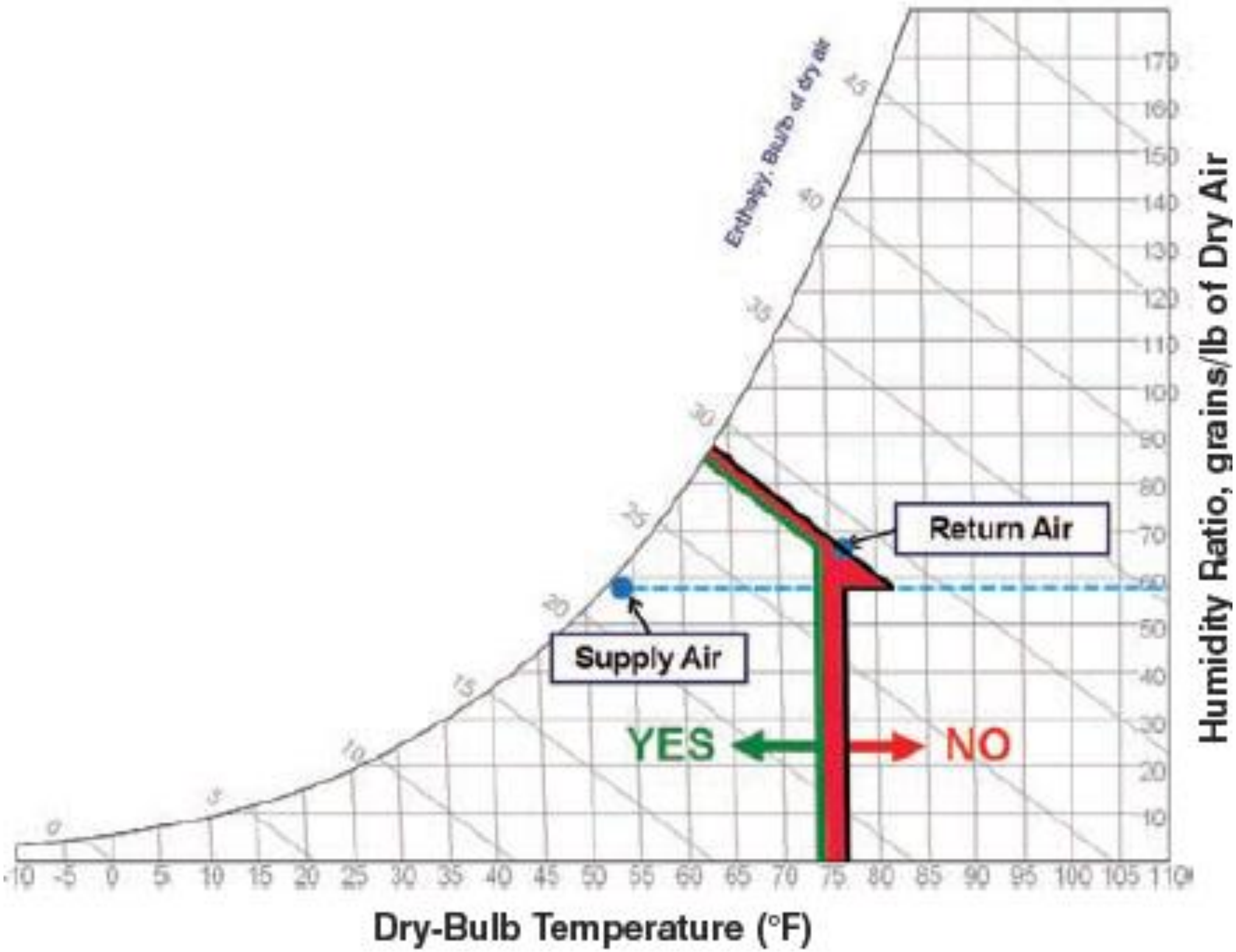
FIXED ENTHALPY ERRORS



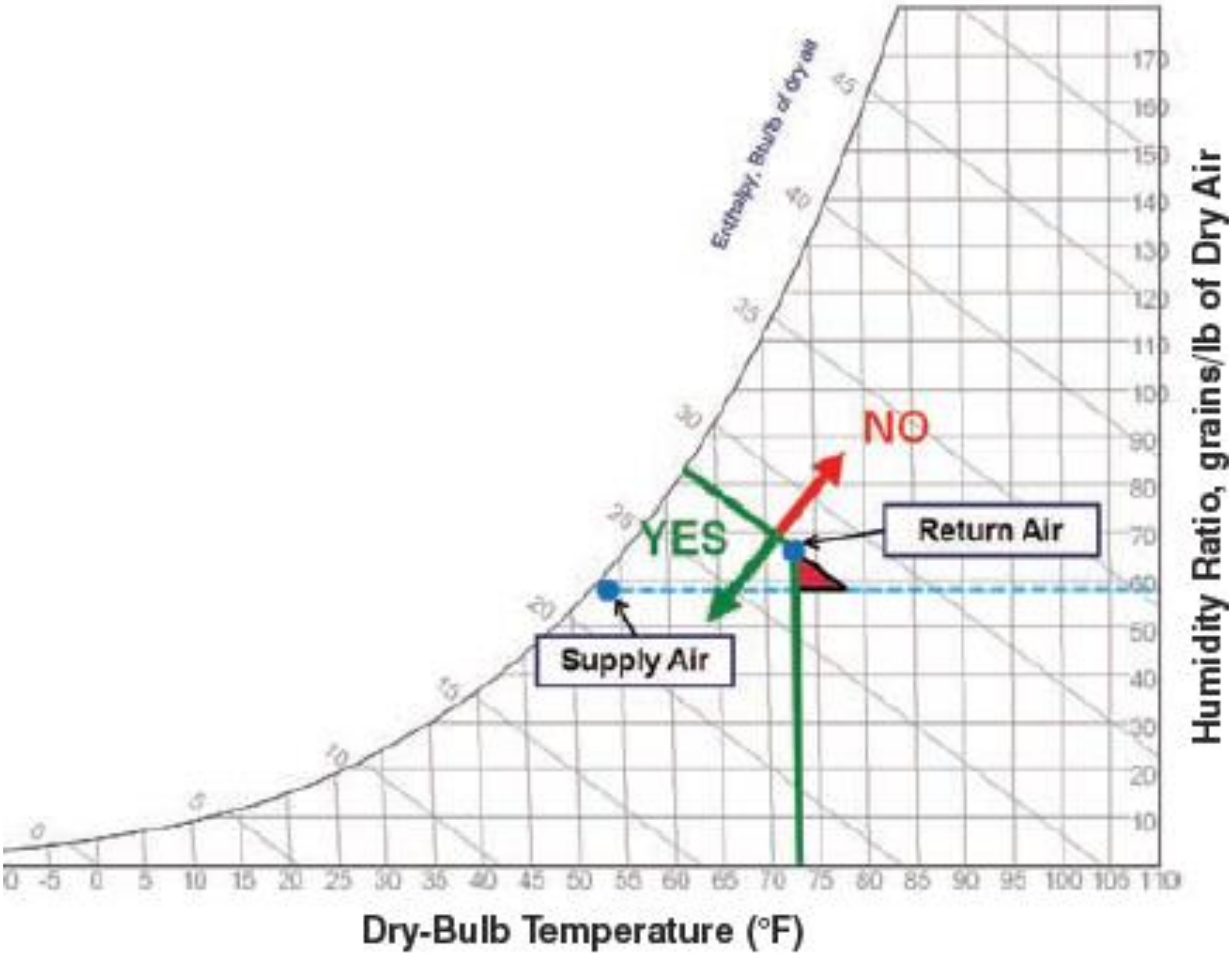
DIFFERENTIAL ENTHALPY ERROR



COMBI ERROR


Enthalpy, Bulb of dry air
Return Air
Supply Air
YES
NO
Humidity Ratio, grains/lb of Dry Air
Dry-Bulb Temperature (°F)

