TAB (test-adjust-balance) in the Sustainable Environment & Lessons Learned

HVAC Excellence
Conference & Training
March 17-18, 2013   Tom Hanlon

Outline:

- Sustainable Environment??
  - ✓ LEED V3
  - ✓ Green Globes
  - ✓ ASHRAE 189
  - ✓ Federal & Local Energy Compliance
- NEBB- Who are we?
- Testing-Adjusting-Balancing (TAB)
  - ✓ Defined: NEBB
  - ✓ Process: Description.
    - Design-Specification
    - Preparation
    - Execution
    - Reporting
- TAB Value:
  - ✓ Lessons Learned

Open Forum and Questions

- Anyone here currently involved in LEED or Sustainable education or projects?
- Any involvement in construction, energy modeling or mechanical/electrical work which would require coordination with the CxA or Measurement-Verification provider?

Sustainable Venues

Sustainability

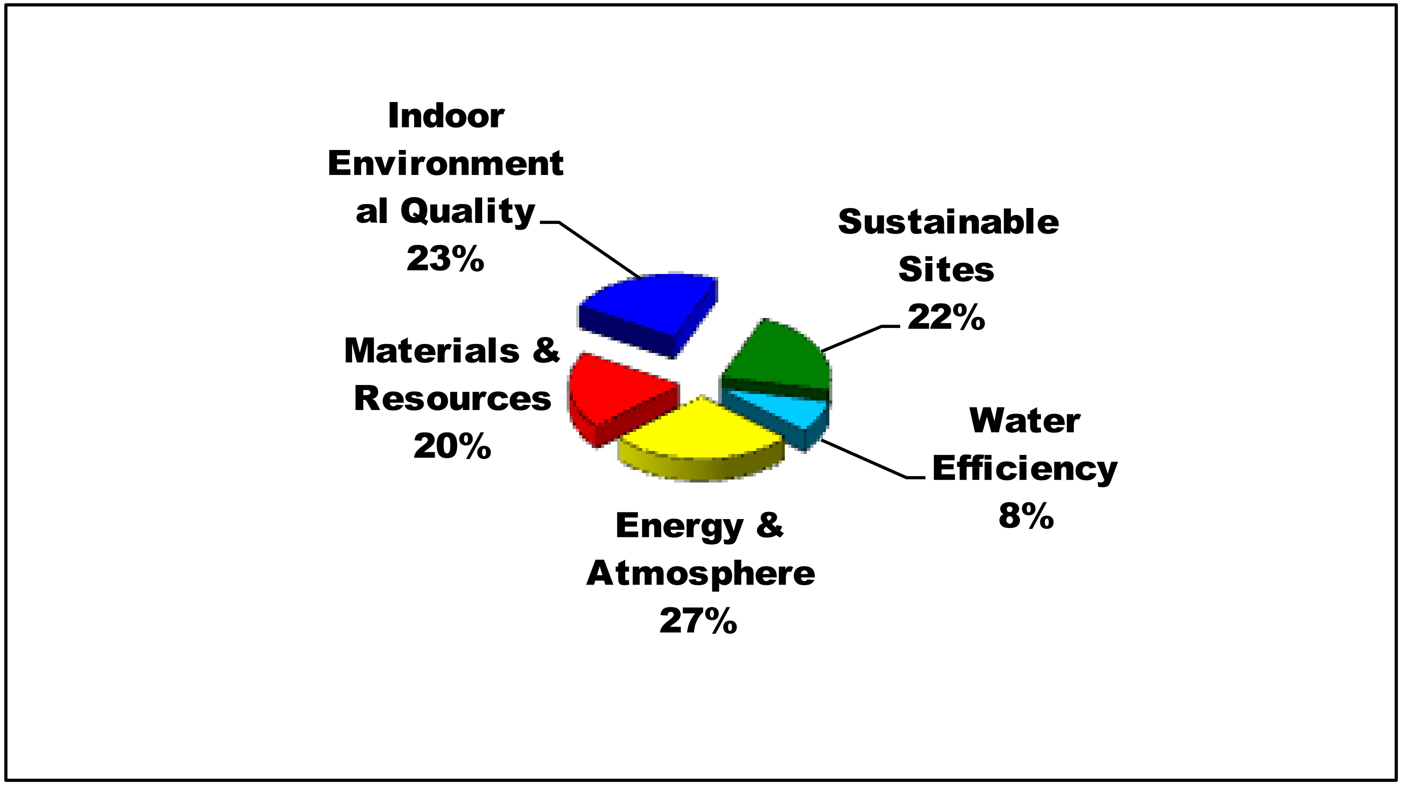
- “**Meet present needs without compromising the ability of future generations to meet their needs.**” (1987 UN Conference)
- Recognizes that the building industry and operations use **energy**, a typically limited and polluting resource.
- Also recognizes the impact of buildings and their systems on human health, physically, psychologically, and culturally.

USGBC & LEED

- LEED® (Leadership in Energy & Environmental Design) Rating System:
  - Initiated by USGBC, a non-profit organization formed to meet concerns over climate change and energy use in buildings.
  - The leading name in the green building industry.
  - Organizes green building into five categories: Sustainable Sites, Water Efficiency, Energy & Atmosphere, Materials & Resources, and Indoor Environmental Quality.

LEED-NC® Point Distribution

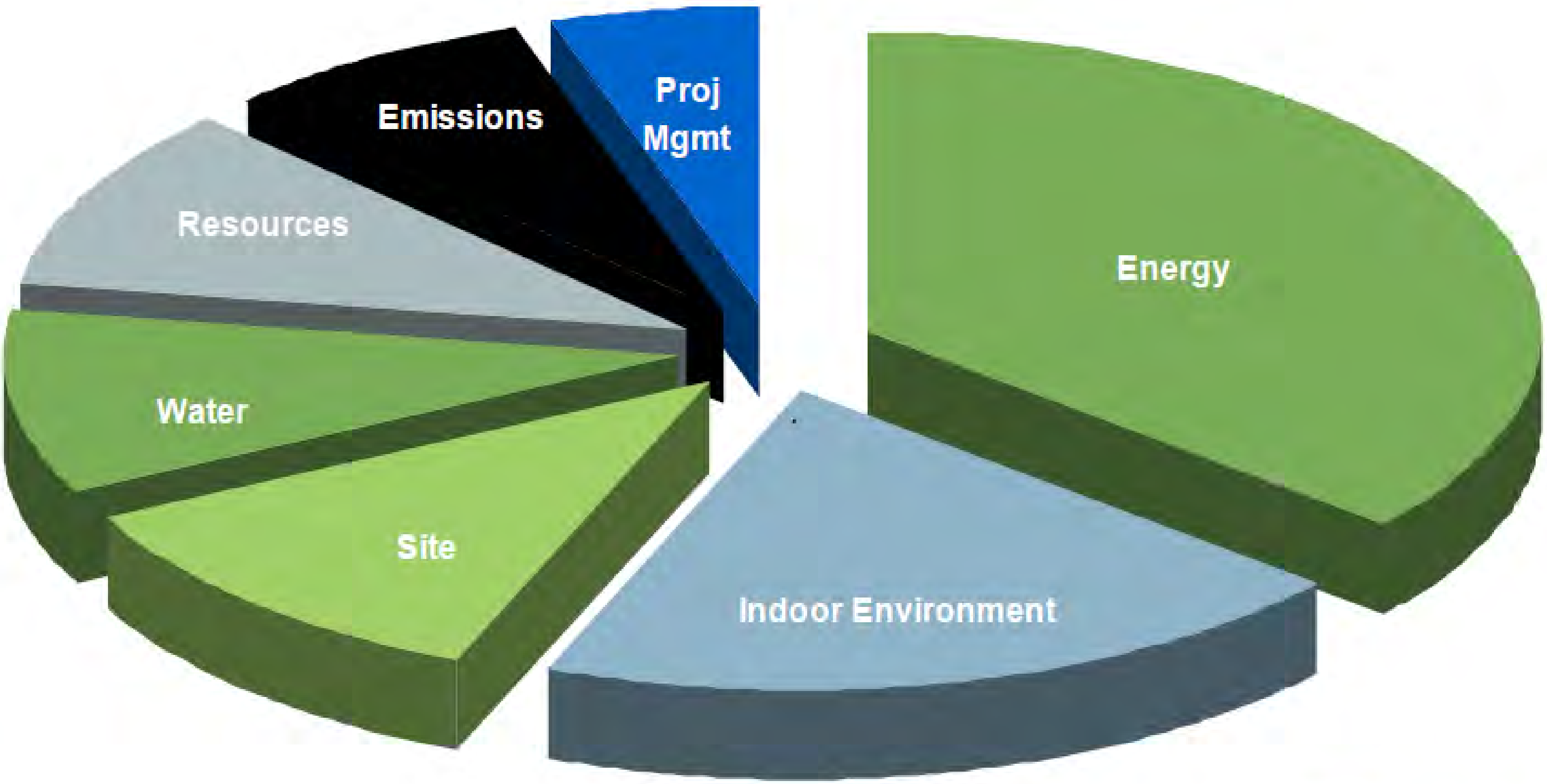
LEED credit categories



GBI & Green Globes

- The Green Building Institute was formed as a competitor in the same market for setting green building standards.
- Uses a less prescriptive approach in certifying buildings.
- Many organizations have adopted the Green Globes® Rating System as an equal alternative to LEED, such as the Department of Veterans Affairs.

Seven Areas of Assessment

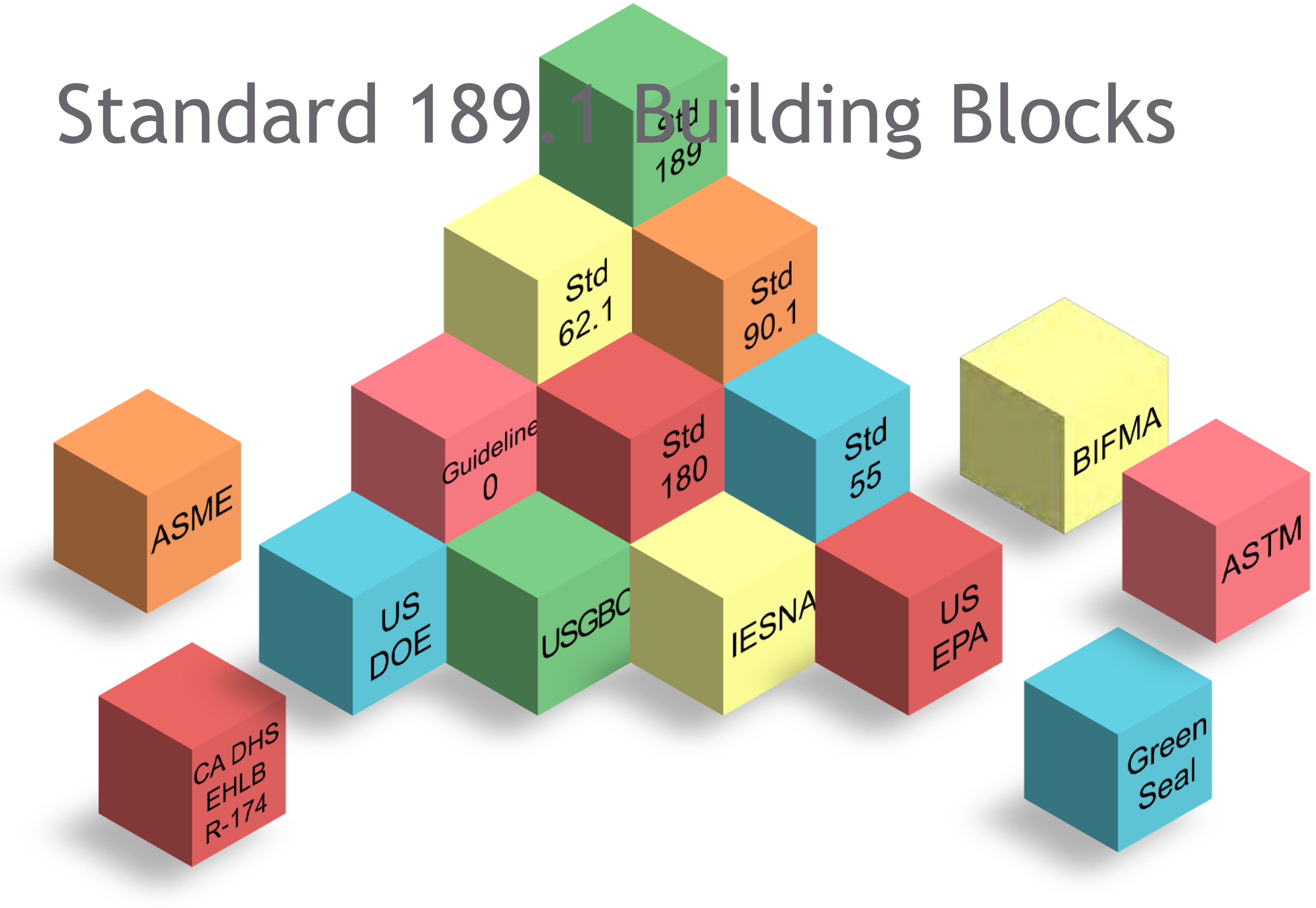


Standard 189.1

(American Society of Heating, Refrigerating, and Air-Conditioning Engineers)

- Sets standards for HVAC design, refrigerant use, indoor air quality, and ventilation.
- International organization comprised of many committees of HVAC&R professionals.
- Has been influencing and raising local building codes for years.

Standard 189.1 Building Blocks



Standard 189.1 Topic Areas

SS	Sustainable Sites
WE	Water Use Efficiency
EE	Energy Efficiency
IEQ	Indoor Environmental Quality
MR	Building's Impact on the Atmosphere, Materials & Resources
CO	Construction and Operations Plans

EPACT 2005

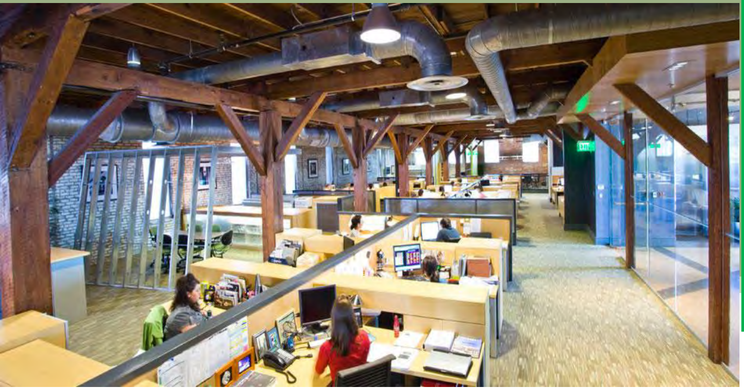
- The Energy Policy Act of 2005 (EPAct 2005), Sec.103,(a)
  1. Requires installation of meters and advanced electric meters on all federal buildings by the year 2012.
  2. According to guidelines set forth by the Department of Energy (DOE) in consultation with other federal agencies.

The New York Times

"Some Buildings Not Living Up to Green Label"

New Categories LEED 2012

- Integrated Process
- Location and Transportation
- ***"Performance"***



Delivering High Performance Building Systems: Solutions for Sustainable Spaces

NEBB overview

- Founded in 1971 By MCAA and SMACNA
- Independent Organization with affiliated firms worldwide
- 700+ Certified Firms worldwide
- 1,000+ Certified Professionals and 850 Certified Technicians worldwide
- Eight certified disciplines
- 27 chapters worldwide

NEBB disciplines

- Building Enclosure Testing (BET)
- Building Systems Commissioning (BSC)
- Clean room Performance Testing (CPT)
- Fume Hood Testing (FHT)
- Retro-Commissioning (RCx)
- Sound Measurement
- Testing, Adjusting & Balancing (TAB)
- Vibration Measurement



NEBB Focus for 2013

- Online testing exam
- Update NEBB's long term Strategic Plan
- Update the NEBB Procedural Standards and consolidated instrument list
- QAP Program – Stand alone
- ***Enrich the training of future Technicians and Professionals***



NEBB Focus for 2013 (continued)

- Strong working relationships with other industry and governmental organizations
- NEBB works with ASHRAE, IAPMO, NIBS, U.S. Department of Energy, EPA, IFMA, AIA, USGBC, BOMA, EPA, AHSE, ASME and others
- Introduction of job analysis review into BSC and RCx certification process review



Testing, Adjusting & Balancing

The NEBB Test & Balance Program provides technical resources, technical training and technical certification for the Certified Test and Balance firm.

- Experience
- Education
- Training
- Testing - Proof of Capability

NEBB TAB Technician Certification (CT)

- BOD-November 2009. "All NEBB Certified Firms will be required to have a NEBB Certified Technician on their NEBB jobs starting January 1, 2012. "
  - 11-2009 approximately 250 CTs
  - 01-2012 requirement, Approximately 2000 CTs.
- How to Implement??
  - Change the NEBB Culture!!
  - Invest and empower our Technicians!!
  - Keep up with system sophisticaion!!
  - Support the growing Cx environment!!

NEBB TAB Technician Certification

- Implementation: Define the education & experience requirements.
  - Four years (1000 hours minimum per year) or more of TAB fieldwork.
  - Two years (1000 hours minimum per year) or more of TAB Fieldwork & has successfully completed the NEBB TAB Technician Home Study Course.
  - Successfully completed a program equivalent to NEBB's Technician Qualification testing program. Typically an instructional seminar.
  - Practical skills affirmed and stipulated by firms CP and Chapter's TCC.

NEBB TAB Certified Professional (CP)

❑ Category A (2yrs)	❑ Category B (4yrs)	❑ Category C (8yrs)	❑ Category D (10yrs)
▪ Hold a Bachelor of Science Degree in Engineering AND ▪ Have at least **two** years of supervisory experience in selected discipline (TAB, S&V or BSC)	▪ Hold an Associates Degree in Engineering Technology AND ▪ Have at least **four** years of supervisory experience in selected Discipline (TAB, S&V or BSC)	▪ Have at least **four** years of experience in selected discipline AND ▪ Have at least **four** years of supervisory experience in selected discipline (TAB, S&V or BSC)	▪ Have at least **four** years of HVAC related experience (including accredited apprenticeship) AND ▪ Have at least **six** years in discipline experience with at least **four** of those years in a supervisory position.

NEBB TAB Certified Professional (CP)

- Implementation: Formal Testing:
  - Change from paper testing, with reference material available to On-line testing delivered in the on-demand format.
  - Required a complete change in question structure. Current test is delivered with random scrambling of questions. Current test bank is 500 questions.
  - Normal test is 150+ questions with four hour limit.
  - Only materials: Calculator, formula sheet, psychrometric chart, straight edge, ductulator

NEBB TAB Certified Professional Exams

- Implementation: Practical Testing
  - Complete "Hands-on" testing @ an approved testing site, administered by NEBB proctors.
  - Air Systems
  - Hydronic Systems
  - Currently 10 approved testing sites nationally, with two under construction.

