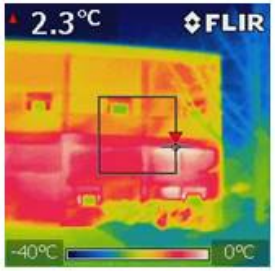
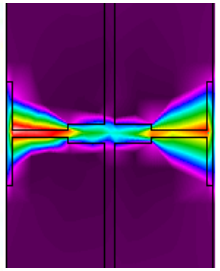
CAE 331/513 Building Science

Fall 2018





October 2, 2018

Psychrometrics (chart and definitions)

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Last time and this time

- Introduced HVAC systems and processes

- Today:
  - Finish HVAC systems and processes
  - Psychrometrics (chart and some equations)
  - Assign HW #3 (due Tuesday Oct 9)

AIR AND WATER DISTRIBUTION SYSTEMS

Typical large central commercial systems

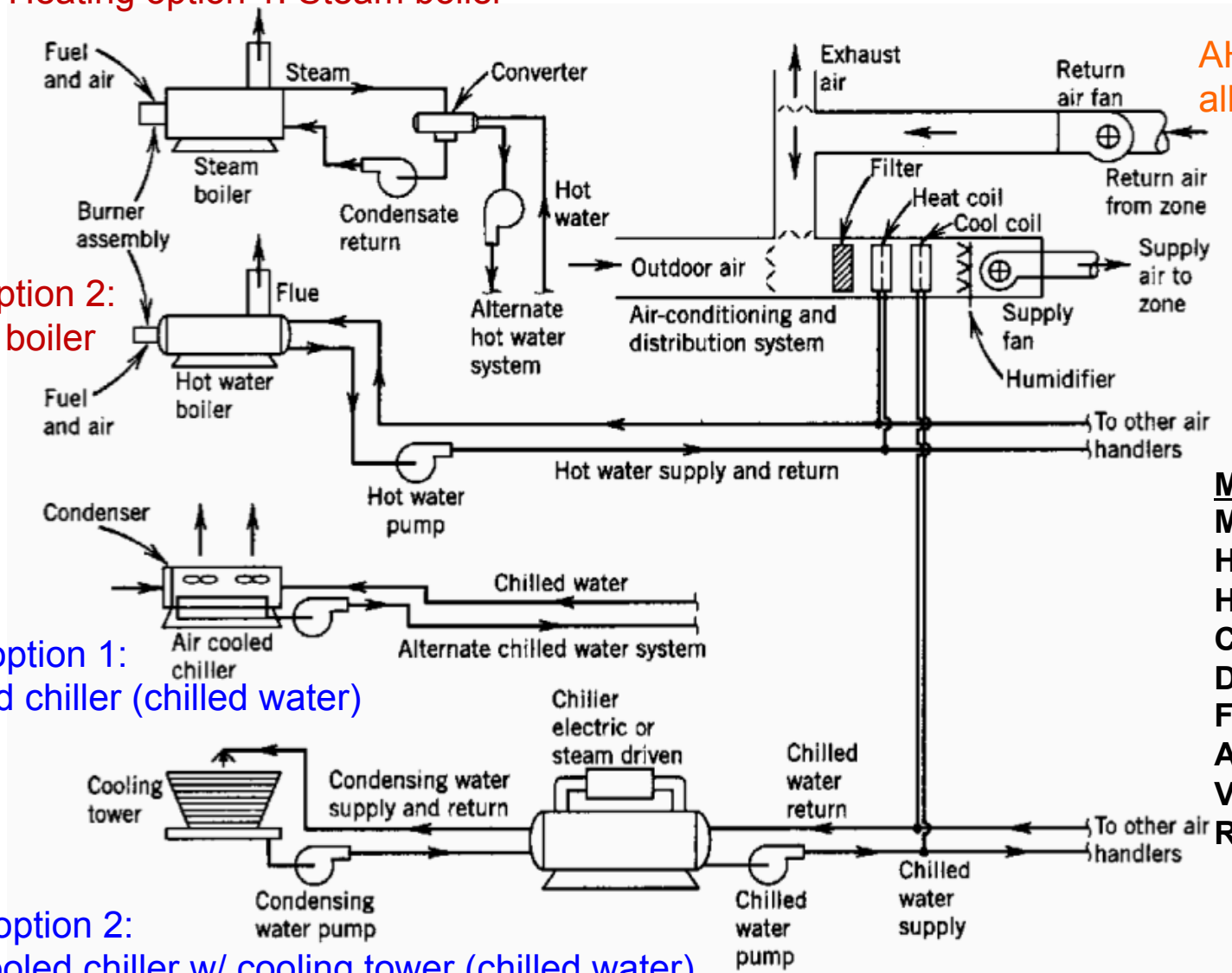
Heating option 1: Steam boiler

Heating option 2:
Hot water boiler

Cooling option 1:
Air cooled chiller (chilled water)

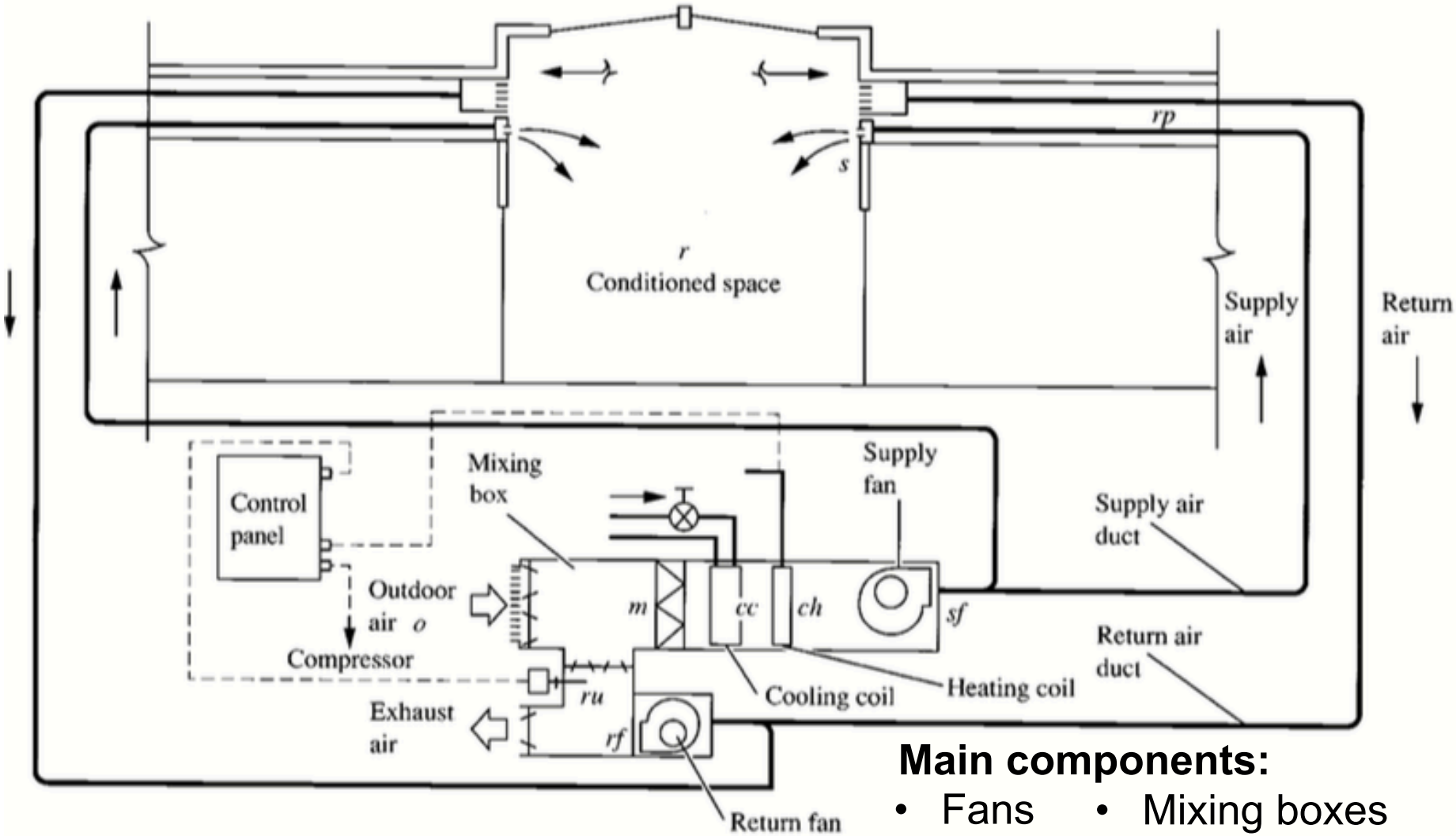
Cooling option 2:
Water cooled chiller w/ cooling tower (chilled water)

AHU serves all rooms



Main processes:
Mixing
Heating
Humidification
Cooling
Dehumidification
Filtration
Air distribution
Ventilation
Recirculation

Typical central commercial air distribution system



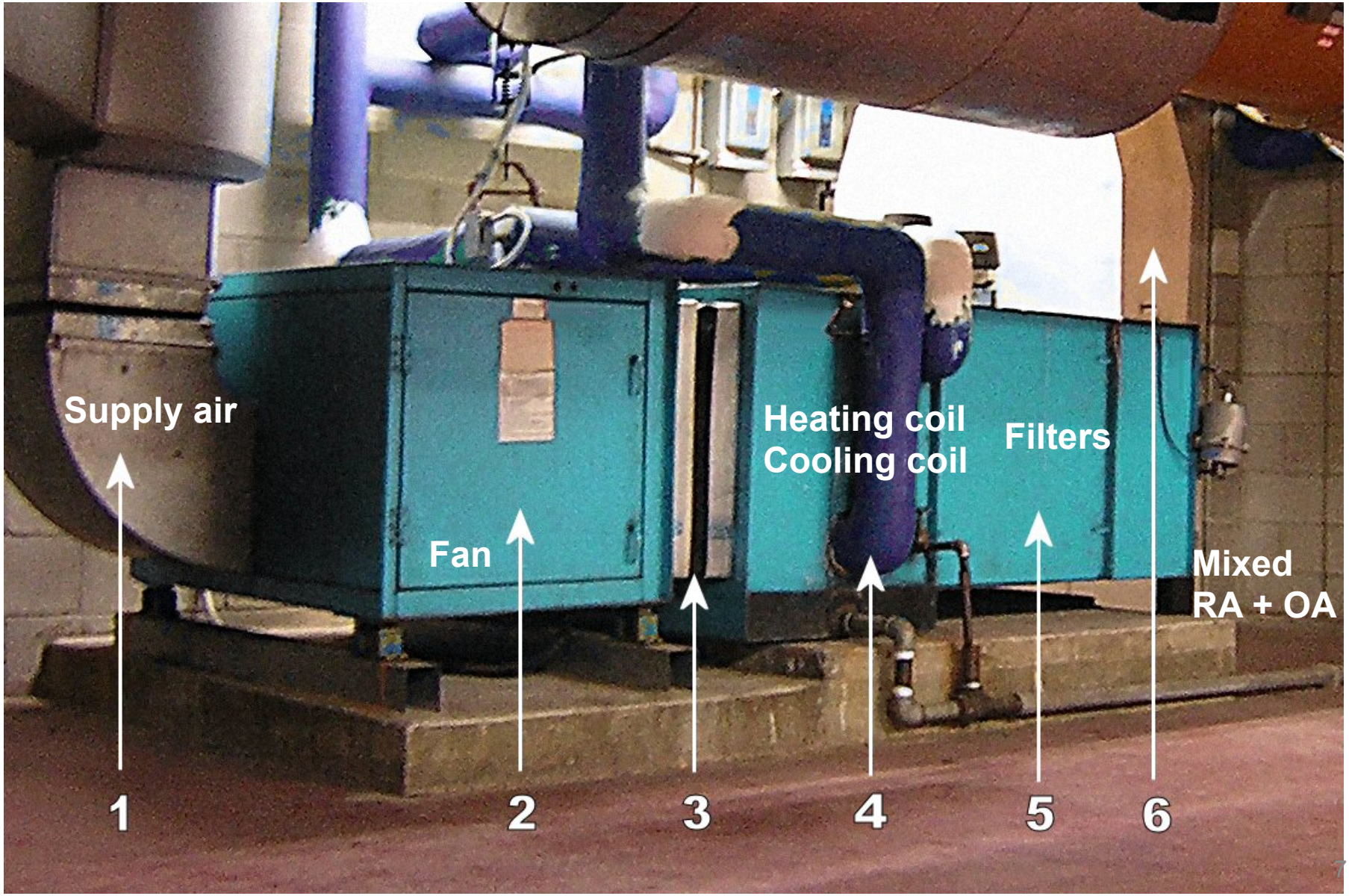
Main components:

- Fans
- Coils
- Filters
- Mixing boxes
- Ducts
- Diffusers

Typical central commercial air handling unit (AHU)

Air Handling Unit (AHU)

Typical central commercial air handling unit (AHU)



Typical large central commercial AHU components

Fan (or “blower”)

Variable frequency drives (VFDs)

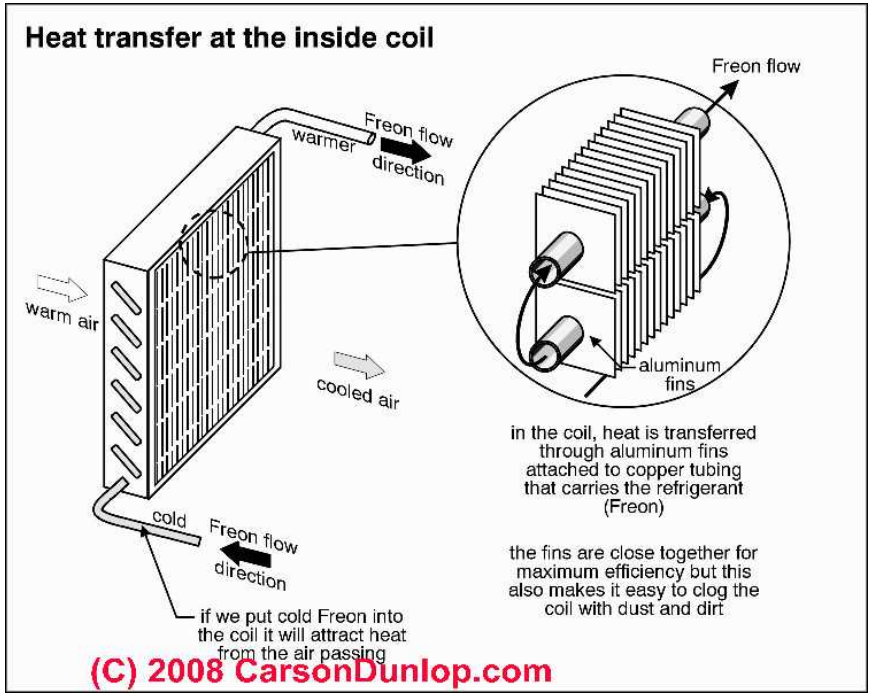
Typical large central commercial AHU components

Mixing box

Dampers

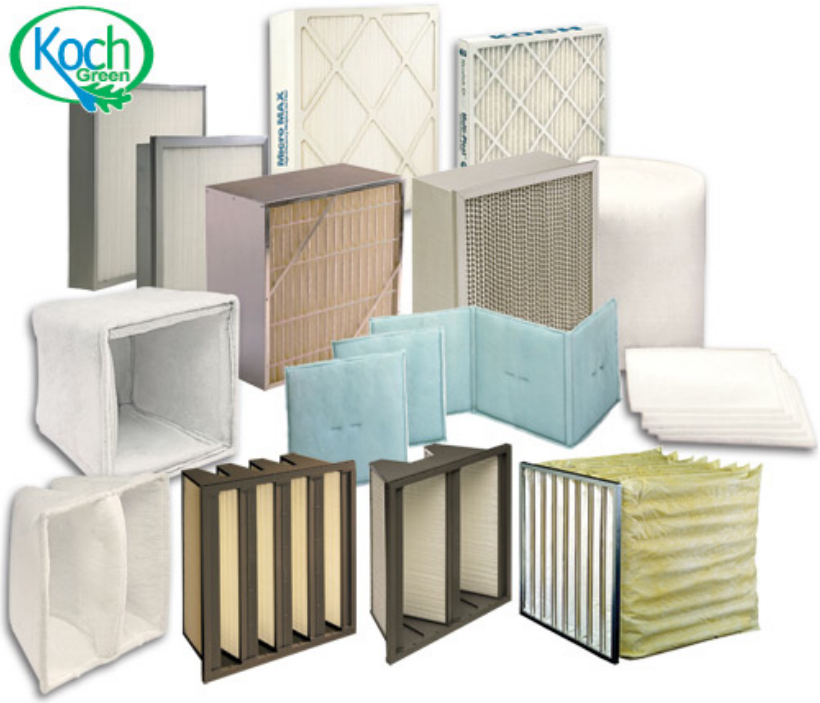
Typical large central commercial AHU components

Heating and cooling coils



Typical large central commercial AHU components

Filter bank



Typical large central commercial AHU components

Filter bank

Typical large central commercial systems

Center for Care and Discovery
University of Chicago Medicine

Typical large central commercial systems

Typical large central commercial systems

Typical large central commercial systems

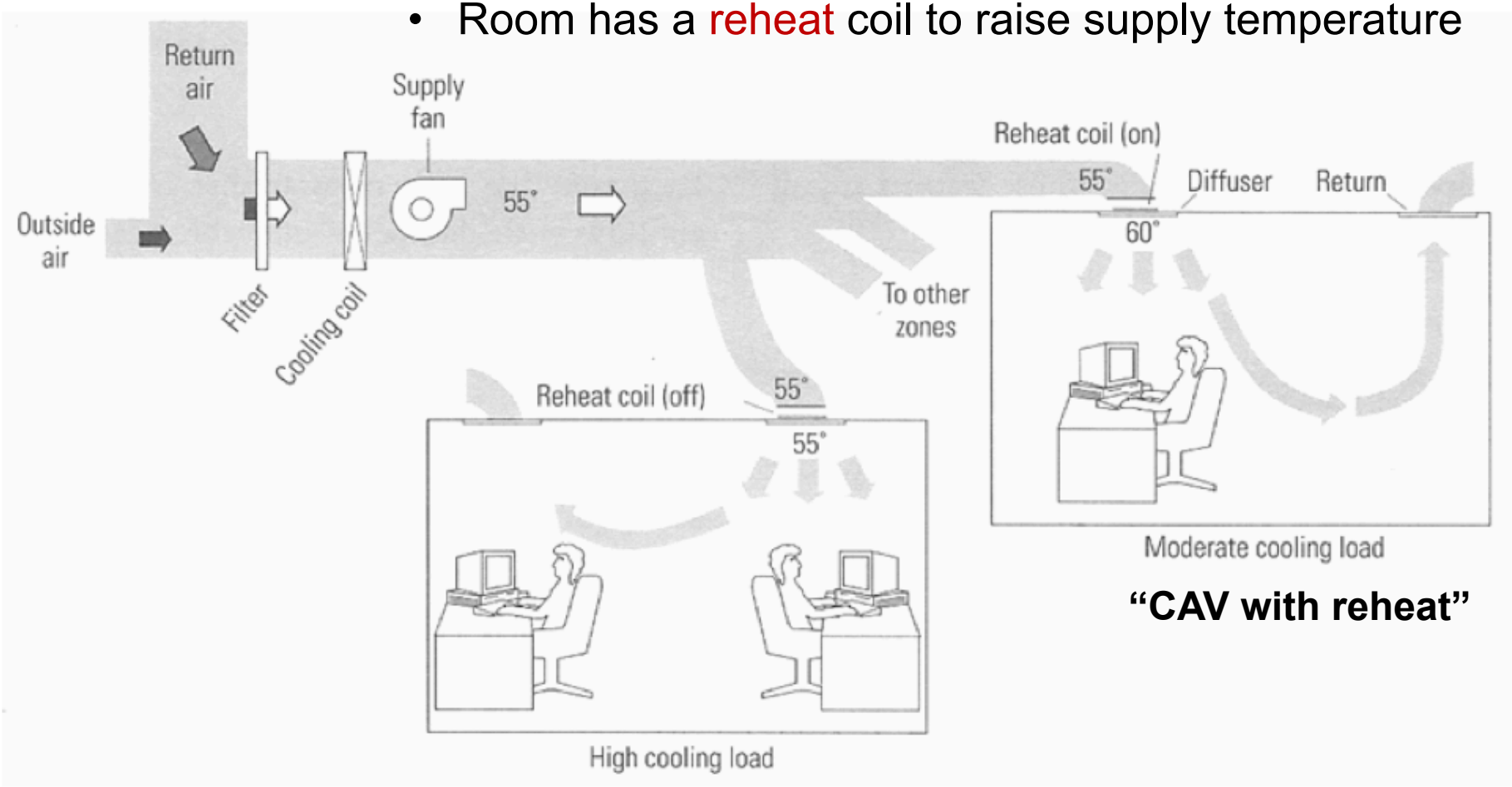
Common commercial air distribution systems

- Constant air volume (**CAV**)
- Variable air volume (**VAV**)
- Dual duct (**DD**)
- Multizone (**MZ**)

Typical constant air volume (CAV) system

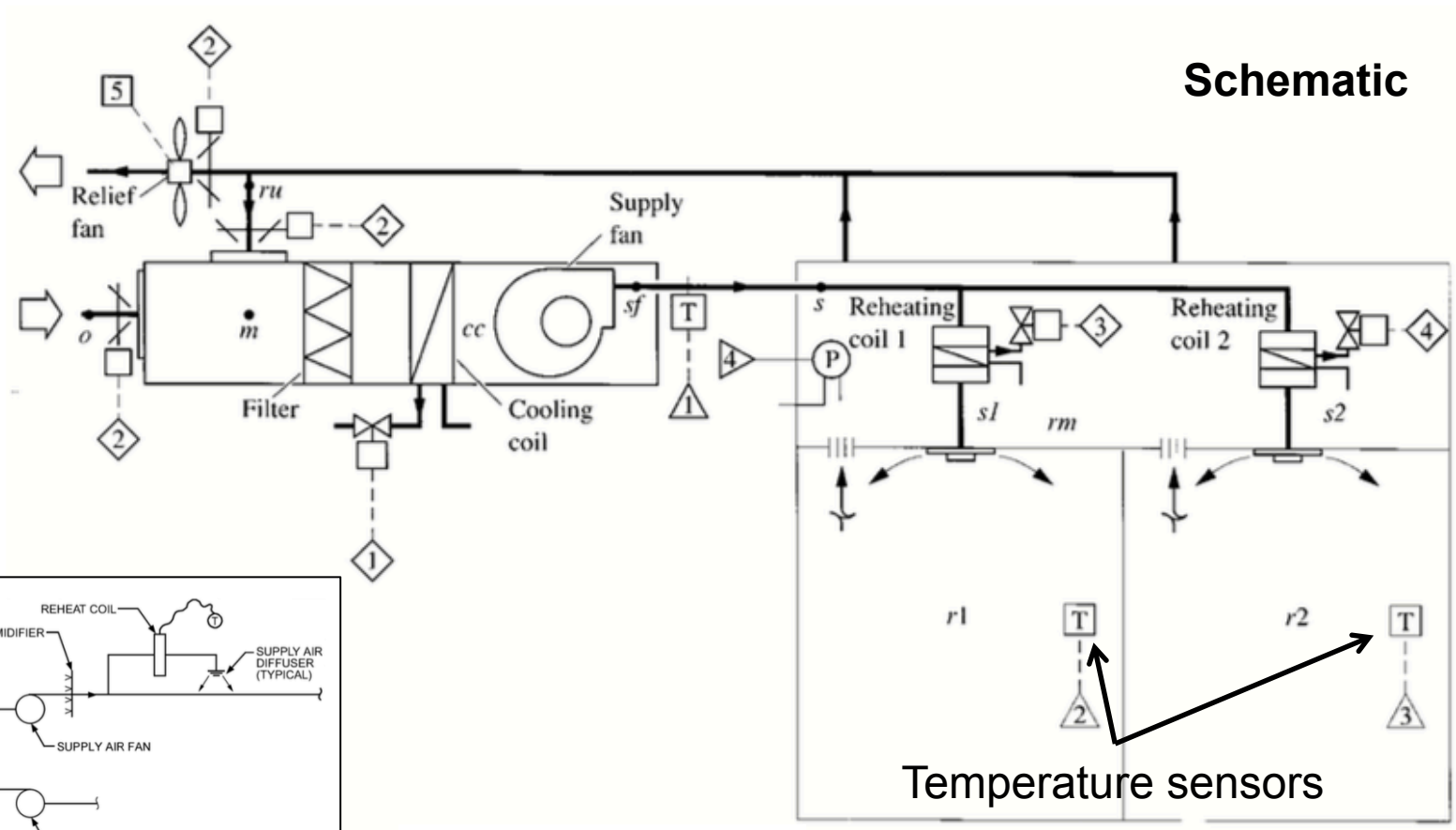
Constant airflow rate and temperature to each room

- Cold air delivered to room
- Room has a reheat coil to raise supply temperature



"CAV with reheat"

Typical constant air volume (CAV) system



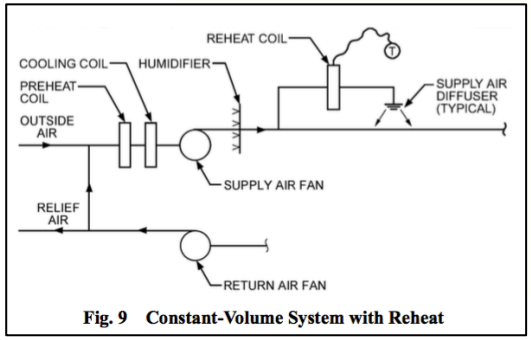
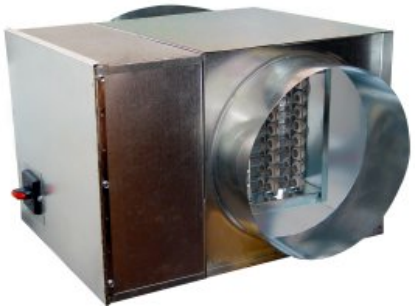