COMBI DIFFERENTIAL



SENSORS AND CALIBRATION

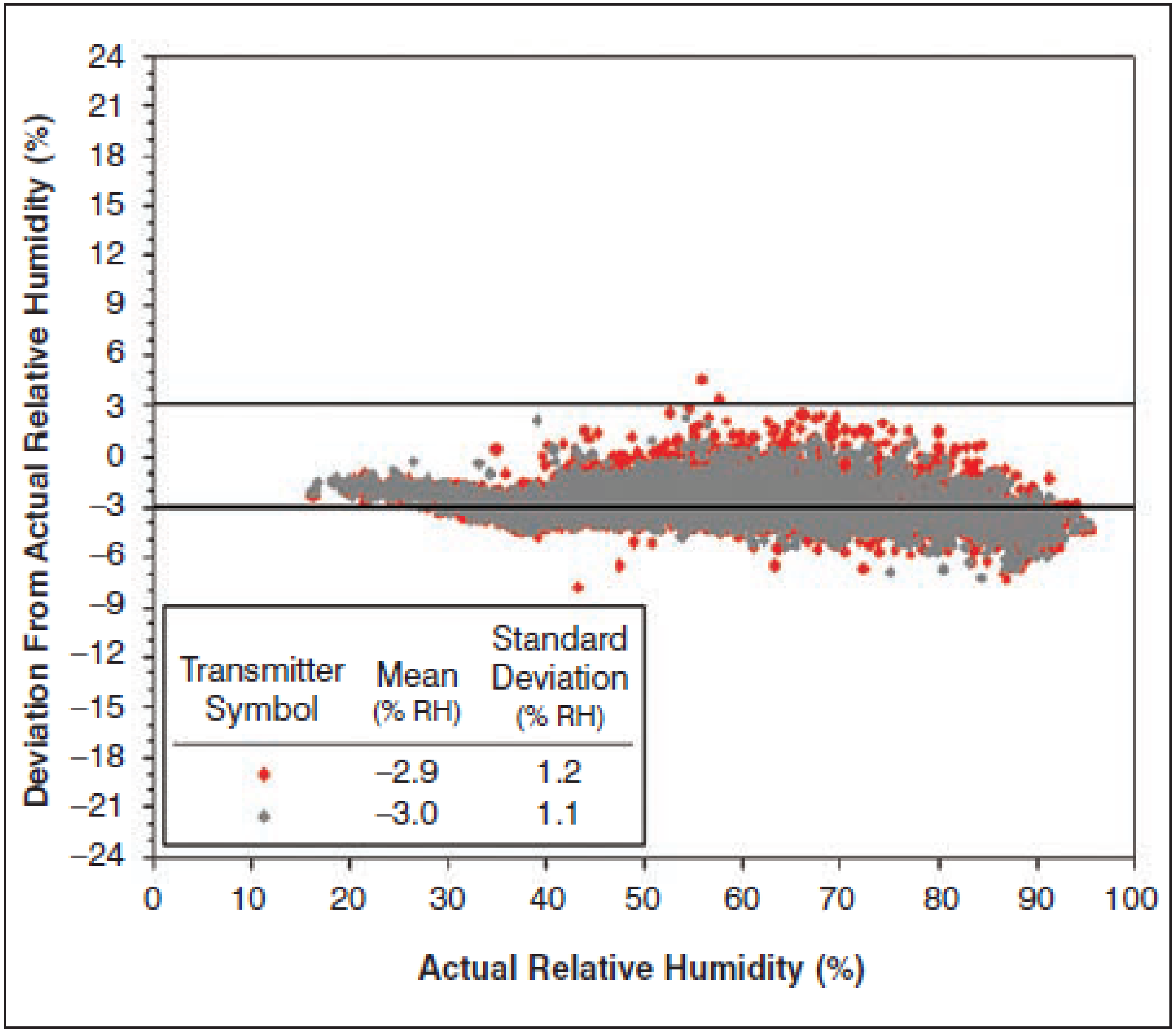


Figure 18: Iowa Energy Center NBCIP study: best humidity sensor.