NEBB TAB Certified Professional Exams

- Two portions of the TAB practical exam are available online at NEBB.org:
  - The two portions are Report Preparation and Error Finding.
  - This is a self administered exam. Candidates can take the exams as their schedule permits.
  - Candidates need not take the written exam prior to the practical exam.

- TAB CP written (online) exams are given twice yearly, March & Sptember.

NEBB Technical Seminars

- Learn about latest technologies and best practices from industry specialists.

- Seminars are posted on www.nebb.org

The TAB Process /

Experience !!

Education!!

Efficiency!!

Certified Professional vs. Technician

- Certified Professional: Develop and plan the work
- Technician: Implement and perform the work
- CP: Report Preparation
- T: Basic knowledge of forms
- CP: Recommending corrective action
- T: Identifying problems
- CP: Setting overall safety plan
- T: Understand Common safety practices

Certified Professional vs. Technician

- CP: Maintain instruments & calibration
- T: Know the proper use of instrumentation
- CP: Experience w/control strategies, sequence of operation, control systems equipment and software
- T: Basic knowledge of controls
- CP: Review, check, sign & stamp final report

Forward: TAB Definition

- ***TESTING*** is the use of specialized and calibrated instruments to measure temperatures, pressures, rotational speeds, electrical characteristics, velocities and air and water quantities for an evaluation of equipment and system performance.

- ***ADJUSTING*** is the final setting of balancing devices such as dampers and valves, adjusting fan speeds and pump impeller sizes, in addition to automatic control devices such as thermostats and pressure controllers to achieve maximum specified system performance and efficiency during normal operation.

- ***BALANCING*** is the methodical regulation of system fluid flows (air or water) through the use of acceptable procedures to achieve the desired or specified airflow or water flow.

Forward: TAB Rationale

“ The TAB phase of any building construction or renovation is intended to verify that all HVAC water- and air-flows and pressures meet the design intent and equipment manufacturer's operating requirements.

It is rare to find an HVAC system of any size that will perform completely satisfactorily without the benefit of final adjustments. This is why it is considered a "best practice" for the designer to specify that TAB work be part of the overall HVAC system installation.”

WBDG WHOLE BUILDING DESIGN GUIDE a program of the National Institute of Building Sciences

TAB Spec. Does it Matter?? YES!!!

Part 1-General:

- Definitions, Industry Standards (AABC, NEBB, ASHRAE)
- Contractor Selection: Who hires!!
- TAB Scope: Discuss special requirements.
- Quality Assurance: Credentials, Standards, Certification.
- Submittals:

❖ Standard submittal. Background, experience, credentials, instruments, certifications, sample forms.

❖ Contract Document Examination Report (Design Review) Due 45 days after Notice to Proceed!! Requires MEP review!!

❖ Site Examination Report. Readiness Check. Good protection for all.

❖ Certified Report. Must be as per the procedural standards and spec compliant. *Knowing what we asked for!! (Design Firm Education)*

Certified Professional CP

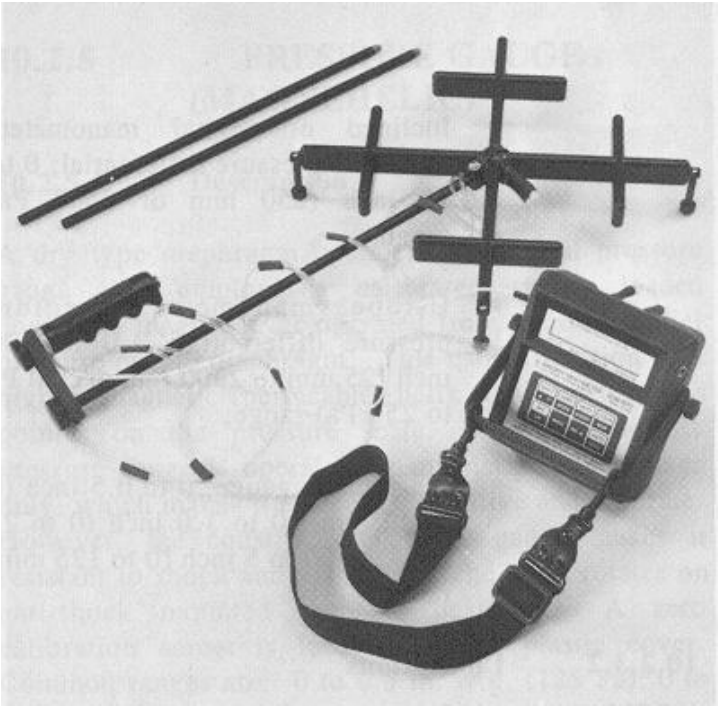
Pre-Balance activities

- Drawing Review & Setup
- Balance Form Creation
- Develop Schedule

Certified Professional CP

Pre-Balance activities

- Coordinate Job Staffing
- Review & Confirm Equipment Submittals
- Review Instrument & Equipment Use.



System Inspections

- **Verify Installation is complete**
- **Verify System Start-up is complete**
- **Good protection for all.**

Training The Technician

NEBB
Testing
Adjusting & Balancing
Fundamentals

Heat &
Heat Transfer

Heat Intensity & Quanity

Temperature

- Fahrenheit (°F)
- Celsius (°C)

Quantity

- BTUH

British Thermal Units per Hour

HEAT TRANSFER-TYPES

- Radiation
- Convection
- Conduction

Air Systems

- Sensible Heat
- Latent Heat
- Total Heat (Enthalpy)

Heat Transfer Equations

Air Equation (Standard Conditions):

$Q = 1.08 \times cfm \times \Delta t$

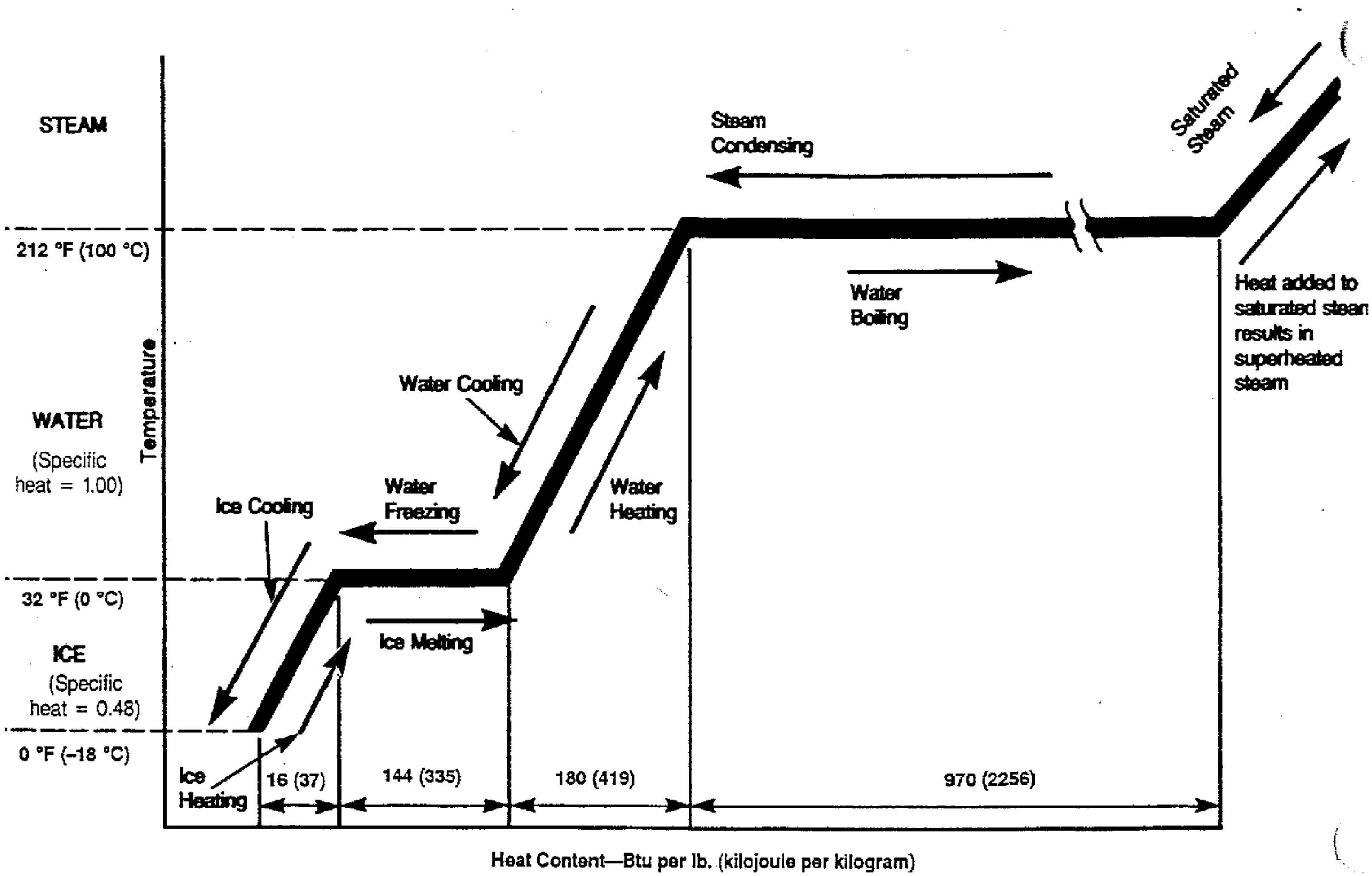
Total Heat Equation:

$Q = 4.5 \times cfm \times \Delta h$

Hydronic Equation :

$Q = 500 \times gpm \times \Delta t$

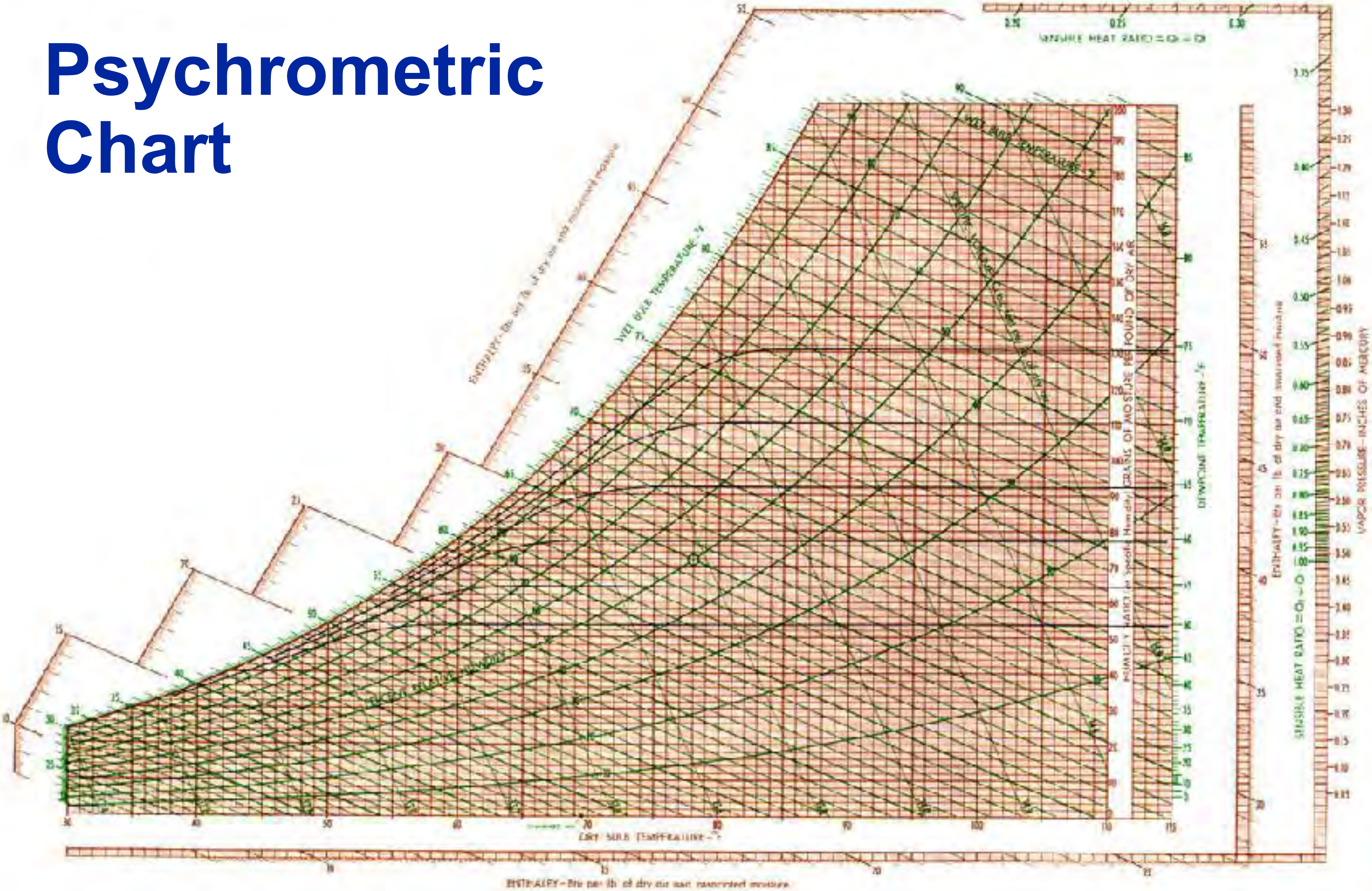
Changes of State



Psychrometry

The Psychrometric Chart

Psychrometric Chart

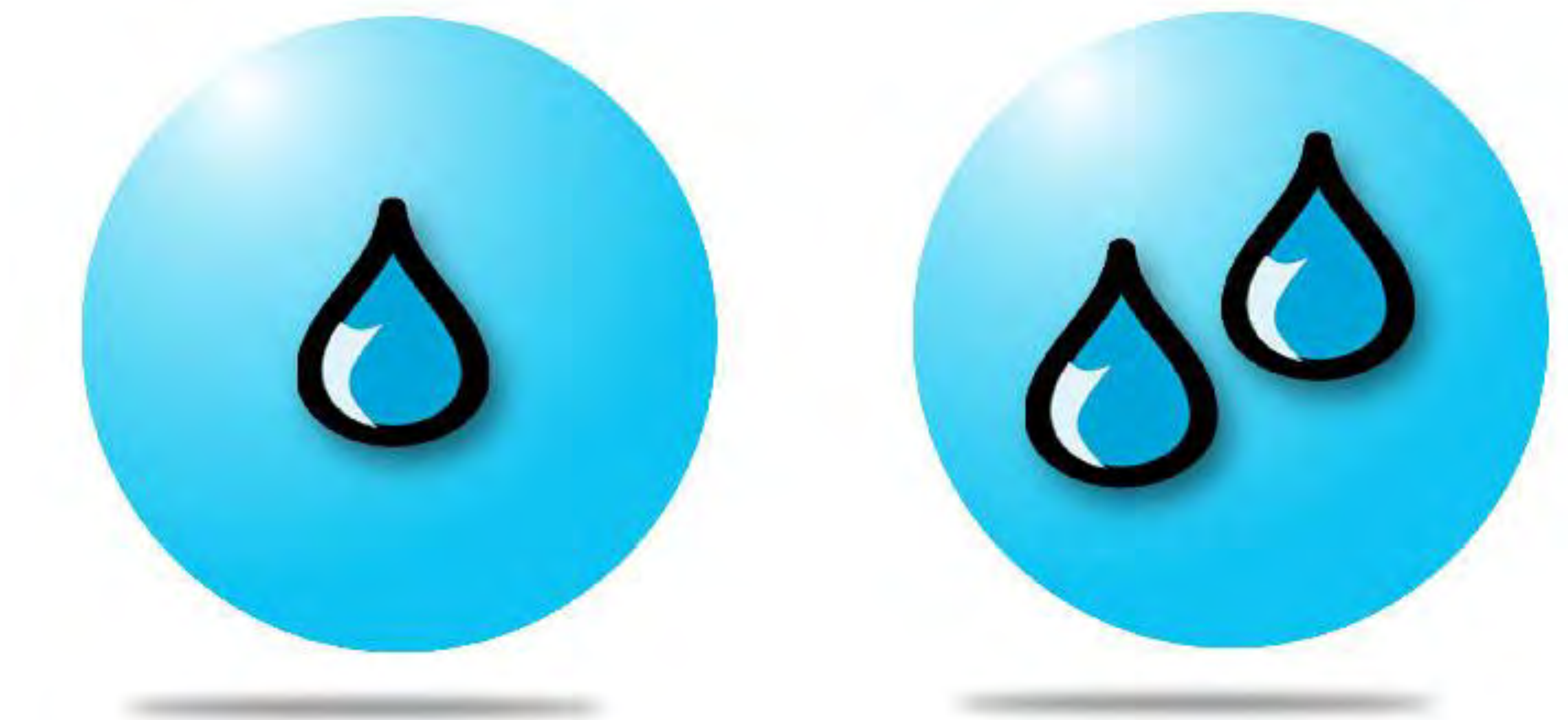


Properties of Air

- Dry-bulb temperature
- Wet-bulb temperature
- Dew-point temperature
- Relative humidity

