Energy Management Training: Energy Efficiency through Auditing

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Agenda

- The Energy Audit and Site Survey
- Understanding Utility Rates
- Common HVAC, Control and EMS
- Identify where the energy goes
- Manual or energy modeling method
- Common ECM, Energy Conserving Measures
- The Final Report – Retro Commissioning

The Energy Audits

- Commonly three levels of Audit available
- Depends on your needs or level of savings you are trying to achieve
- Utility Bills and Site visit are necessary
- Calculation of Heating & Cooling loads
- Simulation via Energy Modeling
- Data Logging of key loads maybe necessary

Safety And Building Access

- Review of site safety rules with auditor
- Attend safety class if required
- Auditor may have safety certification
- Review of building access areas
- Is a lift needed?
- Access to secure areas
- Access to electrical equipment

Level One

- One day walk through
- Review major loads with building supervisor
- Quick review of average utility bills.
- Chasing large KW loads or large gas usage
- Simple Report with ECMs

Level Two

- Detailed site survey
- May data log some loads for actual usage and trending
- Complete heating and cooling load calculations
- Complete lighting survey
- Complete Office equipment survey
- Run Energy modeling program to confirm the actual loads

Level Two

- Detail review of Utility Bills
- Review of Maintenance program
- Calculate the Site/Building EUI – Energy Usage Intensity in Btuh/ft2/Year
- Detailed report with all ECM
- Comparison of EUI to like Site/Building

Level Three

- Detailed Site Survey beyond Level Two
- Identify all energy usage in the building including: HVAC, Lighting – Interior and Exterior, Motors and Drives, Elevators, Domestic Hot Water, Refrigeration, Cooking, PC and Plug loads, plus others
- Same calculations – H/C Loads and energy modeling

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Level Three

- Very Detailed Report commonly referred to as "Investment Grade"
- Could include Process Loads
- Include Utility rebates if available
- Include payback calculations for ECMs

Utility Rates

- Electric
- Kilowatt Hour – Usage or totalize
- Kilowatt – Demand for 15 Minutes
- Power Factor Penalty
- Customer or Meter Charge

Utility Rates

- Electric – Example
- Utility A
  - $20/month Customer Charge
  - $4.00/KW Demand
  - $.05/KWH usage
  - plus Tax
- Customer sets a
  - Demand: 24KW
  - Usage: 10200KWH
- What is the customer's monthly cost?

Utility Rates

- Electric:
  - = $20 + ($4 x 24KW) + ($.05 x 10200KWH) + Tax
  - = $20 + $96 + $510 + Tax
  - = $626 + Tax

Utility Rates

- Electric –
- Items to watch out for
  - BIN prices on Demand or KWH, pay more or less depending on amount
  - Demand billed as a ratchet, billed at 80% of the max for the next 12 months
  - Time of day pricing
  - Fuel Adjustment charge

Utility Rates

- Natural Gas
- CCF or 100 Cubic Feet
- Meter or Customer Charge
- One Cubic Foot is 1000 Btuh Input

Utility Rates

- Natural Gas – Example
- Utility B:
  - $12/month Customer Charge
  - $.65/CCF(100 cu ft)
  - Tax
- Customer B:
  - Uses 1000CCF per month
- What is the total Gas cost?

Utility Rates

- Natural Gas – Example
- Utility B:
  - 1000CCF per month usage
  - $12/month Customer Charge
  - $.65/CCF(100 cu ft)
  - Tax
- What is the total Gas cost?
  - = $12 + ($.65 x 1000) + Tax
  - = $12 +$650 + Tax
  - = $662 + Tax

Utility Rates

- Natural Gas –
- Items to watch out for
  - CCF charge may vary depending on the time of year
  - Fuel Adjustment charge

Utility Rates

- Propane Gas
  - Cost per Gallon Delivered
  - Tank Rental
  - One Gallon of Propane is 93,000 BTUH Input

Utility Rates

- Propane Gas – Example
  - Usually not regulated by the state
  - $2.00/gallon

Utility Rates

- Water and Sewage
- Cost per Unit or 748 gallons
- Meter or Customer Charge
- Fire Protection Charge
- Sewage is a percentage of Water – may be able to negotiate a change if your facility has water cooled chillers with cooling towers and you sub-meter that make up water

Utility Rates

- Water – Example
- Utility C:
  - $12/month Customer Charge
  - $1.00/Unit usage
  - Sewage Charge is 80% of Water Usage
  - tax
- Customer C:
  - Usage of 25 units in a month
- What is the customer cost?