Fig. 9 Constant-Volume System with Reheat

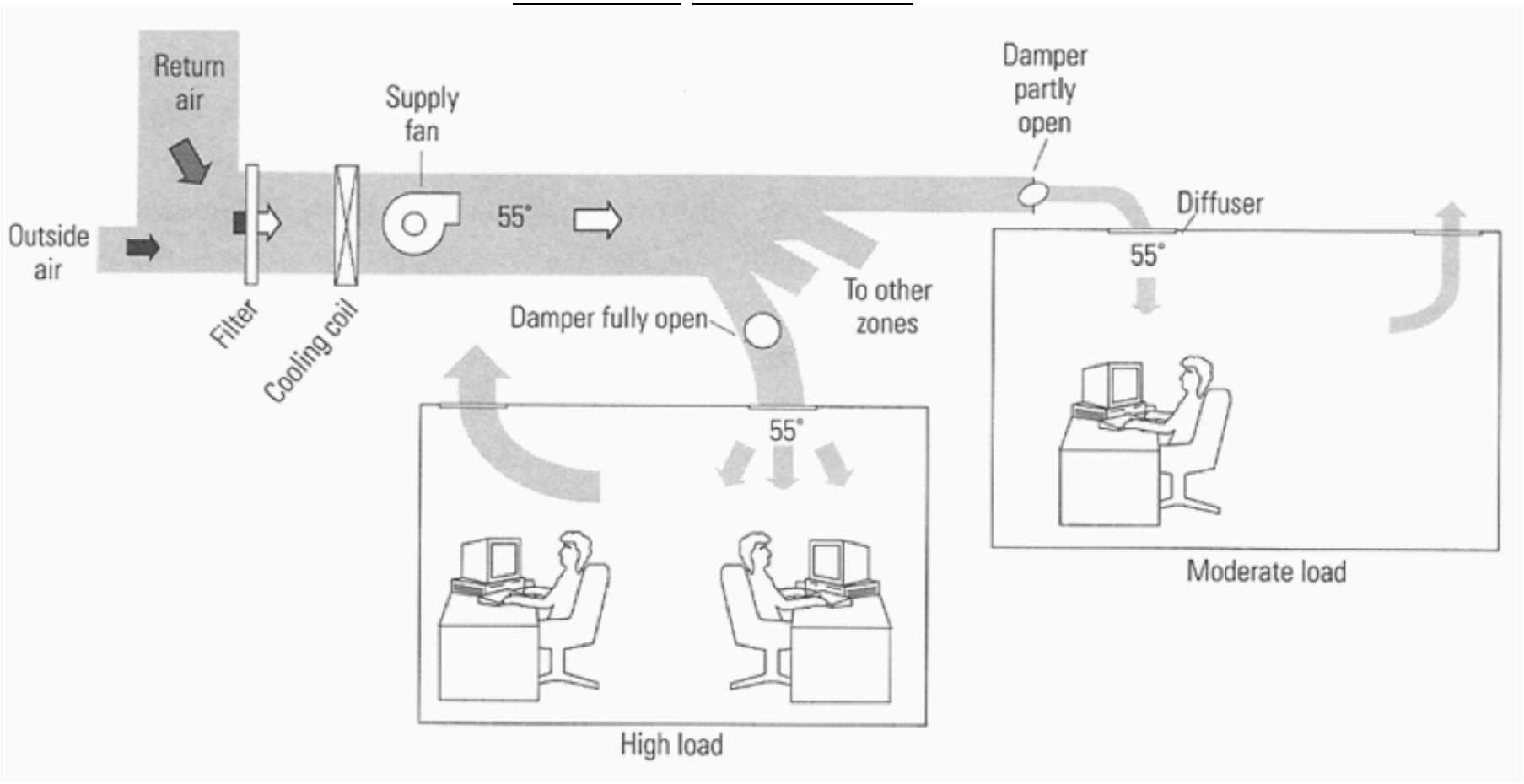
ASHRAE Systems and Equipment Handbook



Typical variable air volume (VAV) system

Same temperature air delivered to each room

- <u>Different</u> <u>airflow rate</u> delivered to each room



Typical variable air volume (VAV) system

Same temperature air delivered to each room

- <u>Different</u> <u>airflow rate</u> delivered to each room

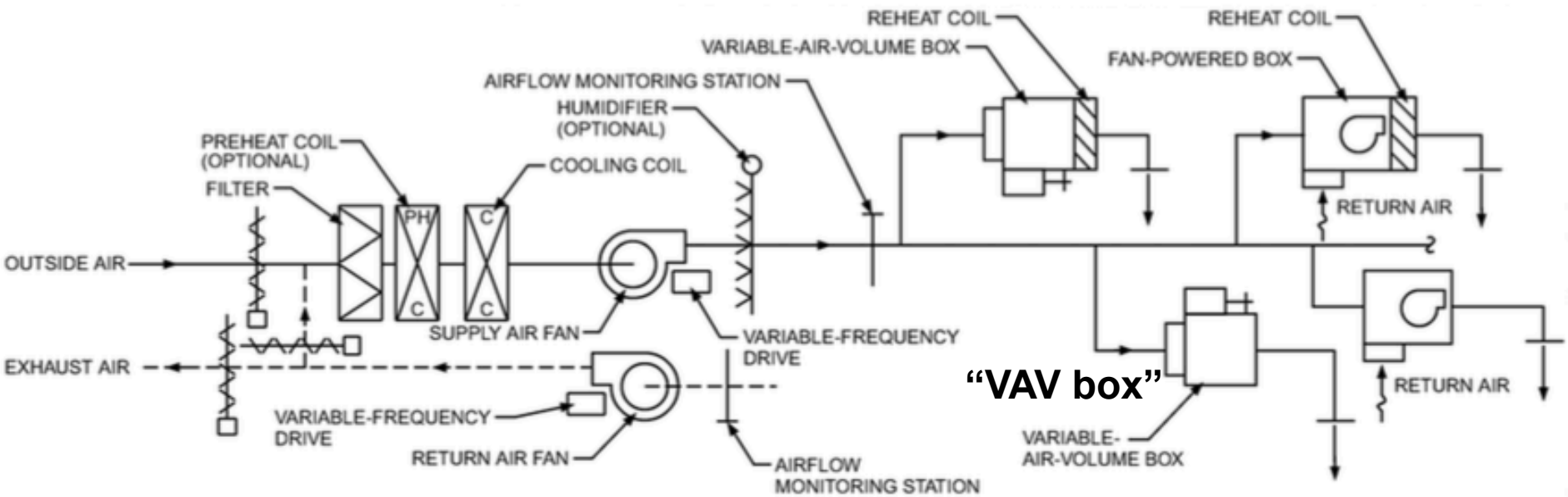
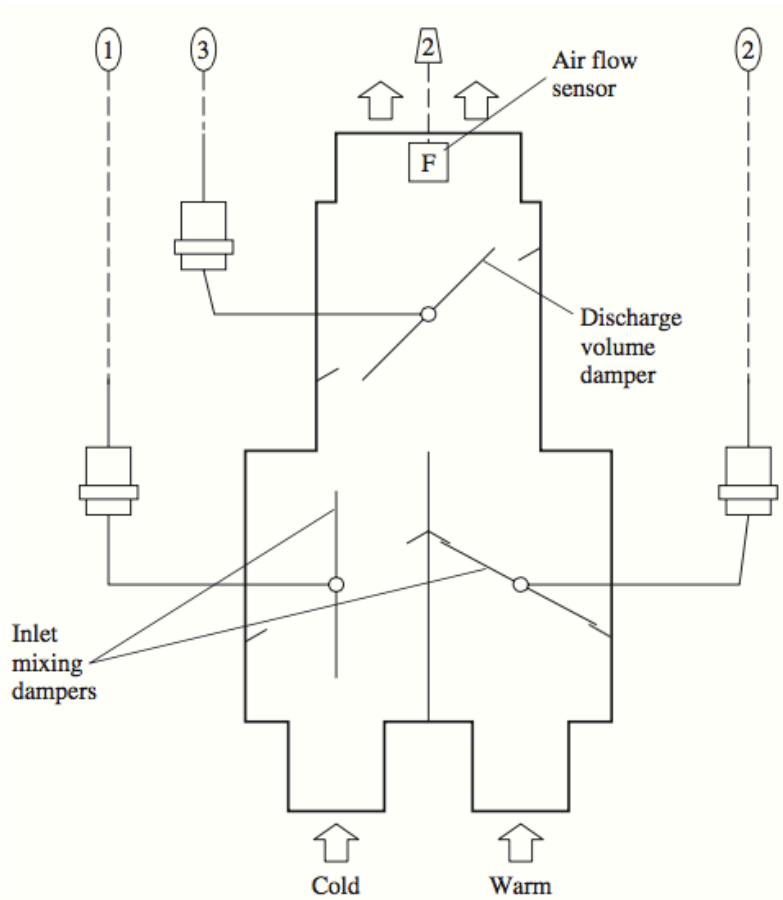
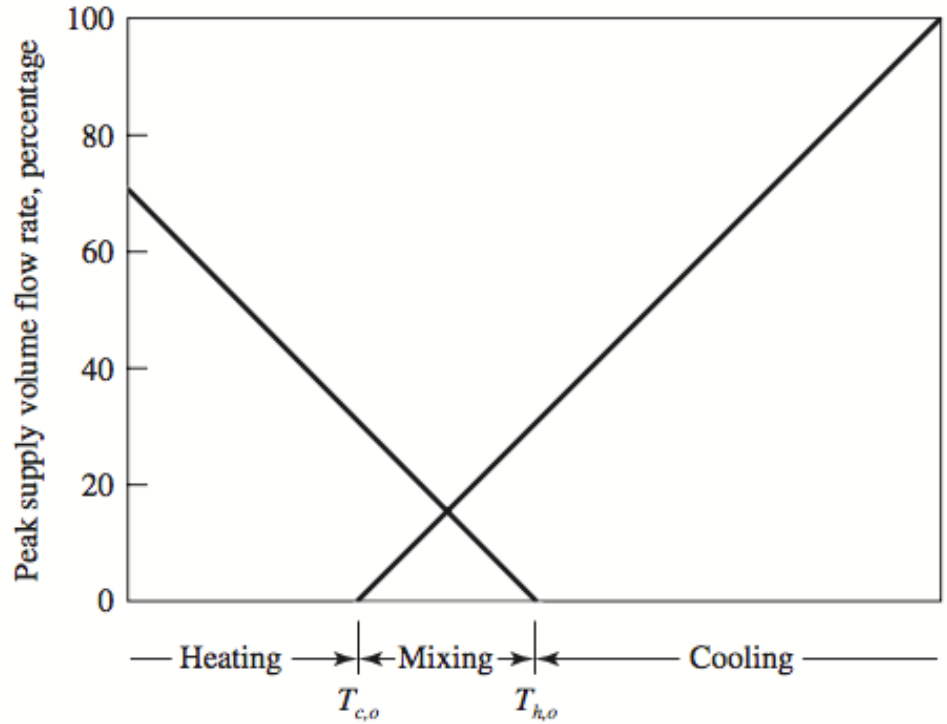


Fig. 10 Variable-Air-Volume System with Reheat and Induction and Fan-Powered Devices

Typical variable air volume (VAV) system





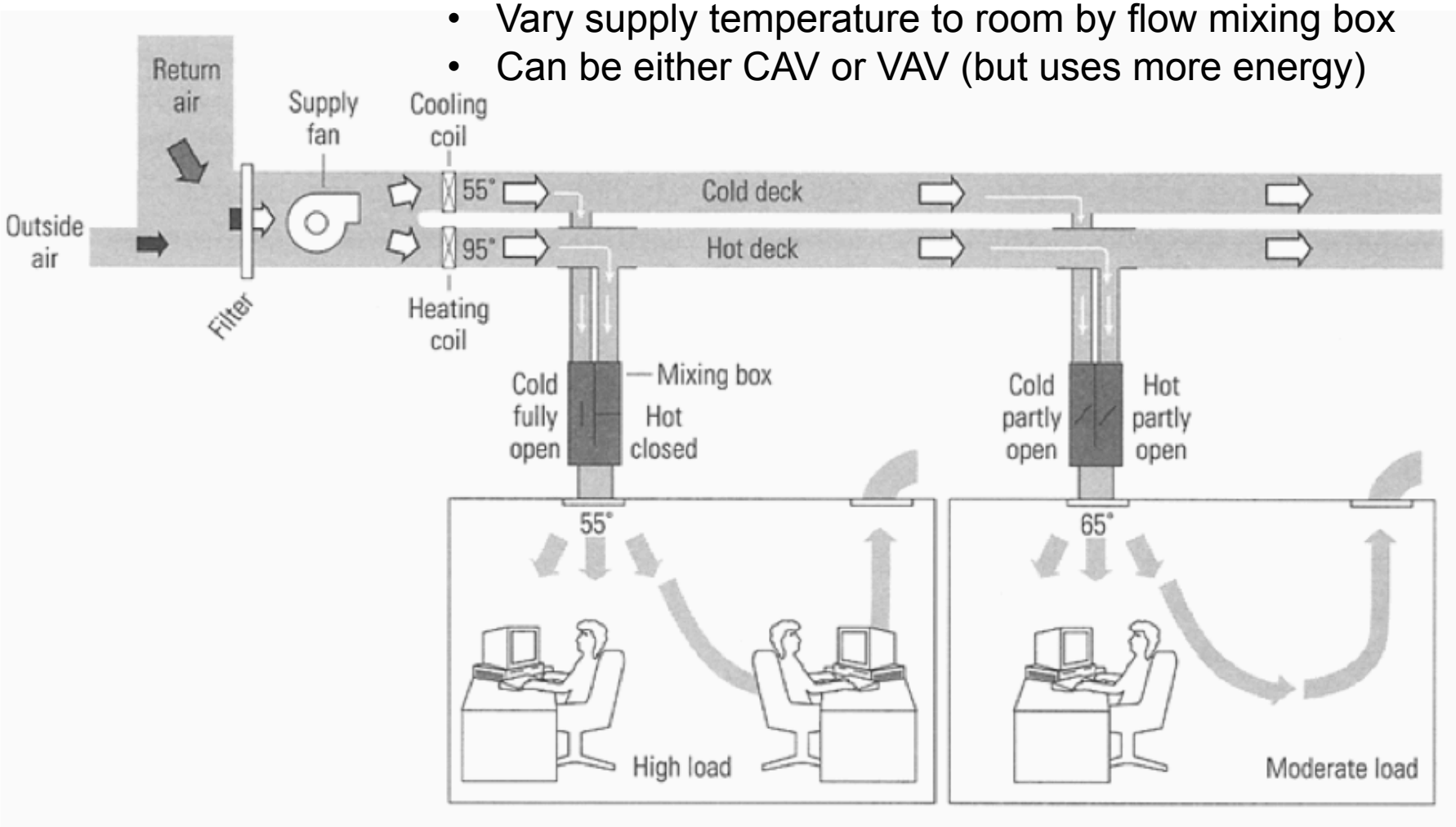
VAV box: A zone-level flow control device

- Damper with an automatic actuator

Typical dual duct (DD) system (older systems)

1 hot deck and 1 cold deck

- Vary supply temperature to room by flow mixing box
- Can be either CAV or VAV (but uses more energy)



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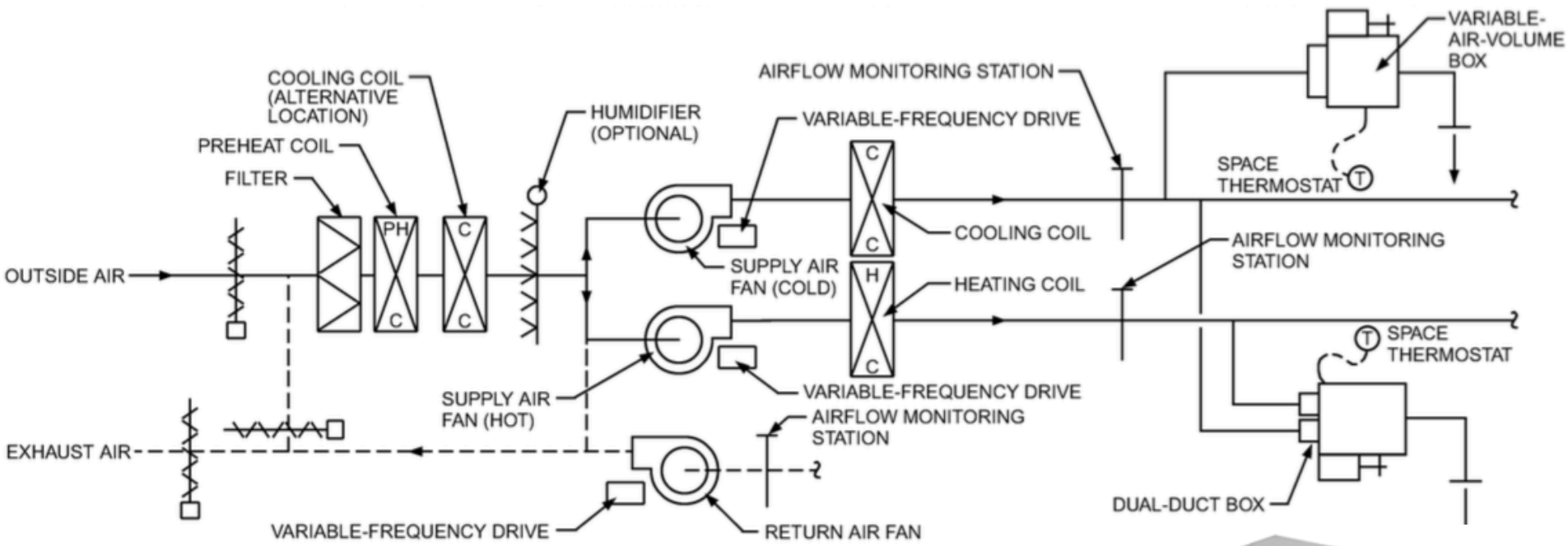
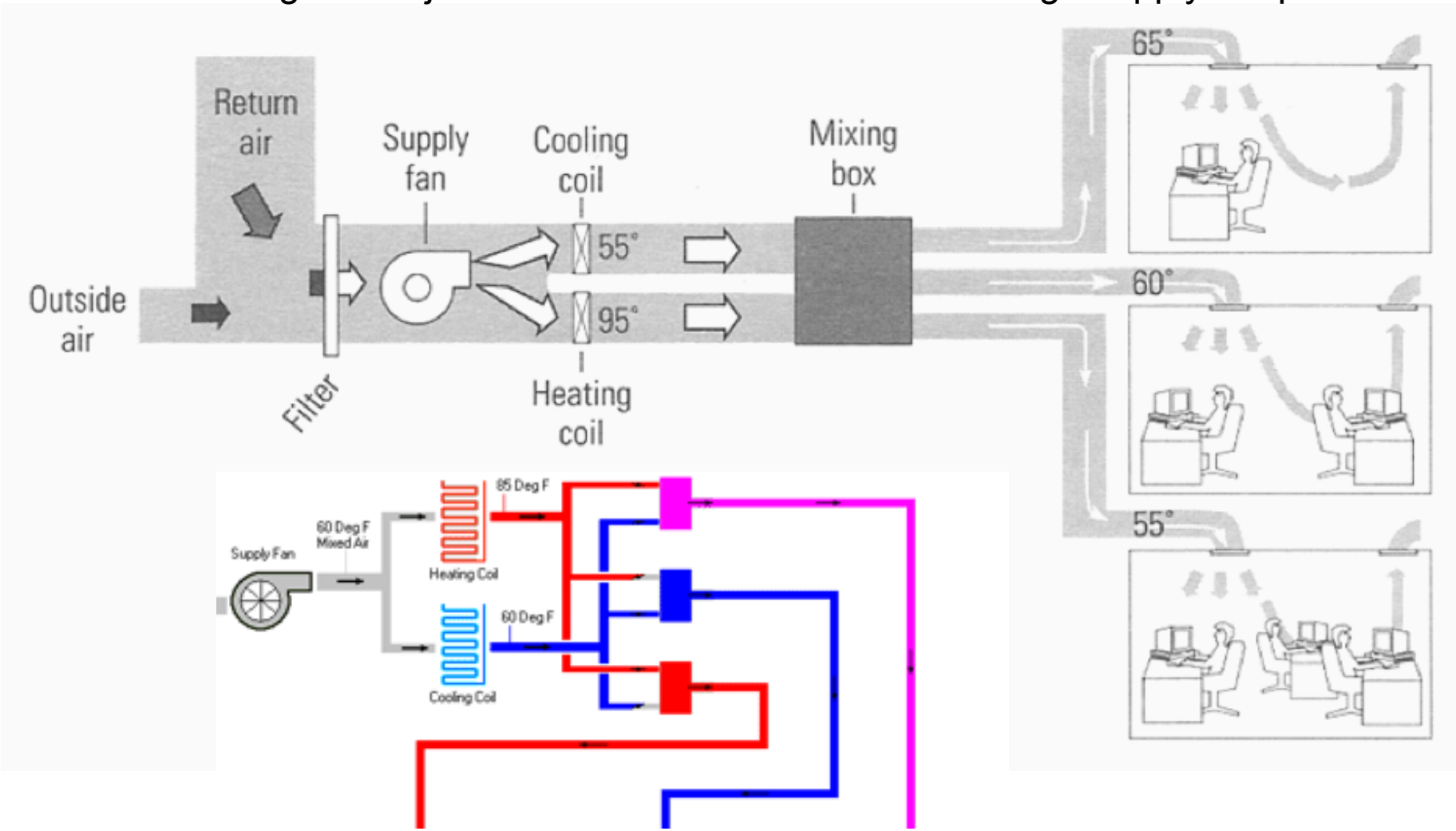


Fig. 12 Dual-Fan, Dual-Duct System

Typical multi-zone (MZ) system

Same airflow rate to each room

- Mixing box adjusts mixture of hot and cold to change supply temperature



Typical multi-zone (MZ) system

Same airflow rate to each room

- Mixing box adjusts mixture of hot and cold to change supply temperature

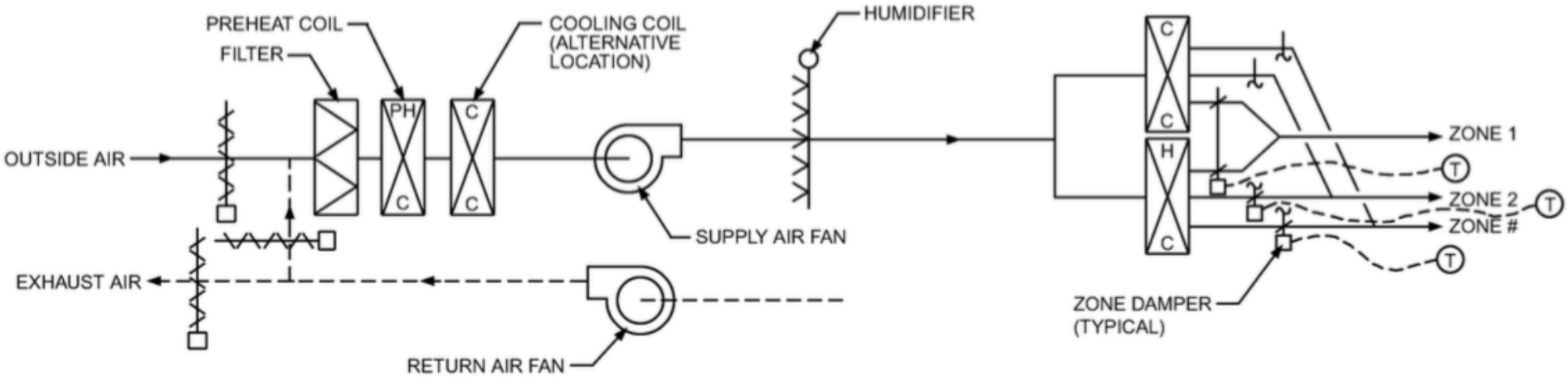


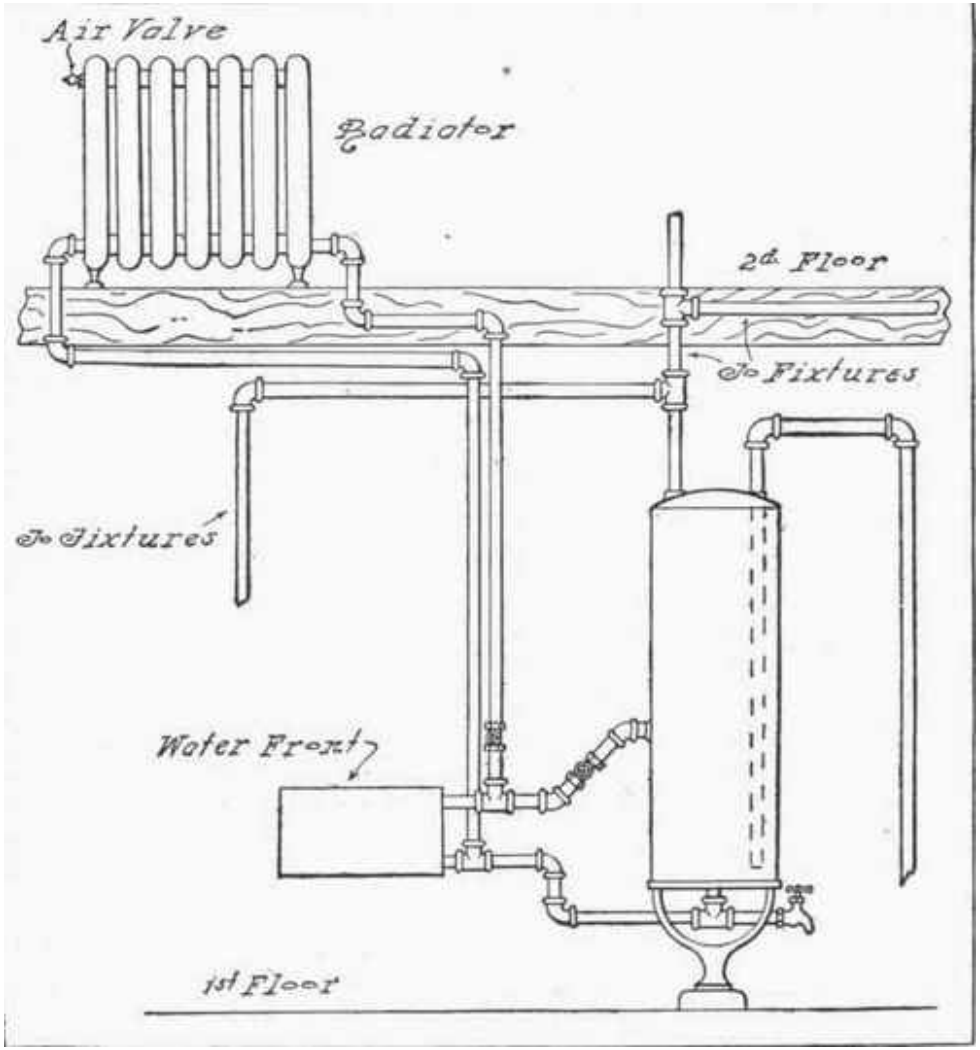
Fig. 13 Multizone System

Air + water systems

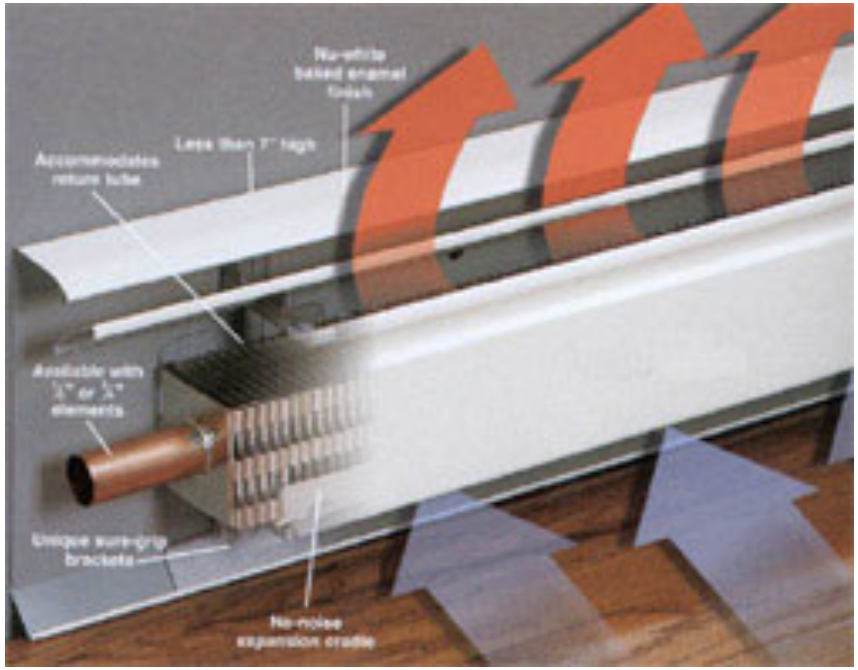
- Many commercial buildings use a combination of conditioned air and zone water coils
- Ventilation requires air movement
- But zone heating and cooling loads can be met with coils
  - We mostly use fan coils now
  - We previously mostly used radiators (like in Alumni Hall)

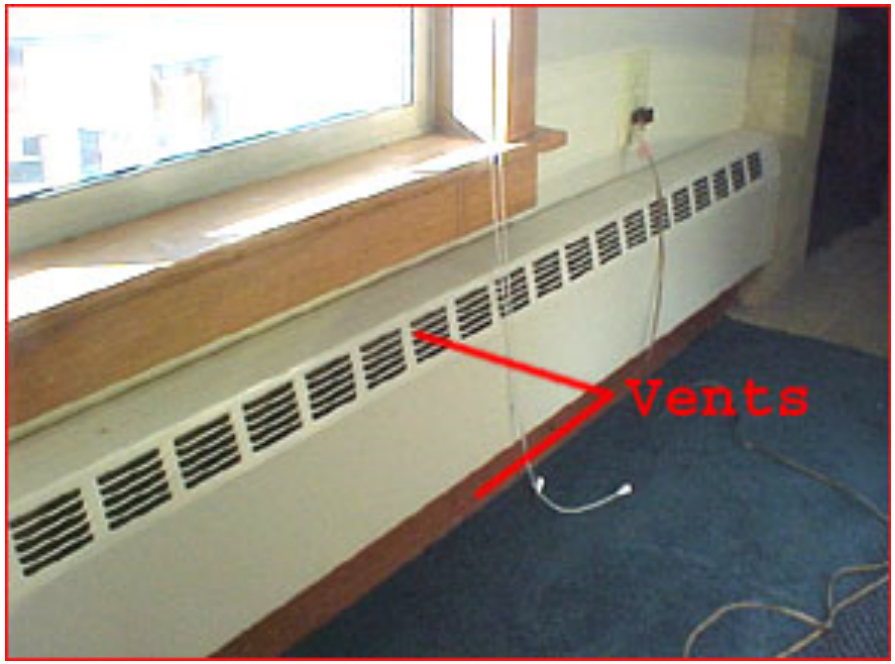
Radiator systems (for heating)

What modes of heat transfer are involved?