Dry & Wet Bulb Thermometer

Relative Humidity



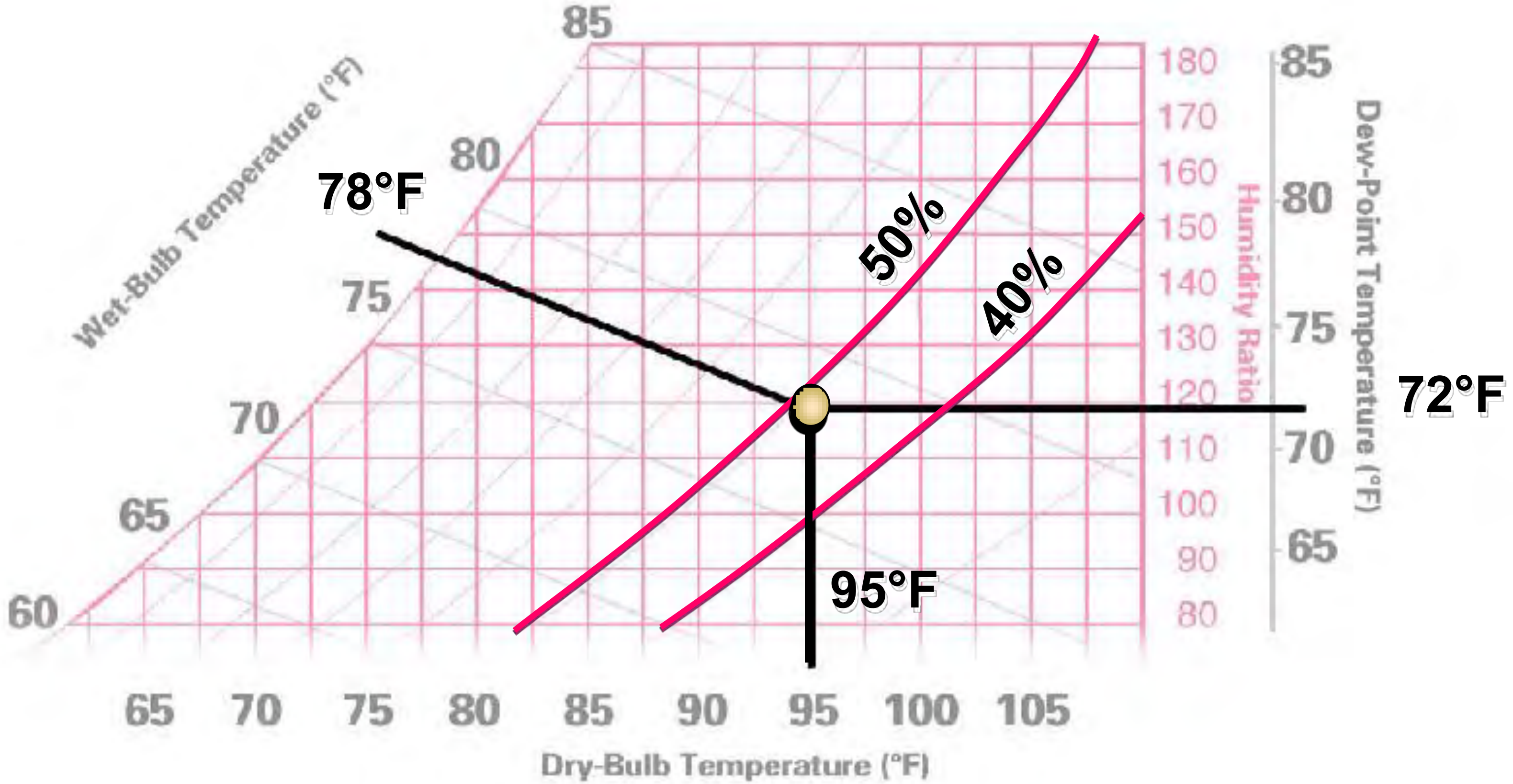
50%

100%
(saturated)

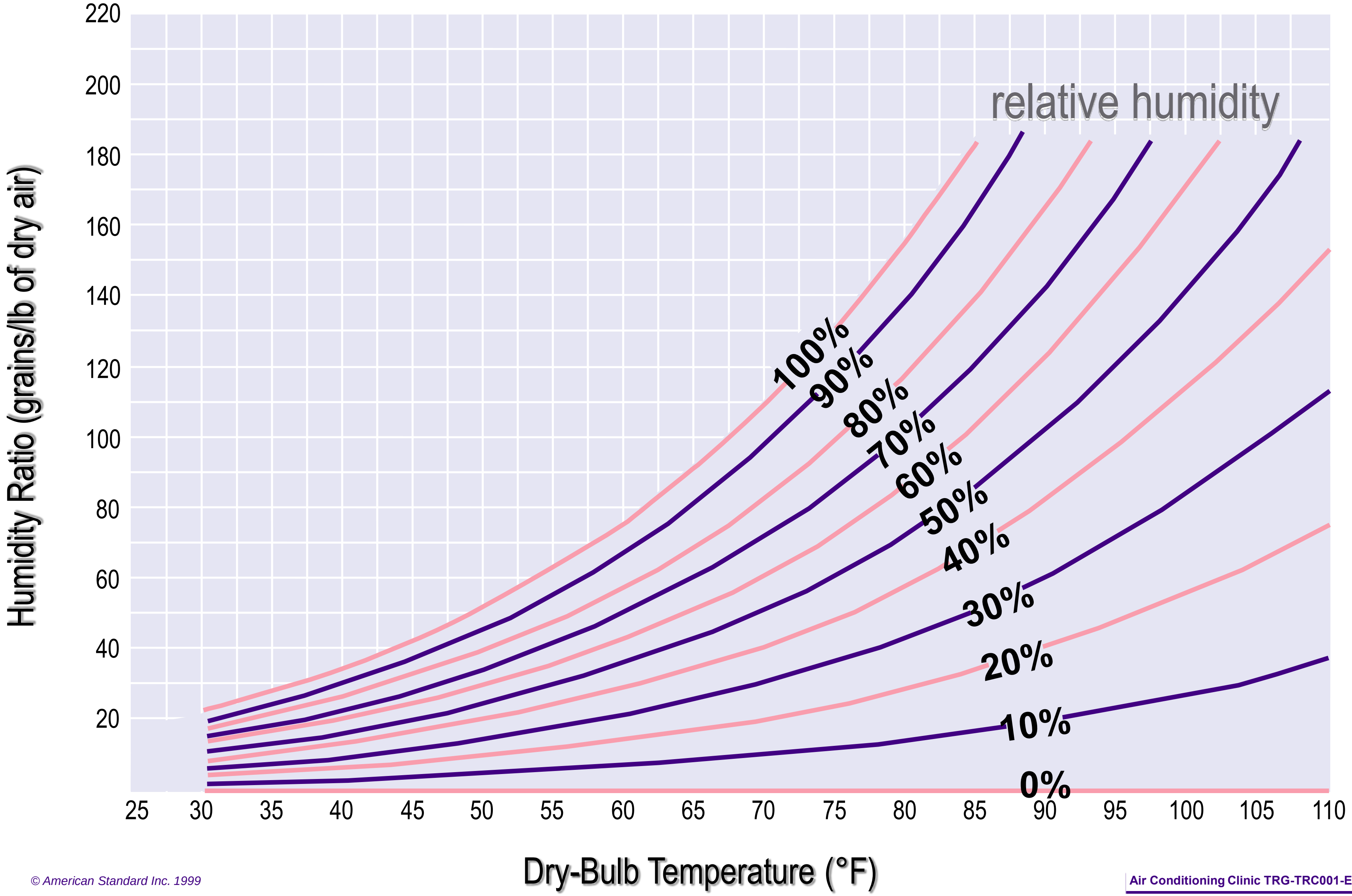
Summer Design Conditions

- 95°F DB (dry bulb)
- 78°F WB (wet bulb)

Point of Intersection

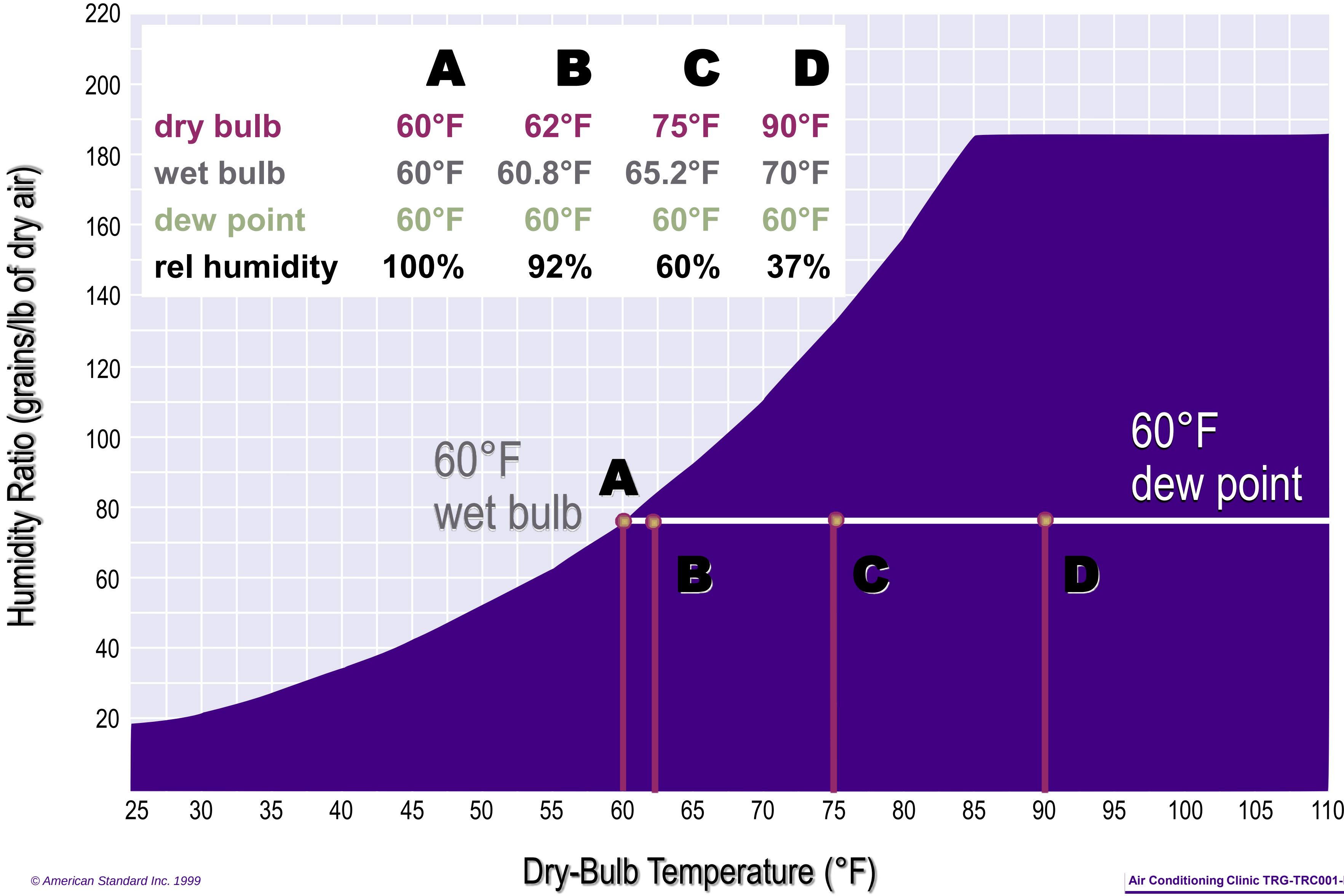


Relative Humidity Curves

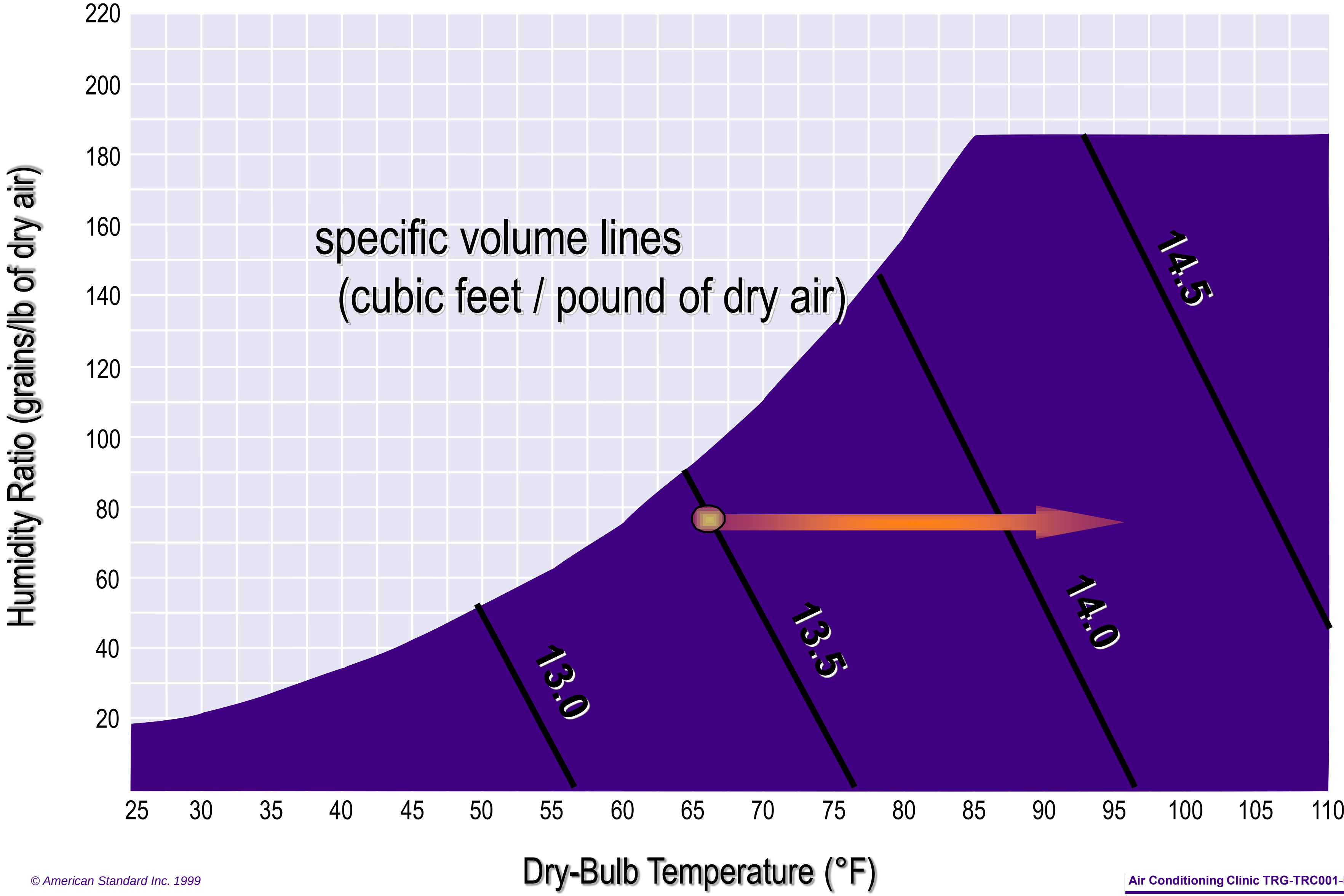


Dry Bulb, Wet Bulb and Dew Point

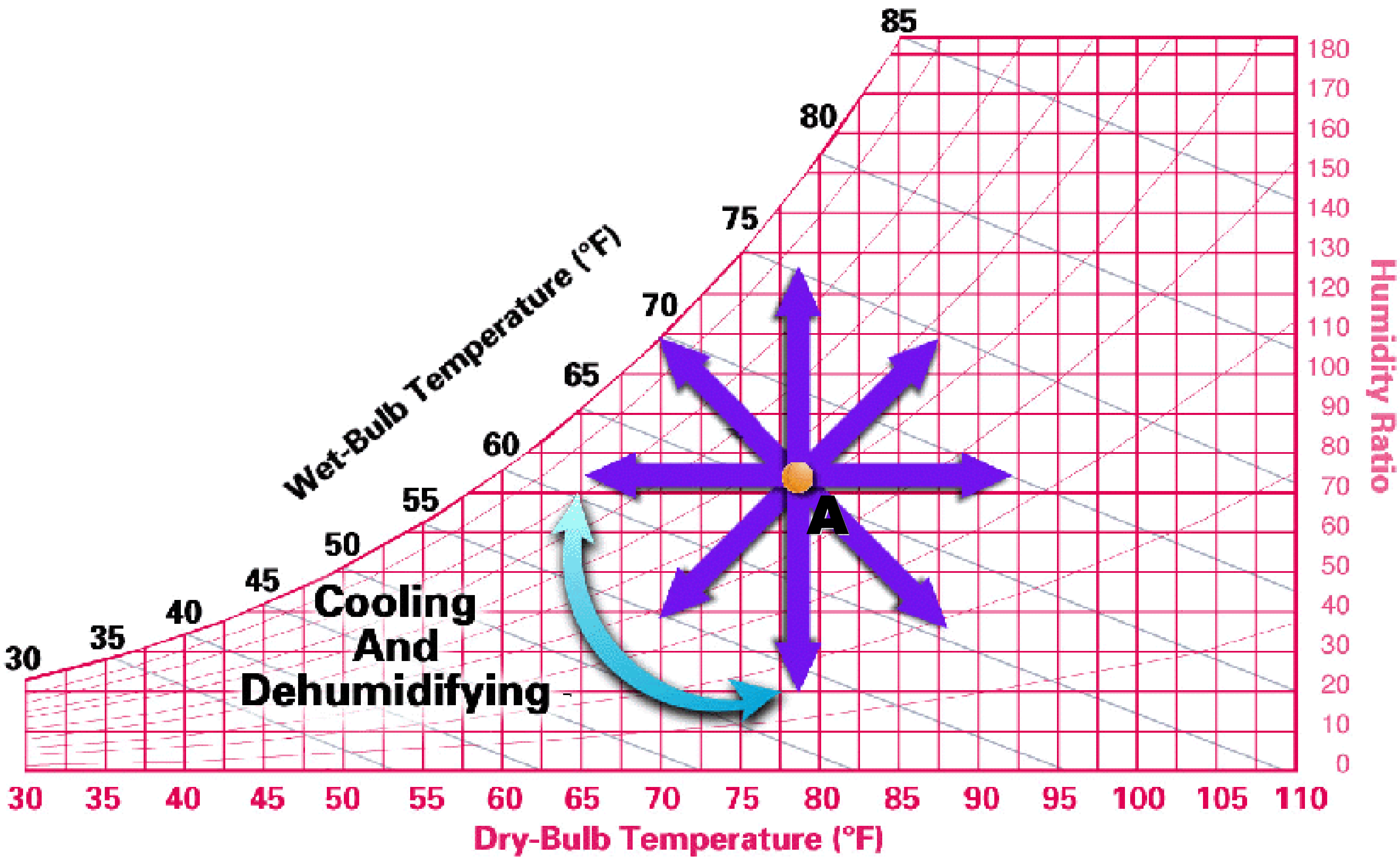
	A	B	C	D
dry bulb	60°F	62°F	75°F	90°F
wet bulb	60°F	60.8°F	65.2°F	70°F
dew point	60°F	60°F	60°F	60°F
rel humidity	100%	92%	60%	37%