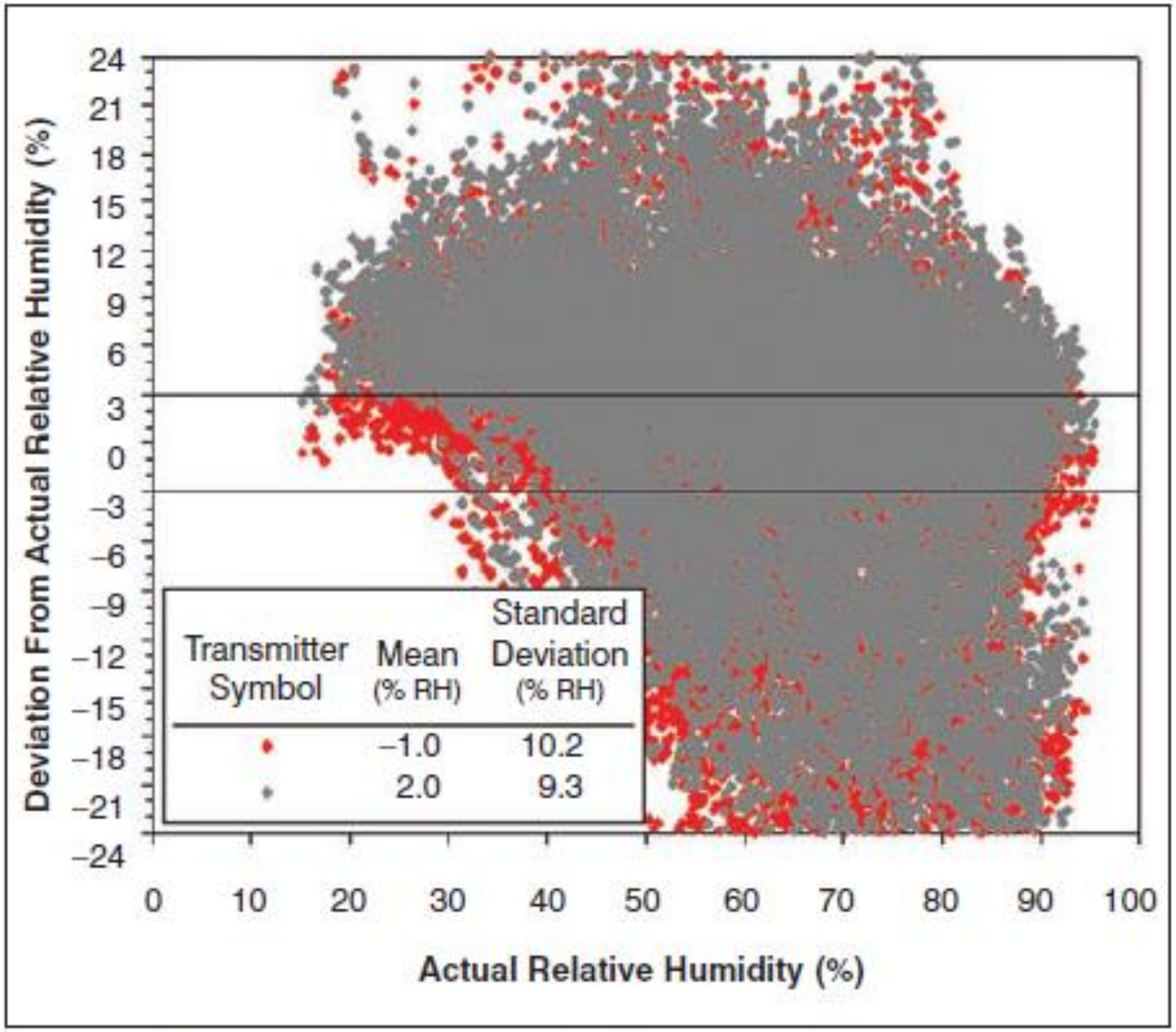
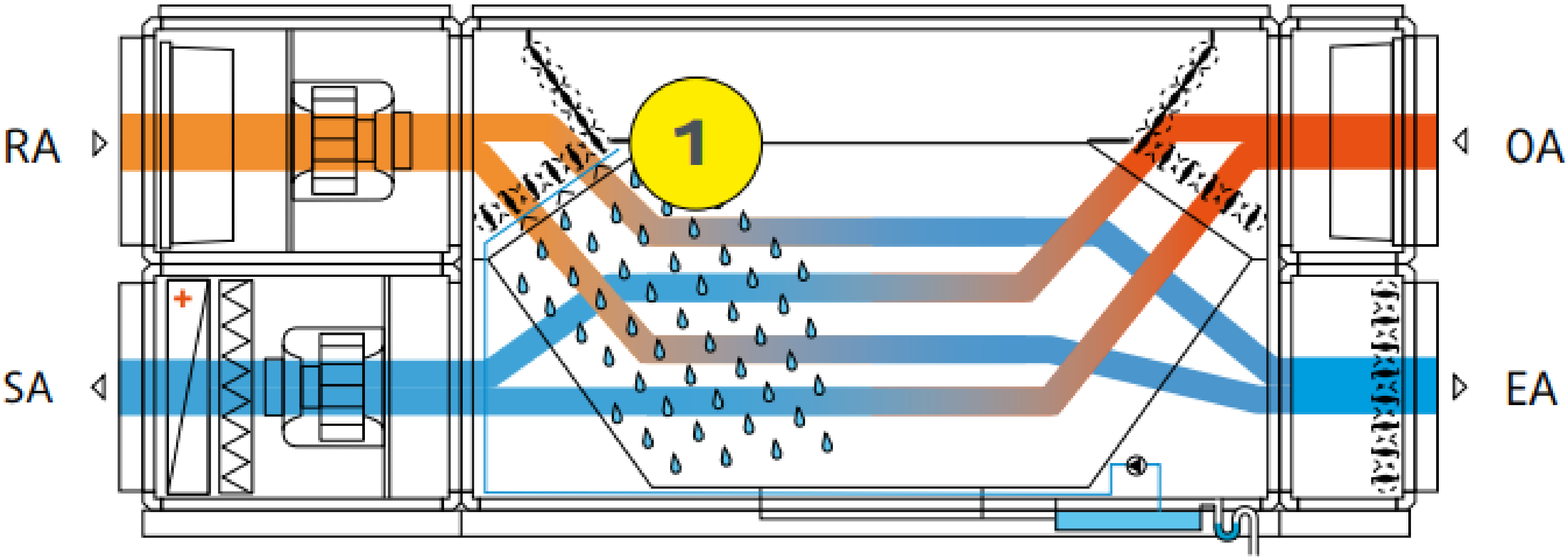