Utility Rates

- Water – Example
- Utility C:
  - $12/month Customer Charge
  - $1.00/Unit usage
  - Sewage Charge is 80% of Water Usage
  - tax
- Customer C:
  - Usage of 25 units in a month
- What is the customer cost?
  - = $12 + ($1 x 25units) + [($1 x 25 units) x 0.8] + Tax
  - = $12 +$25 + $20 + Tax
  - = $57 + Tax

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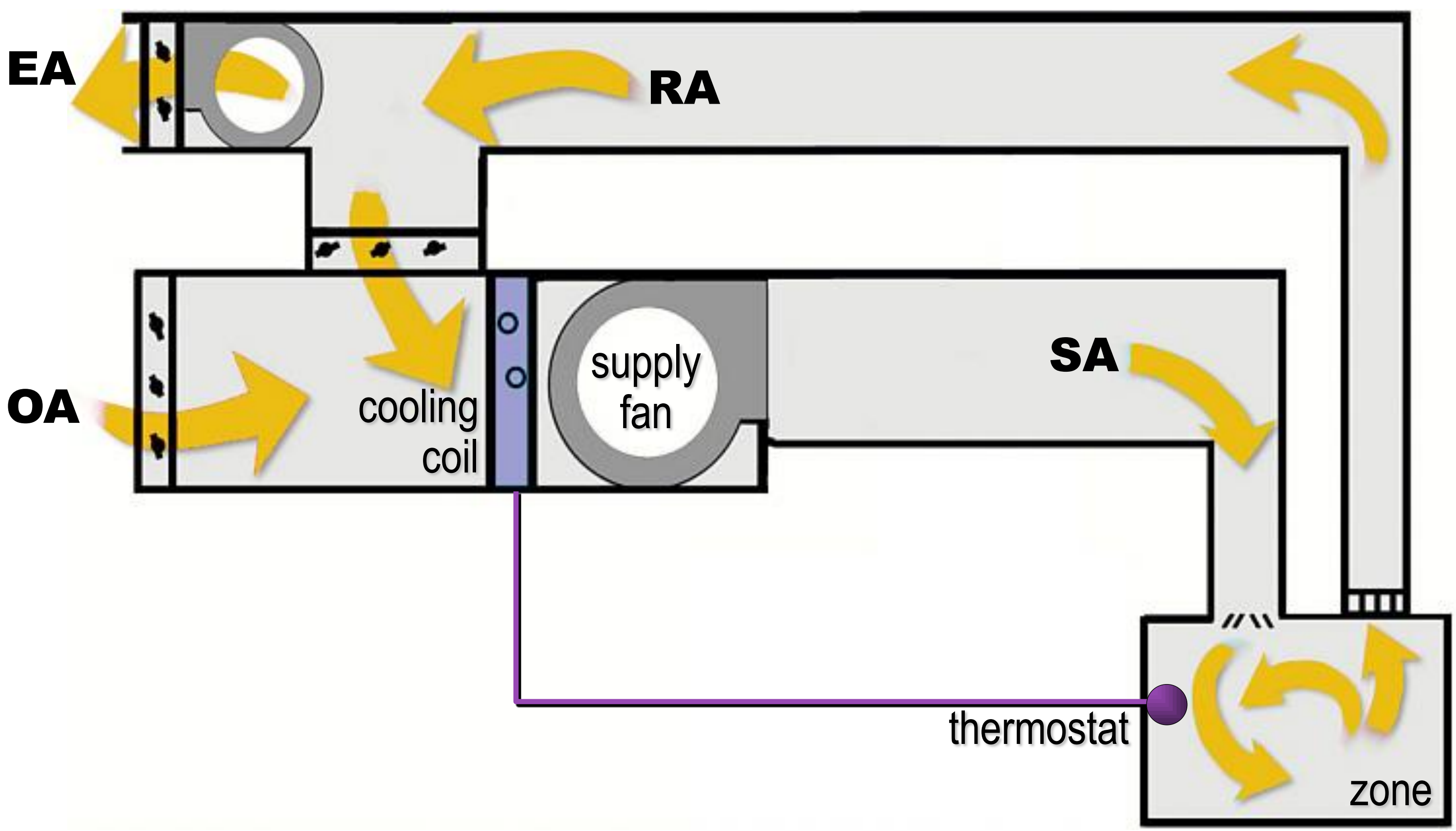
HVAC Systems