Specific Volume



Removing Sensible Heat and Moisture

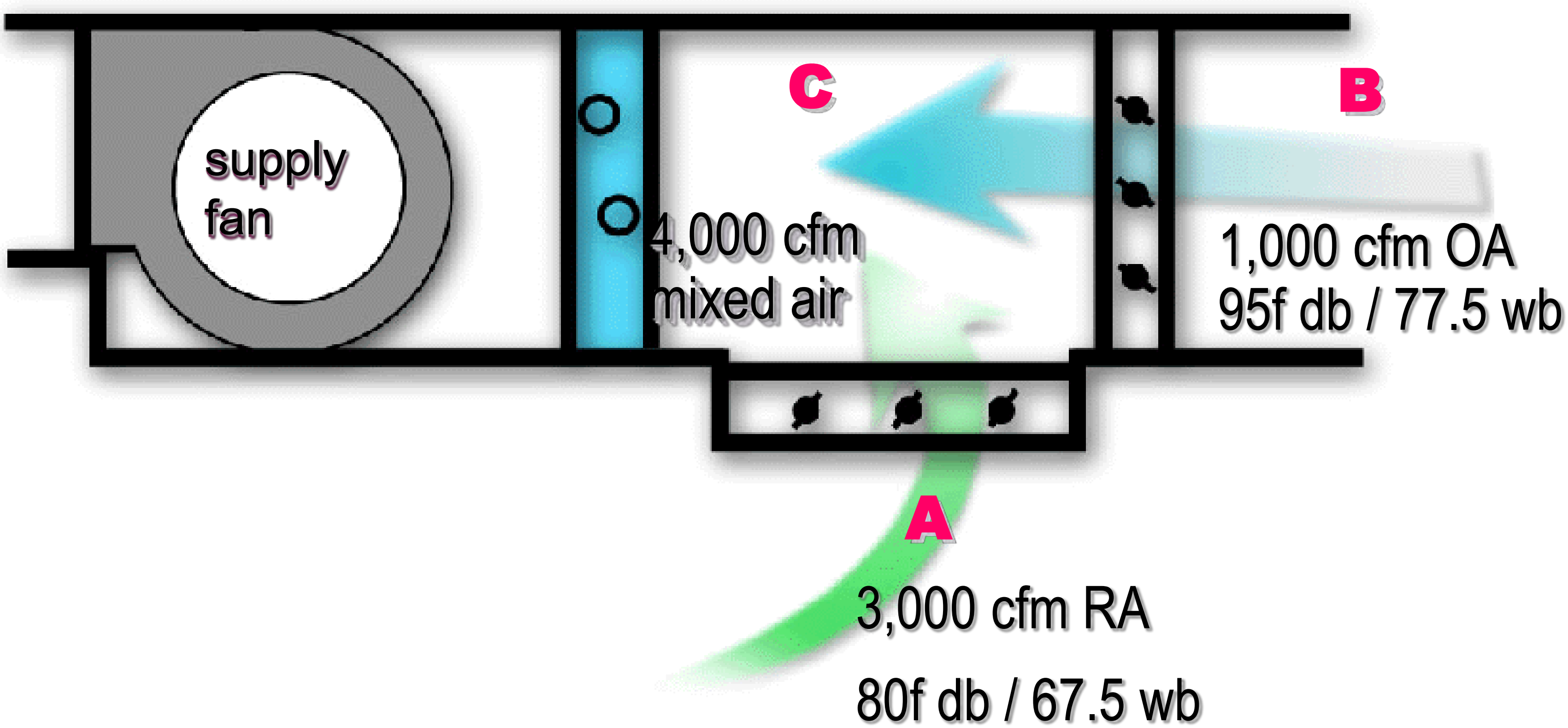


Psychrometry Problem #1

Given the Following: Dry Bulb Temp 90f & 76f
Dew Point find the following:

- Wet Bulb Temp.
- Grains of Moisture
- Specific Volume

Determining Entering Air Conditions

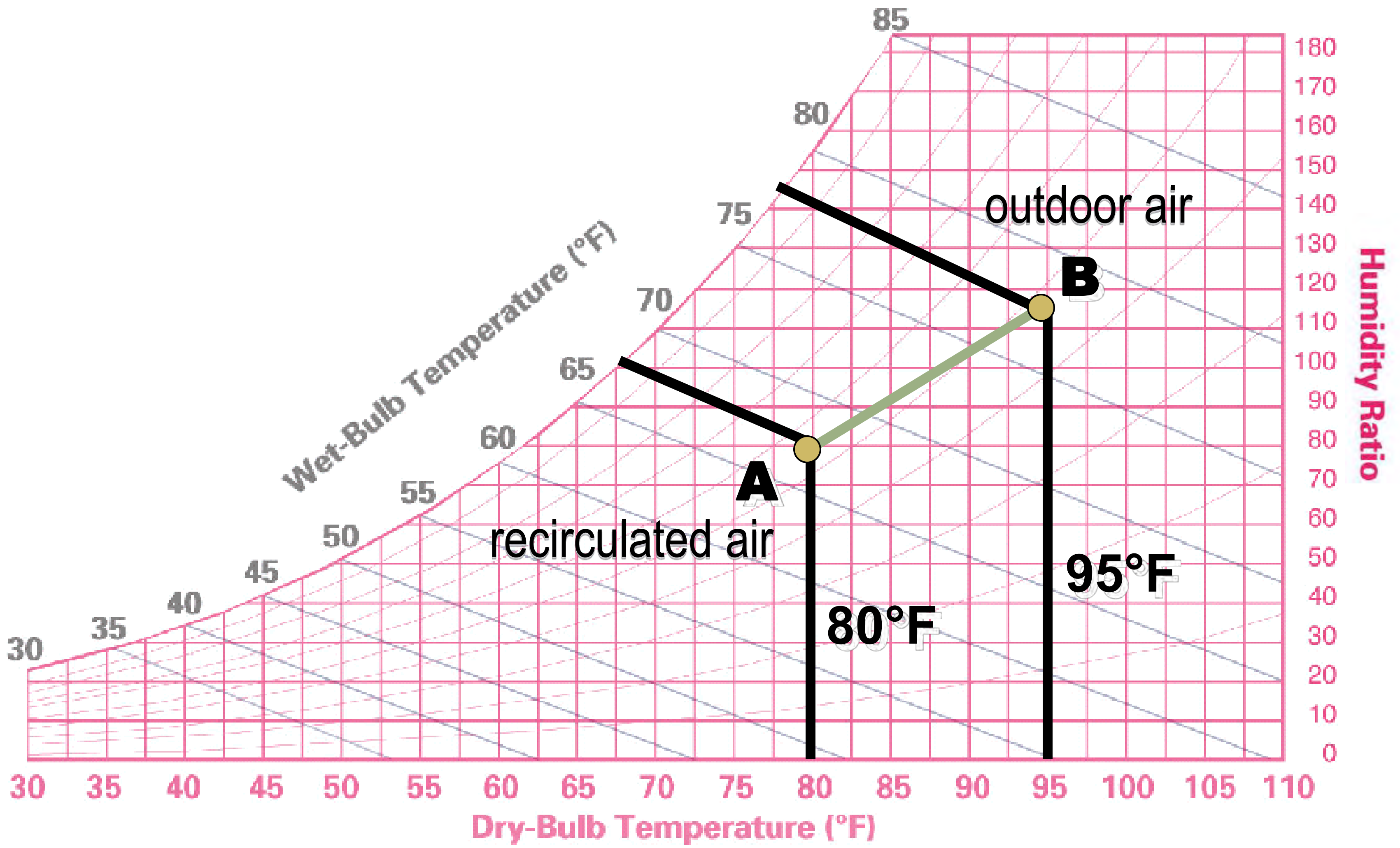


$$95°F \times 0.25 = 23.75°F$$

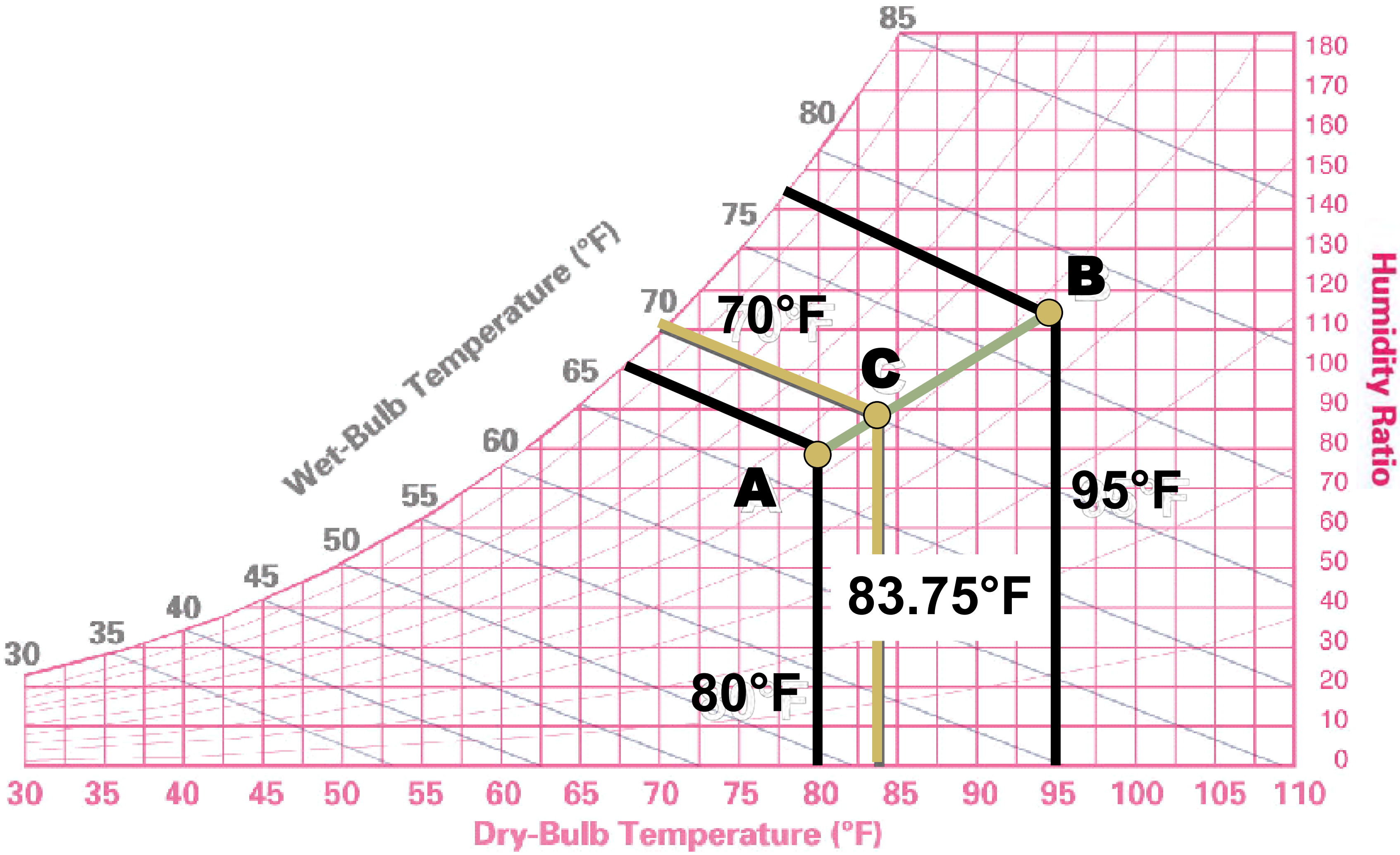
$$80°F \times 0.75 = 60.00°F$$

$$\text{mixture} = 83.75°F$$

Determining Entering Air Conditions



Determining Entering Air Conditions



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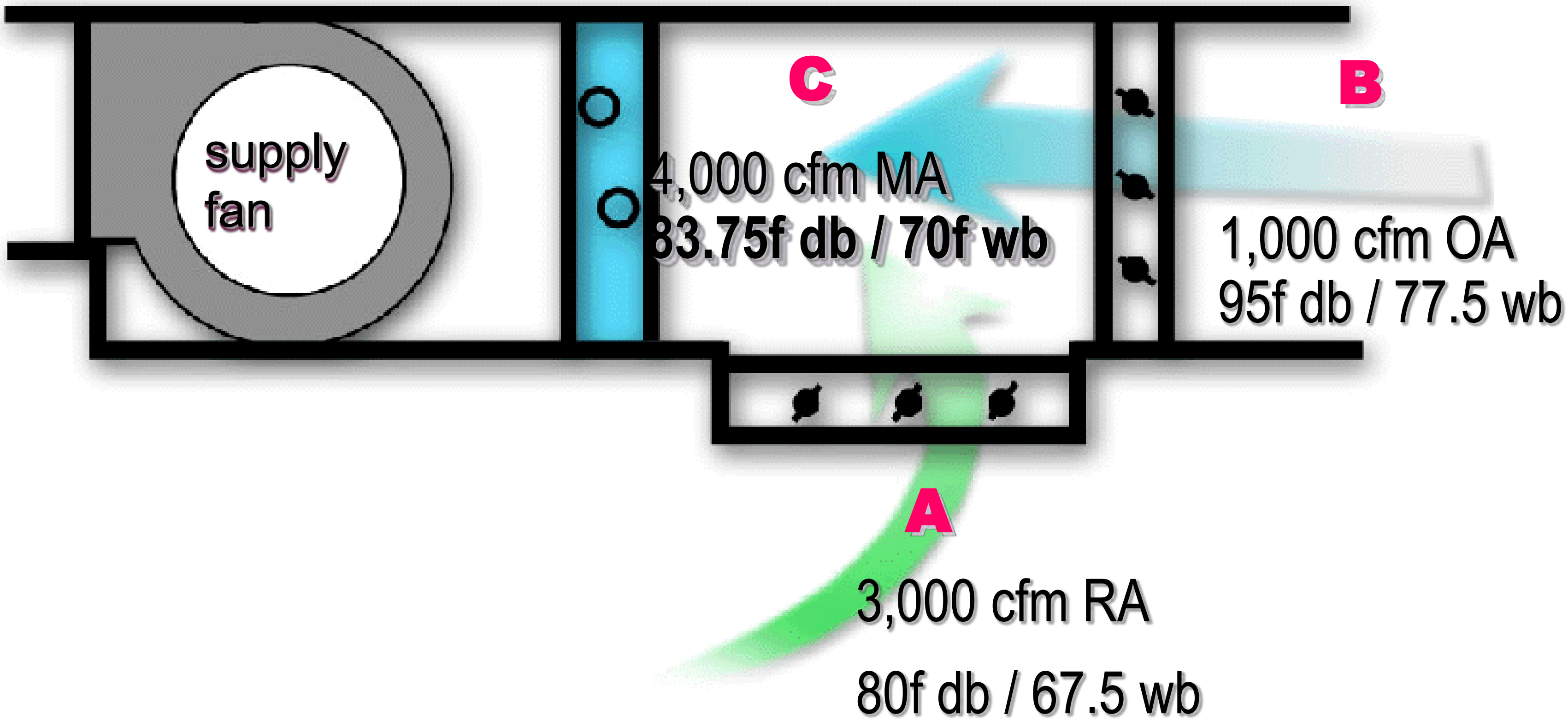
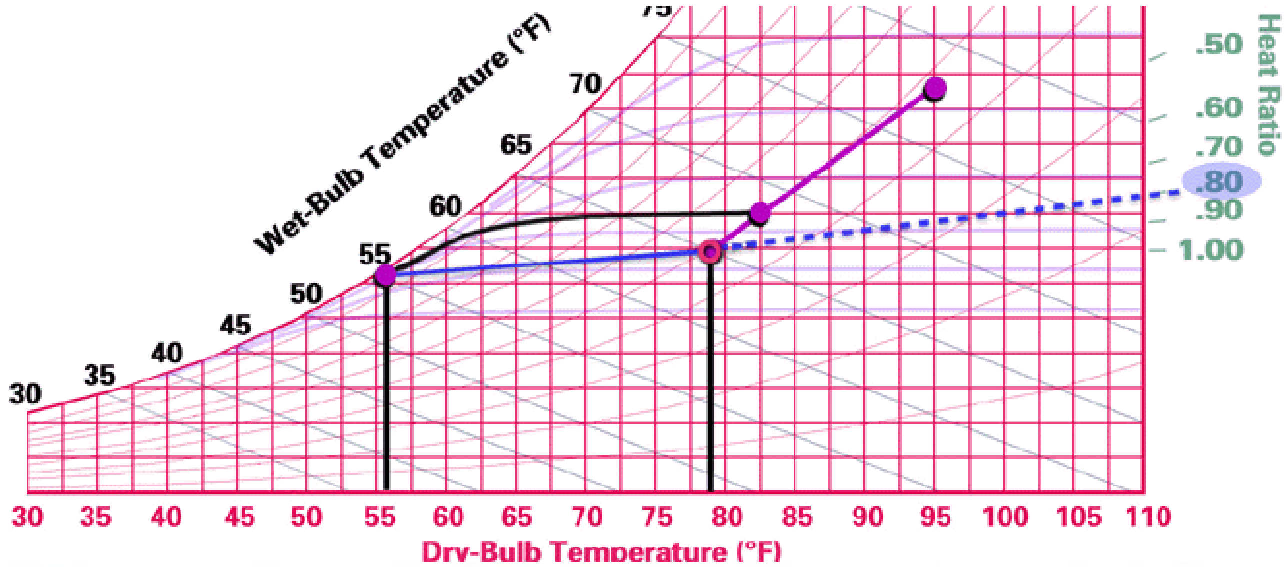


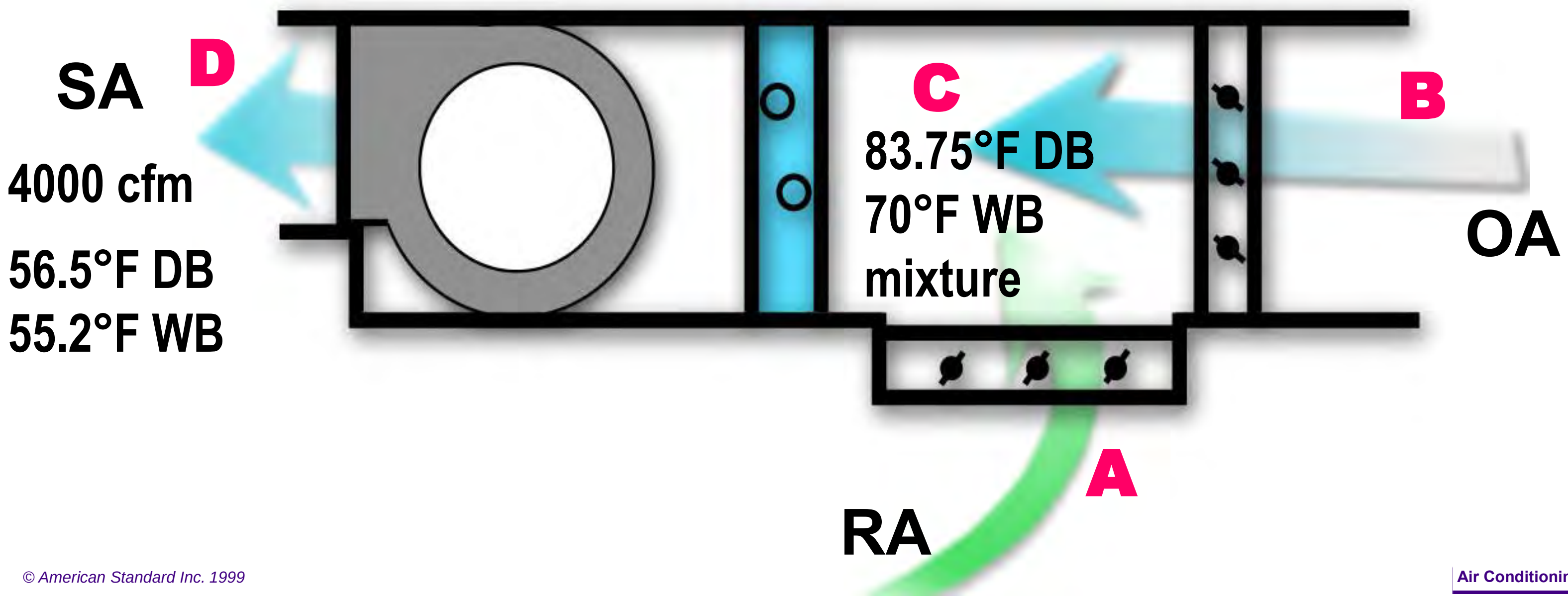
What is Enthalpy?