Water-based baseboard systems (heating)





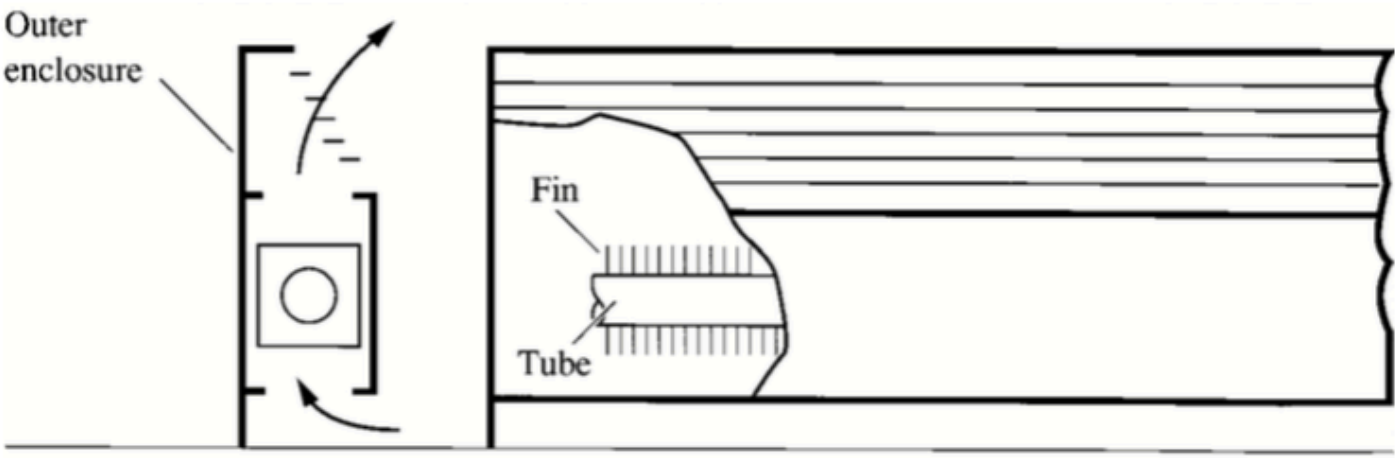


FIGURE 8.8 Baseboard finned-tube heater.

Water-based baseboard systems (heating)

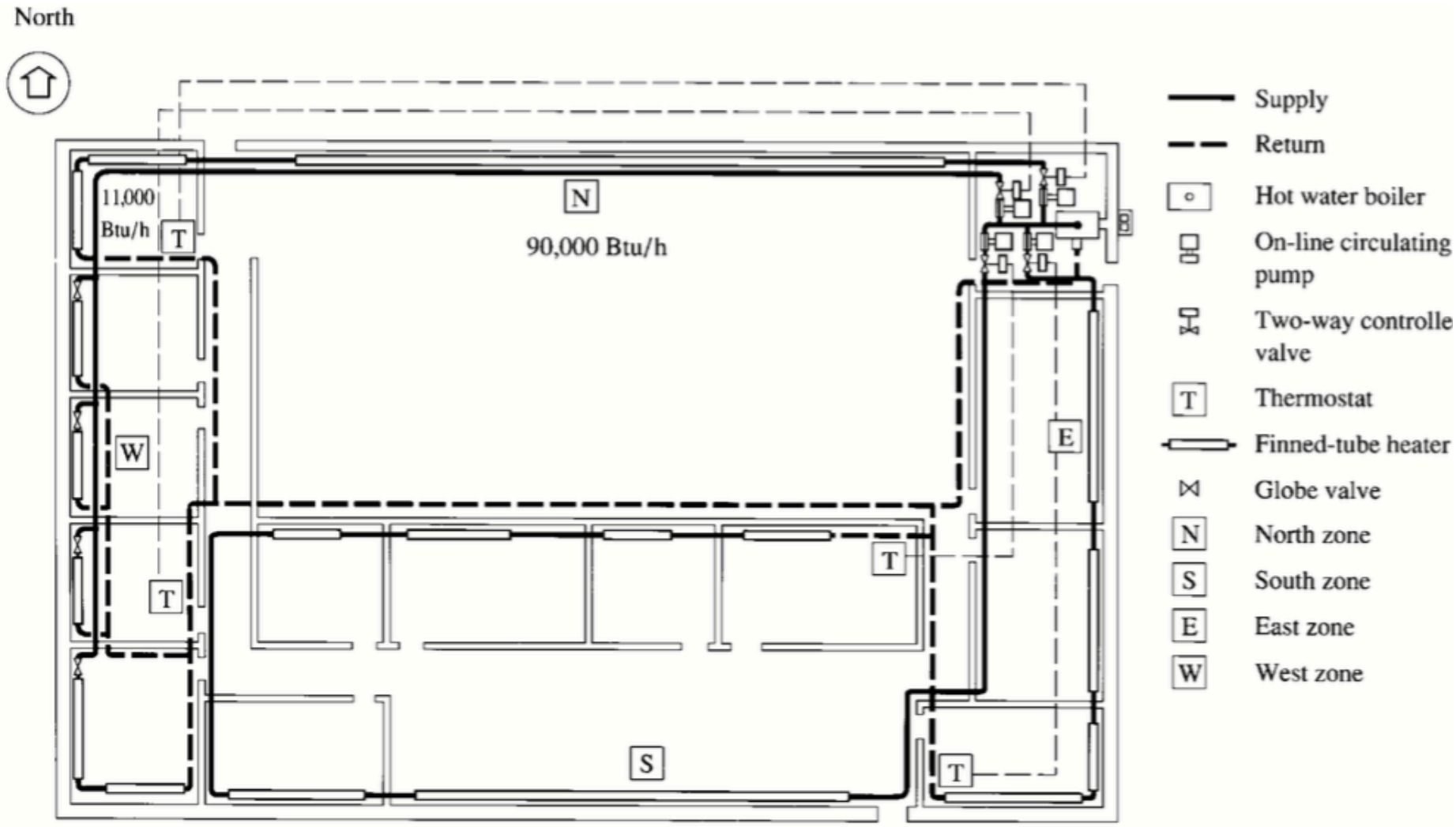
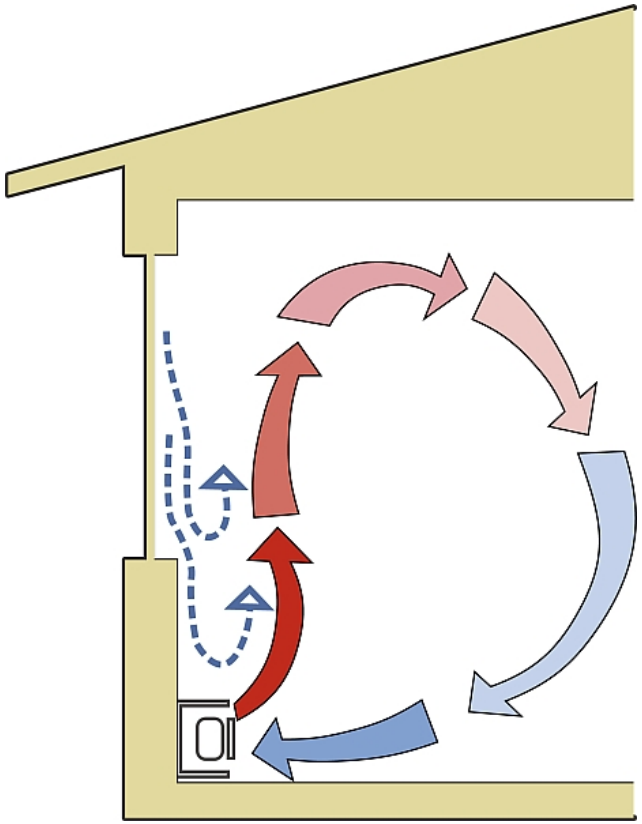
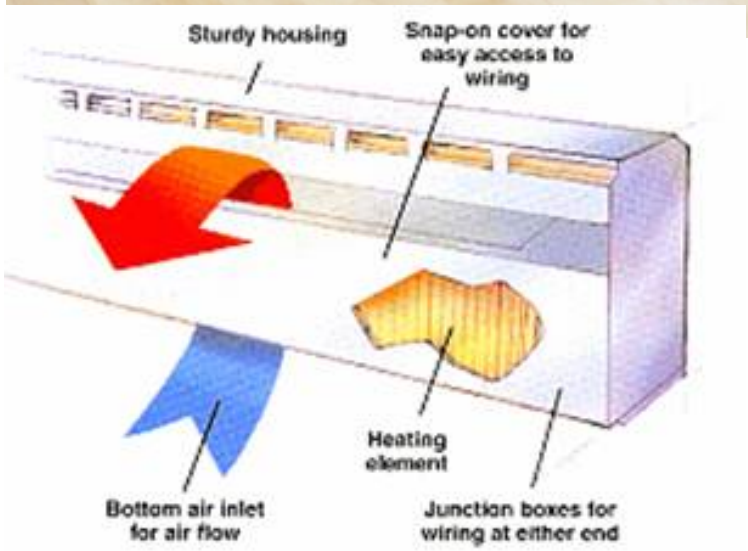


FIGURE 8.7 A two-pipe individual-loop low-temperature hot water heating system for a factory.

Electric baseboard systems (for heating)





Fan coils: Modern radiator replacement w/ fan

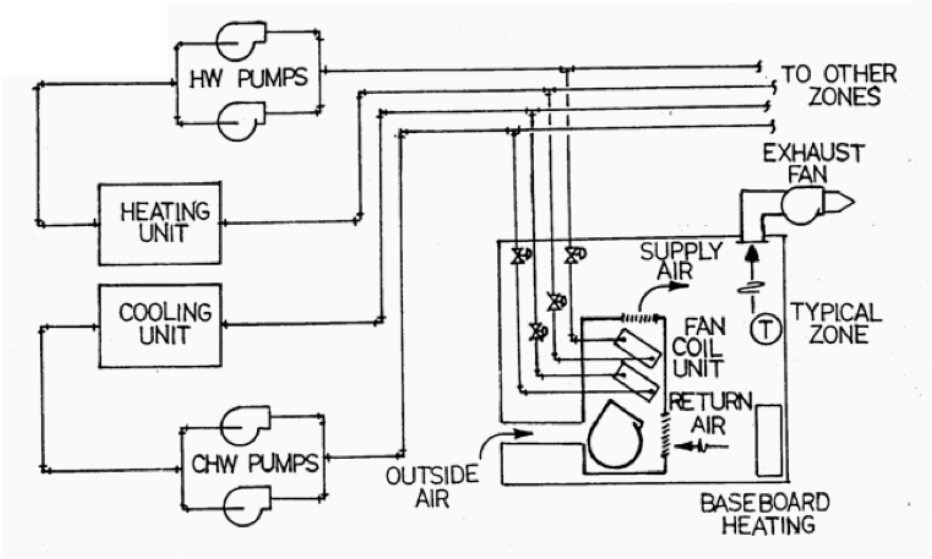
Combines air and water

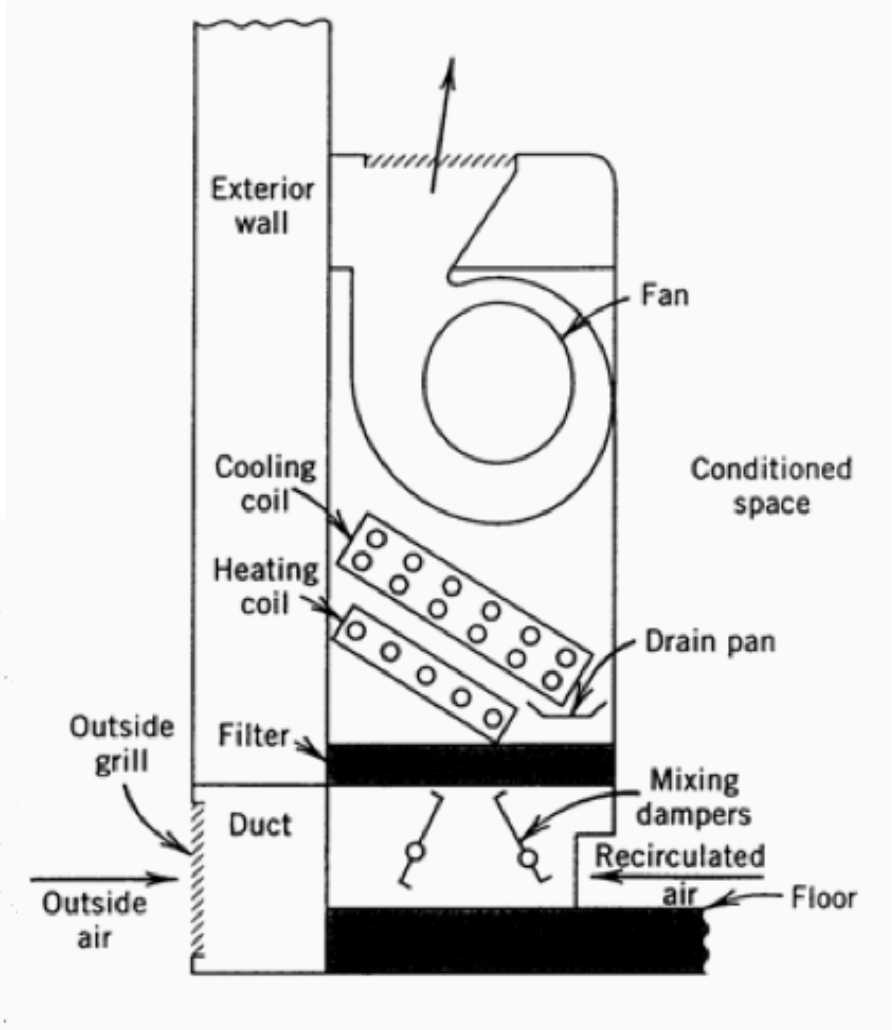
Wall installation

Overhead/ceiling installation

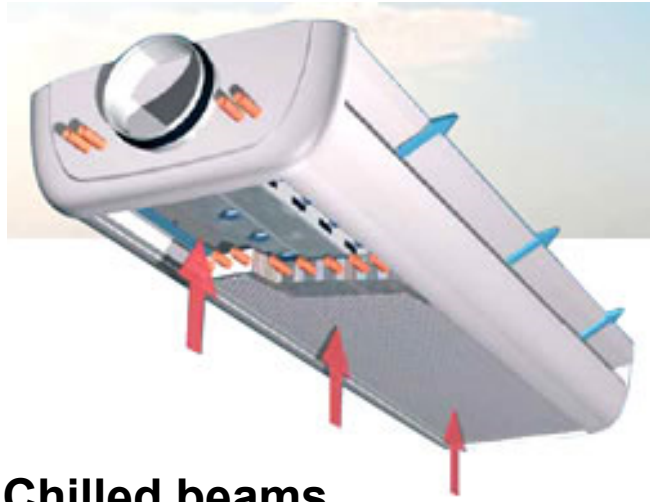
Fan coils: Modern radiator replacement w/ fan

- One or two coils (H or C)
- Thermostat controls water flow
- Ventilation is met with conditioned or unconditioned outdoor air





Other: Chilled beams and radiant panels



Chilled beams

Radiant panels

PSYCHROMETRICS

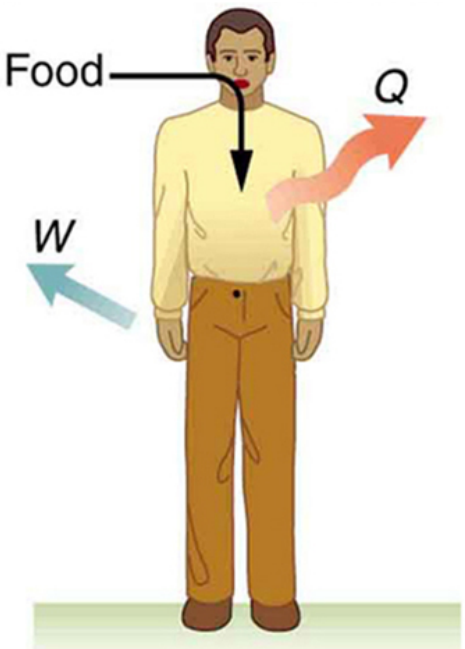
Remember our human thermal comfort lecture?

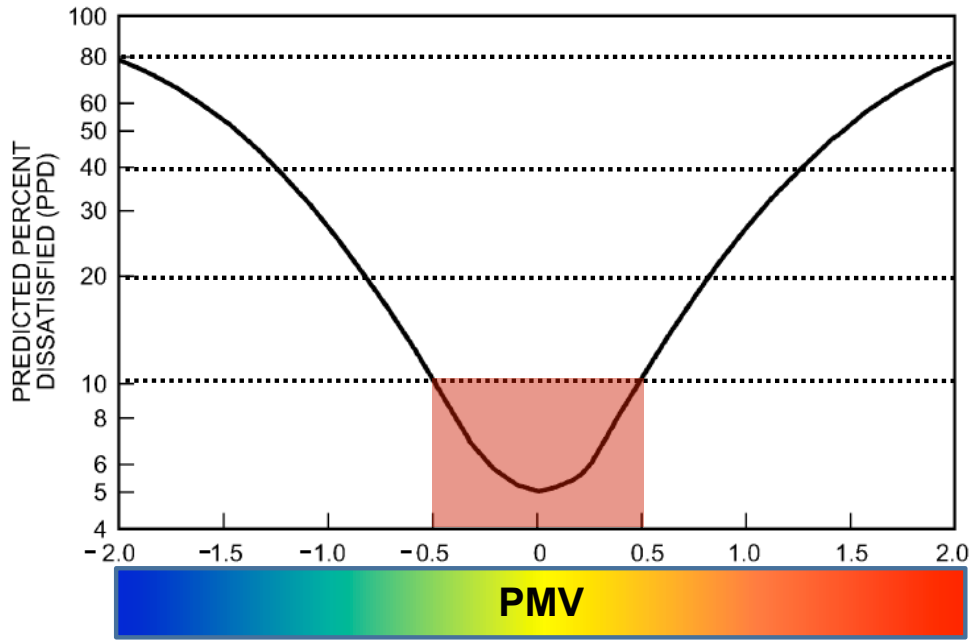
- Human thermal comfort

$$A_D = 0.202 m^{0.425} l^{0.725}$$

$$\dot{Q} = MA_{skin}$$

A_D = DuBois surface area, m^2
m = mass, kg
l = height, m

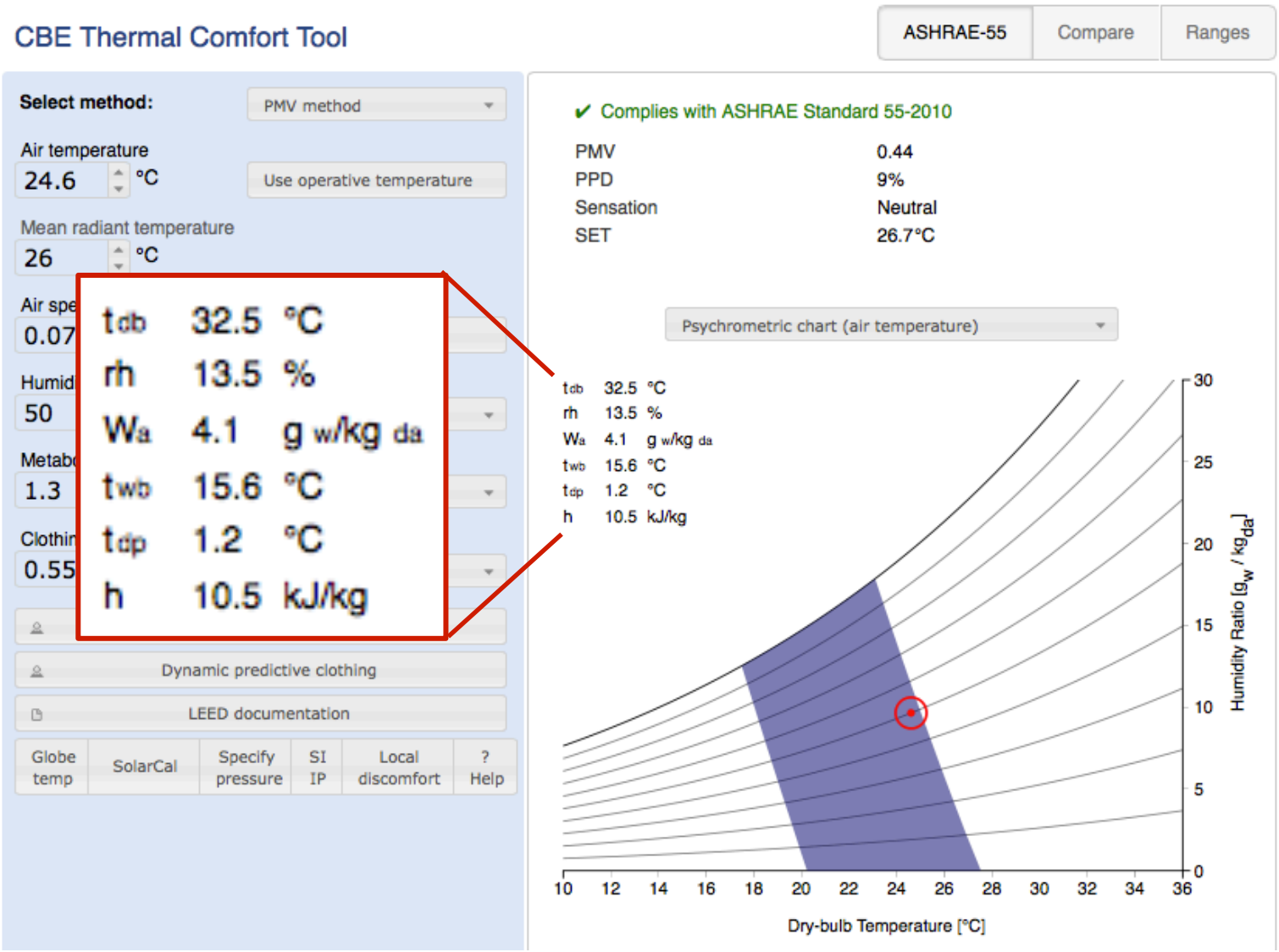




$$1 \text{ met} = 18.4 \frac{\text{Btu}}{\text{h} \cdot \text{ft}^2} = 58 \frac{\text{W}}{\text{m}^2}$$

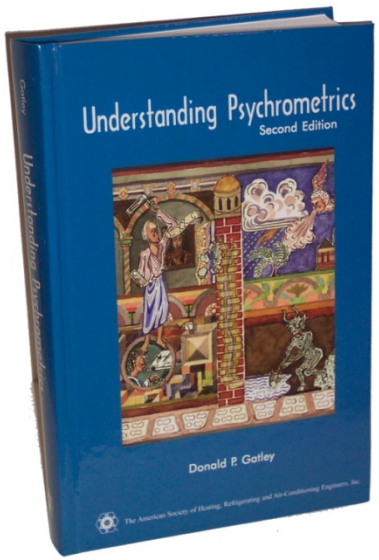
-3	-2	-1	0	+1	+2	+3
cold	cool	slightly cool	neutral	slightly warm	warm	hot

ASHRAE comfort zone: CBE Thermal Comfort Tool



http://smap.cbe.berkeley.edu/comforttool

Psychrometrics



<u>Psychrometrics</u> is the science and engineering of air/vapor mixtures

- For architectural engineers and building scientists, the vapor is **water vapor**
- We use psychrometrics to relate the thermodynamic and physical properties of moist air

Applying psychrometrics

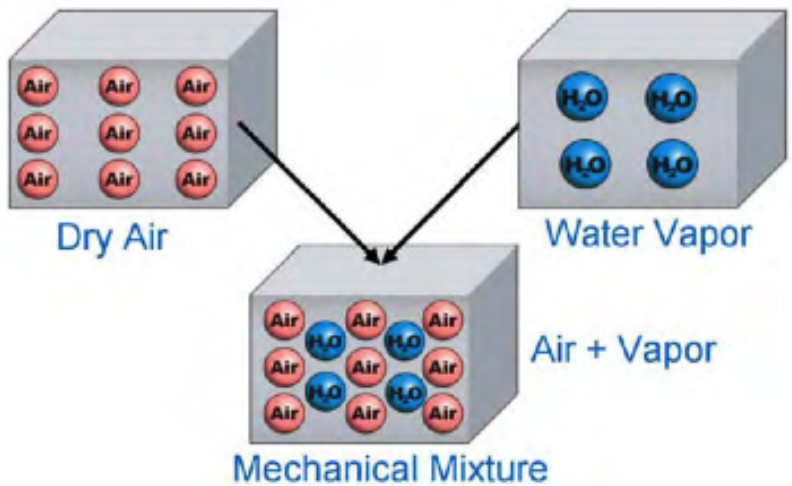
- We need to understand air temperature and moisture content to understand **human thermal comfort**
  - In hot, humid weather we design HVAC systems to remove moisture by dehumidification/cooling
  - In dry, cold weather, we add moisture by humidifiers

- We are also concerned about moisture for energy use, structural, aesthetic, and indoor air quality reasons

- Psychrometrics also involves learning how to use and combine a variety of moist air parameters

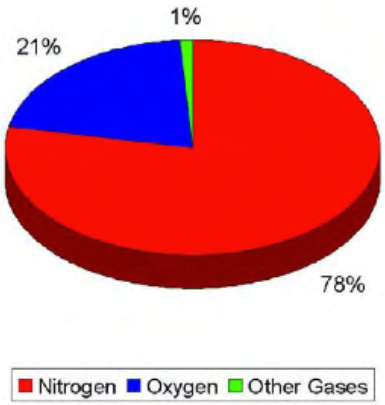
Some definitions for psychrometrics

- **Atmospheric air** contains:
  - Many gaseous components
  - Water vapor
  - Contaminants (particulate matter and gaseous pollutants)
- **Dry air** is atmospheric air with all of the water vapor removed
- **Moist air** is a two-component mixture of dry air and water vapor



Standard composition of dry air

Gas	Molecular weight (g/mol)	Volume %
Nitrogen (N_2)	32.000	78.084
Oxygen (O_2)	28.016	20.946
Argon (Ar)	39.444	0.9340
Carbon Dioxide (CO_2)	44.010	0.03697
Neon (Ne)	20.179	0.00182
Helium (He)	4.002	0.00052
Methane (CH_4)	16.042	0.00014
Krypton	83.800	0.00010



Where does water fit in?