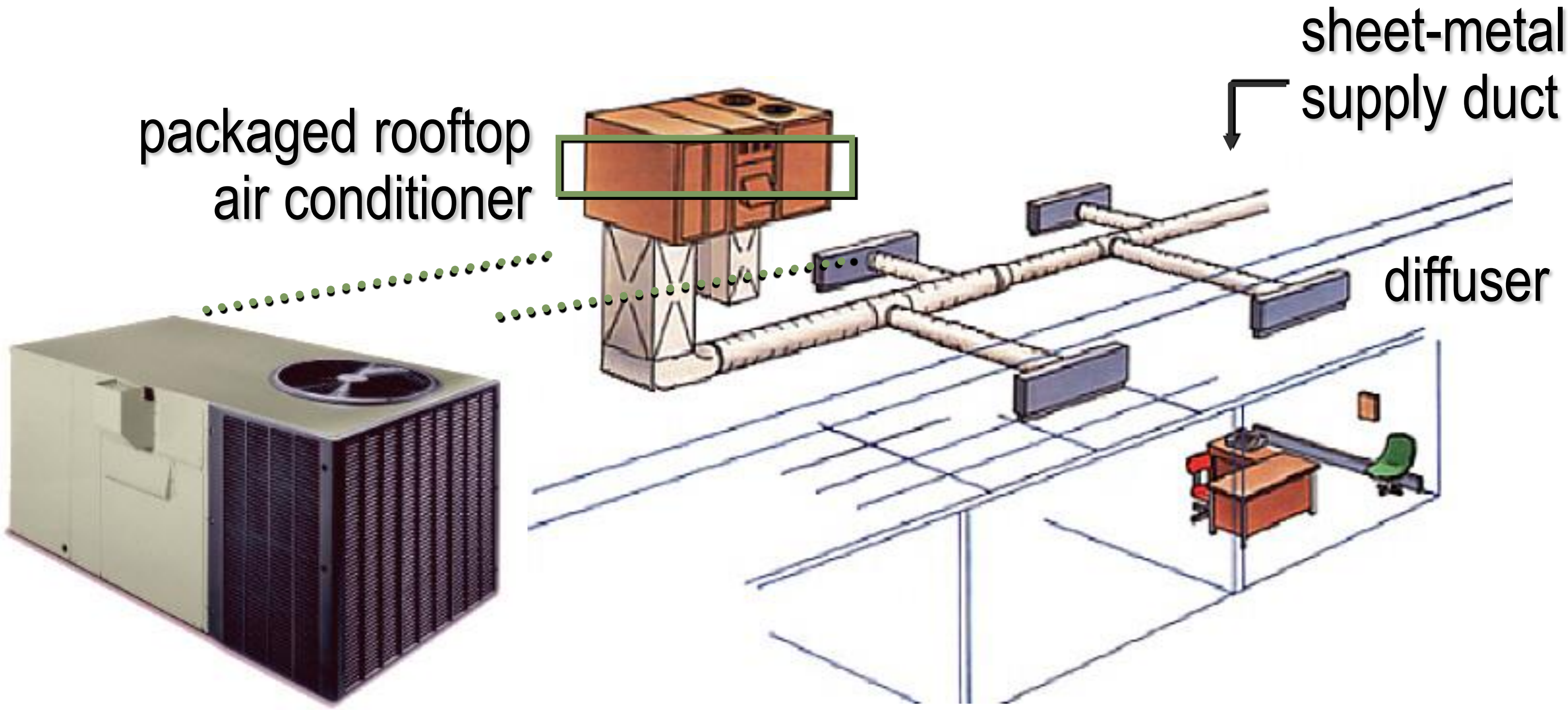
- Constant Volume
- Variable Volume
- DX Cooling or DX Units
- Chilled Water Systems
- Air Cooled Style
- Water Cooled Style