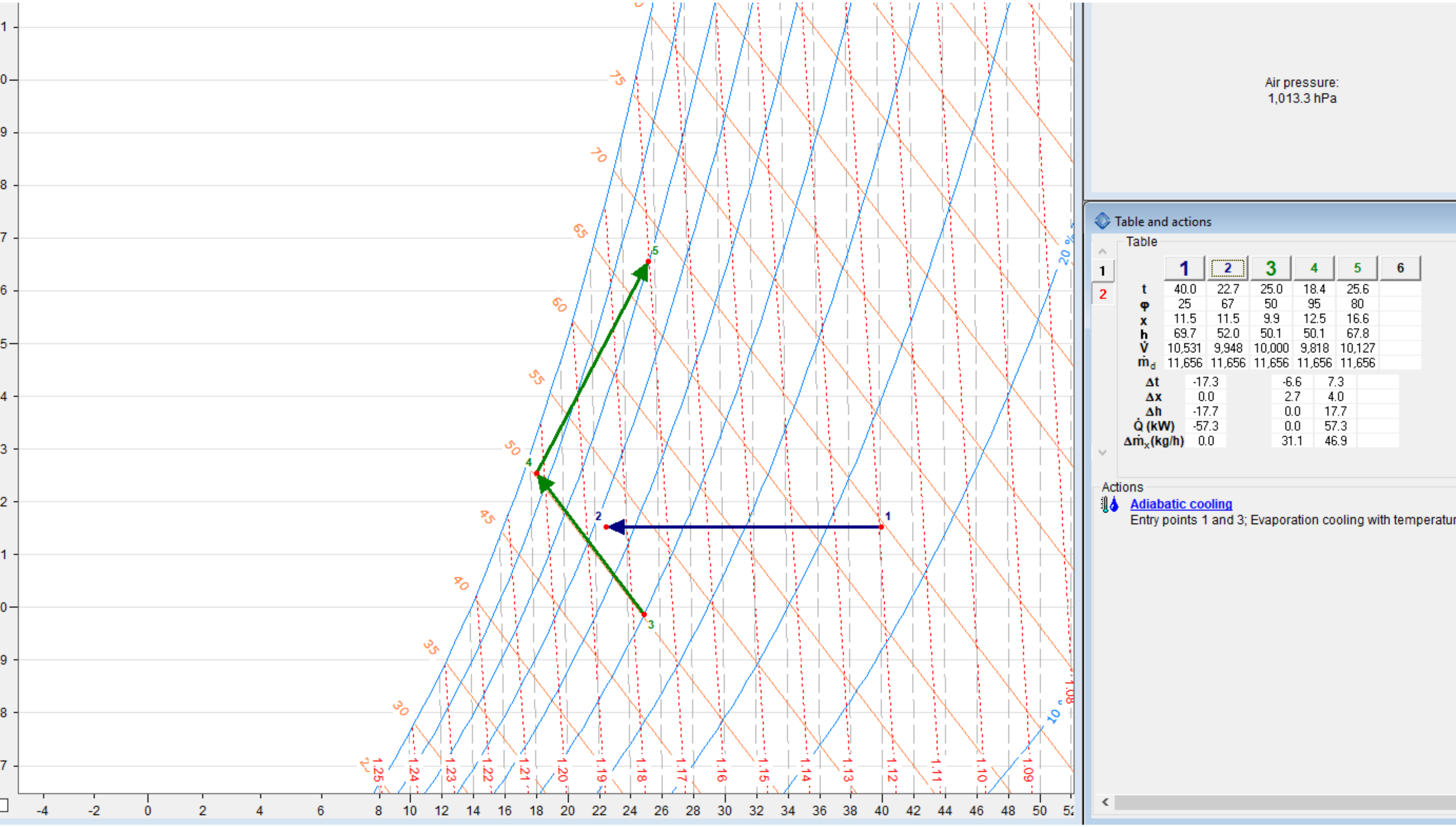