Standard composition of moist air

Gas	Molecular weight (g/mol)	Volume %
Nitrogen (N_2)	32.000	78.084%
Oxygen (O_2)	28.016	20.946%
Water (H_2O)	**18.015**	**0 to 4%**
Argon (Ar)	39.444	0.9340%
Carbon Dioxide (CO_2)	44.010	0.03697%
Neon (Ne)	20.179	0.00182%
Helium (He)	4.002	0.00052%
Methane (CH_4)	16.042	0.00014%
Krypton	83.800	0.00010%

Key terms for describing moist air

- To describe and deal with moist air, we need to be able to describe the relative portions of dry air and water vapor

- There are several different measures…

- Which one you use depends on what data you have to start with and what quantity you are trying to find

- If you know **two psychrometric properties**, you can usually get all the others

Key terms for describing moist air

Key terms to learn today:

1. Dry bulb temperature
2. Vapor pressure
3. Saturation
4. Relative humidity
5. Absolute humidity (or humidity ratio)
6. Dew point temperature
7. Wet bulb temperature
8. Enthalpy
9. Density
10. Specific volume

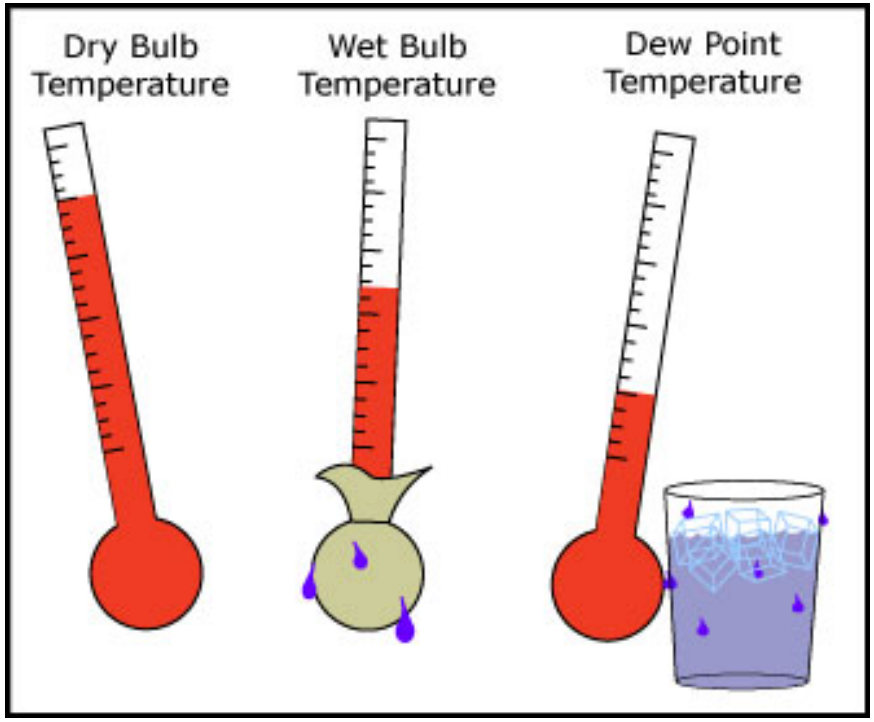
Three different temperatures: T, T_{dew}, and T_{wb}

The standard temperature, T, we are all familiar with is called the **dry-bulb** temperature, or T_d

- It is a measure of internal energy

We can also define:

- **Dew-point** temperature, T_{dew}
  - Temperature at which water vapor changes into liquid (condensation)
  - Air is maximally saturated with water vapor
- **Wet-bulb** temperature, T_{wb}
  - The temperature that a parcel of air would have if it were cooled to saturation (100% relative humidity) by the evaporation of water into it



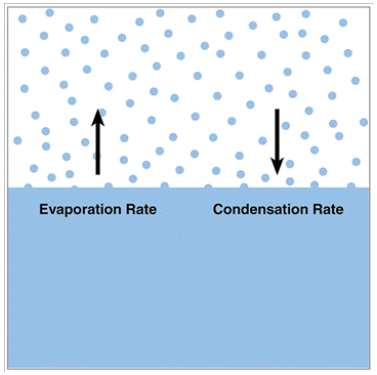
*Units of Celsius, Fahrenheit, or Kelvin

✓ The energy needed to evaporate liquid water (heat of vaporization) is taken from the air in the form of sensible heat and converted to latent heat, which lowers the temperature at constant enthalpy

Key concepts: Vapor pressure and Saturation

- Air can hold moisture (i.e., **water vapor**)
- **Vapor pressure** is the pressure exerted by a vapor in thermodynamic equilibrium with its condensed phases

p_w *Units of pressure, psia (Pa or kPa)
(aka "partial pressure")



- The amount of moisture air can hold in vapor form before condensation occurs is dependent on temperature
  - We call the limit ***saturation***

p_{ws} *Units of pressure, psia (Pa or kPa)
(aka "saturation vapor pressure")

Key concept: Relative humidity, ϕ

- **Relative humidity** (RH, or ϕ) is the <u>ratio</u> of the vapor pressure of water vapor in a sample of air to the **saturation** vapor pressure at the dry bulb temperature of the sample

- Relative humidity ≠ absolute humidity!

$$\phi = \frac{p_w}{p_{ws}}$$

Key concept: Saturation vapor pressure, p_{ws}

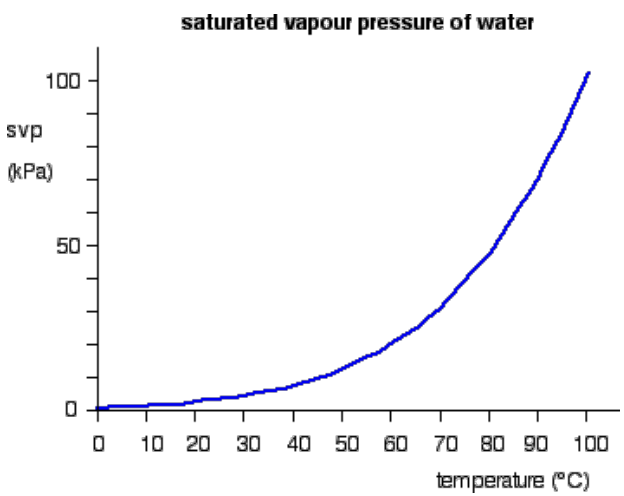
- The **saturation vapor pressure** is the partial pressure of water vapor at saturation (p_{ws}) *Units of pressure, **Pa** (or **kPa**) and **psia**
  - Cannot absorb any more moisture at that temperature
- We can look up p_{ws} in tables (as a function of T)
  - Table 3 in Chapter 1 of the ASHRAE Handbook of Fundamentals
- We can also use empirical equations

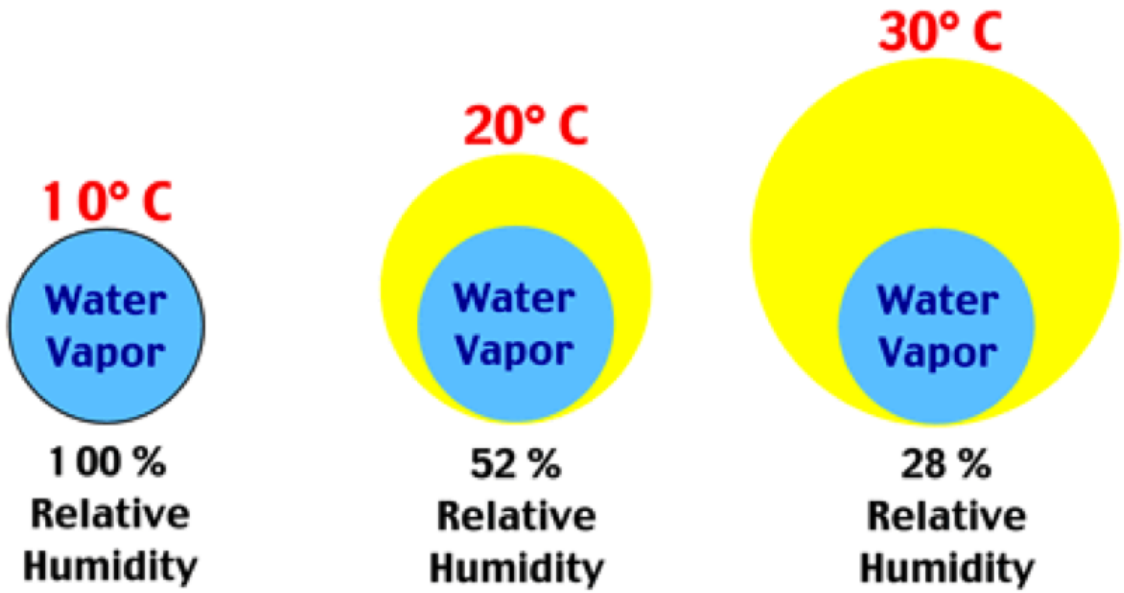
Temp., °F t	Absolute Pressure p_{ws}, psia	Specific Volume, ft³/lb$_w$			Specific Enthalpy, Btu/lb$_w$			Specific Entropy, Btu/lb$_w$·°F			Temp., °F t
		Sat. Solid v_i/v_f	Evap. v_{ig}/v_{fg}	Sat. Vapor v_g	Sat. Solid h_i/h_f	Evap. h_{ig}/h_{fg}	Sat. Vapor h_g	Sat. Solid s_i/s_f	Evap. s_{ig}/s_{fg}	Sat. Vapor s_g	
–13	0.009177	0.01741	28990	28990	–164.91	1220.33	1055.42	–0.3375	2.7321	2.3946	–13
–12	0.009700	0.01741	27490	27490	–164.46	1220.32	1055.86	–0.3365	2.7259	2.3895	–12
–11	0.010249	0.01741	26073	26073	–164.00	1220.30	1056.30	–0.3355	2.7198	2.3844	–11
–10	0.010827	0.01741	24736	24736	–163.54	1220.28	1056.74	–0.3344	2.7137	2.3793	–10
–9	0.011435	0.01741	23473	23473	–163.08	1220.26	1057.18	–0.3334	2.7077	2.3743	–9
–8	0.012075	0.01741	22279	22279	–162.62	1220.24	1057.63	–0.3324	2.7016	2.3692	–8
–7	0.012747	0.01742	21151	21152	–162.15	1220.22	1058.07	–0.3314	2.6956	2.3642	–7
–6	0.013453	0.01742	20086	20086	–161.69	1220.20	1058.51	–0.3303	2.6896	2.3593	–6
–5	0.014194	0.01742	19078	19078	–161.23	1220.17	1058.95	–0.3293	2.6837	2.3543	–5
–4	0.014974	0.01742	18125	18125	–160.76	1220.15	1059.39	–0.3283	2.6777	2.3494	–4
–3	0.015792	0.01742	17223	17223	–160.29	1220.12	1059.83	–0.3273	2.6718	2.3445	–3
–2	0.016651	0.01742	16370	16370	–159.83	1220.10	1060.27	–0.3263	2.6659	2.3396	–2
–1	0.017553	0.01742	15563	15563	–159.36	1220.07	1060.71	–0.3252	2.6600	2.3348	–1
0	0.018499	0.01743	14799	14799	–158.89	1220.04	1061.15	–0.3242	2.6542	2.3300	0
1	0.019492	0.01743	14076	14076	–158.42	1220.01	1061.59	–0.3232	2.6483	2.3251	1
2	0.020533	0.01743	13391	13391	–157.95	1219.98	1062.03	–0.3222	2.6425	2.3204	2
3	0.021625	0.01743	12742	12742	–157.48	1219.95	1062.47	–0.3212	2.6368	2.3156	3

Relative humidity and temperature

- **Relative humidity** (RH, or ϕ) is a <u>function of temperature</u>

$$\phi = \frac{p_w}{p_{ws}}$$





Key concept: Humidity ratio, W

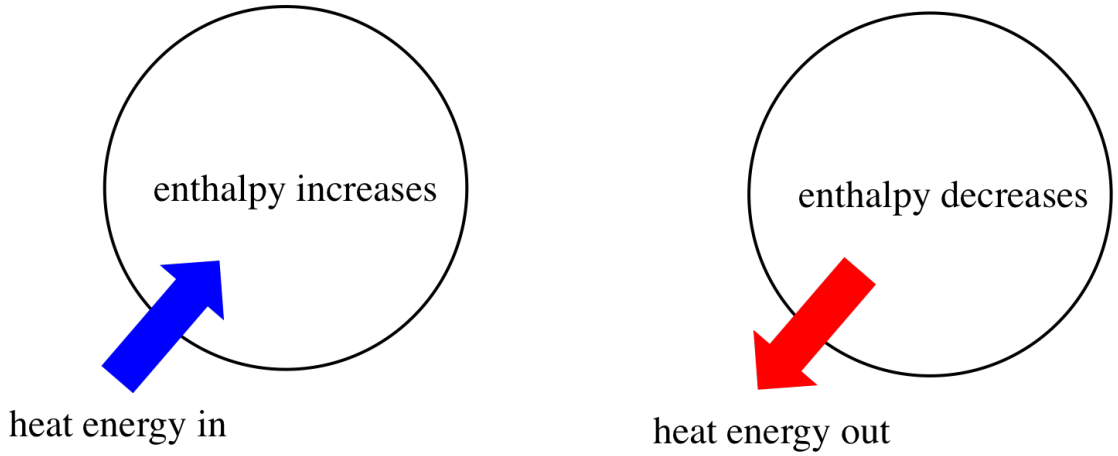
- The **humidity ratio** is a measure of the mass of water vapor present in a parcel of air (a measure of *absolute humidity*)

- The humidity ratio is simply the mass of water vapor that exists in a parcel of mass of *dry air*
  - Units of mass of water vapor per mass of dry air
    - kg/kg (kg_w/kg_{da})
    - g/kg (g_w/kg_{da})
    - lb/lb (lb_w/lb_{da})

$$W = \frac{\text{mass of water vapor}}{\text{mass of dry air}} \quad [\frac{kg_w}{kg_{da}}][\frac{lb_w}{lb_{da}}]$$

Key concept: Enthalpy

- **Enthalpy** is a measure of the amount of energy in a system
  - Units of Joules or BTU (or J/kg or BTU/lb)
- The enthalpy of moist air is the total enthalpy of the dry air plus the water vapor mixture per mass of moist air
- Includes:
  - Enthalpy of dry air, or sensible heat
  - Enthalpy of evaporated water, or latent heat



Key concept: Density and specific volume

Air density

- Density is a measure of the mass of moist air per unit volume of air
- Includes mass of dry air + water vapor

$$\rho = \frac{\text{mass of moist air}}{\text{volume of moist air}} \quad [\frac{\text{kg}}{\text{m}^3}][\frac{\text{lb}}{\text{ft}^3}]$$

Specific volume

- Specific volume is the volume of unit mass of dry air at a given temperature, expressed as m^3/kg (inverse of dry air density)

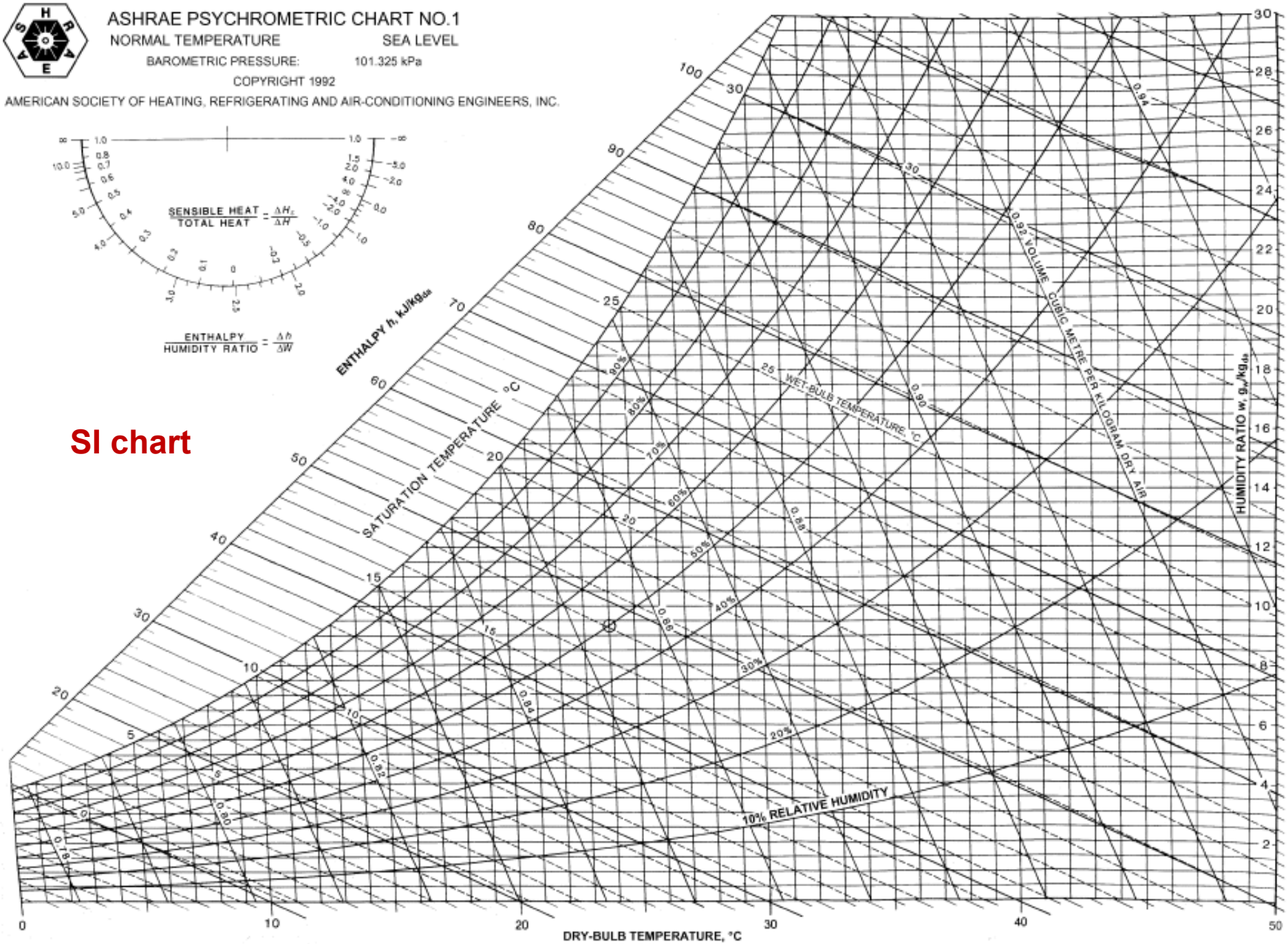
$$\upsilon = \frac{\text{volume of dry air}}{\text{mass of dry air}} \quad [\frac{\text{m}^3}{\text{kg}_{da}}][\frac{\text{ft}^3}{\text{lb}_{da}}]$$

The Psychrometric Chart

- There are both simple and complex ways to estimate these properties
  - Equations and tables (more complex, save for next lecture)
  - Graphically using …

- **The Psychrometric Chart**
  - Plots dry bulb temperature (T) on the x-axis and humidity ratio (W) on the y-axis
    - Shows relationships between T and W and relative humidity, wet-bulb temperature, vapor pressure, specific volume, and enthalpy
  - Charts are unique at each value of atmospheric pressure (p)

- Both SI and IP versions are on BB in the ASHRAE materials folder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NORMAL TEMPERATURE
SEA LEVEL
BAROMETRIC PRESSURE: 101.325 kPa
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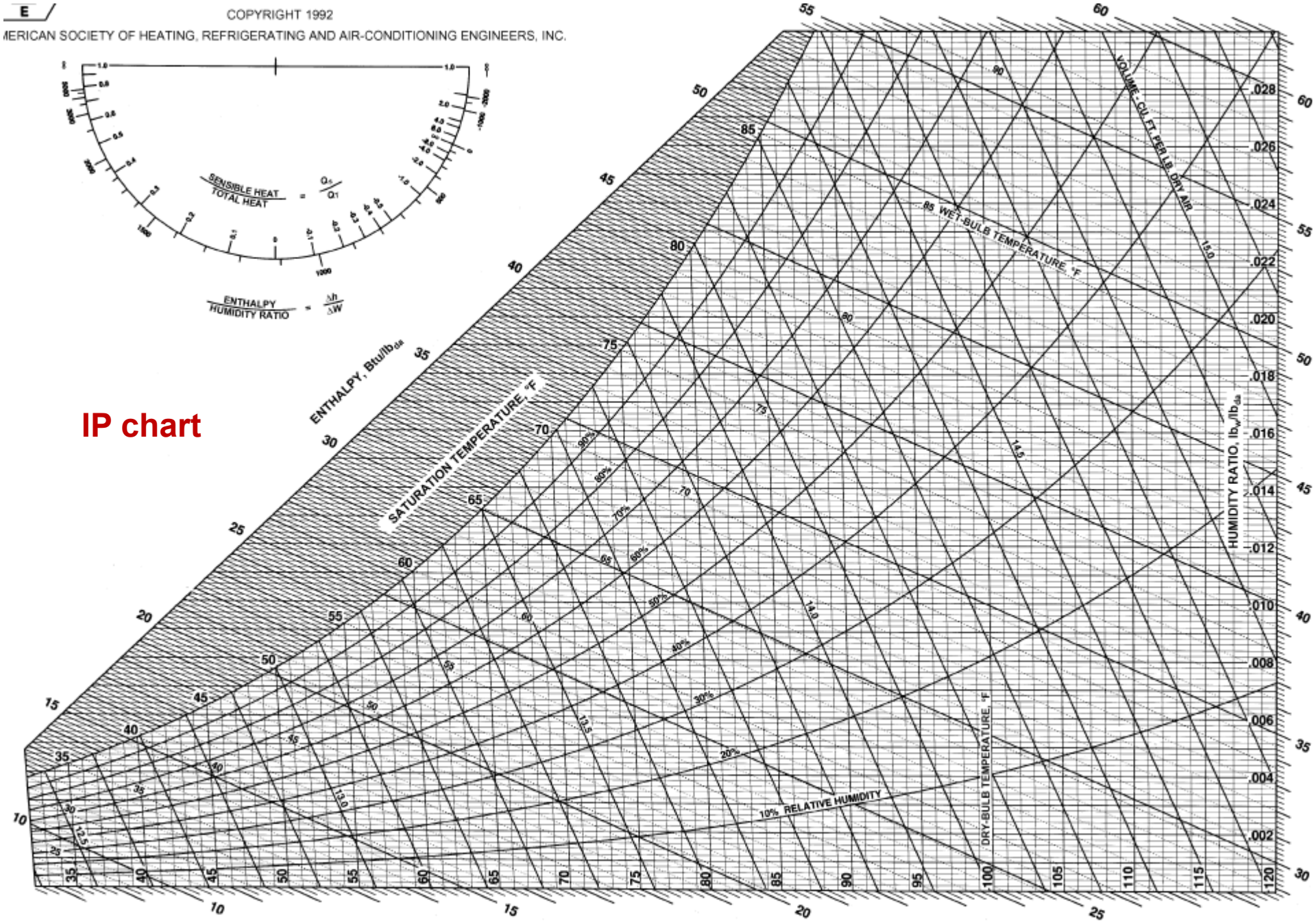
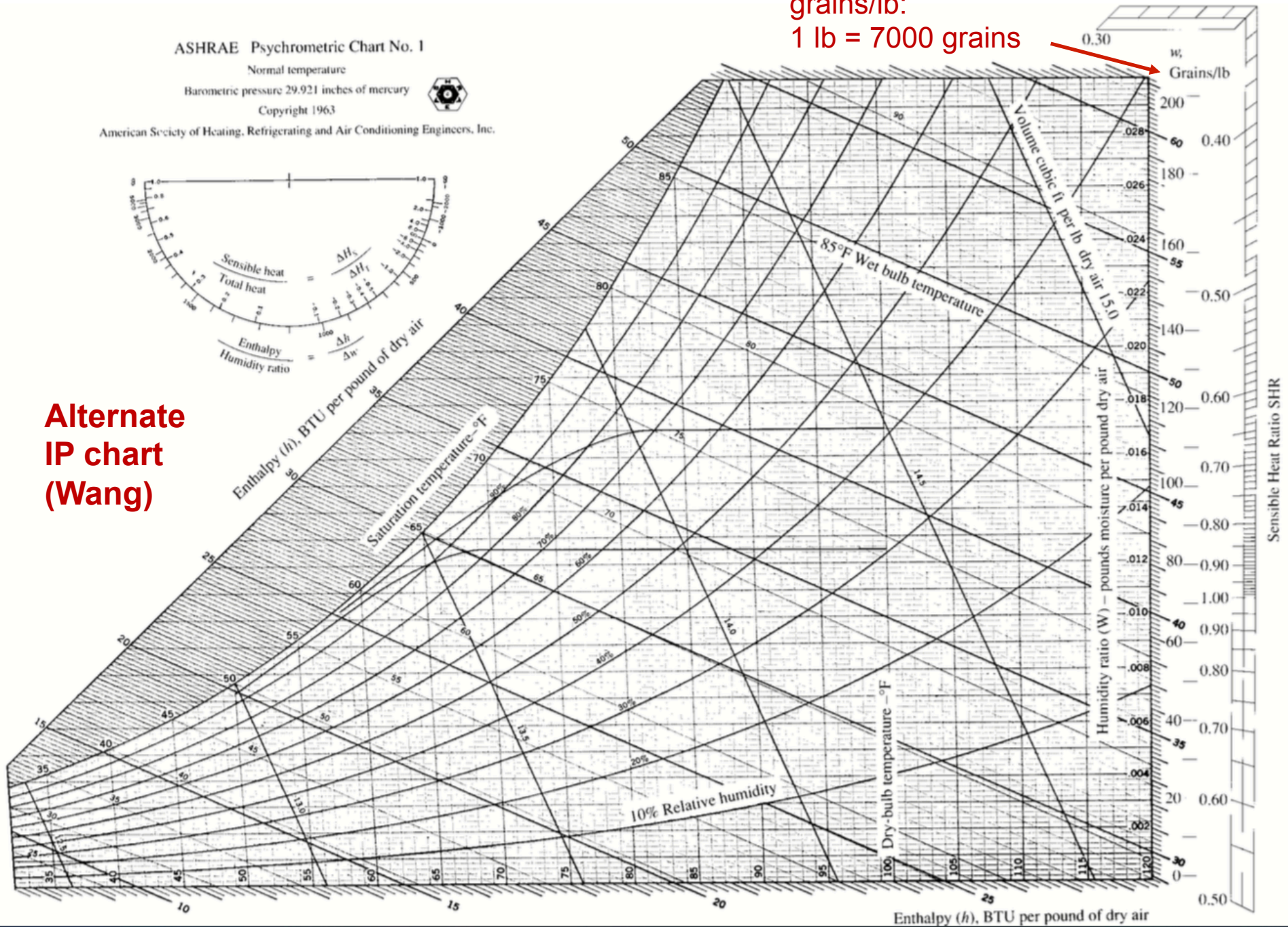
ENTHALPY h, kJ/kgda
SATURATION TEMPERATURE °C
WET-BULB TEMPERATURE, °C
VOLUME CUBIC METRE PER KILOGRAM DRY AIR
HUMIDITY RATIO w, gw/kgda
10% RELATIVE HUMIDITY
DRY-BULB TEMPERATURE, °C
SI chart



IP chart

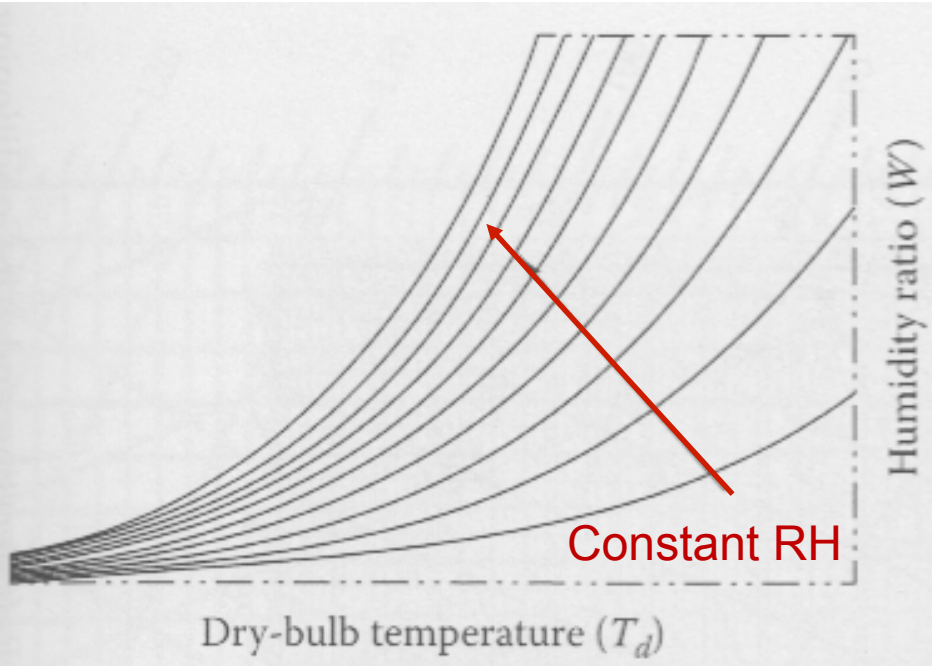
grains/lb:
1 lb = 7000 grains



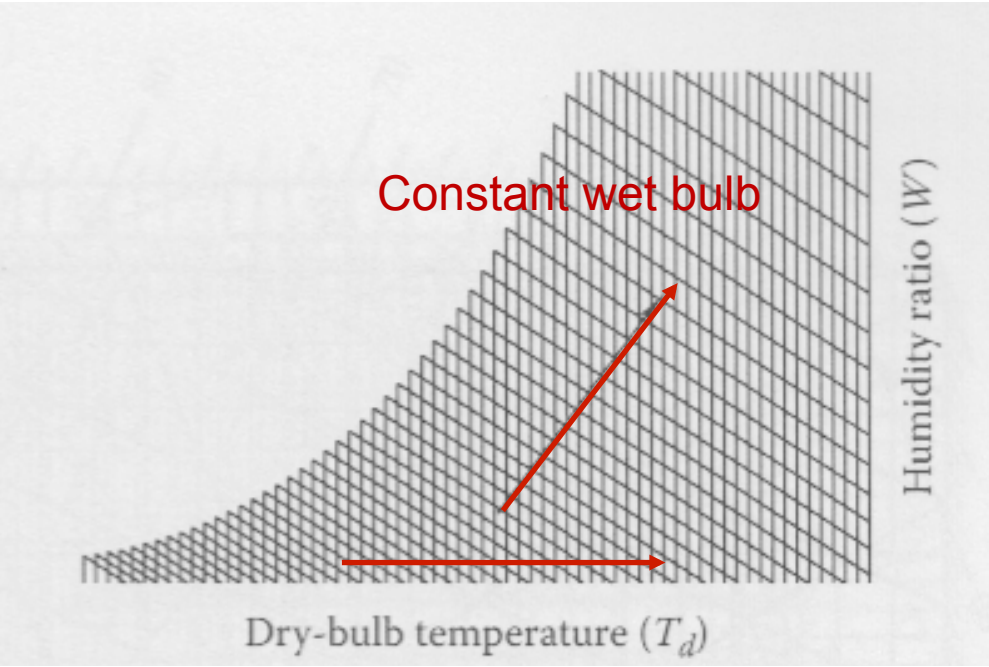
Alternate IP chart (Wang)