Single Zone, Constant Volume

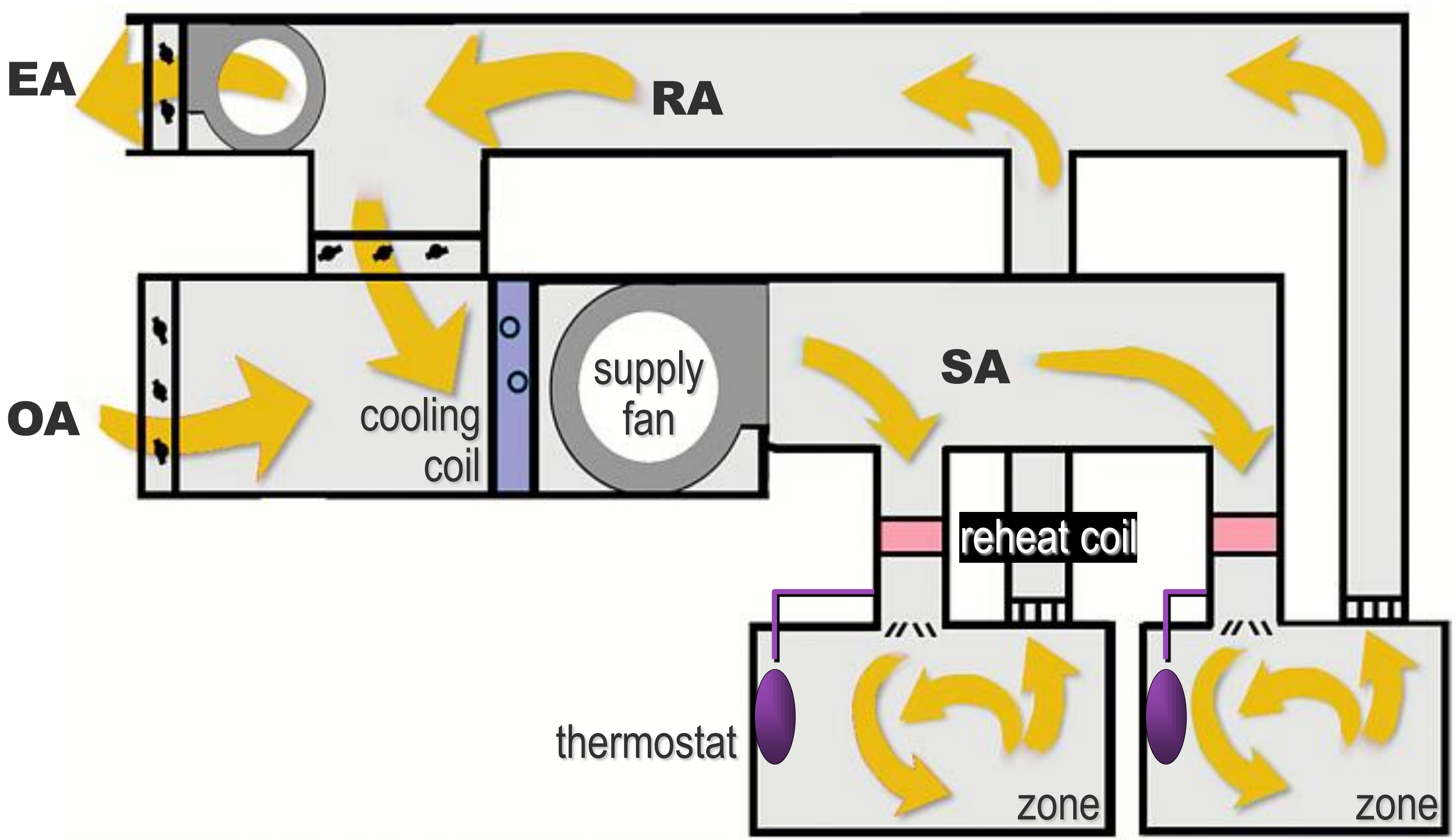


single zone, constant volume