The total heat energy in one pound of air (Btu/lb) at its present condition.

Enthalpy (*h*) = Sensible Heat + Latent Heat

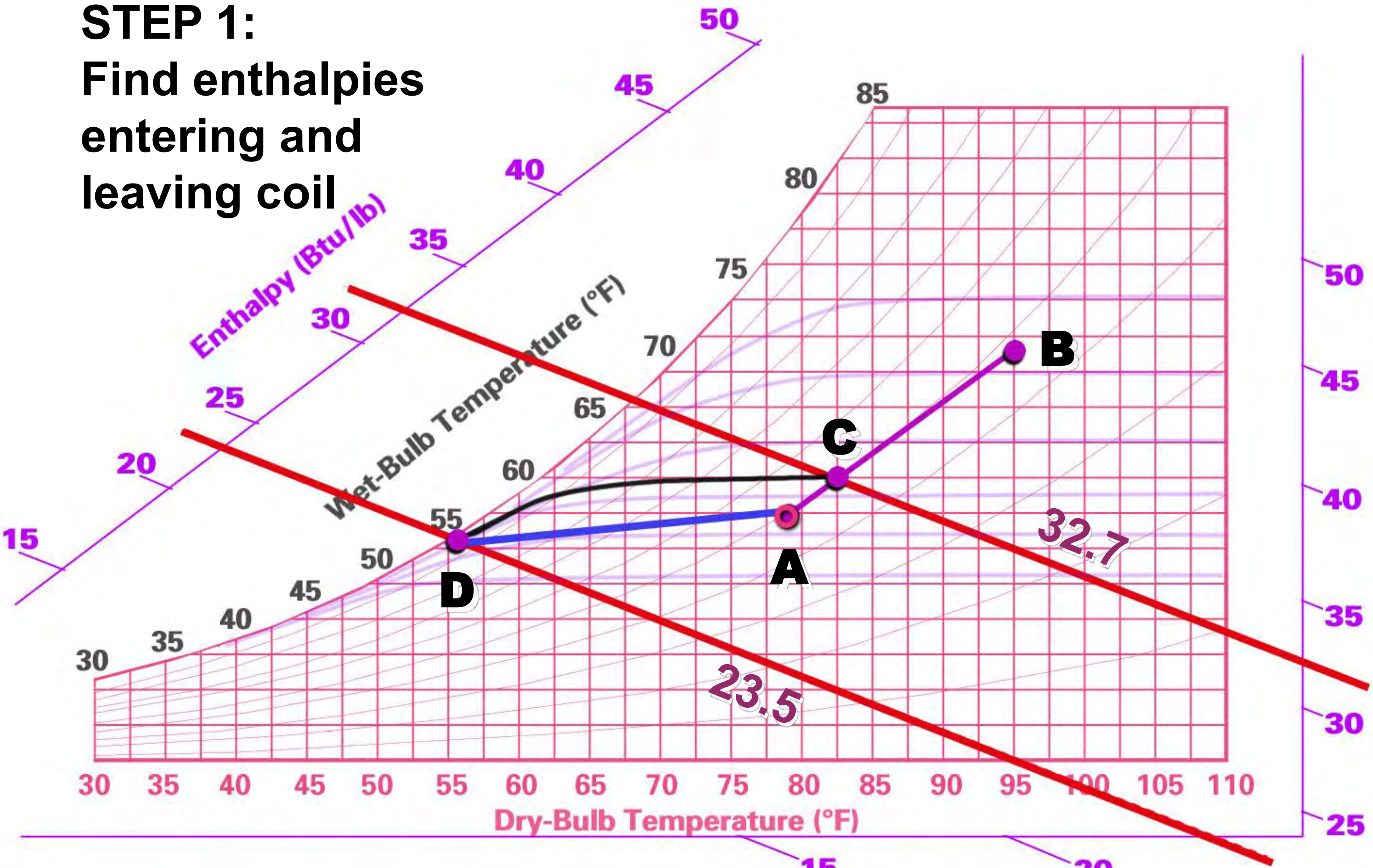
Determining Supply Airflow





Determining Tons of Refrigeration

STEP 1:
Find enthalpies entering and leaving coil



Determining Tons of Refrigeration

STEP 2: Solve the total refrigeration load equation

$$\text{Refrigeration Load (Btu/hr)} = 4.5 \times \text{Supply Airflow} \times (h_1 - h_2)$$

h_1 = enthalpy of air entering coil (Btu/lb)
h_2 = enthalpy of air leaving coil (Btu/lb)

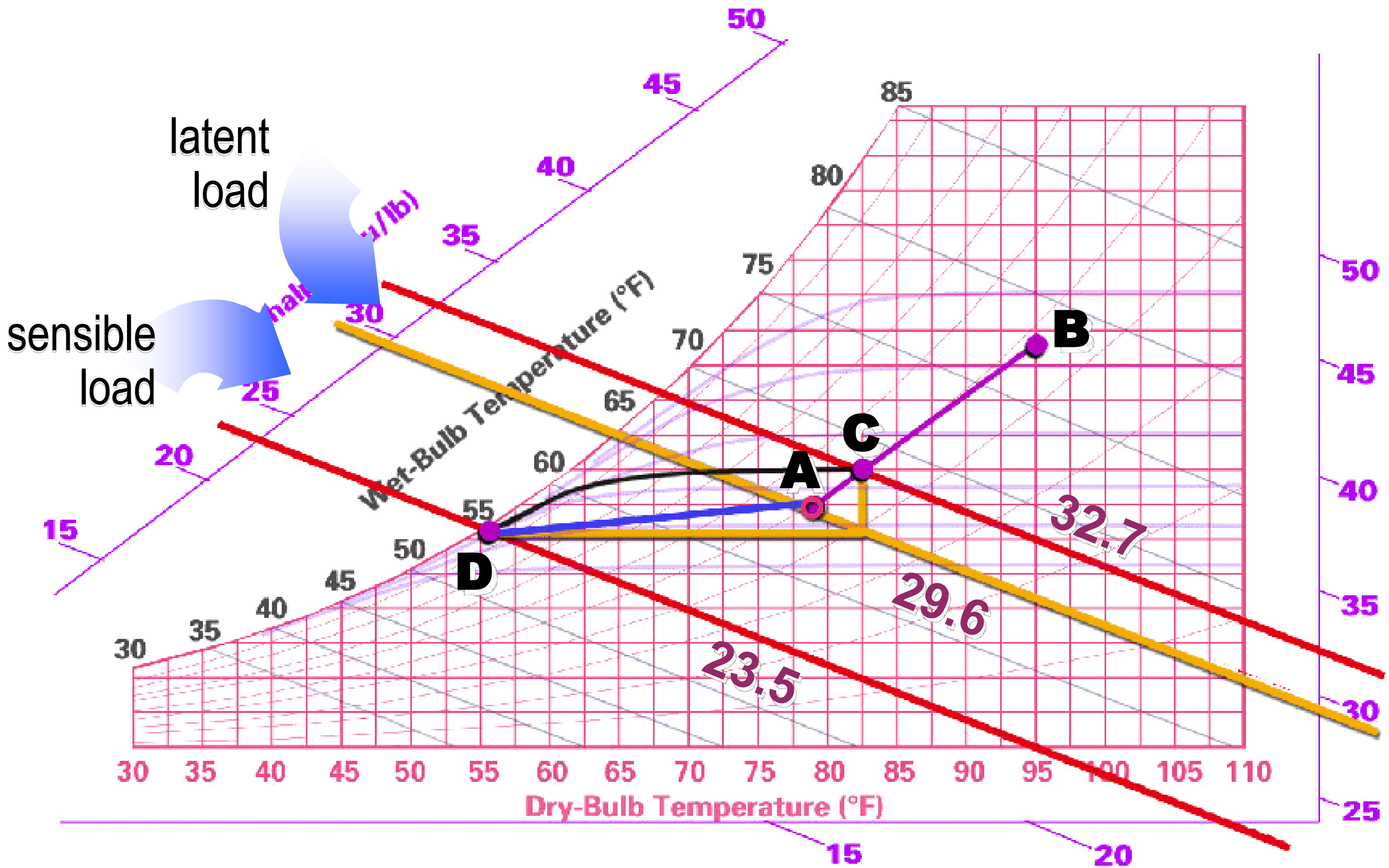
Determining Tons of Refrigeration

STEP 2: Solve the total refrigeration load equation

$$4.5 \times 4000 \text{ cfm} \times (32.7 - 23.5) = 165{,}600 \text{ Btu/hr}$$

$$\frac{165{,}600 \text{ Btu/hr}}{12{,}000 \text{ Btu/hr/ton}} = 13.8 \text{ tons of refrigeration}$$

Sensible and Latent Coil Loads



Air Systems Testing

Fluid Statics - Dynamics

Statics

- Air – Inches of water

Dynamics

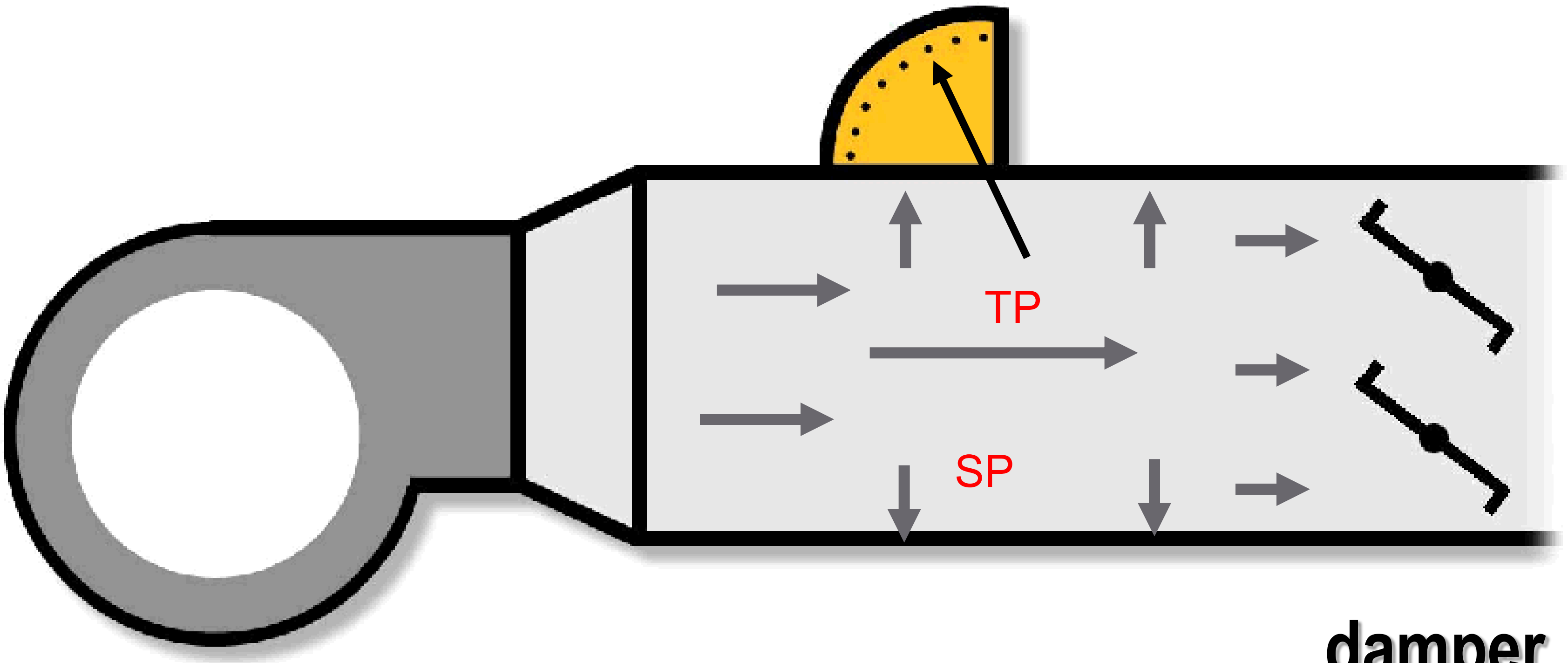
- Q = V x A for air & water
- where: Q= cfm V=Velocity A= Duct Area F^2

Pressures

- Static Pressure SP
- Total Pressure TP
- TP = SP + VP (in.w.g. or Pascals)

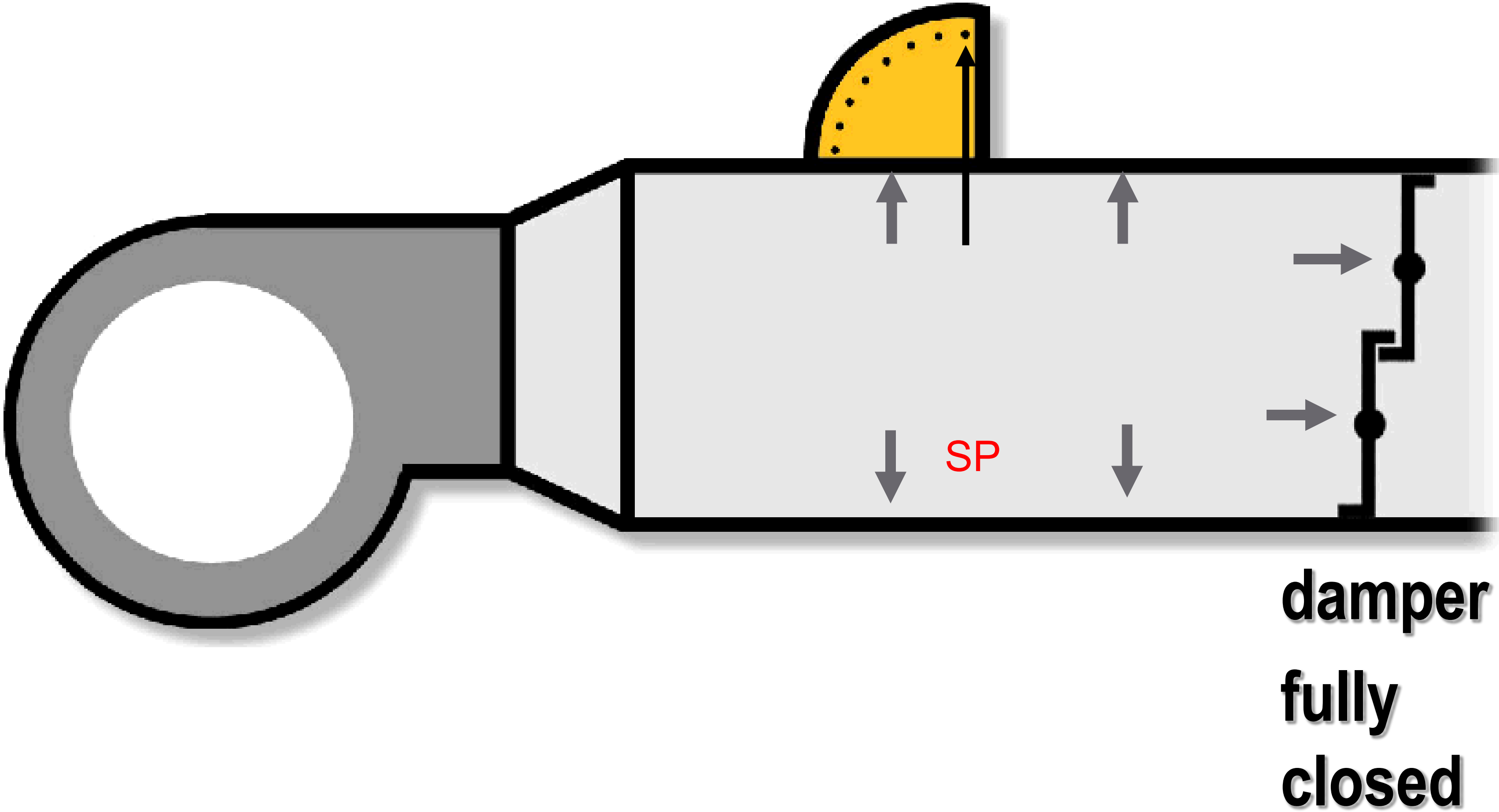
- Velocity Pressure VP
- $VP = (V/4005)^2$ IP