Deciphering the psychrometric chart

Lines of constant RH



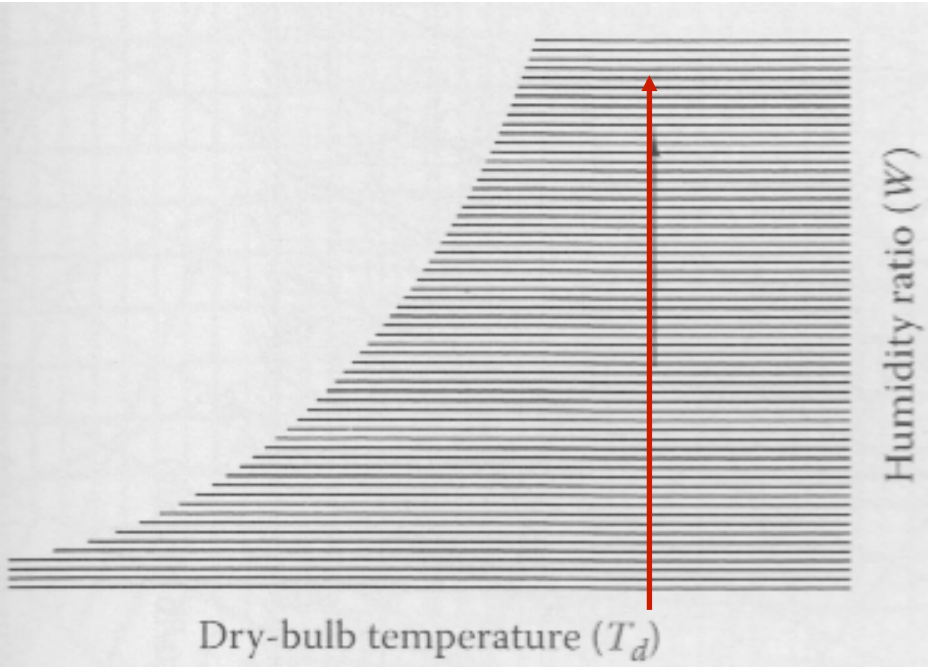
Lines of constant wet-bulb and dry-bulb



Constant dry bulb temperature

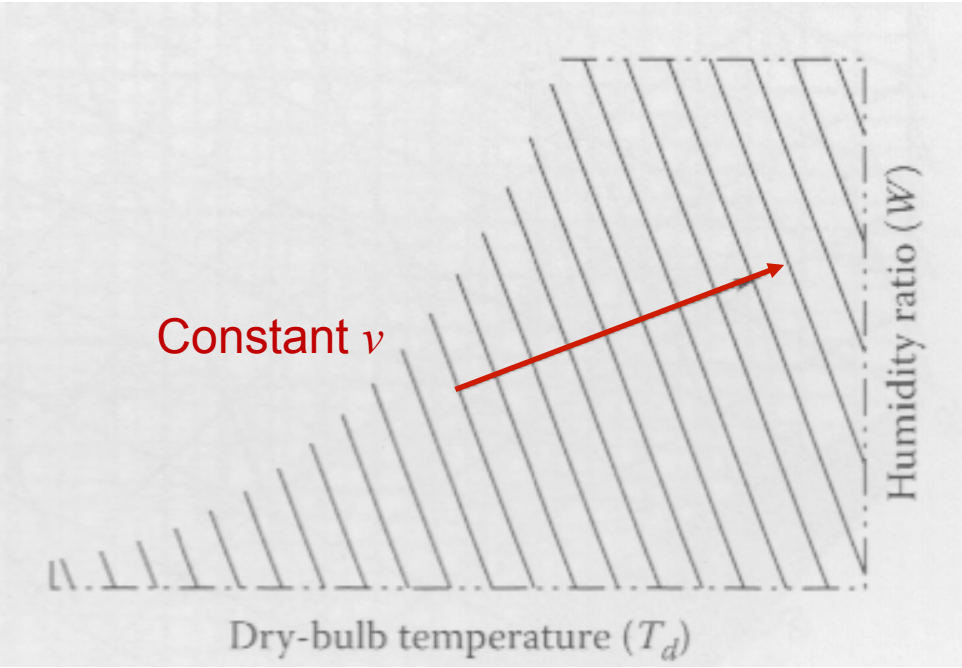
Deciphering the psychrometric chart

Lines of constant humidity ratio



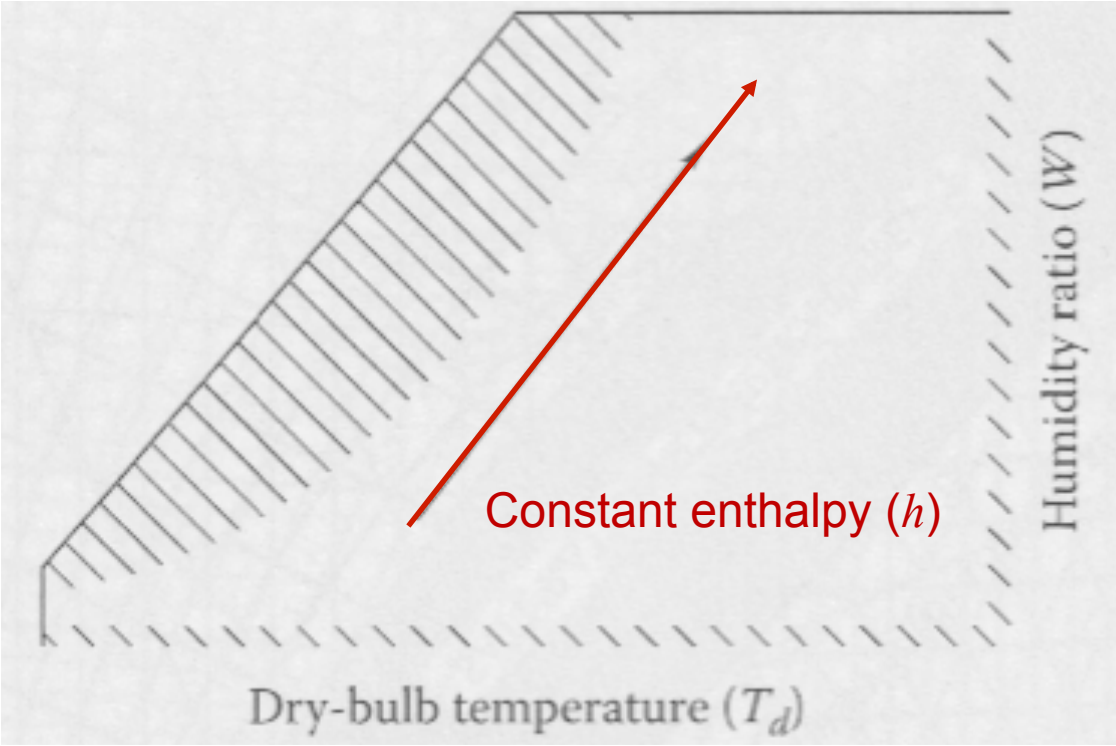
Constant W

Lines of constant specific volume



Deciphering the psychrometric chart

Lines of constant enthalpy



Some psychrometric examples

Moist air exists at 22°C dry-bulb temperature with 50% RH

Find the following:

(a) the humidity ratio, W

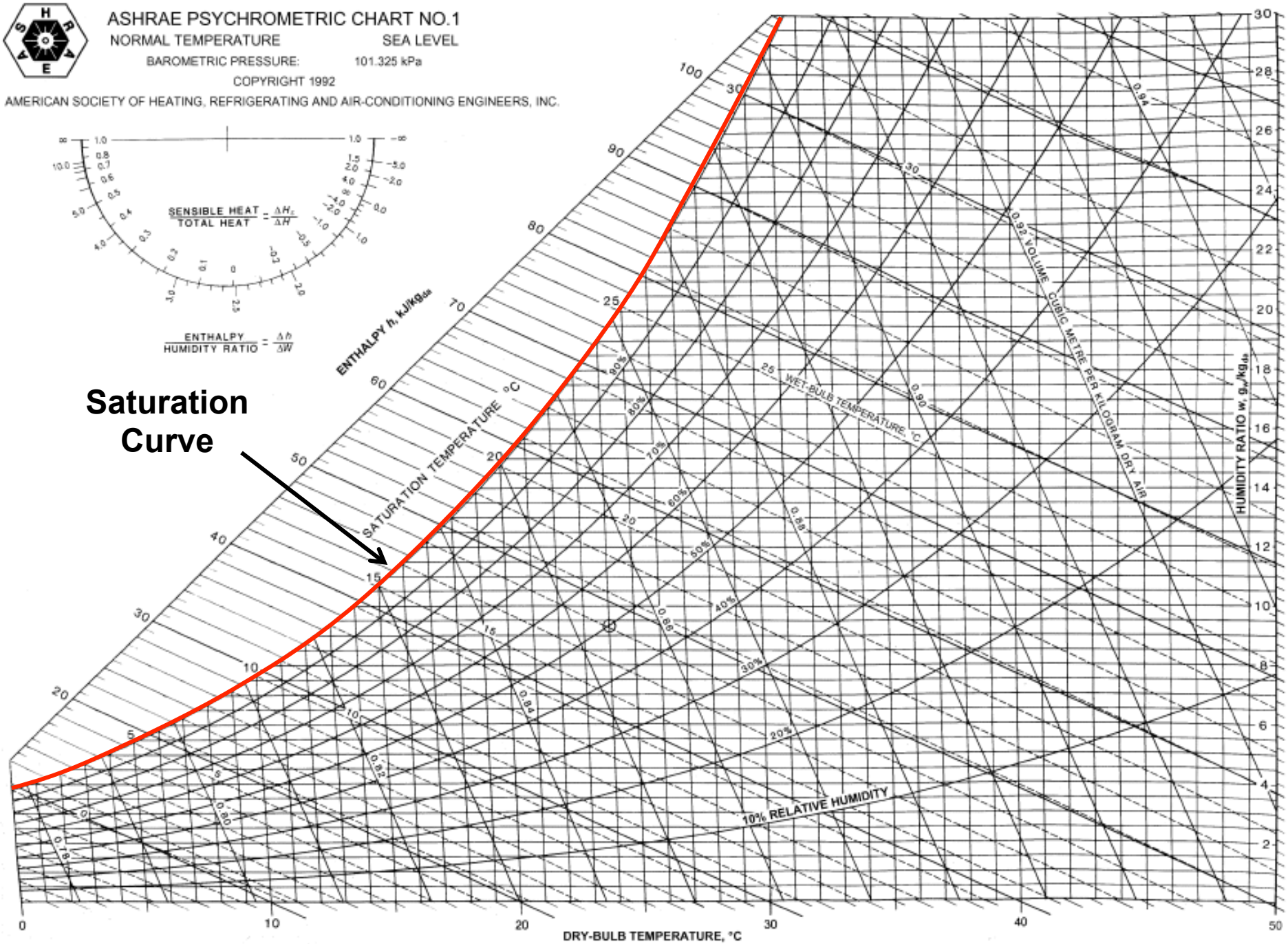
(b) dew point temperature, T_{dew}

(c) wet-bulb temperature, T_{wb}

(d) enthalpy, h

(e) specific volume, v

(f) dry air density, ρ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SEA LEVEL
BAROMETRIC PRESSURE: 101.325 kPa
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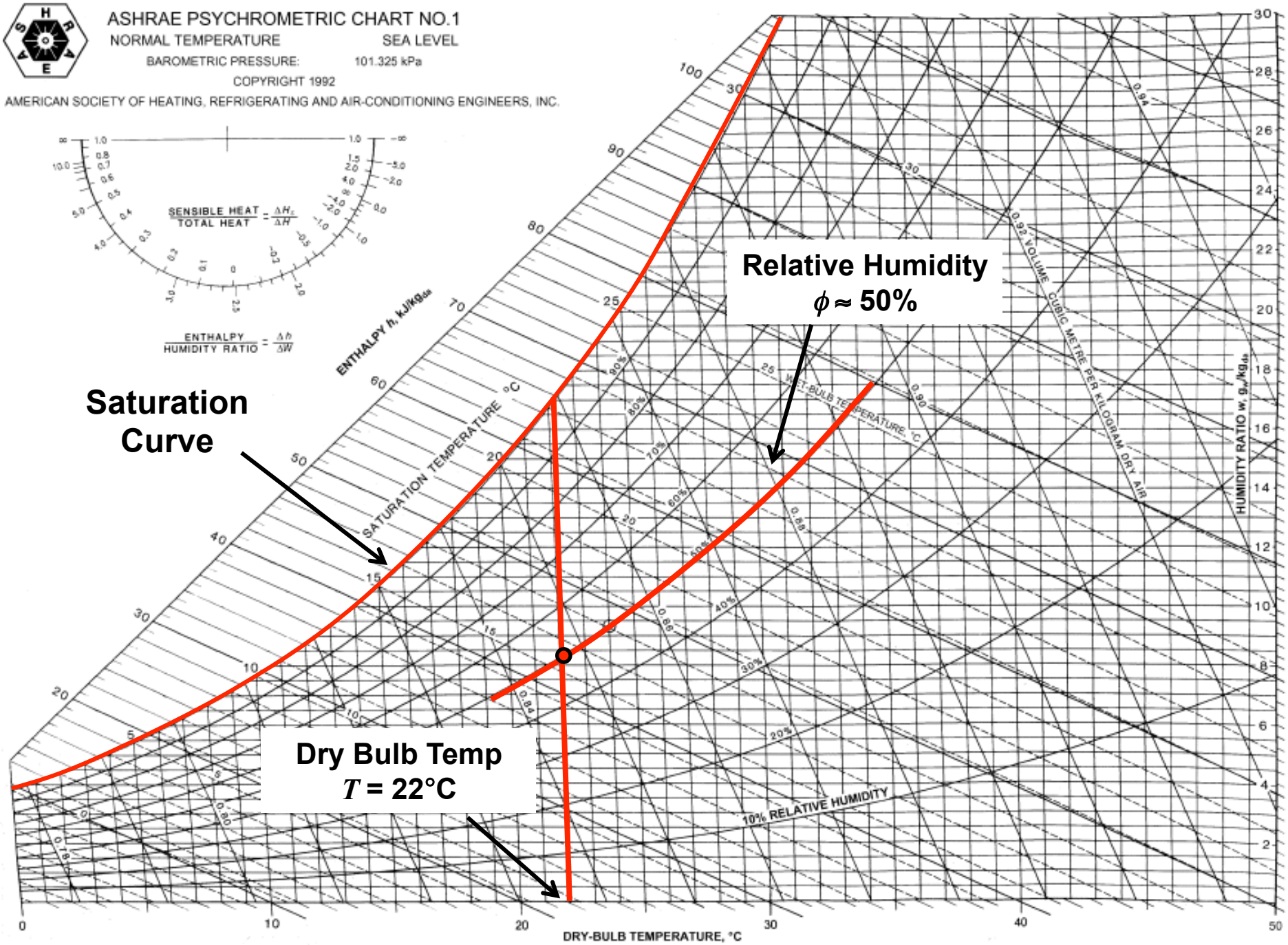
ENTHALPY h, kJ/kgda
SATURATION TEMPERATURE °C
WET-BULB TEMPERATURE, °C
VOLUME CUBIC METRE PER KILOGRAM DRY AIR
HUMIDITY RATIO w, gw/kgda
10% RELATIVE HUMIDITY
DRY-BULB TEMPERATURE, °C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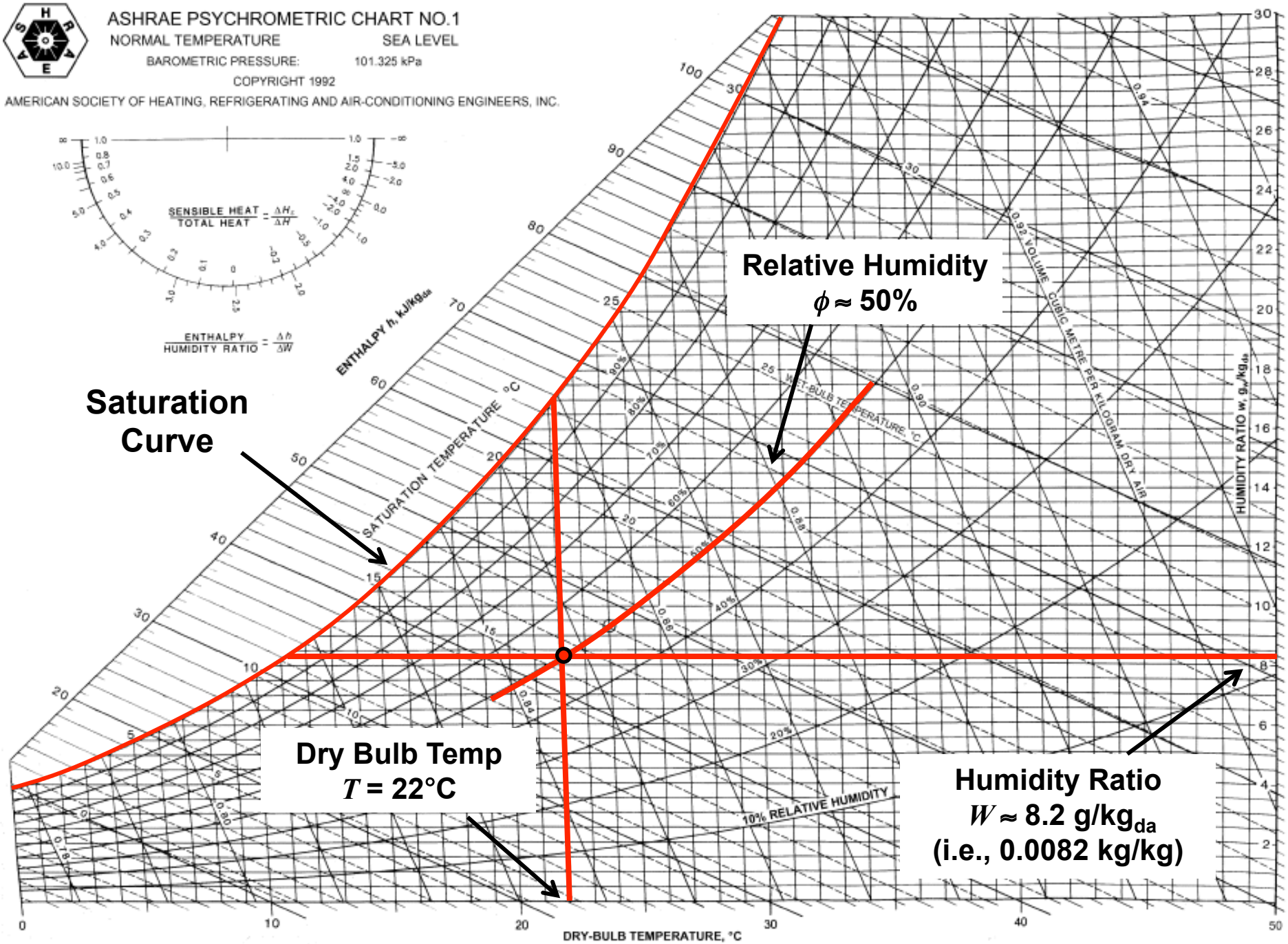
ENTHALPY h, kJ/kgda
SATURATION TEMPERATURE °C
Saturation Curve
Relative Humidity
ϕ ≈ 50%
Dry Bulb Temp
T = 22°C
WET-BULB TEMPERATURE, °C
VOLUME CUBIC METRE PER KILOGRAM DRY AIR
HUMIDITY RATIO w, gw/kgda
10% RELATIVE HUMIDITY
DRY-BULB TEMPERATURE, °C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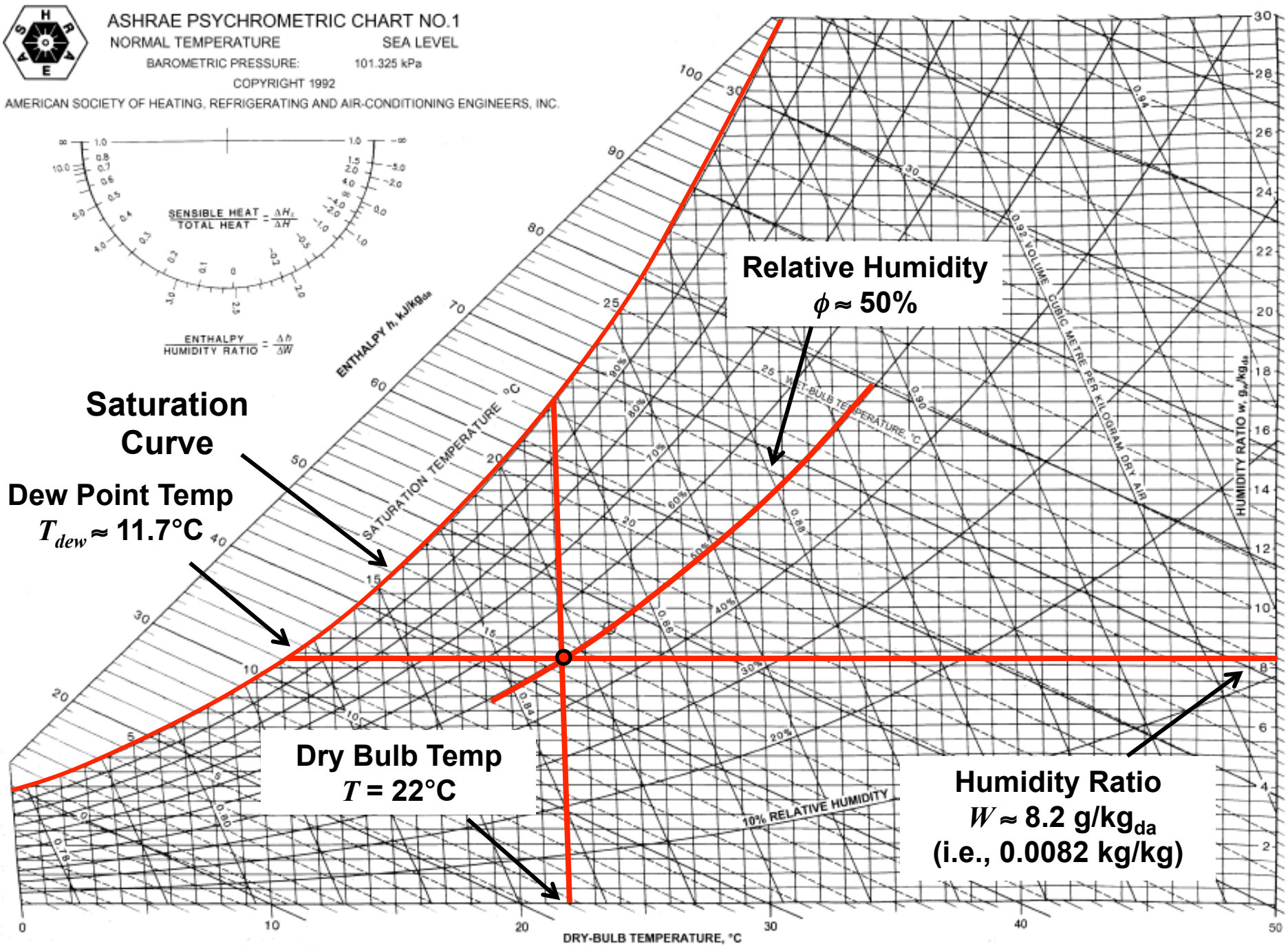
VOLUME CUBIC METRE PER KILOGRAM DRY AIR
HUMIDITY RATIO w, gw/kgda
10% RELATIVE HUMIDITY
DRY-BULB TEMPERATURE, °C
Saturation Curve
Relative Humidity
$\phi \approx 50\%$
Dry Bulb Temp
$T = 22°C$
Humidity Ratio
$W \approx 8.2$ g/kg$_{da}$
(i.e., 0.0082 kg/kg)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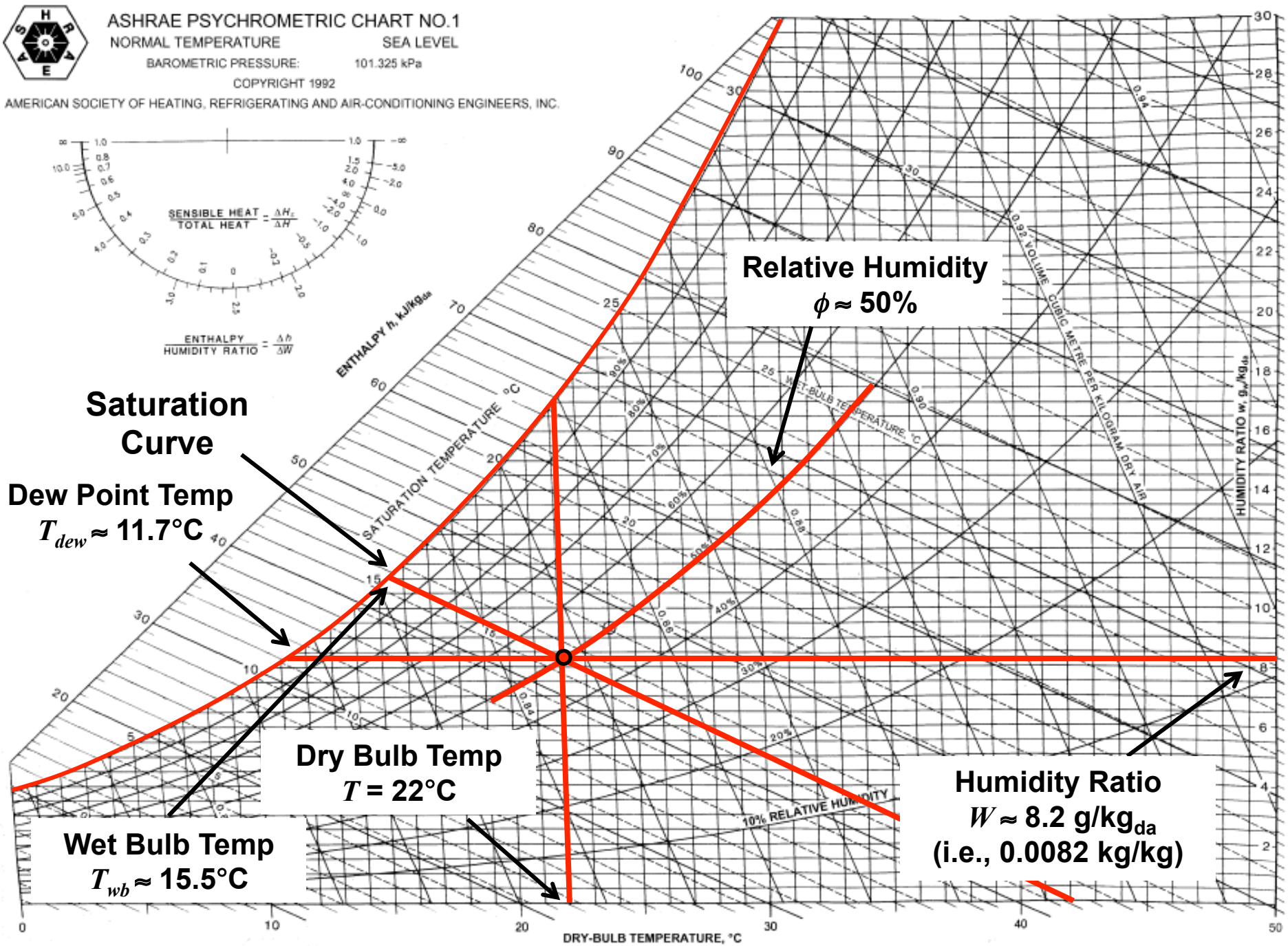
HUMIDITY RATIO w, gw/kgda
10% RELATIVE HUMIDITY
DRY-BULB TEMPERATURE, °C
Relative Humidity
$\phi \approx 50\%$
Saturation Curve
Dew Point Temp
$T_{dew} \approx 11.7°C$
Dry Bulb Temp
$T = 22°C$
Humidity Ratio
$W \approx 8.2$ g/kg$_{da}$
(i.e., 0.0082 kg/kg)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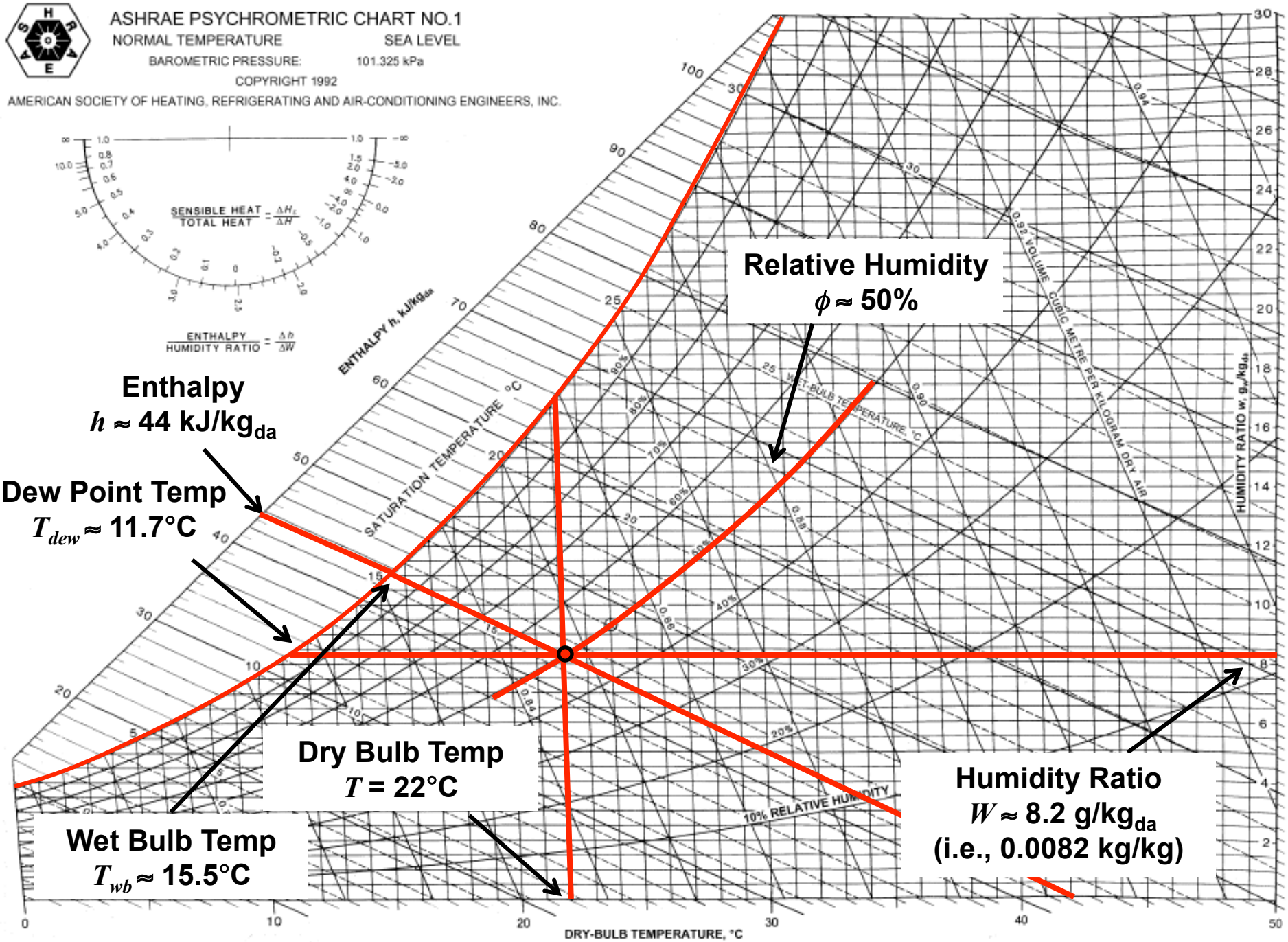
HUMIDITY RATIO w, gw/kgda
10% RELATIVE HUMIDITY
DRY-BULB TEMPERATURE, °C
Relative Humidity
$\phi \approx 50\%$
Saturation Curve
Dew Point Temp
$T_{dew} \approx 11.7°C$
Dry Bulb Temp
$T = 22°C$
Wet Bulb Temp
$T_{wb} \approx 15.5°C$
Humidity Ratio
$W \approx 8.2$ g/kg$_{da}$
(i.e., 0.0082 kg/kg)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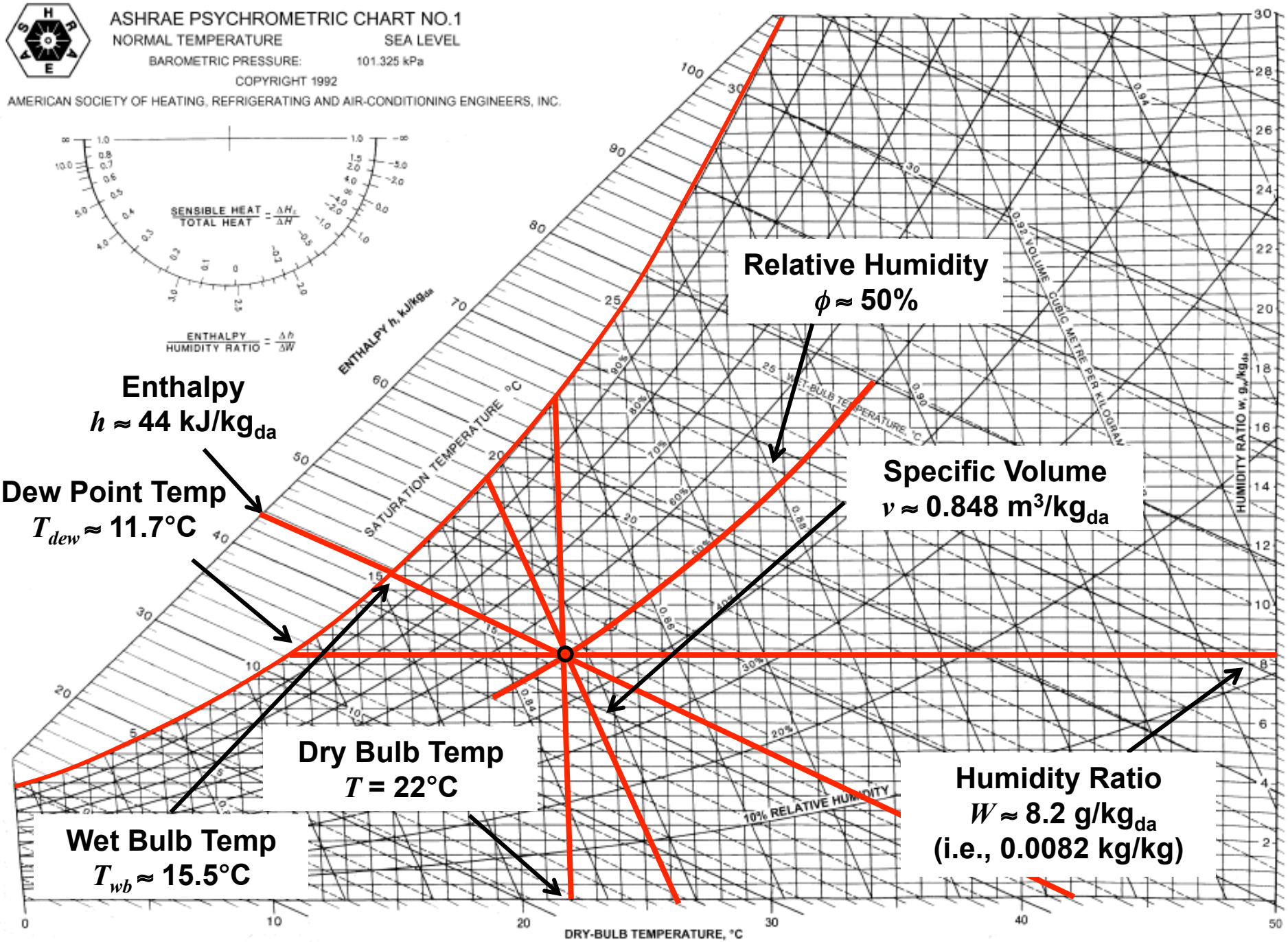
WET-BULB TEMPERATURE, °C
VOLUME CUBIC METRE PER KILOGRAM DRY AIR
HUMIDITY RATIO w, gw/kgda
10% RELATIVE HUMIDITY
DRY-BULB TEMPERATURE, °C
Relative Humidity
ϕ ≈ 50%
Enthalpy
h ≈ 44 kJ/kgda
Dew Point Temp
Tdew ≈ 11.7°C
Dry Bulb Temp
T = 22°C
Wet Bulb Temp
Twb ≈ 15.5°C
Humidity Ratio
W ≈ 8.2 g/kgda
(i.e., 0.0082 kg/kg)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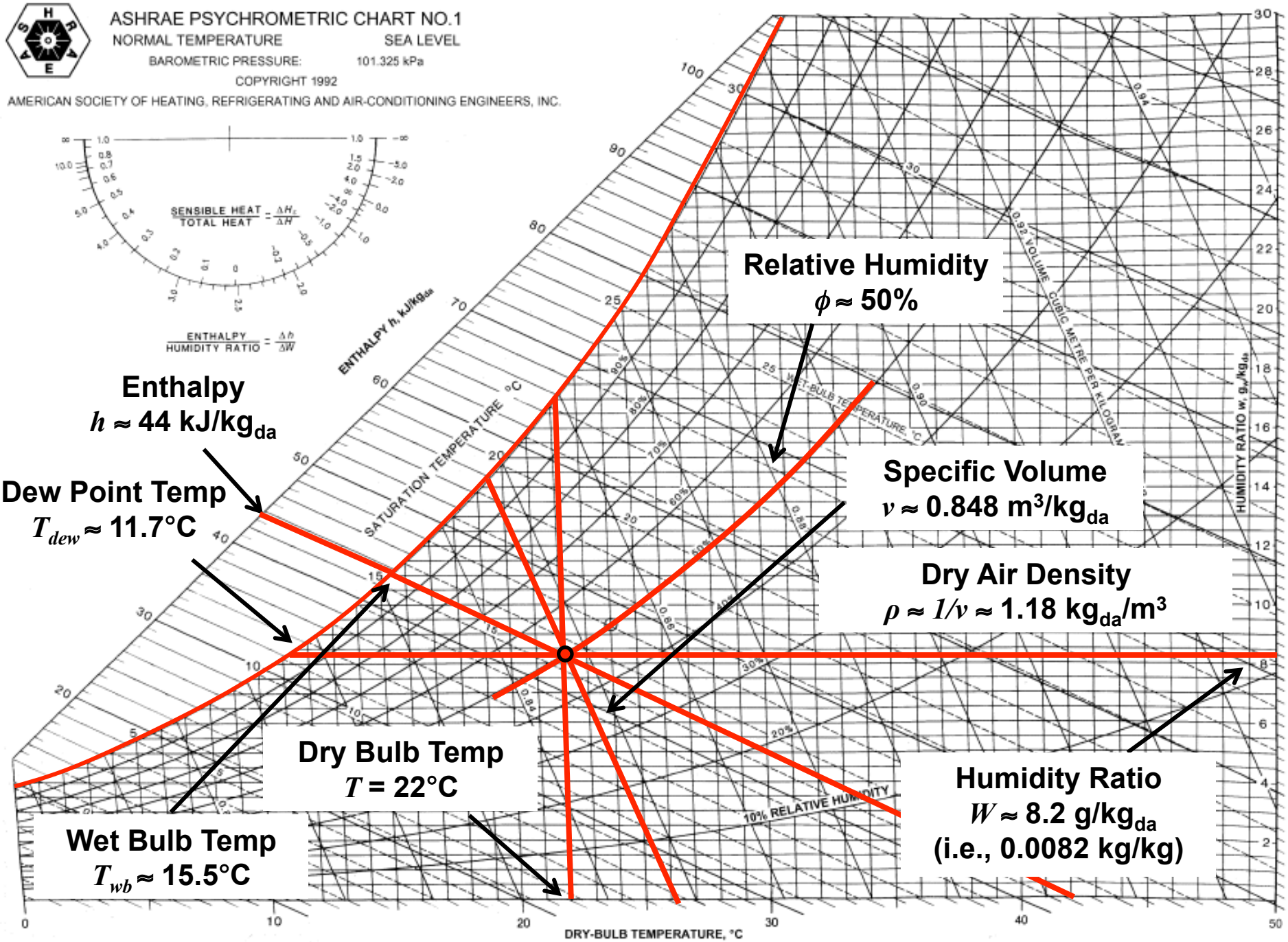
VOLUME CUBIC METRE PER KILOGRAM
HUMIDITY RATIO w, gw/kgda
10% RELATIVE HUMIDITY
DRY-BULB TEMPERATURE, °C
Relative Humidity
$\phi \approx 50\%$
Enthalpy
$h \approx 44$ kJ/kg$_{da}$
Dew Point Temp
$T_{dew} \approx 11.7$°C
Specific Volume
$v \approx 0.848$ m^3/kg$_{da}$
Dry Bulb Temp
$T = 22$°C
Wet Bulb Temp
$T_{wb} \approx 15.5$°C
Humidity Ratio
$W \approx 8.2$ g/kg$_{da}$
(i.e., 0.0082 kg/kg)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HUMIDITY RATIO w, gw/kgda
10% RELATIVE HUMIDITY
DRY-BULB TEMPERATURE, °C
Relative Humidity
$\phi \approx 50\%$
Enthalpy
$h \approx 44$ kJ/kg$_{da}$
Dew Point Temp
$T_{dew} \approx 11.7°C$
Specific Volume
$v \approx 0.848$ m^3/kg$_{da}$
Dry Air Density
$\rho \approx 1/v \approx 1.18$ kg$_{da}$/m^3
Dry Bulb Temp
$T = 22°C$
Humidity Ratio
$W \approx 8.2$ g/kg$_{da}$
(i.e., 0.0082 kg/kg)
Wet Bulb Temp
$T_{wb} \approx 15.5°C$