Packaged DX Rooftop System

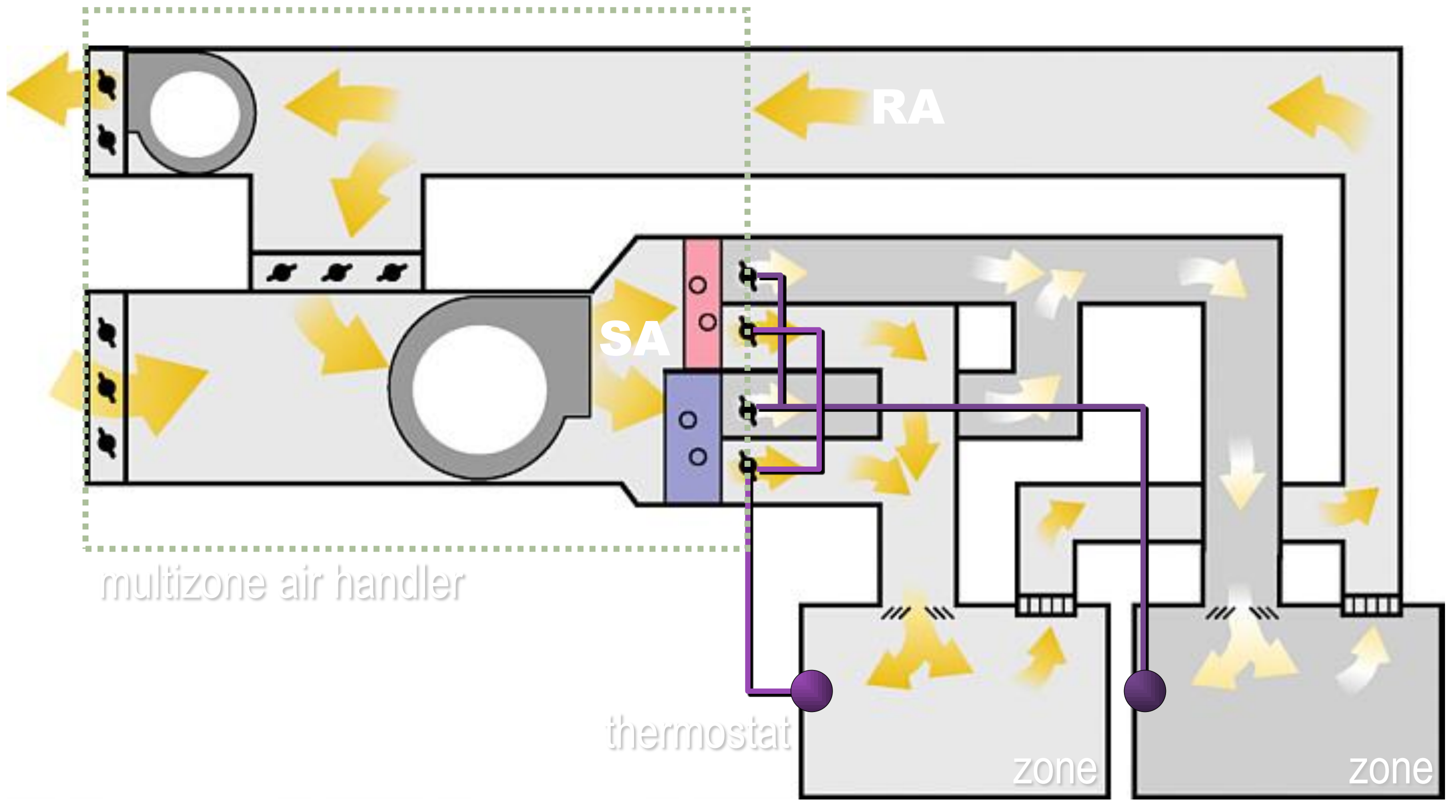


Multiple Zones, Constant Volume



multiple zones, constant volume