Figure 19: Iowa Energy Center NBCIP study: one of the worst humidity sensors.

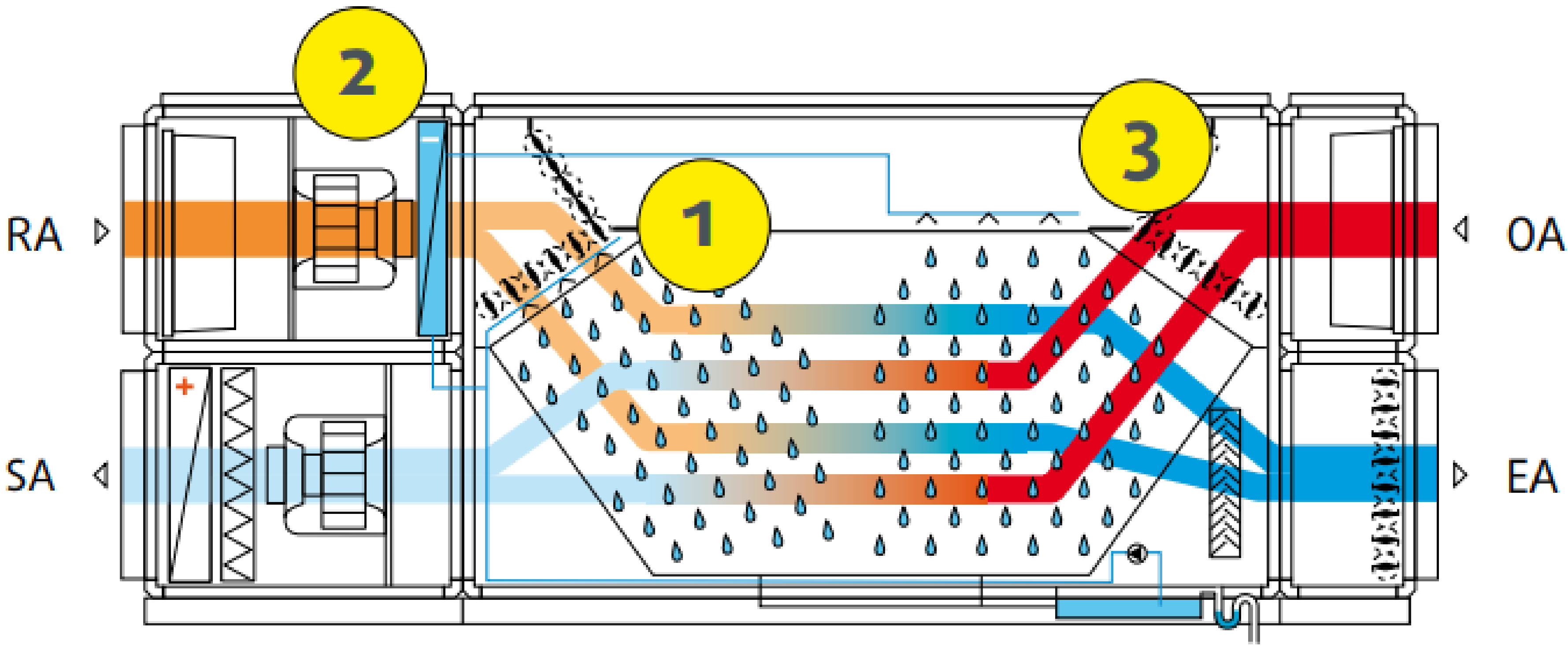
ADIABATIC/EVAPORATIVE COOLING

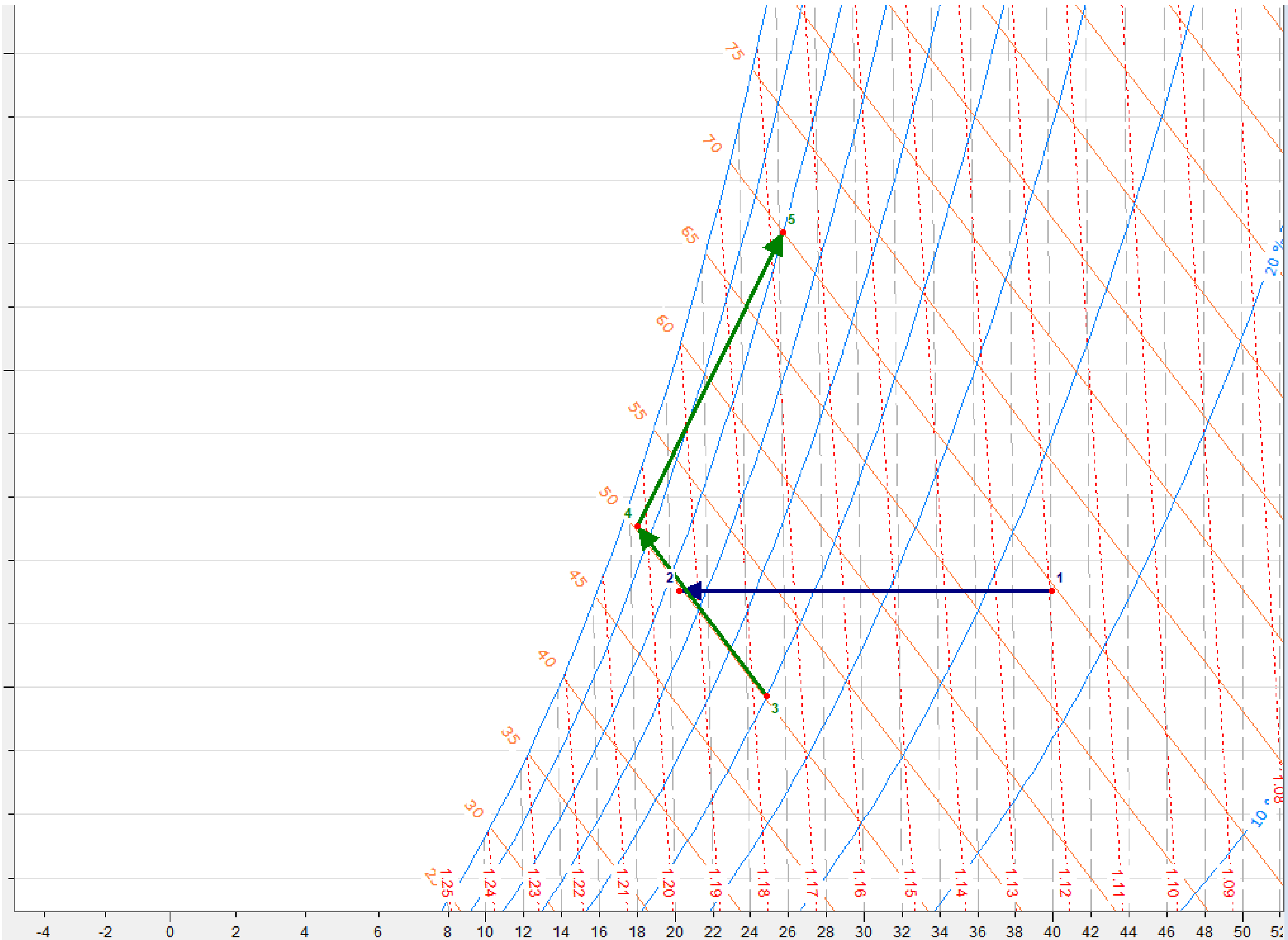




	1	2	3	4	5	6
t	40.0	22.7	25.0	18.4	25.6	
φ	25	67	50	95	80	
x	11.5	11.5	9.9	12.5	16.6	
h	69.7	52.0	50.1	50.1	67.8	
V̇	10,531	9,948	10,000	9,818	10,127	
$\dot{m}_d$	11,656	11,656	11,656	11,656	11,656	