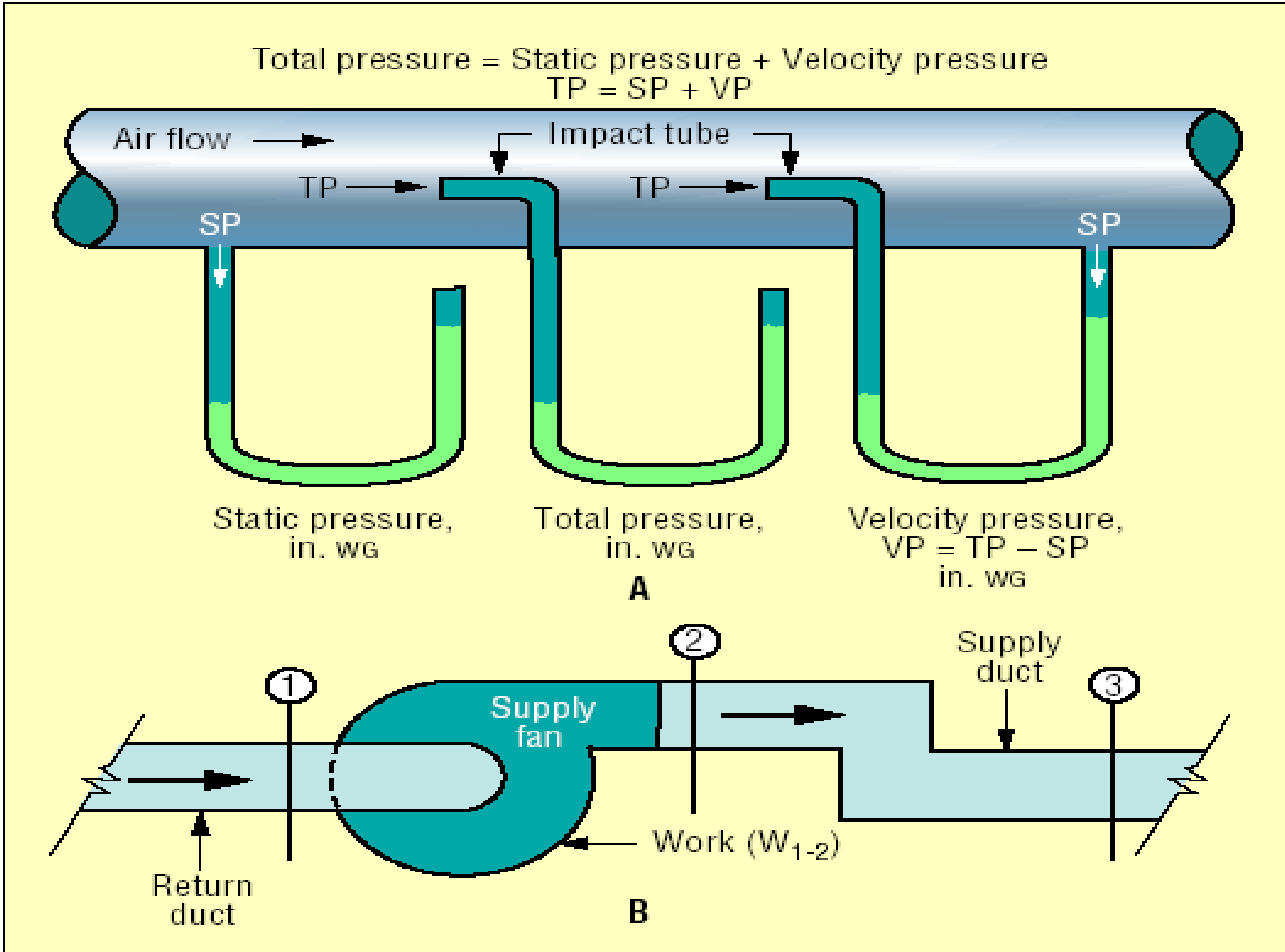
Total Pressure vs. Static Pressure

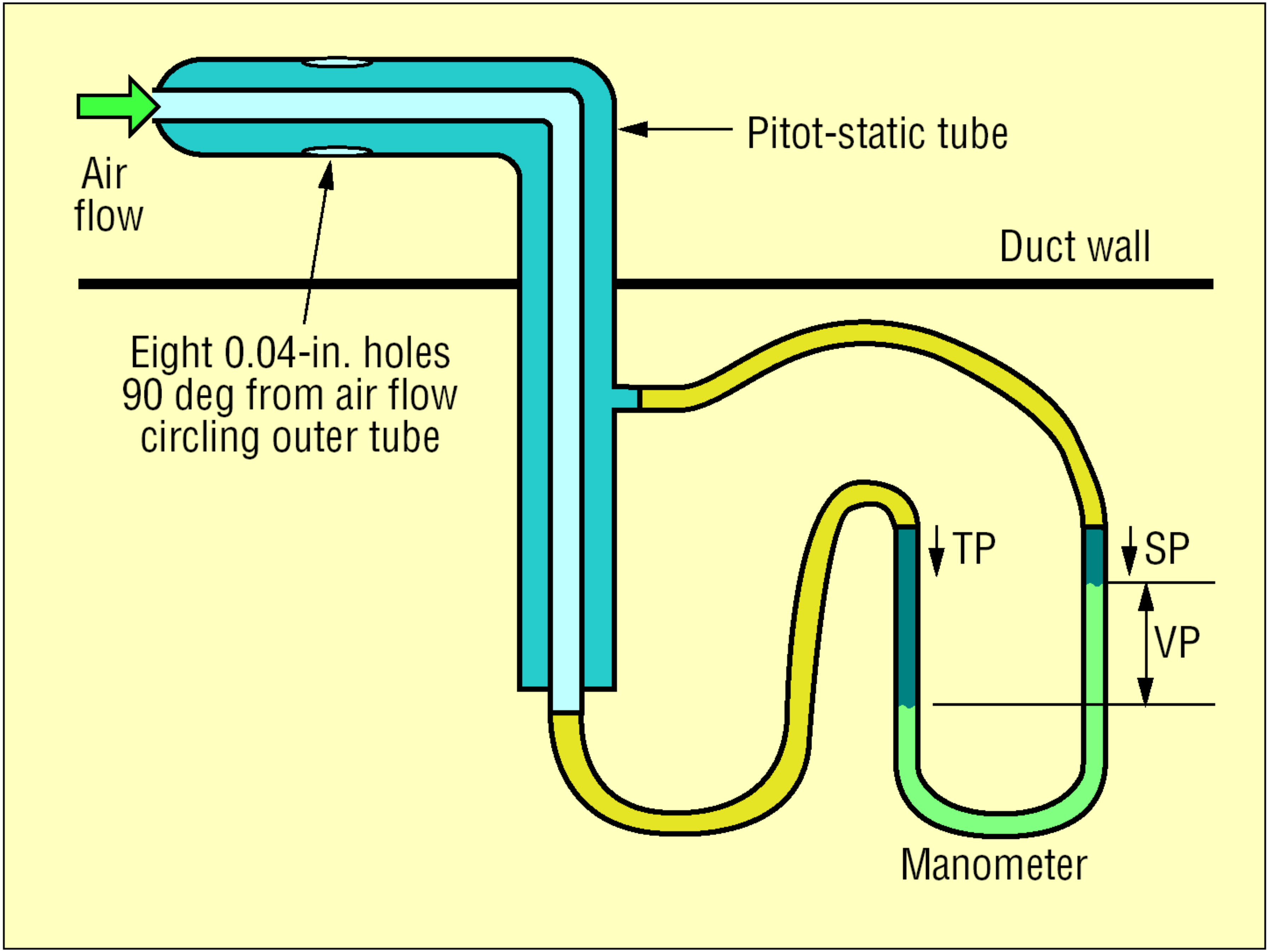


damper partially open

Velocity Pressure vs. Static Pressure

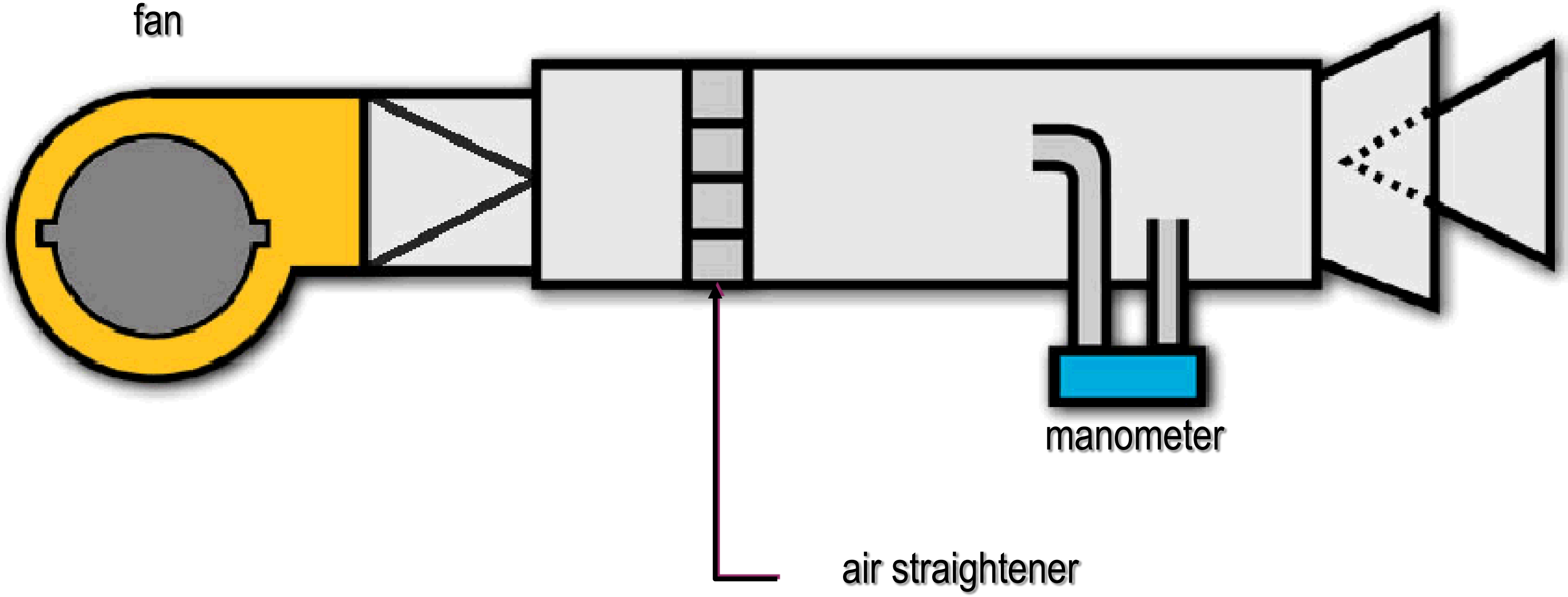



Total pressure = Static pressure + Velocity pressure
TP = SP + VP
Air flow
Impact tube
TP
TP
SP
SP
Static pressure,
in. WG
Total pressure,
in. WG
Velocity pressure,
VP = TP – SP
in. WG
A
Supply fan
Supply
duct
1
2
3
Work (W1-2)
Return
duct
B

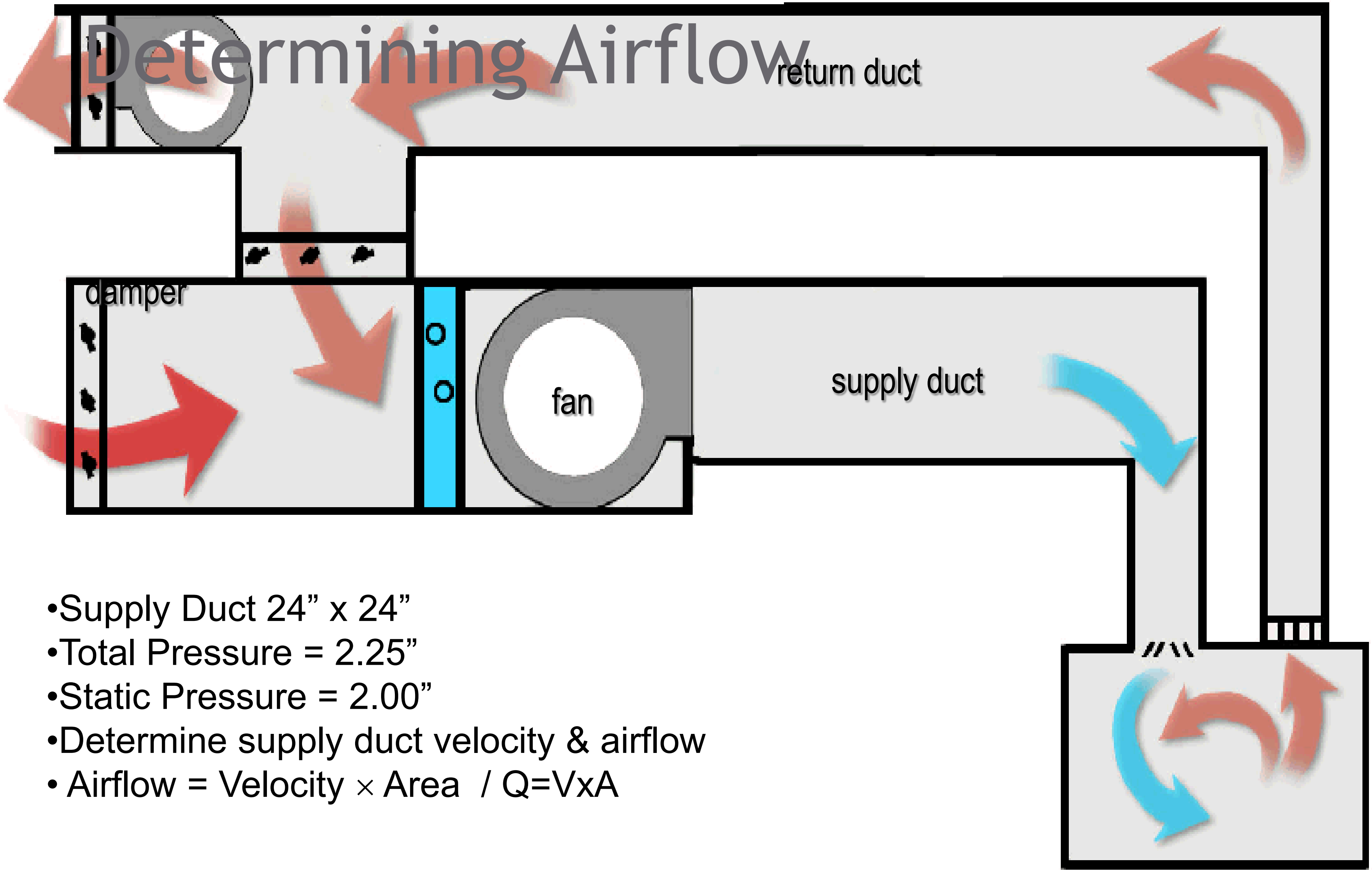


Air flow
Pitot-static tube
Duct wall
Eight 0.04-in. holes 90 deg from air flow circling outer tube
TP
SP
VP
Manometer

Fan Performance Test



Determining Airflow



- Supply Duct 24” x 24”
- Total Pressure = 2.25”
- Static Pressure = 2.00”
- Determine supply duct velocity & airflow
- Airflow = Velocity × Area / Q=VxA

Determining Fan Airflow

Velocity Pressure (P_v) = $P_t - P_s$

$$\text{Velocity (V)} = 4005 \times \sqrt{\frac{Pv}{\ }}$$

Airflow = Velocity $\times$ Area

Determining Fan Airflow

Velocity Pressure (P_v)0.25" = 2.25"$_t$ – 2.00"$_s$

Velocity (V)2002 fpm = $4005 \times \sqrt{.25}$

Area: 24" x 24" / 144 = 4' sq.

Airflow = Velocity × Area

2002(fpm) X 4 (area) = 8008 CFM

TAB Math Fan Laws #1

- $CFM_2/CFM_1=RPM_1/RPM_2$ (**FAN LAW #1**)
- Can be expressed as:
- (CFM2/CFM1) x RPM1=RPM2
- A unit flowing 8008 CFM @ 1300 RPM with 1.5" SP, using 5.55 BHP is to be adjusted to flow 9000 CFM. Find the new fan speed.

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- A unit flowing 8008 CFM @ 1300 RPM with 1.5" SP, using 5.55 BHP is to be adjusted to flow 9000 CFM. Find the new fan speed.
- (9000/8008) x 1300 = 1461 RPM New Fan Speed

TAB Math Fan Laws #2

$(CFM_2/CFM_1)^2 = P_1/P_2$

- Can be expressed as:
- $(CFM2/CFM1)^2 \times P1 = P2$
- A unit flowing 8008 CFM @ 1300 RPM with 1.5" SP, using 5.55 BHP is to be adjusted to flow 9000 CFM. Find the new static pressure.

TAB Math Fan Laws #2

$(CFM_2/CFM_1)^2 = P_1/P_2$

- Can be expressed as:
- $(CFM2/CFM1)^2 \times P1=P2$
- A unit flowing 8008 CFM @ 1300 RPM with 1.5” SP, using 5.55 BHP is to be adjusted to flow 9000 CFM. Find the new static pressure.
- $(9000/8008)^2$ x 1.5” = 1.89” New Static Pressure

TAB Math Fan Laws #3

$(CFM_2/CFM_1)^3 = BHP_1/BHP_2$

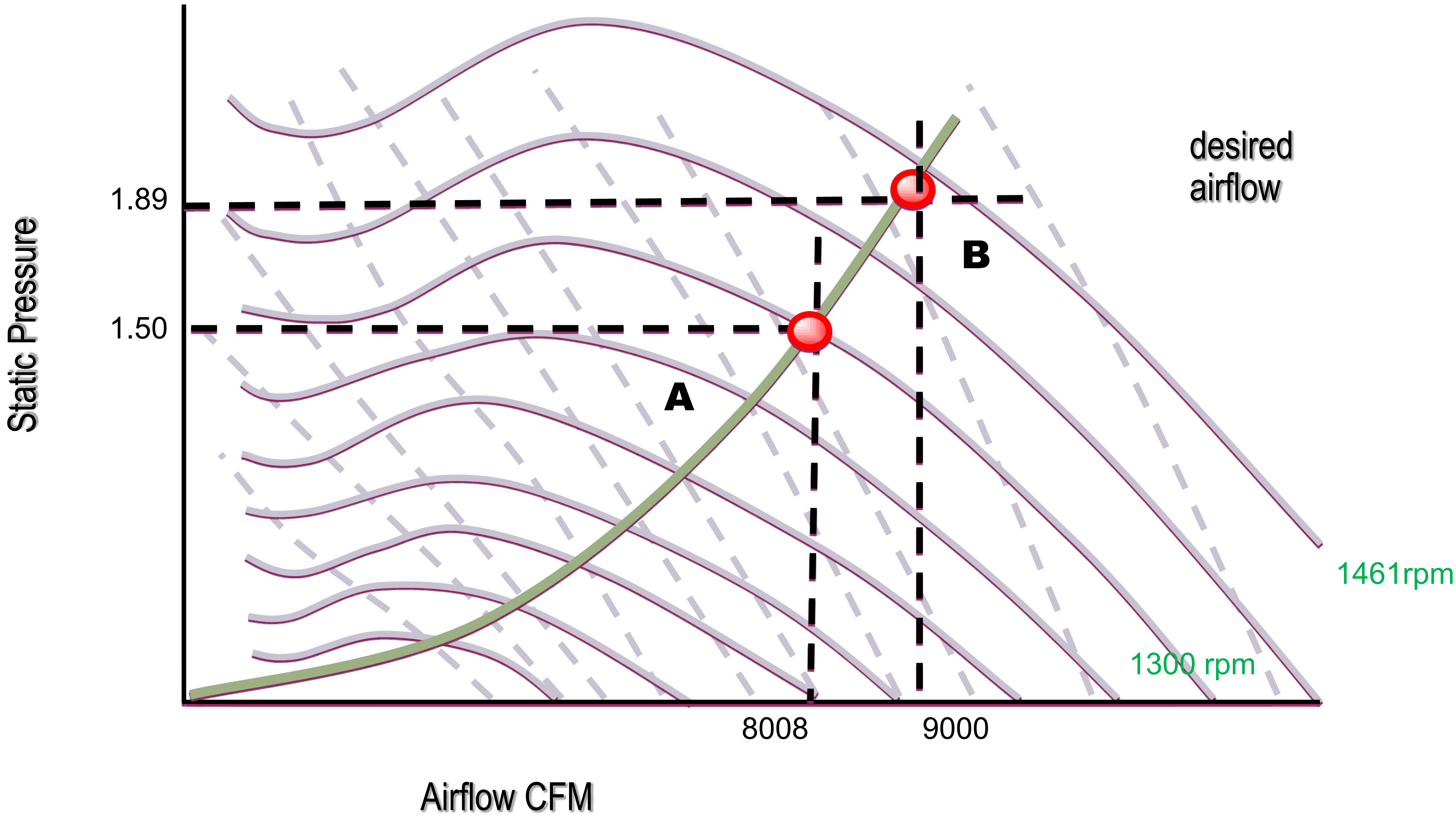
- Can be expressed as:
- $(CFM2/CFM1)^3 \times BHP1 = BHP2$
- A unit flowing 8008 CFM @ 1300 RPM with 1.5” SP, using 5.55 BHP is to be adjusted to flow 9000 CFM. Find the new fan Brake Horsepower.