Multizone Air Handler



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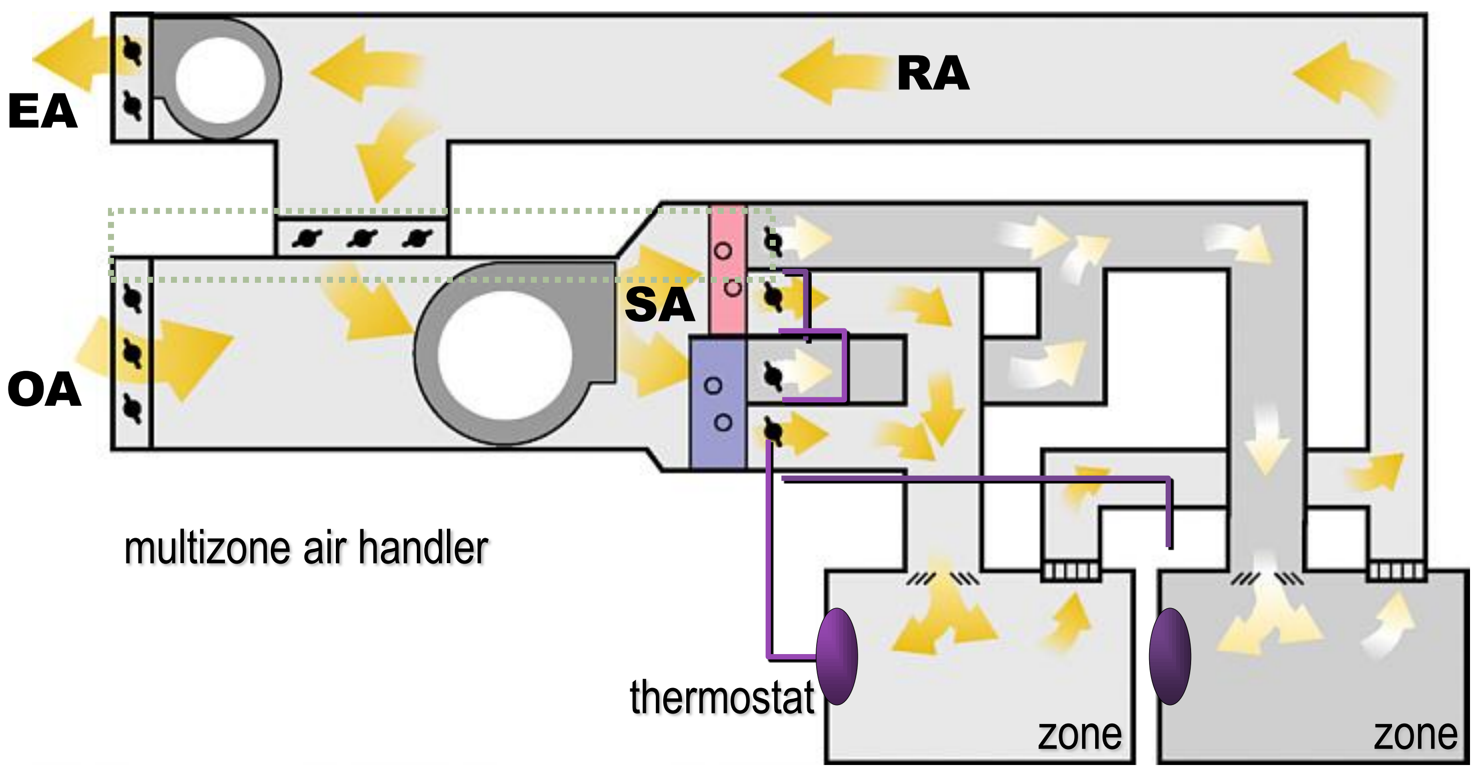