	1→2	2→3	3→4	4→5	5→6
Δt	-17.3		-6.6	7.3	
Δx	0.0		2.7	4.0	
Δh	-17.7		0.0	17.7	
Q̇ (kW)	-57.3		0.0	57.3	
$\Delta\dot{m}_x$(kg/h)	0.0		31.1	46.9	


RA
OA
SA
EA
1
2
3



Air pressure:
1,013.3 hPa

Table and actions

Table

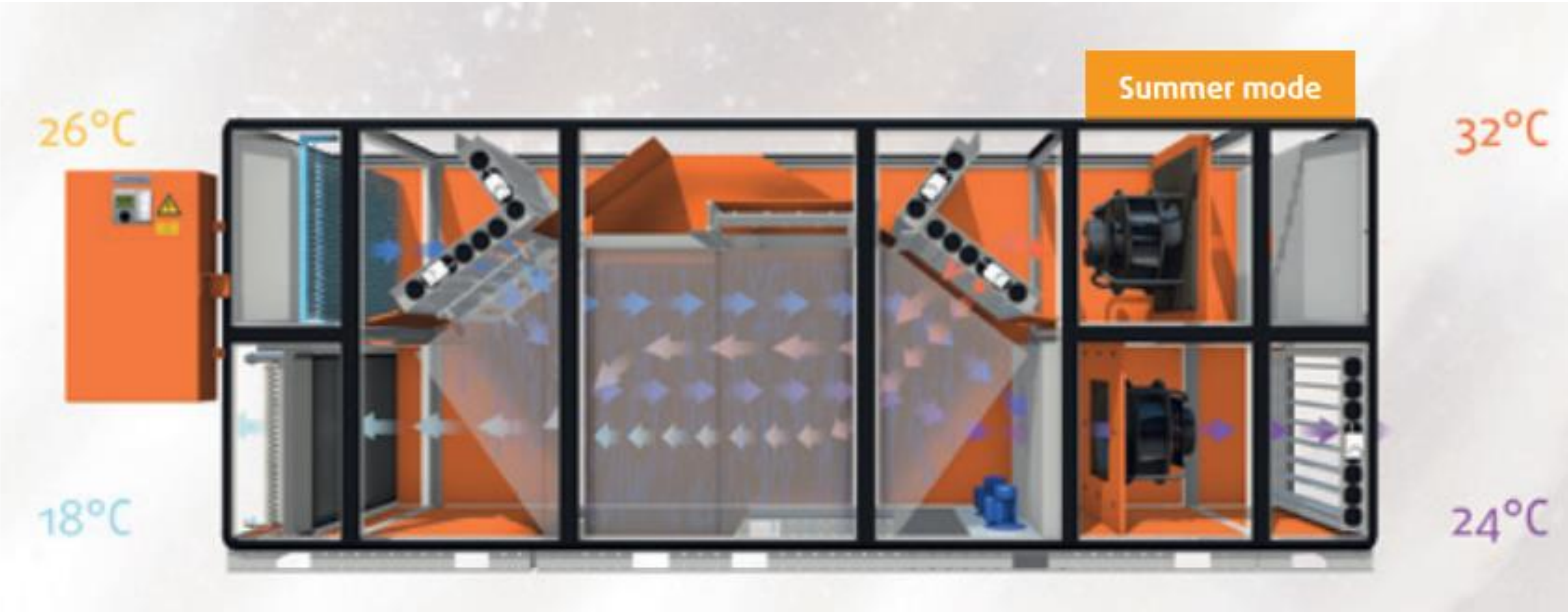
	1	2	3	4	5	6
t	40.0	20.5	25.0	18.4	26.2	
φ	25	76	50	95	80	
x	11.5	11.5	9.9	12.5	17.2	
h	69.7	49.8	50.1	50.1	70.0	
$\dot{V}$	10,531	9,875	10,000	9,818	10,158	
$\dot{m}_d$	11,656	11,656	11,656	11,656	11,656	

	1–2	2–3	3–4	4–5	5–6
Δt	-19.5		-6.6	7.9	
Δx	0.0		2.7	4.6	
Δh	-19.9		0.0	19.9	
$\dot{Q}$ (kW)	-64.4		0.0	64.4	
$\Delta\dot{m}_x$ (kg/h)	0.0		31.1	54.1	