TAB Math Fan Laws #3

$(CFM_2/CFM_1)^3 = BHP_1/BHP_2$

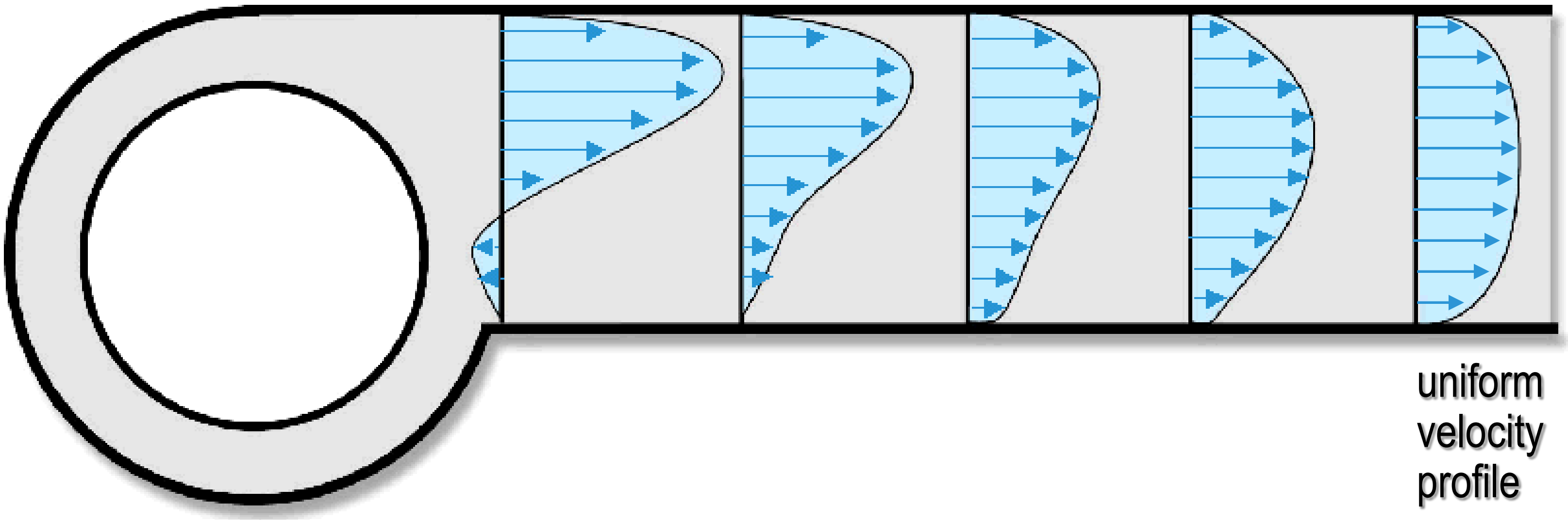
- Can be expressed as:
- $(CFM2/CFM1)^3 \times BHP1 = BHP2$
- A unit flowing 8008 CFM @ 1300 RPM with 1.5" SP, using 5.55 BHP is to be adjusted to flow 9000 CFM. Find the new fan Brake Horsepower.
- $(9000/8008)^3 \times 5.55 = 7.85$ New Brake Horsepower

Design System Resistance Curve

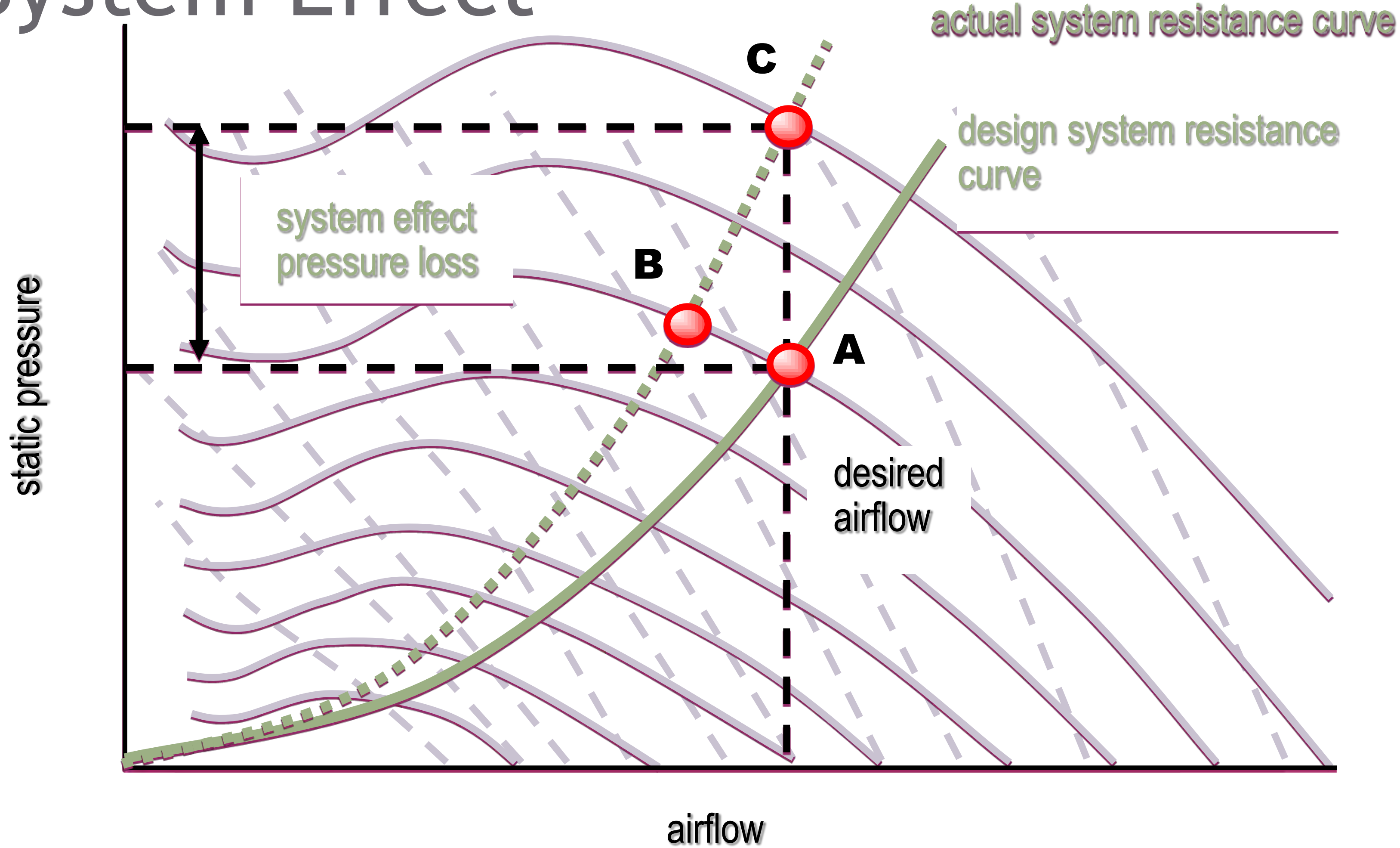


SYSTEM EFFECTS

System Effect



System Effect



Hydronic System TAB Procedures

(2) TYPES OF SYSTEMS

CLOSED SYSTEM	OPEN SYSTEM

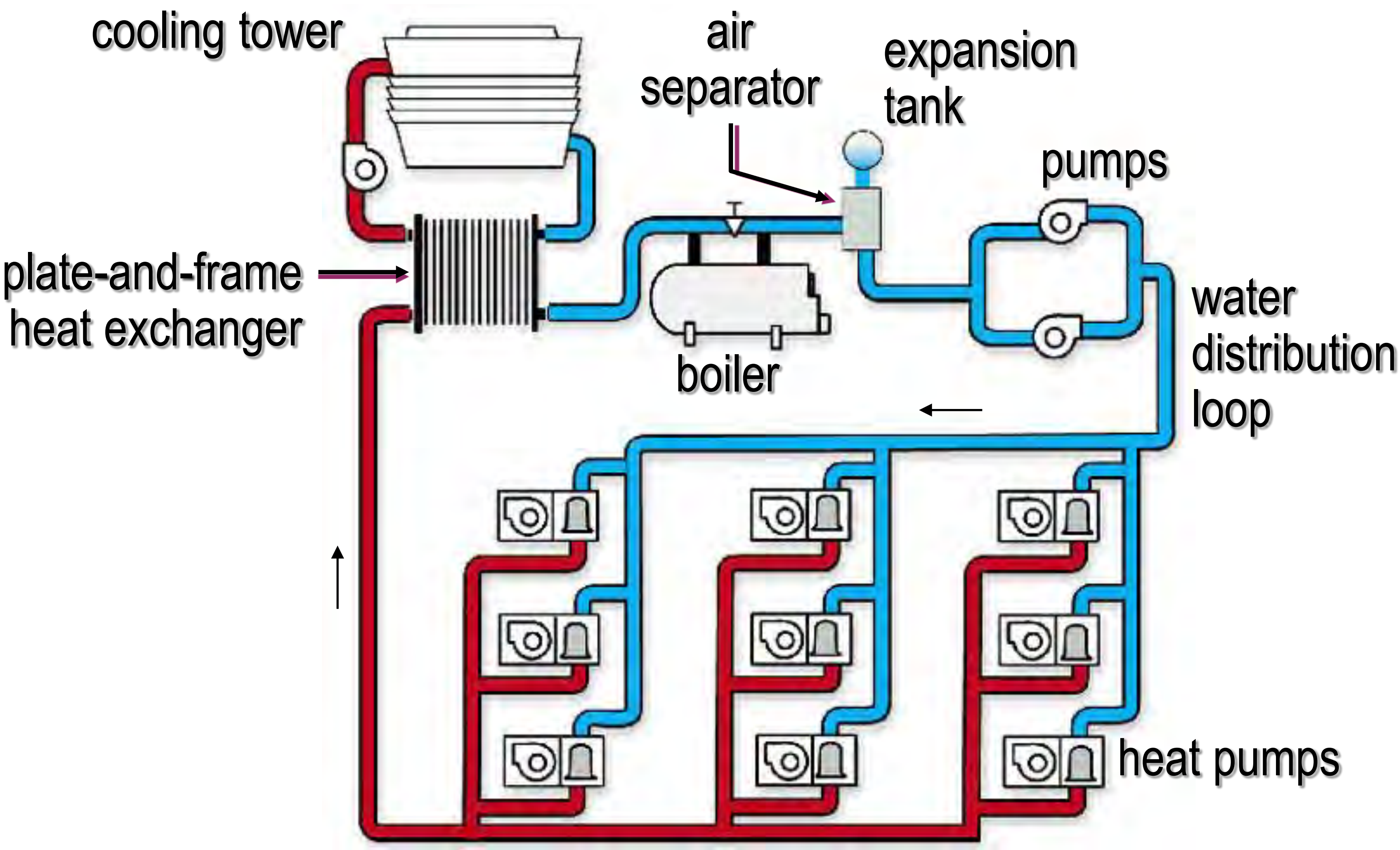
CLOSED SYSTEM

- NOT OPEN TO ATMOSPHERE
- NO STATIC HEAD COMPONENT
- PRESSURIZED SYSTEM
  - CHILLED WATER SYSTEMS
  - HOT WATER HEATING SYSTEMS

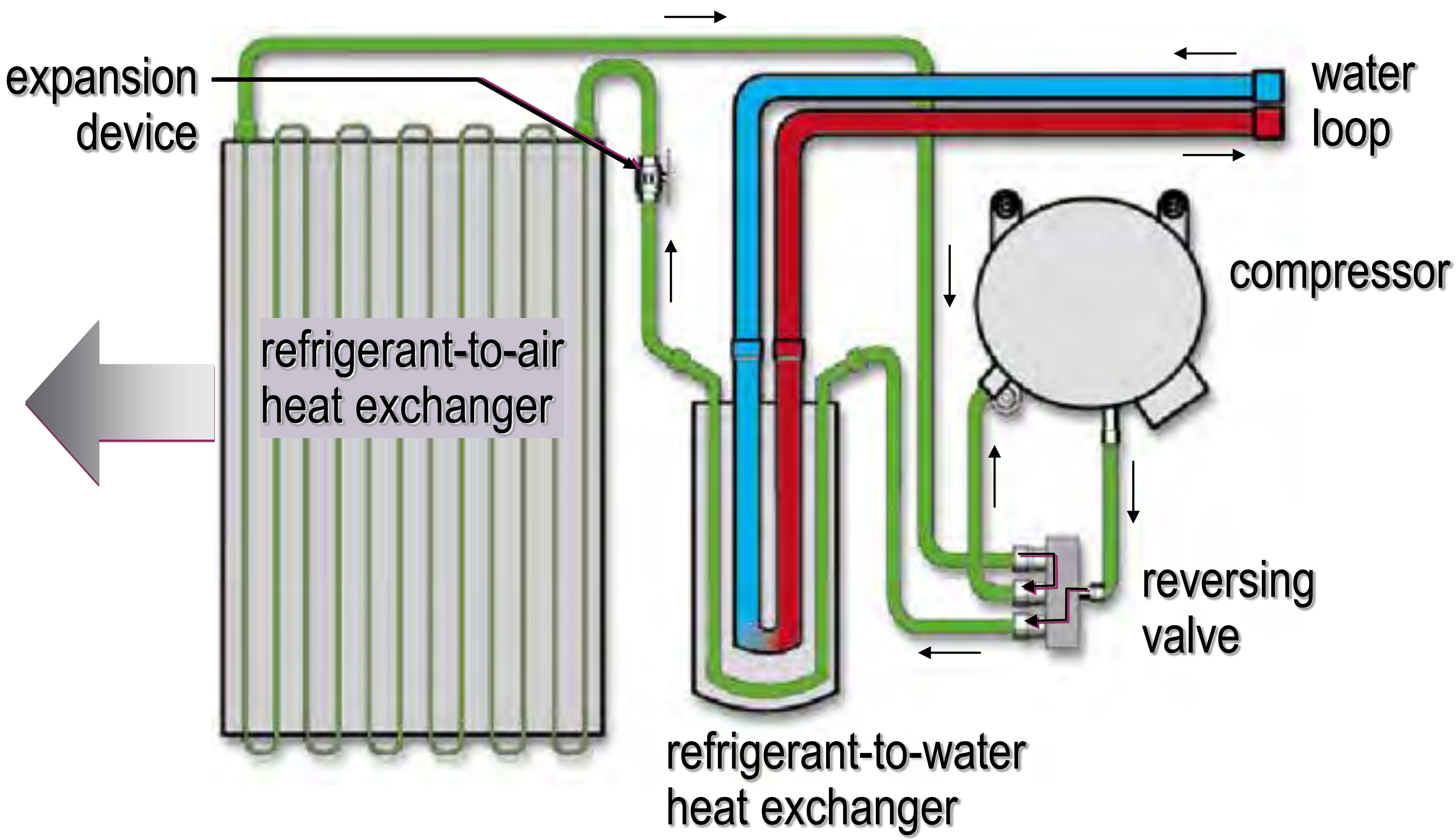
OPEN SYSTEM

- OPEN TO ATMOSPHERE
- STATIC HEAD + FRICTION LOSS
- NPSH AVAILABLE = 33.4'
- UNPRESSURIZED SYSTEM
  - CONDENSER WATER SYSTEM

Water-Source Heat Pump System

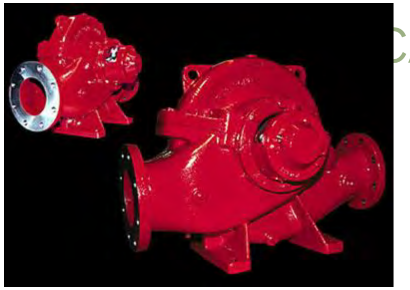


Heat Pump in Cooling Mode



(2) PRIMARY STYLES OF PUMPS

- BASE MOUNTED
  - HORI CASE



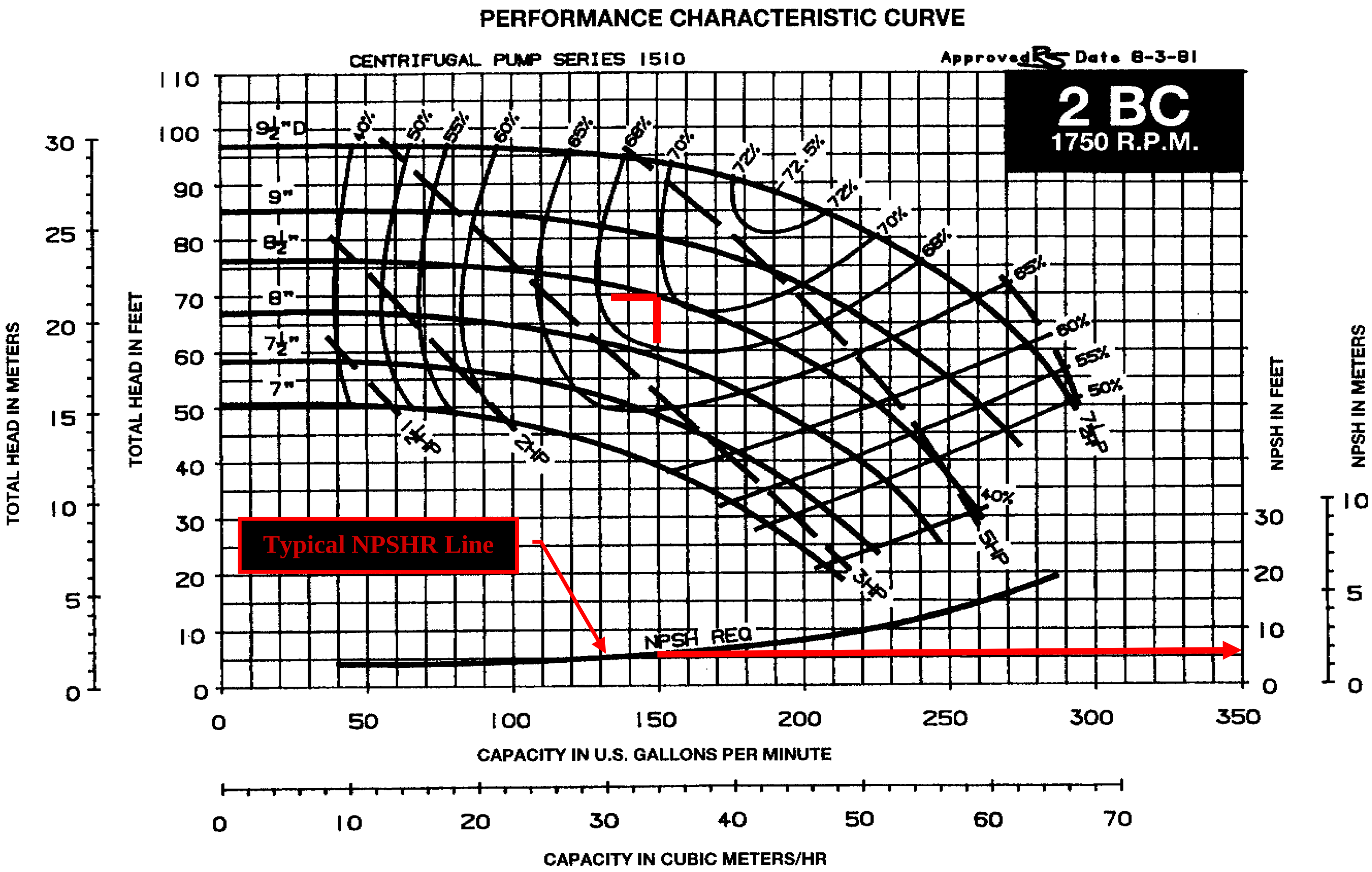
  - END SUCTION

- PIPE SUPPORTED

PUMP PRESSURES

- Dynamic Suction Head
- Dynamic Discharge Head
- Total Dynamic head
- NPSH / Net Positive Suction Head / Calculated Value

TYPICAL PUMP CURVE



PUMP AFFINITY LAWS

AS A FUNCTION OF:
IMPELLER DIAMETER

- $Q_1 = (D_1/D_2) \times Q_2$
- $H_1 = (D_1/D_2)^2 \times H_2$
- $P_1 = (D_1/D_2)^3 \times P_2$

AS A FUNCTION OF:
MOTOR SPEED

$Q_1 = (RPM_1/RPM_2) \times Q_2$
$H_1 = (RPM_1/RPM_2)^2 \times H_2$
$P_1 = (RPM_1/RPM_2)^3 \times P_2$

Capacity varies directly with motor speed or impeller diameter.