Some psychrometric examples

Moist air exists at 30°C dry-bulb temperature with a 15°C dew point temperature

Find the following:

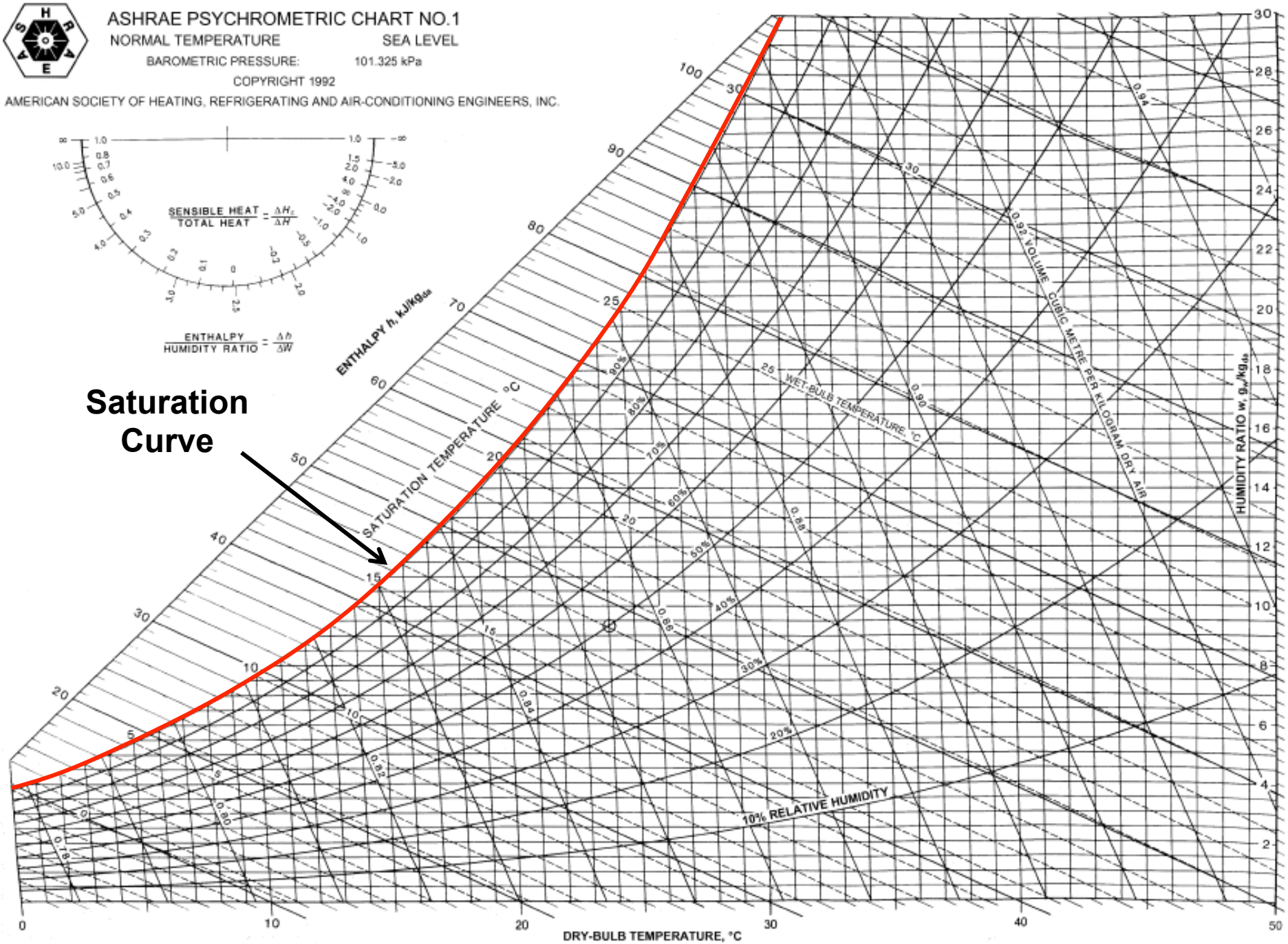
(a) the humidity ratio, W

(b) wet-bulb temperature, T_{wb}

(c) enthalpy, h

(d) specific volume, v

(e) relative humidity, ϕ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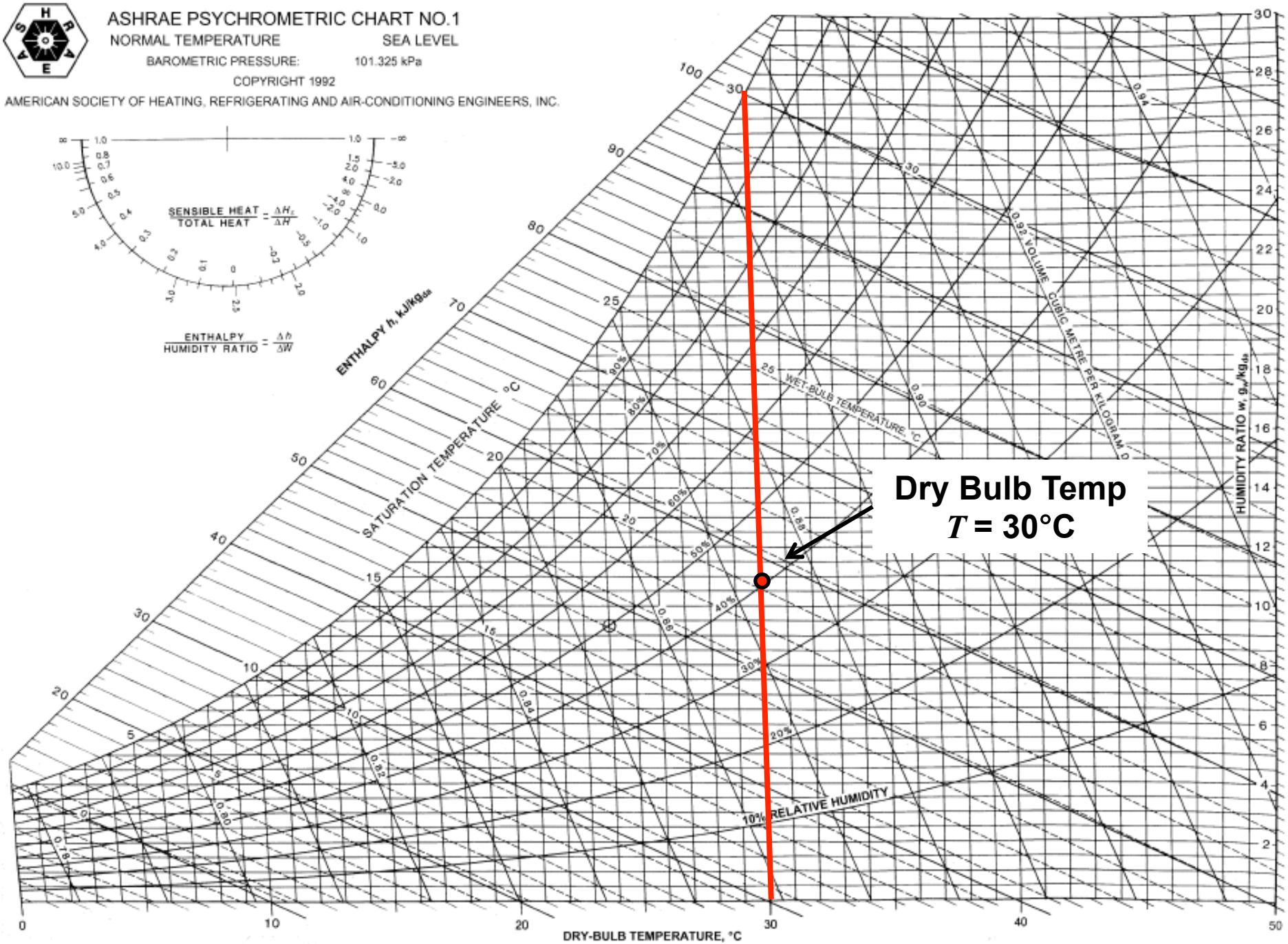
ENTHALPY h, kJ/kgda
SATURATION TEMPERATURE °C
WET-BULB TEMPERATURE, °C
VOLUME CUBIC METRE PER KILOGRAM DRY AIR
HUMIDITY RATIO w, gw/kgda
10% RELATIVE HUMIDITY
DRY-BULB TEMPERATURE, °C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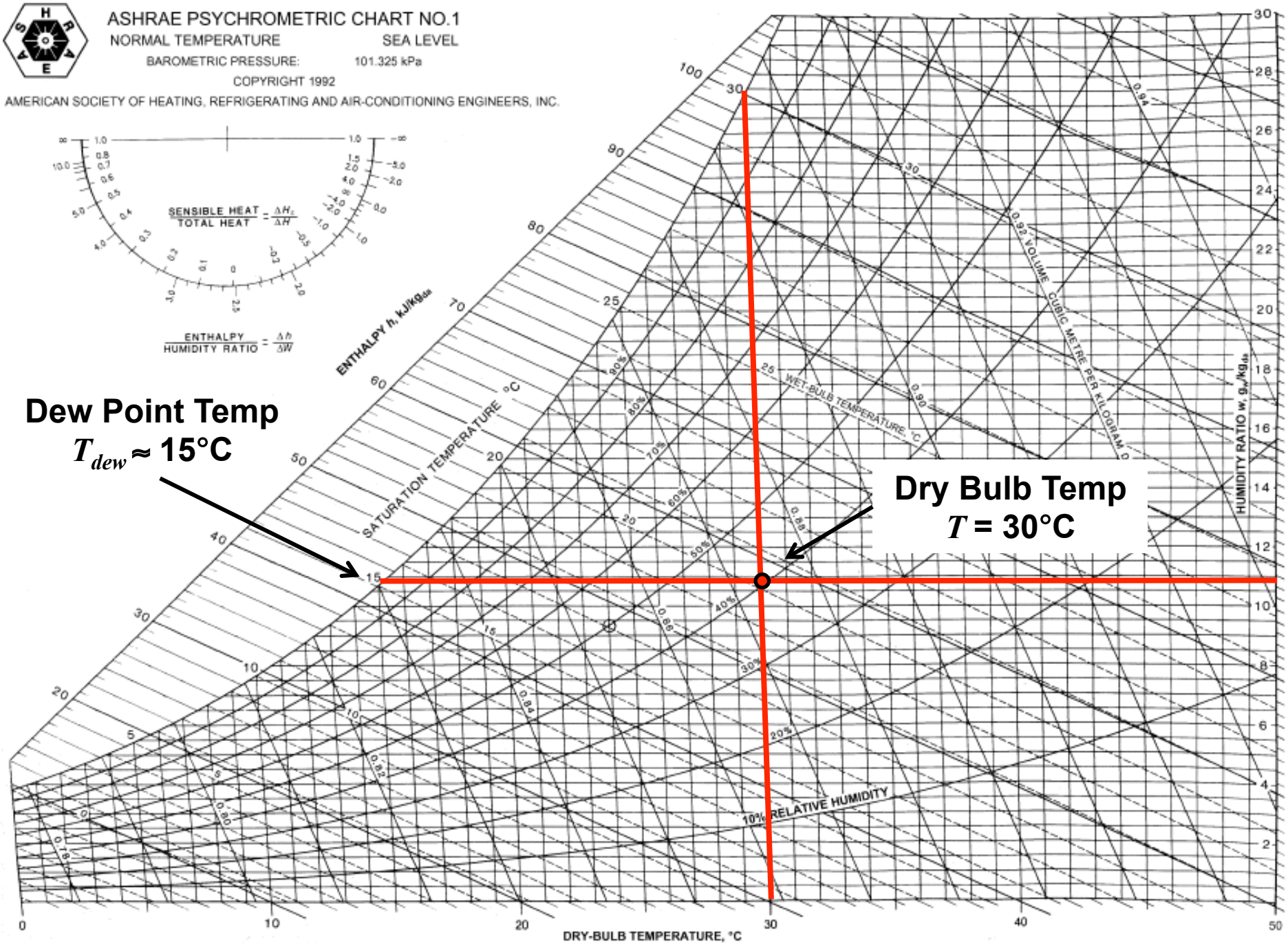
SATURATION TEMPERATURE °C
WET-BULB TEMPERATURE, °C
VOLUME CUBIC METRE PER KILOGRAM
RELATIVE HUMIDITY
HUMIDITY RATIO w, gw/kgda
DRY-BULB TEMPERATURE, °C
Dry Bulb Temp
T = 30°C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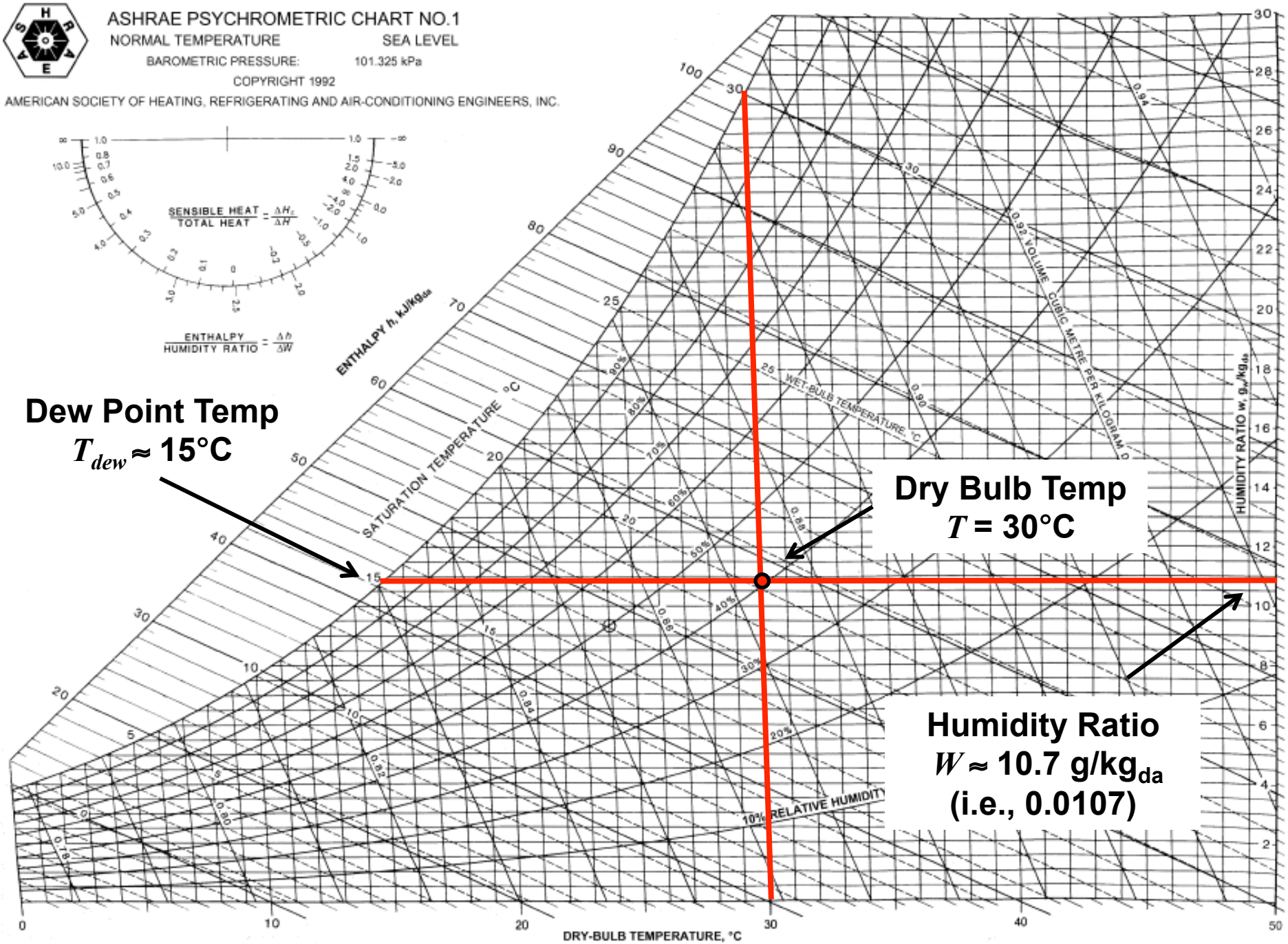
VOLUME CUBIC METRE PER KILOGRAM
HUMIDITY RATIO w, gw/kgda
RELATIVE HUMIDITY
DRY-BULB TEMPERATURE, °C
Dew Point Temp
$T_{dew} \approx 15°C$
Dry Bulb Temp
$T = 30°C$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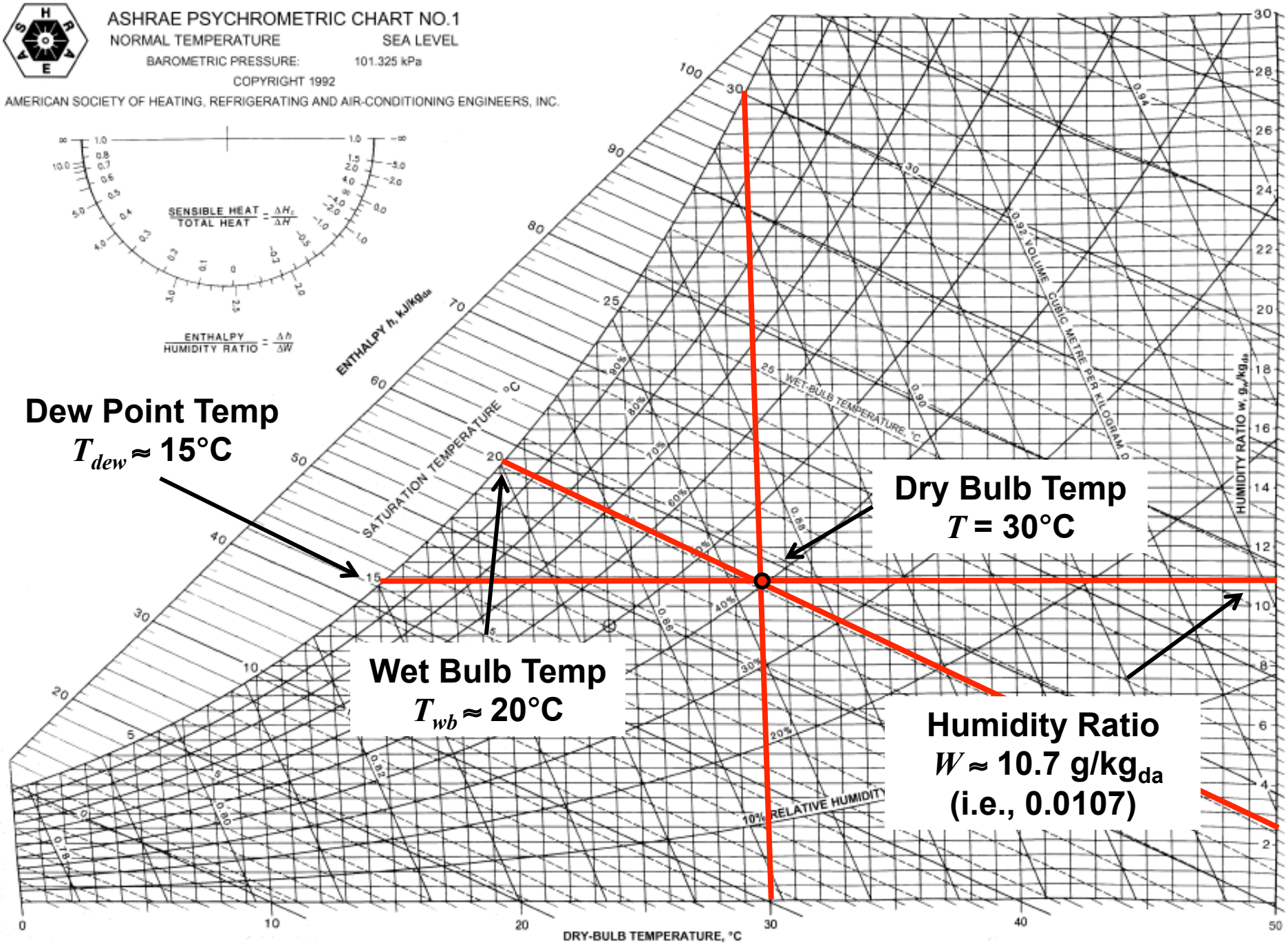
VOLUME CUBIC METRE PER KILOGRAM
RELATIVE HUMIDITY
HUMIDITY RATIO w, gw/kgda
DRY-BULB TEMPERATURE, °C
Dew Point Temp
$T_{dew} \approx 15°C$
Dry Bulb Temp
$T = 30°C$
Humidity Ratio
$W \approx 10.7$ g/kg$_{da}$
(i.e., 0.0107)