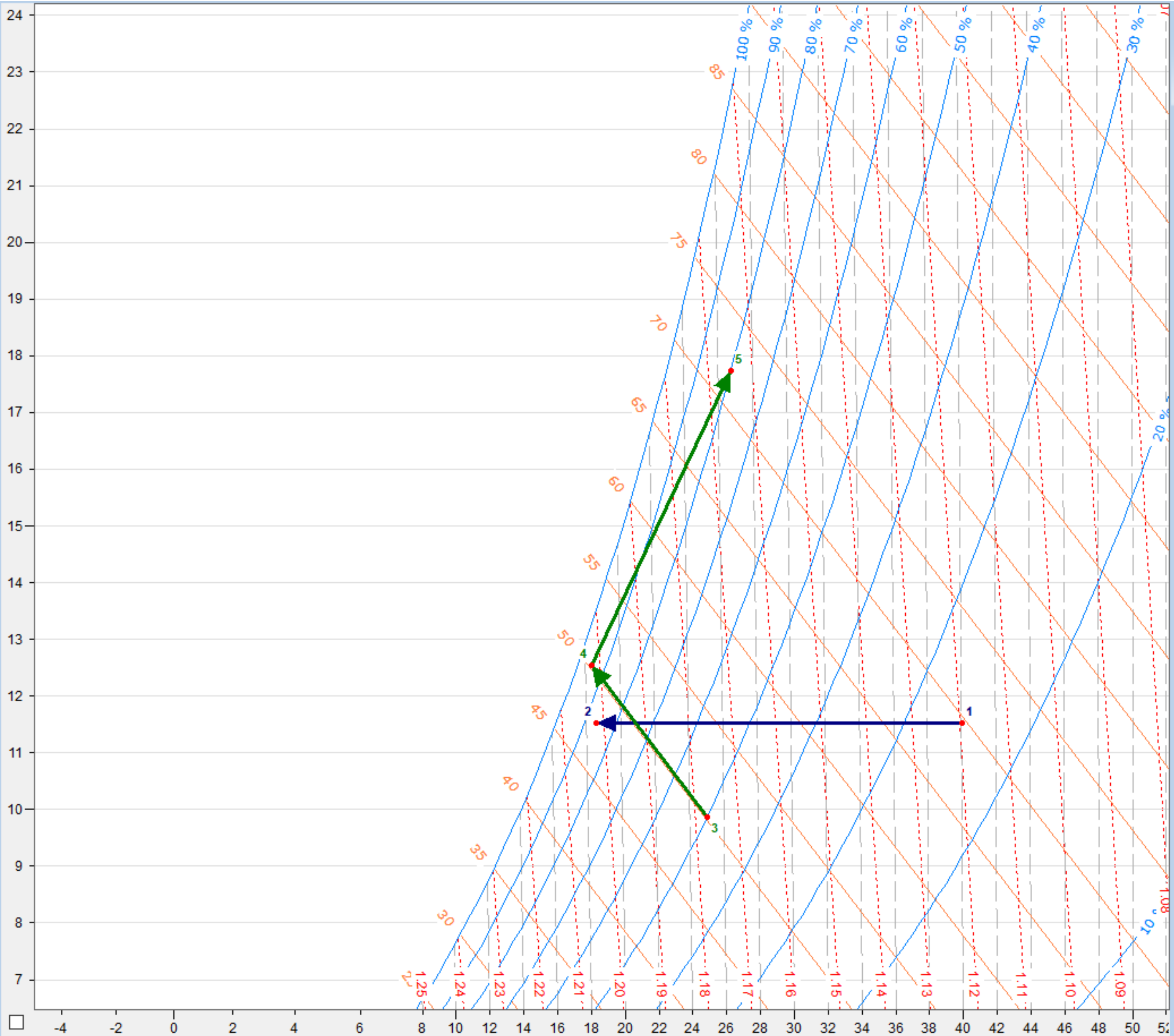
Actions

Adiabatic cooling

Entry points 1 and 3; Evaporation cooling with temp


Summer mode
26°C
32°C
18°C
24°C


Summer mode
26°C
32°C
18°C
26°C



t (°C)	x (g/kg)	φ(%)	h (kJ/kg)	ρ (kg/m³)	p_D (hP
16.1	18.7	100	45.5	1.212	18.3

Air pressure:
1,013.3 hPa

Table and actions

Table

	1	2	3	4	5	6
t	40.0	18.6	25.0	18.4	26.8	
φ	25	86	50	95	80	
x	11.5	11.5	9.9	12.5	17.7	
h	69.7	47.8	50.1	50.1	72.0	
$\dot{V}$	10,531	9,810	10,000	9,818	10,185	
$\dot{m}_d$	11,656	11,656	11,656	11,656	11,656	

Δt	-21.4		-6.6	8.4	
Δx	0.0		2.7	5.2	
Δh	-21.9		0.0	21.9	
$\dot{Q}$ (kW)	-70.9		0.0	70.9	
$\Delta\dot{m}_x$(kg/h)	0.0		31.1	60.7	

Actions

Adiabatic cooling

Entry points 1 and 3; Evaporation cooling with temperature tra

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