Capacity, or flow, of a centrifugal pump varies proportionately with any changes in the speed or impeller diameter. So, for example, doubling the speed of a given pump would double the flow *in a given system*.

Head varies as the square of speed or impeller diameter.

Head, or differential pressure produced, varies with the squared ratio of any change in speed or impeller diameter. 1 & 2 Together also state that head varies as the square of changes in flow - the System Curve relationship.

Power varies as the cube of speed or impeller diameter.

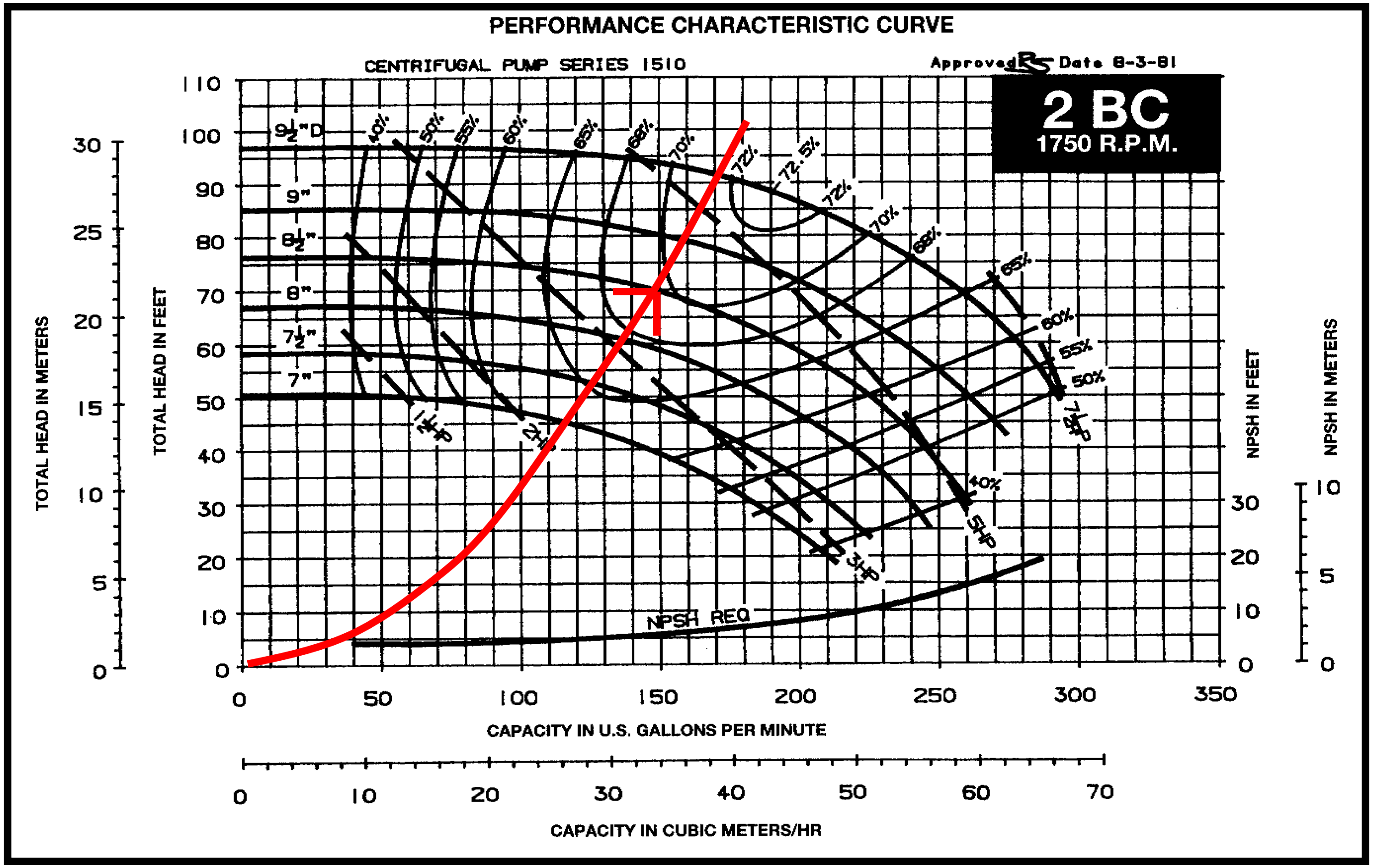
Power, or motor horsepower required to drive the pump, varies with the cubed ratio of any change in speed or impeller diameter.

THE SYSTEM CURVE

- Graphical representation of the second ***Affinity Law***. Head varies as the *square* of flow change.
- Provides a solid Analytical Tool.
- Applicable to a given system in a given state ("a given snap shot"). System curve analysis is steady-state in nature, not dynamic.

SYSTEM CURVE

The system curve can be generated utilizing the second affinity law.



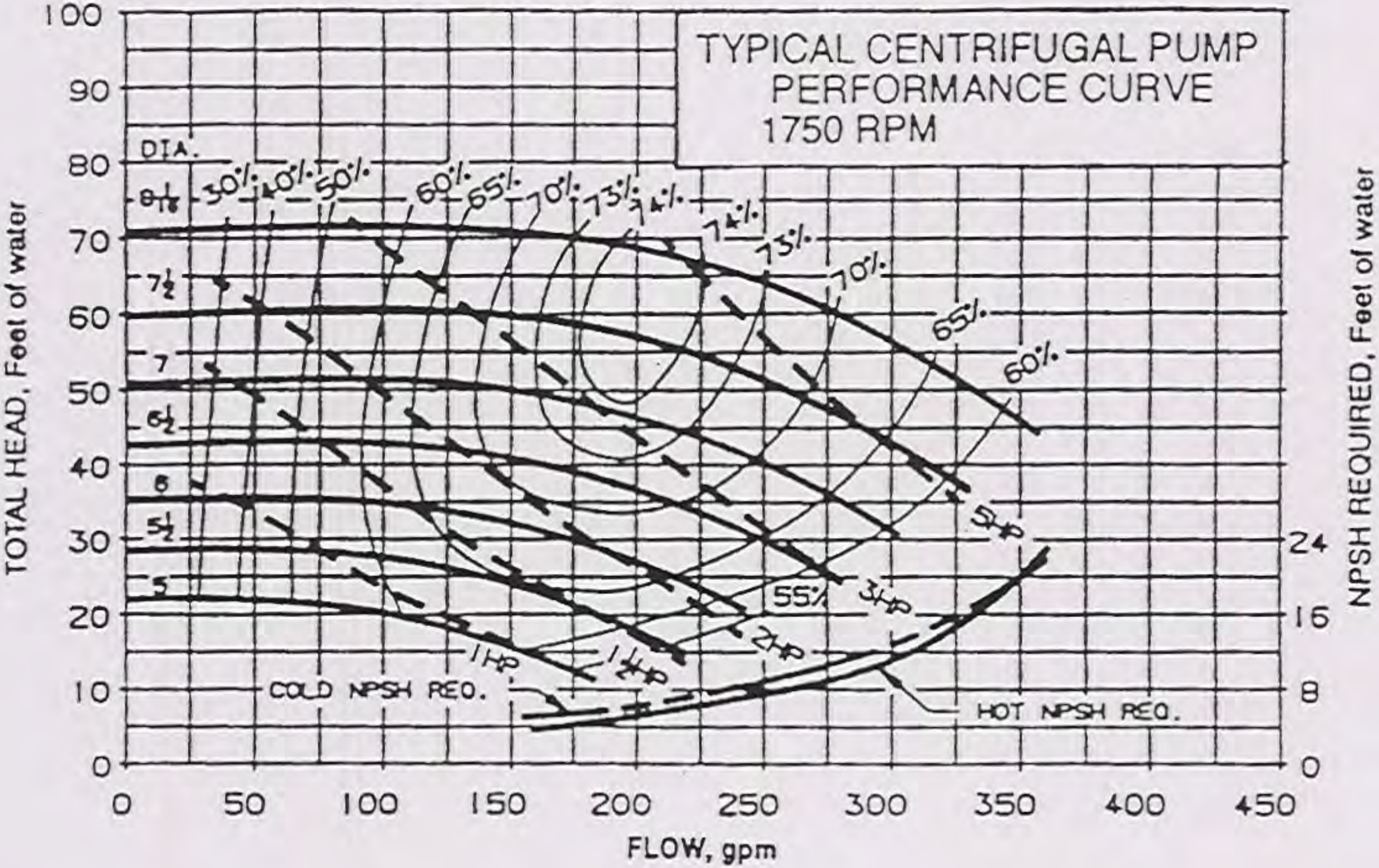
PUMP PRESSURES

- Dynamic Suction Head
- Dynamic Discharge Head
- Total Dynamic head
- NPSH / Net Positive Suction Head / Calculated Value

HYDRONIC EQUATIONS

- $Q = 500 \times GPM \times \Delta T$
- $Q = (SH \times 60 \times 8.33) \times GPM \times \Delta T$
- $\Delta P_2 / \Delta P_1 = (gpm_2 / gpm_1)^2$
- $\Delta P = (gpm / C_v)^2$

Pump Curves



TYPICAL CENTRIFUGAL PUMP
PERFORMANCE CURVE
1750 RPM
TOTAL HEAD, Feet of water
NPSH REQUIRED, Feet of water
FLOW, gpm
DIA.
COLD NPSH REQ.
HOT NPSH REQ.

A PROBLEM

- Using the pump curve determine the pump's impeller size if the "shutoff head" is 60'?
- For this pump what is the flow if the total dynamic head is 52'?
- What is the pump efficiency?
- What is the horsepower consumption?

Thanks for attending our presentation on NEBB'S *TAB Procedures*





TAB Case Study

Retrocommissioning

"Retro-commissioning is the application of the commissioning process to existing buildings. Retro-commissioning is a process that seeks to improve how building equipment and systems function together. Depending on the age of the building, retro-commissioning can often resolve problems that occurred during design or construction, or address problems that have developed throughout the building's life. In all, retro-commissioning improves a building's operations and maintenance (O&M) procedures to enhance overall building performance."

Retrocommissioning Process

- Energy Use and Cost Benchmarking
- Review Construction Documents. Compliance
- Review TAB Report.
- Inspect Facility “Tune on the fly”.

Project Symptoms

- Drafty interior conditions.
- Continuous build positive pressure issues.
- Numerous “hot & cold” spots.
- High Energy costs.
- Unstable Unit operation.
- Questionable equipment performance capability.
- Questionable system design.
- Intermittent Broadcast equipment cooling issues.

Project Discovery

- 34,000 SqFt Project. 4 years old.
- Never properly tested-balanced-calibrated-commissioned.
- Building pressure +.25" to +.40". Controls set point .40"
- Actual airflows 200% of reported. System operating wide open.
- No schedules. All air terminals overridden to occupied for 4 years.
- Duct static pressure set points @ 1.50 – 2.00.

Project Action

- Tested airflows & calibrations at terminals. All measured 200% + flow versus reported.
- Suggested TAB the entire building. Owner-yes!
- TAB Scope:
- TAB terminals.
- Calibrate controls.
- Repair leaking sensor lines.
- Install new settings from RVS.

PROJECT ENERGY & Flows

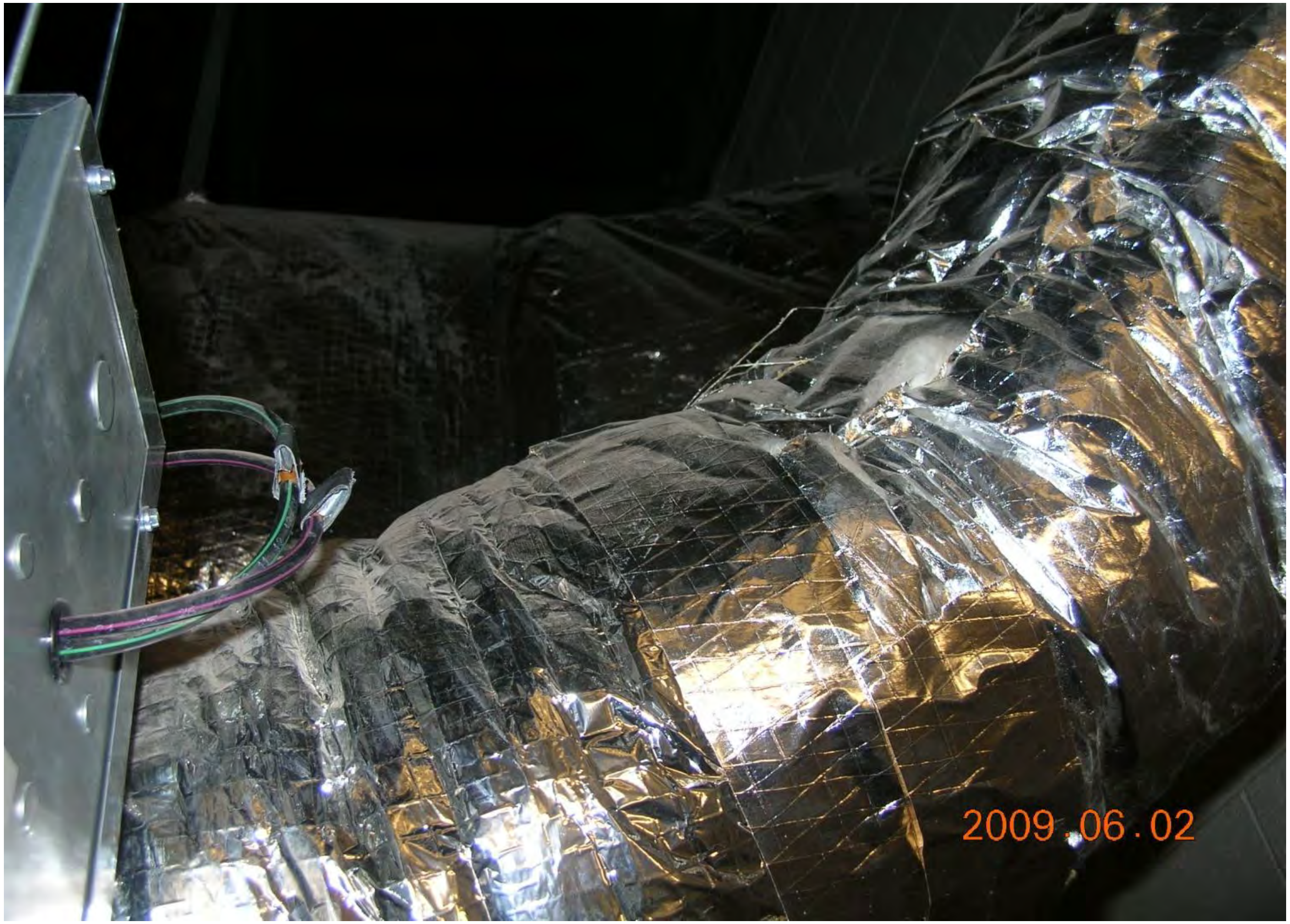
Item	Before	After Projected	Savings (%) Projected	Remarks
Electricity Consumption (kWh)*	800,797	700,697	12.5%	
Average Peak Demand (kW)	2016	1814	!0%	
Electricity Consumption (kWh/SF/year)	23.55	20.00	10%	Range $18 to $28
Electricity Load Factor (%)	99.7 %	95%	4.7%	
Total Electricity Cost ($/year)	$61,617.00	$52,374	15%	
Occupied Supply Air / Avg CFM	60, 500 Max	48,500 Max		
	46,500 Min	9700 Min		
Unoccupied Supply Air / Avg CFM	60,500 Max	>10,000 Max		
	46,500 Min	>2500 Min		

Project Action

- Isolated preheat coil. Dramatically reduced CHW demand!!
- Reduced operating unit static pressures to .75".
- Reduced building static pressure to +.04"
- Noticeable improvement in comfort.

We're still working on it!!

Details
Leaking Sensor Lines



HVAC-Excellence Take-Away's!!!

- Our Building Environment has changed, our task is more complex with opportunities everywhere!!!
- The HVAC-TAB Technician of the future will be the most tech-savy, sophiticated person on the job-site. Will possess multiple skills (mechanical, controls, electrical, computer, networking, report preparation and COMMUNICATION!!
- Invigorate the young / start in High Schools, ASHRAE student activities!!!
- Let's work together to fill this ***growing need***!!

Thanks !!

Questions??