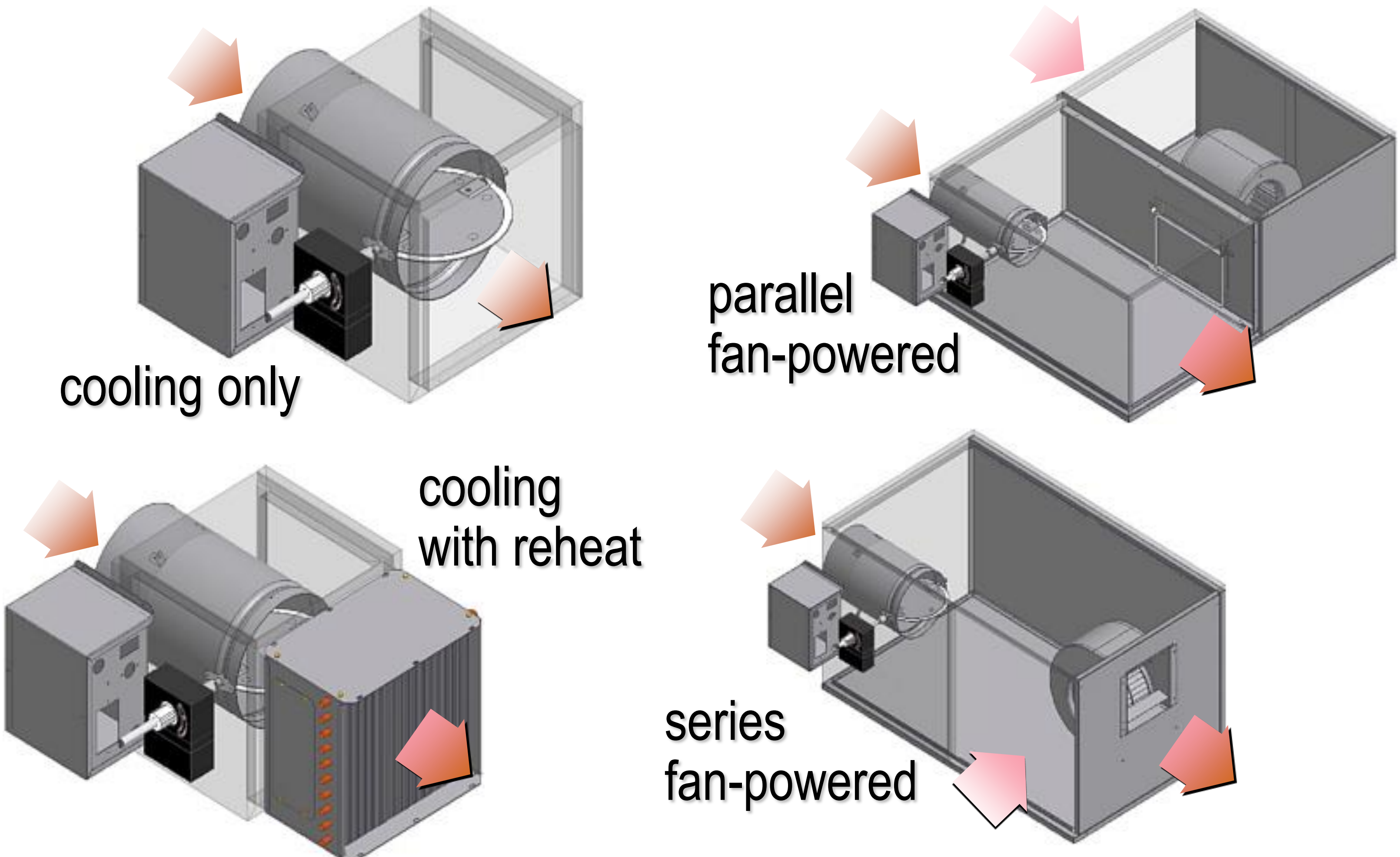
multiple zones, constant volume
Multizone Air Handler