ASHRAE PSYCHROMETRIC CHART NO.1
NORMAL TEMPERATURE
SEA LEVEL
BAROMETRIC PRESSURE: 101.325 kPa
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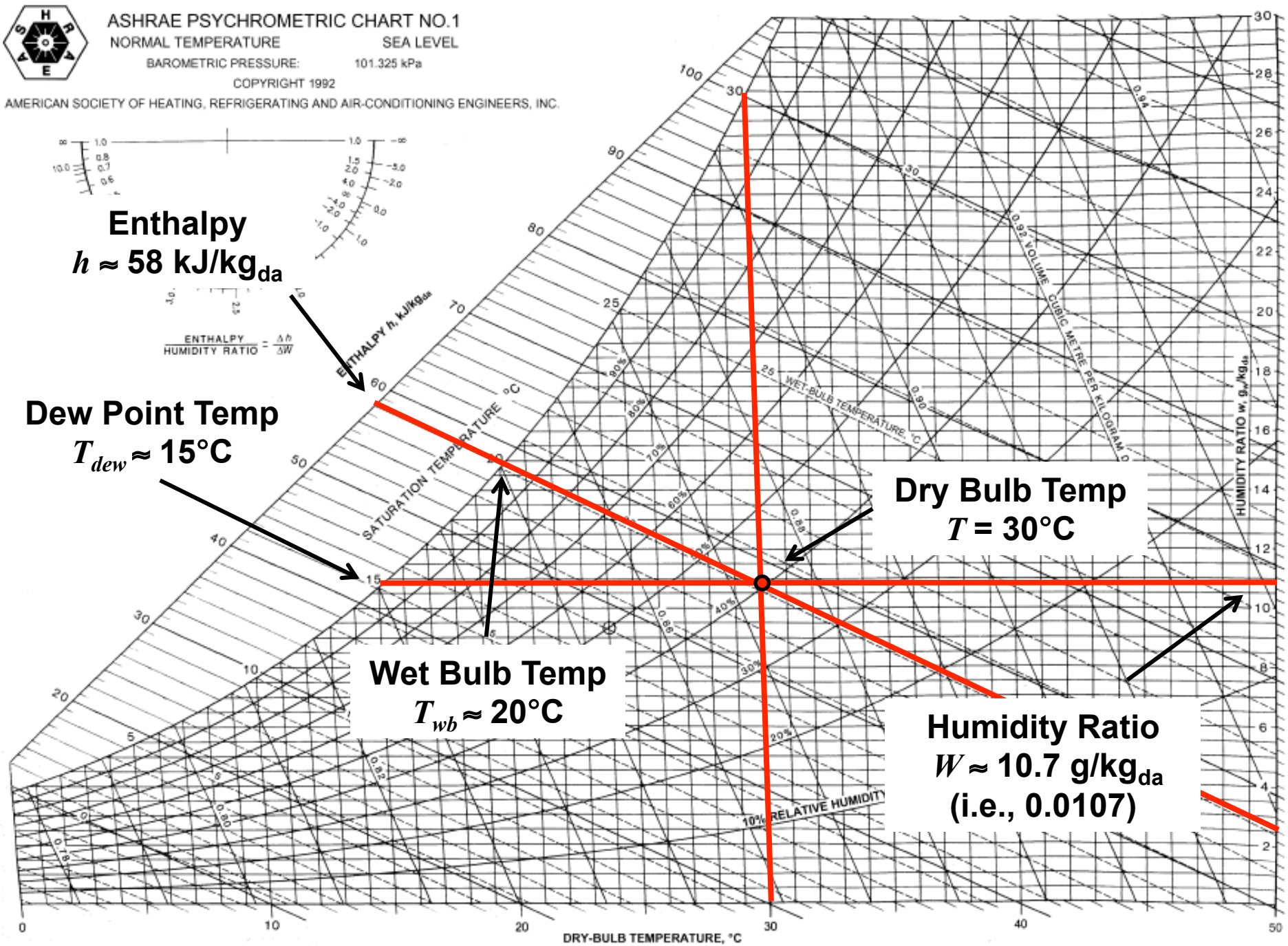
AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS, INC.
SENSIBLE HEAT / TOTAL HEAT = ΔHs / ΔH
ENTHALPY / HUMIDITY RATIO = Δh / ΔW
ENTHALPY h, kJ/kgda
SATURATION TEMPERATURE °C
WET-BULB TEMPERATURE, °C
VOLUME CUBIC METRE PER KILOGRAM
HUMIDITY RATIO w, gw/kgda
RELATIVE HUMIDITY
DRY-BULB TEMPERATURE, °C
Dew Point Temp
$T_{dew} \approx 15°C$
Dry Bulb Temp
$T = 30°C$
Wet Bulb Temp
$T_{wb} \approx 20°C$
Humidity Ratio
$W \approx 10.7$ g/kg$_{da}$
(i.e., 0.0107)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NORMAL TEMPERATURE
SEA LEVEL
BAROMETRIC PRESSURE: 101.325 kPa
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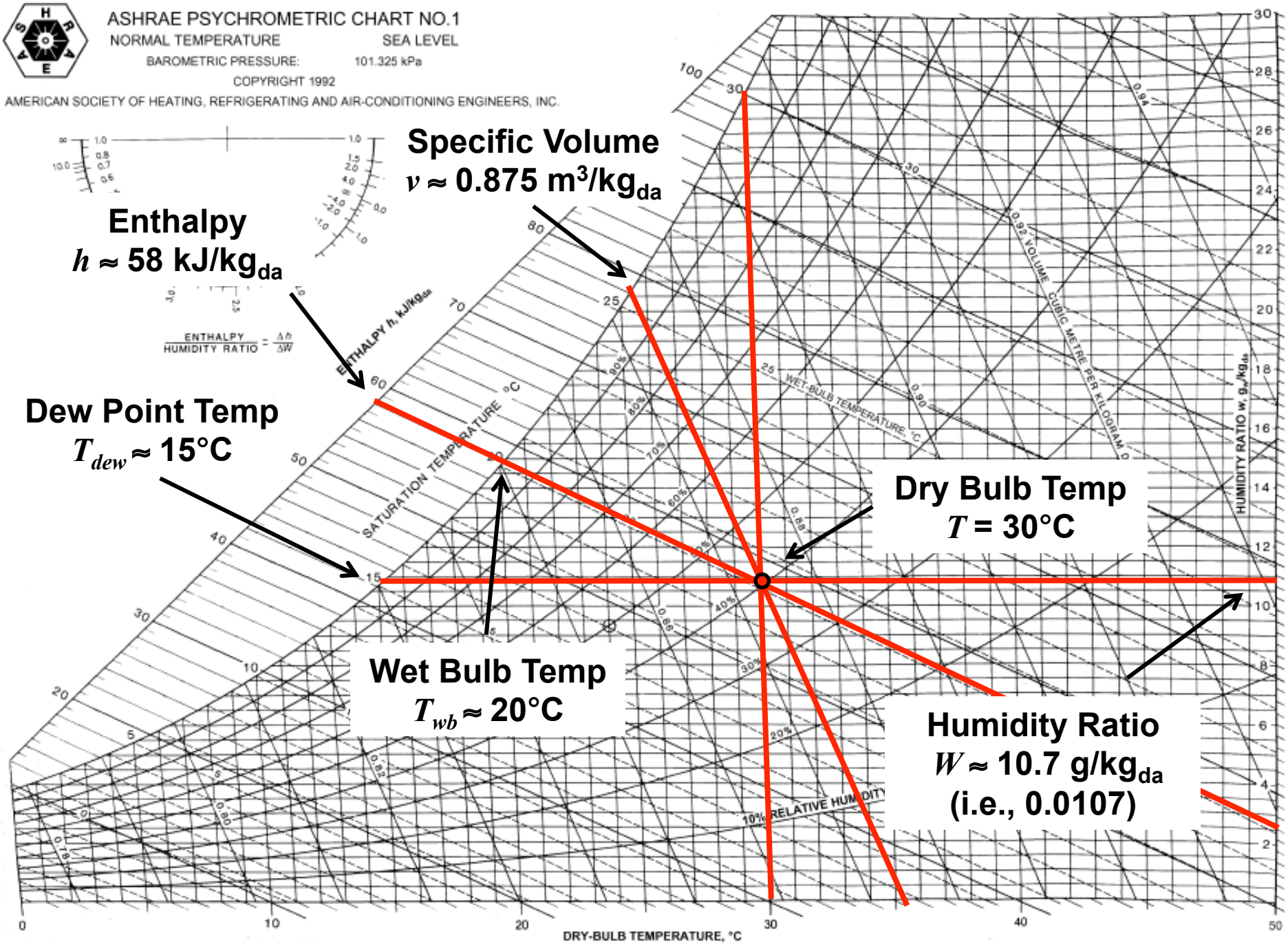
Enthalpy
$h \approx 58$ kJ/kg$_{da}$
Dew Point Temp
$T_{dew} \approx 15$°C
Dry Bulb Temp
$T = 30$°C
Wet Bulb Temp
$T_{wb} \approx 20$°C
Humidity Ratio
$W \approx 10.7$ g/kg$_{da}$
(i.e., 0.0107)
ENTHALPY h, kJ/kg$_{da}$
SATURATION TEMPERATURE °C
WET-BULB TEMPERATURE, °C
VOLUME CUBIC METRE PER KILOGRAM
RELATIVE HUMIDITY
HUMIDITY RATIO w, g$_w$/kg$_{da}$
DRY-BULB TEMPERATURE, °C
ENTHALPY / HUMIDITY RATIO = Δh/ΔW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NORMAL TEMPERATURE
SEA LEVEL
BAROMETRIC PRESSURE: 101.325 kPa
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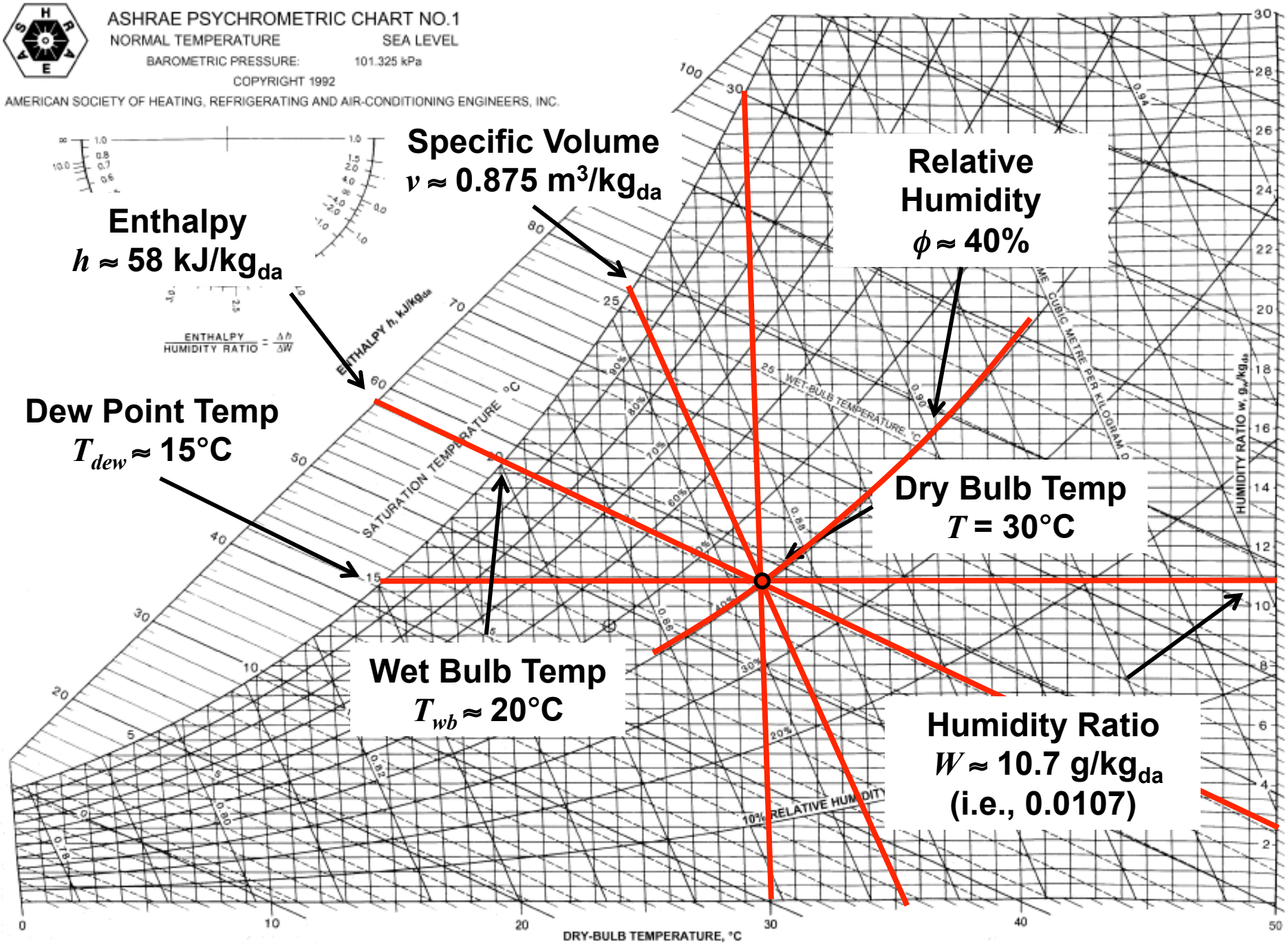
Specific Volume
$v \approx 0.875\ m^3/kg_{da}$
Enthalpy
$h \approx 58\ kJ/kg_{da}$
Dew Point Temp
$T_{dew} \approx 15°C$
Dry Bulb Temp
$T = 30°C$
Wet Bulb Temp
$T_{wb} \approx 20°C$
Humidity Ratio
$W \approx 10.7\ g/kg_{da}$
(i.e., 0.0107)
ENTHALPY h, kJ/kg_da
SATURATION TEMPERATURE °C
WET-BULB TEMPERATURE, °C
VOLUME CUBIC METRE PER KILOGRAM
HUMIDITY RATIO w, g_w/kg_da
RELATIVE HUMIDITY
DRY-BULB TEMPERATURE, °C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NORMAL TEMPERATURE
SEA LEVEL
BAROMETRIC PRESSURE: 101.325 kPa
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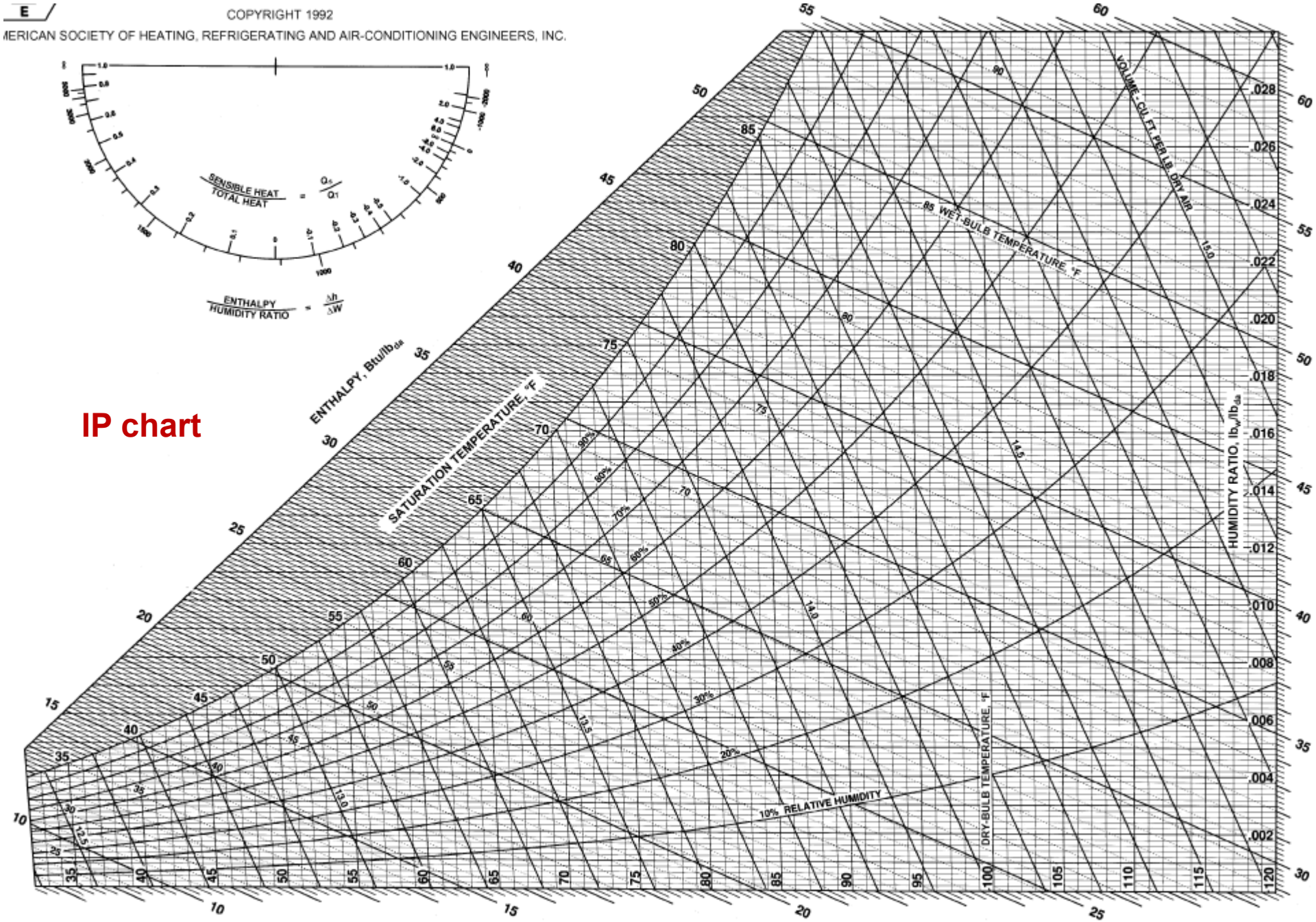
Specific Volume
$v \approx 0.875\ m^3/kg_{da}$
Relative Humidity
$\phi \approx 40\%$
Enthalpy
$h \approx 58\ kJ/kg_{da}$
Dew Point Temp
$T_{dew} \approx 15°C$
Dry Bulb Temp
$T = 30°C$
Wet Bulb Temp
$T_{wb} \approx 20°C$
Humidity Ratio
$W \approx 10.7\ g/kg_{da}$
(i.e., 0.0107)
ENTHALPY h, kJ/kg_da
SATURATION TEMPERATURE °C
WET-BULB TEMPERATURE °C
CUBIC METRE PER KILOGRAM
HUMIDITY RATIO w, g_w/kg_da
RELATIVE HUMIDITY
DRY-BULB TEMPERATURE, °C

Psychrometrics: IP units example

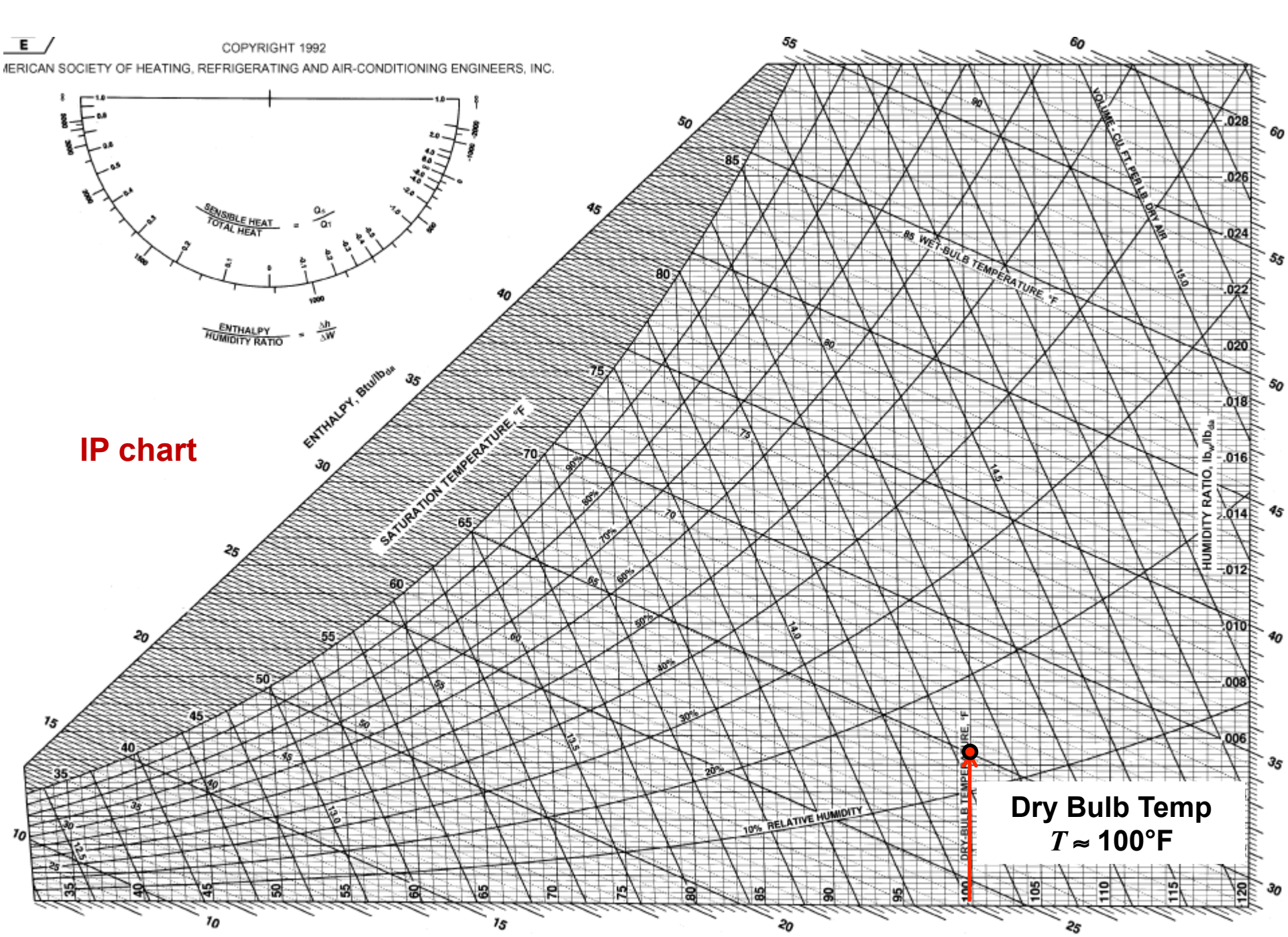
- Moist air exists at 100°F dry bulb, 65°F wet bulb and 14.696 psia

Find:

a) Humidity ratio
b) Enthalpy
c) Dew-point temperature
d) Relative humidity
e) Specific volume



IP chart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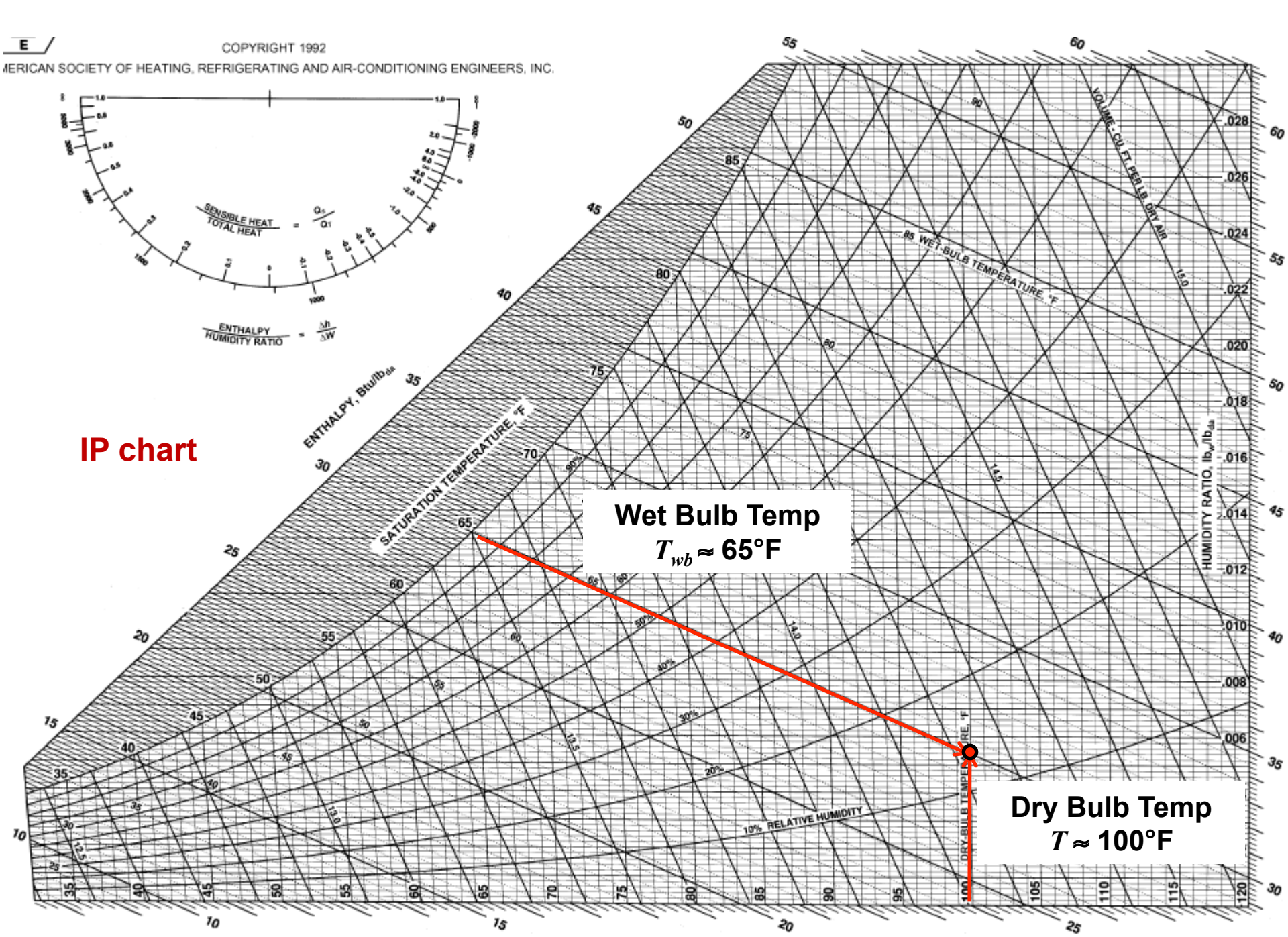
SENSIBLE HEAT / TOTAL HEAT = Qs / Qt
ENTHALPY / HUMIDITY RATIO = Δh / ΔW
ENTHALPY, Btu/lbda
SATURATION TEMPERATURE, °F
VOLUME-CU. FT. PER LB. DRY AIR
WET-BULB TEMPERATURE, °F
HUMIDITY RATIO, lbw/lbda
DRY-BULB TEMPERATURE, °F
10% RELATIVE HUMIDITY
IP chart
Dry Bulb Temp
T ≈ 100°F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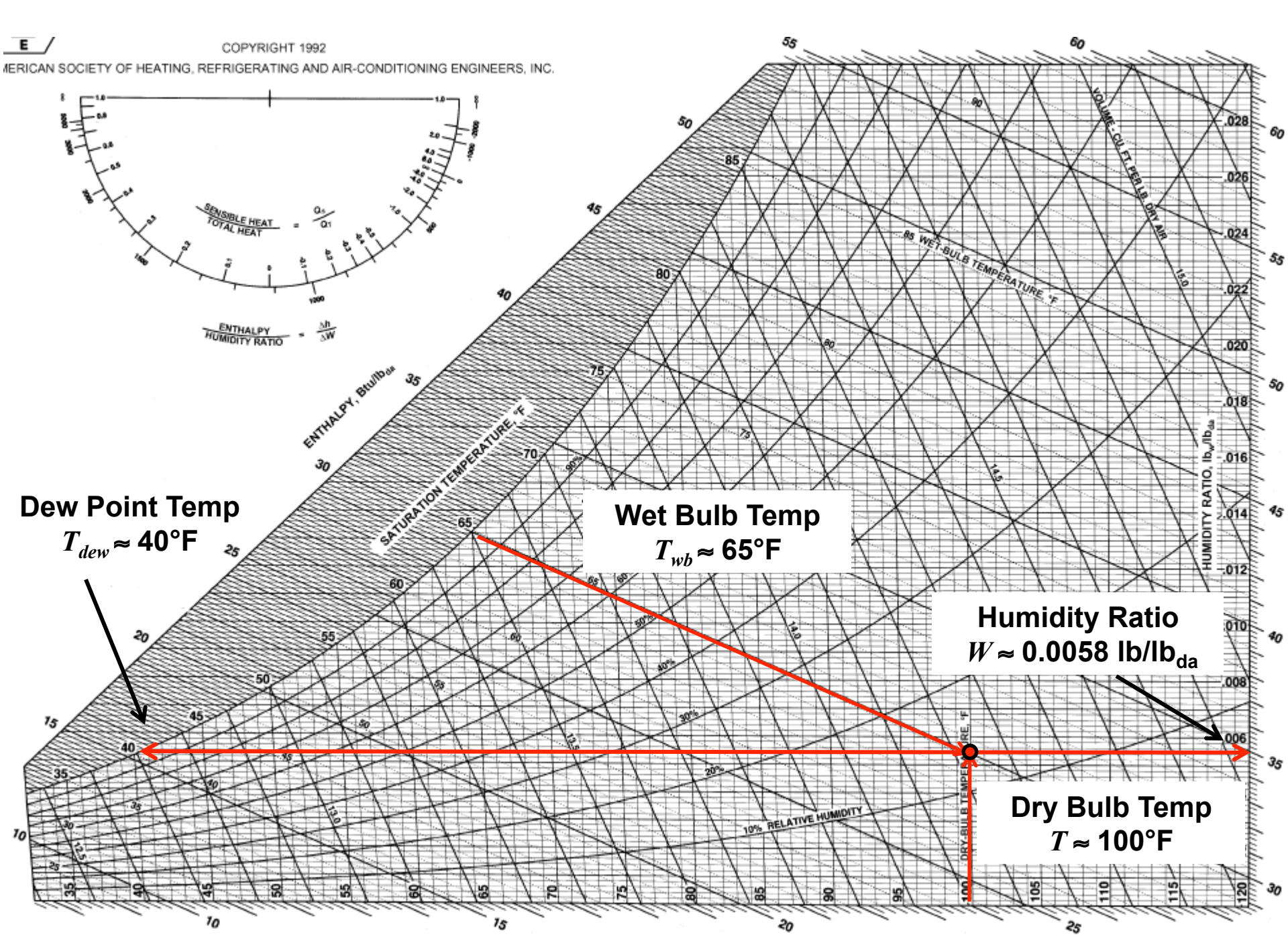
IP chart
ENTHALPY, Btu/lb da
SATURATION TEMPERATURE, °F
VOLUME - CU. FT. PER LB. DRY AIR
WET-BULB TEMPERATURE, °F
HUMIDITY RATIO, lbw/lbda
DRY-BULB TEMPERATURE, °F
10% RELATIVE HUMIDITY
Wet Bulb Temp
$T_{wb} \approx 65°F$
Dry Bulb Temp
$T \approx 100°F$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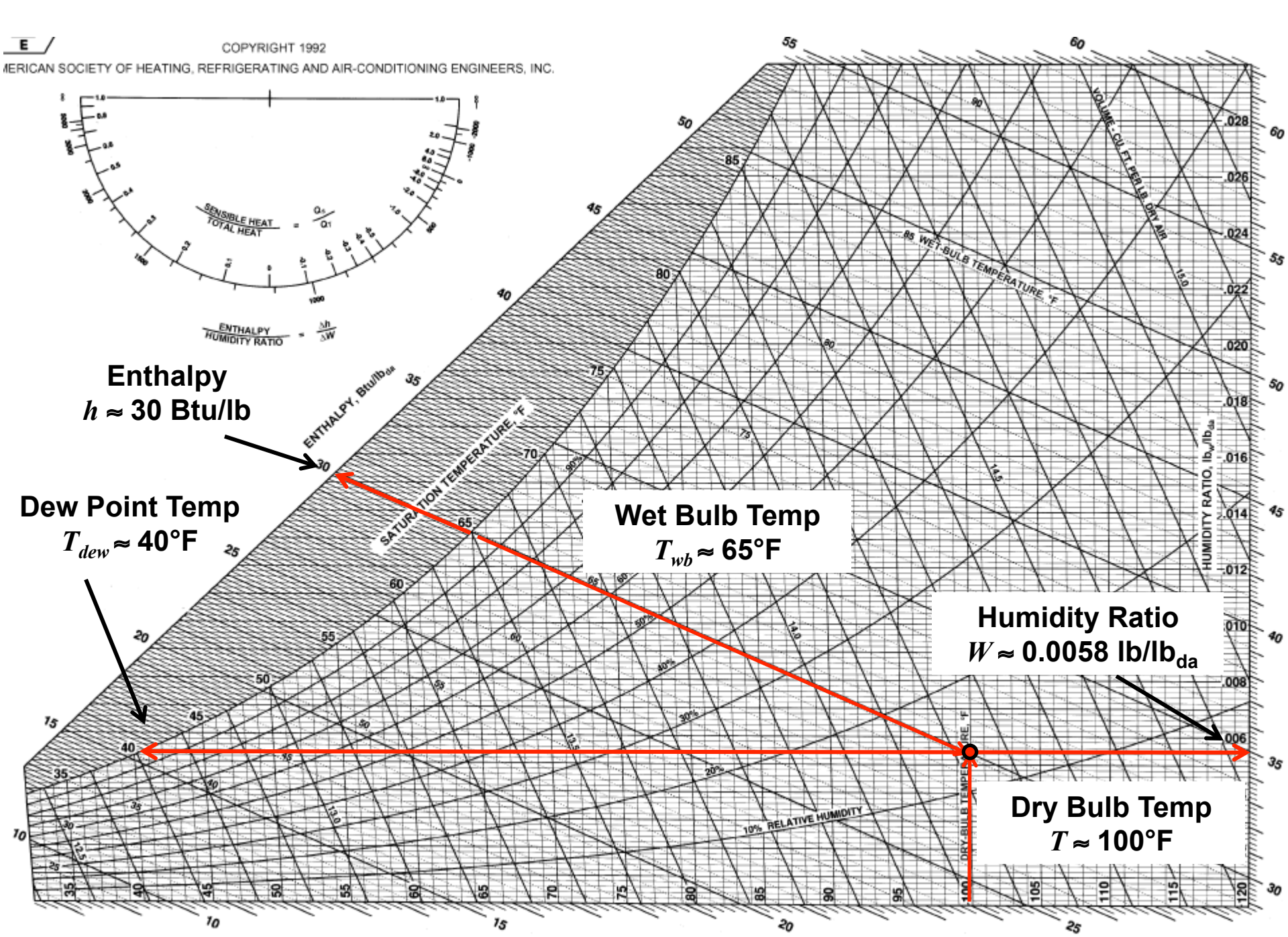
VOLUME-CU. FT. PER LB. DRY AIR
WET-BULB TEMPERATURE, °F
HUMIDITY RATIO, lbw/lbda
DRY-BULB TEMPERATURE, °F
10% RELATIVE HUMIDITY
Dew Point Temp
$T_{dew} \approx 40°F$
Wet Bulb Temp
$T_{wb} \approx 65°F$
Humidity Ratio
$W \approx 0.0058$ lb/lb$_{da}$
Dry Bulb Temp
$T \approx 100°F$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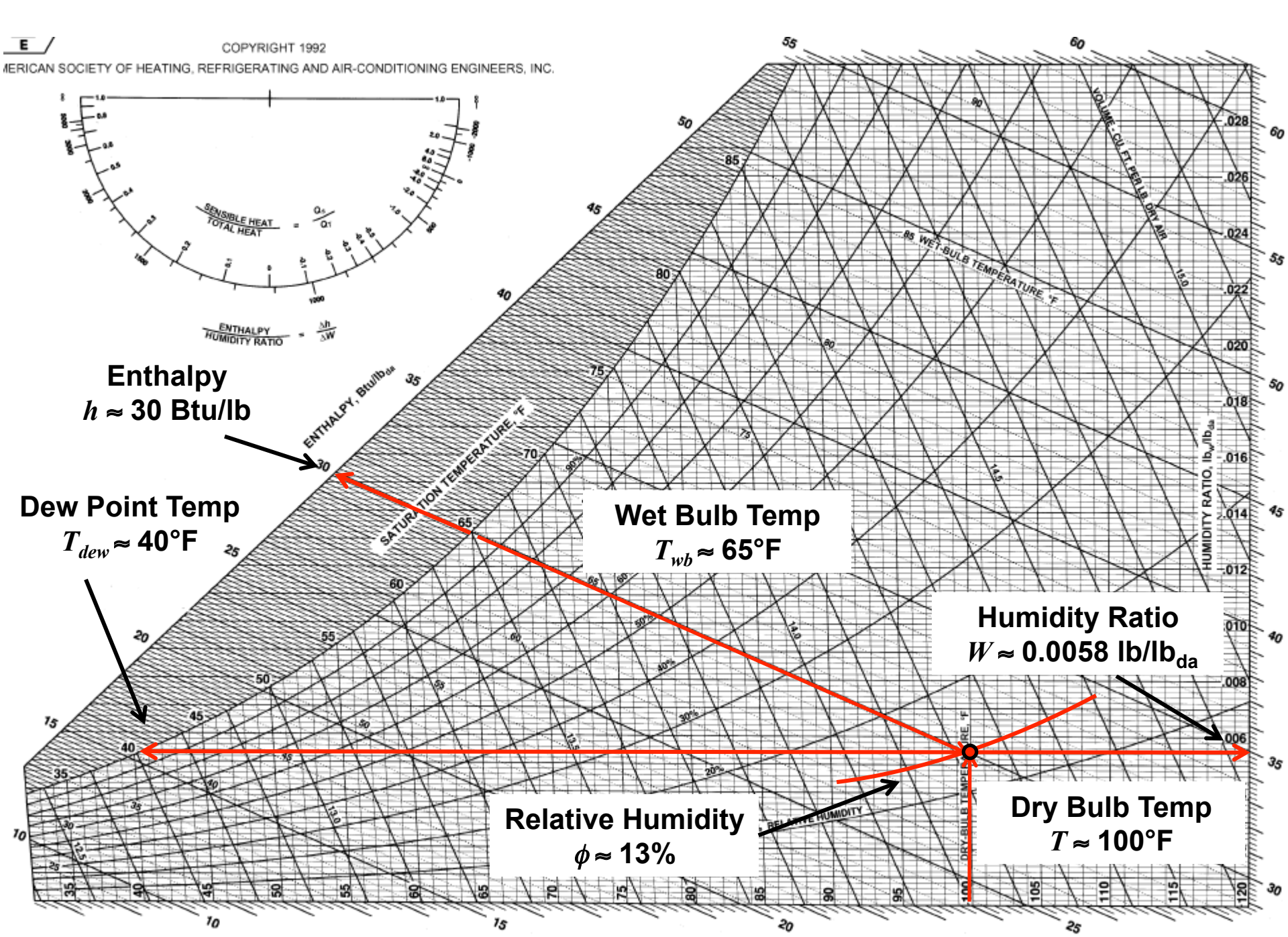
ENTHALPY / HUMIDITY RATIO = Δh / ΔW
ENTHALPY, Btu/lbda
SATURATION TEMPERATURE, °F
VOLUME-CU. FT. PER LB. DRY AIR
WET-BULB TEMPERATURE, °F
HUMIDITY RATIO, lbw/lbda
DRY-BULB TEMPERATURE, °F
10% RELATIVE HUMIDITY
Enthalpy
h ≈ 30 Btu/lb
Dew Point Temp
Tdew ≈ 40°F
Wet Bulb Temp
Twb ≈ 65°F
Humidity Ratio
W ≈ 0.0058 lb/lbda
Dry Bulb Temp
T ≈ 100°F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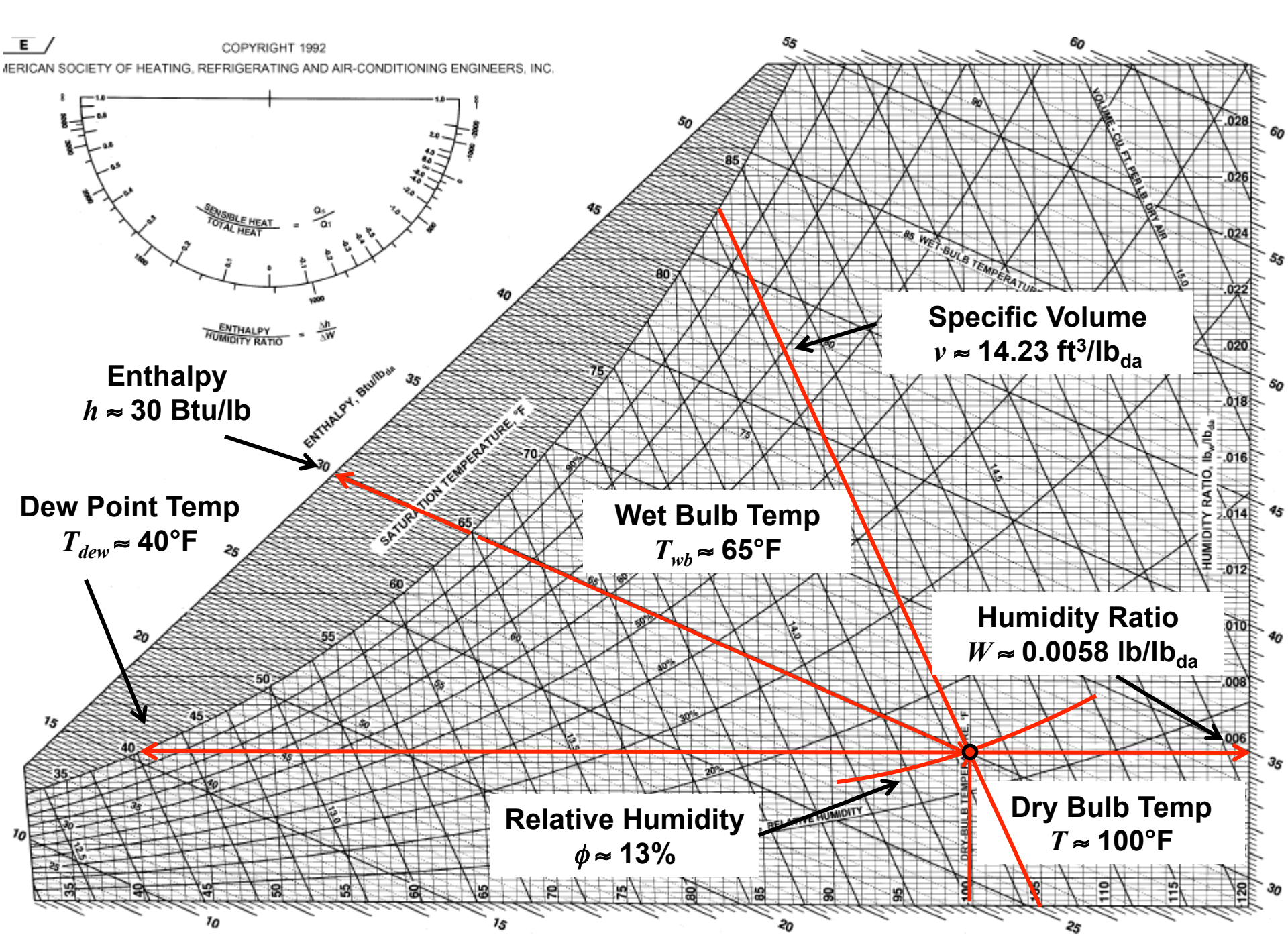
ENTHALPY / HUMIDITY RATIO = Δh / ΔW
ENTHALPY, Btu/lbda
SATURATION TEMPERATURE, °F
WET-BULB TEMPERATURE, °F
VOLUME, CU FT PER LB DRY AIR
HUMIDITY RATIO, lbw/lbda
RELATIVE HUMIDITY
DRY-BULB TEMPERATURE, °F
Enthalpy
h ≈ 30 Btu/lb
Dew Point Temp
Tdew ≈ 40°F
Wet Bulb Temp
Twb ≈ 65°F
Humidity Ratio
W ≈ 0.0058 lb/lbda
Relative Humidity
ϕ ≈ 13%
Dry Bulb Temp
T ≈ 100°F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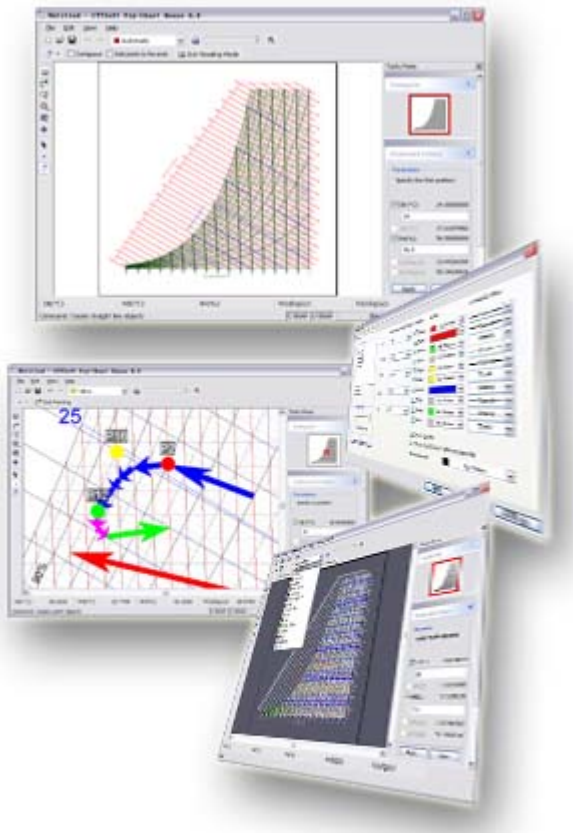
ENTHALPY / HUMIDITY RATIO = Δh / ΔW
ENTHALPY, Btu/lbda
SATURATION TEMPERATURE, °F
VOLUME, CU. FT. PER LB. DRY AIR
WET-BULB TEMPERATURE
HUMIDITY RATIO, lbw/lbda
DRY-BULB TEMPERATURE, °F
RELATIVE HUMIDITY
Specific Volume
v ≈ 14.23 ft³/lbda
Enthalpy
h ≈ 30 Btu/lb
Dew Point Temp
Tdew ≈ 40°F
Wet Bulb Temp
Twb ≈ 65°F
Humidity Ratio
W ≈ 0.0058 lb/lbda
Relative Humidity
ϕ ≈ 13%
Dry Bulb Temp
T ≈ 100°F

Applying psychrometrics

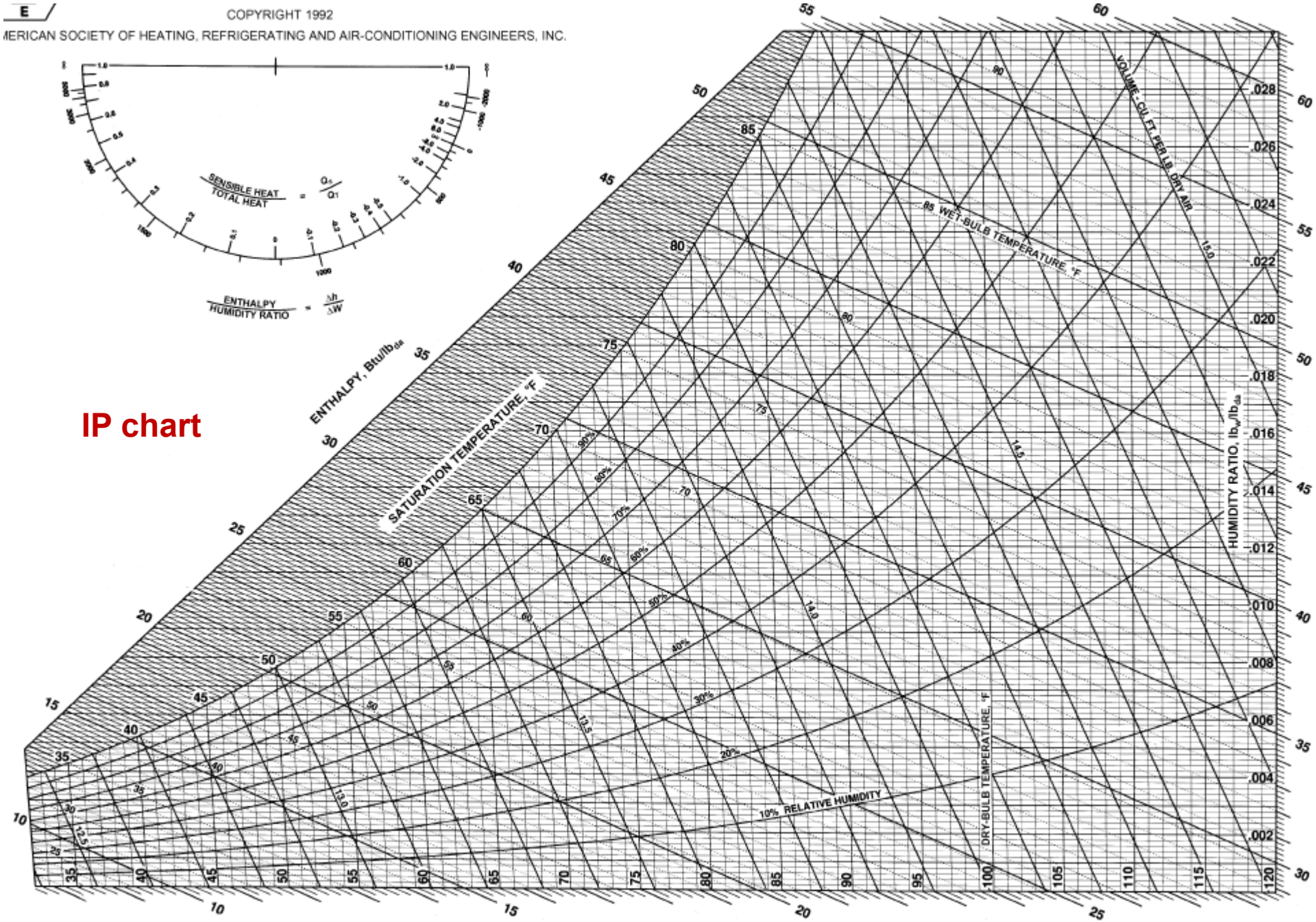


- We can also use psychrometric charts or software
  - Psych and Psychpro
    - Very popular psych chart and analysis software
    - I think at least one of these is in the AM 218 lab
- There are a bunch of online calculators as well
  - http://www.psychrometric-calculator.com
  - http://www.sugartech.co.za/psychro/
  - http://www.wolframalpha.com/examples/Psychrometrics.html
- And smart phone apps too
- You can also make your own (i.e., in Excel)
  - You will have a HW problem where you have to do this

Psychrometrics also involves learning how to use and combine those quantities to determine things like sensible and latent heating and cooling loads (i.e., ***processes***) (covered in a future lecture)

Using these parameters

- Question:
  - What is the mass of water vapor in this classroom right now?



IP chart