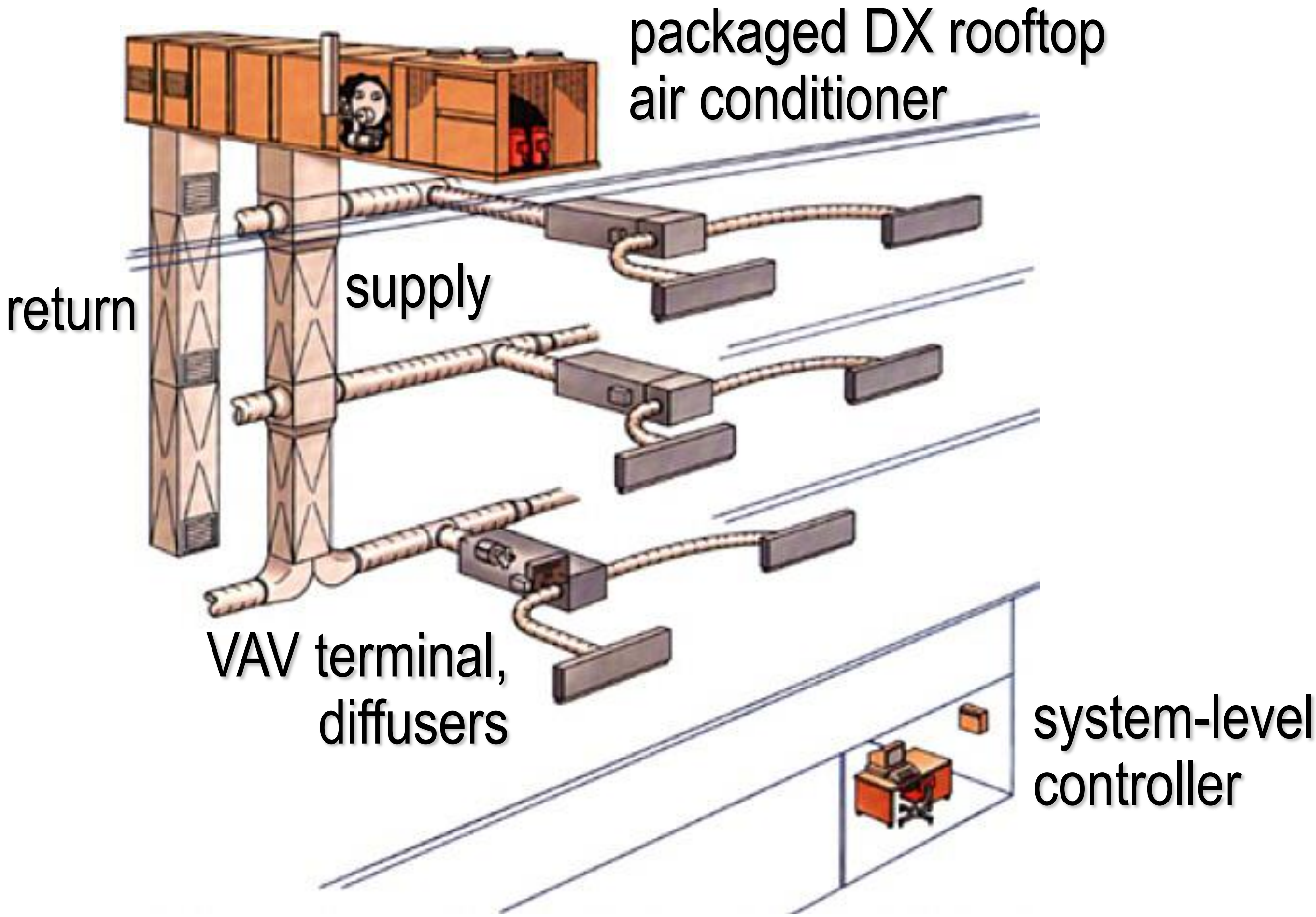
multiple zones, variable volume

VAV Terminal Units

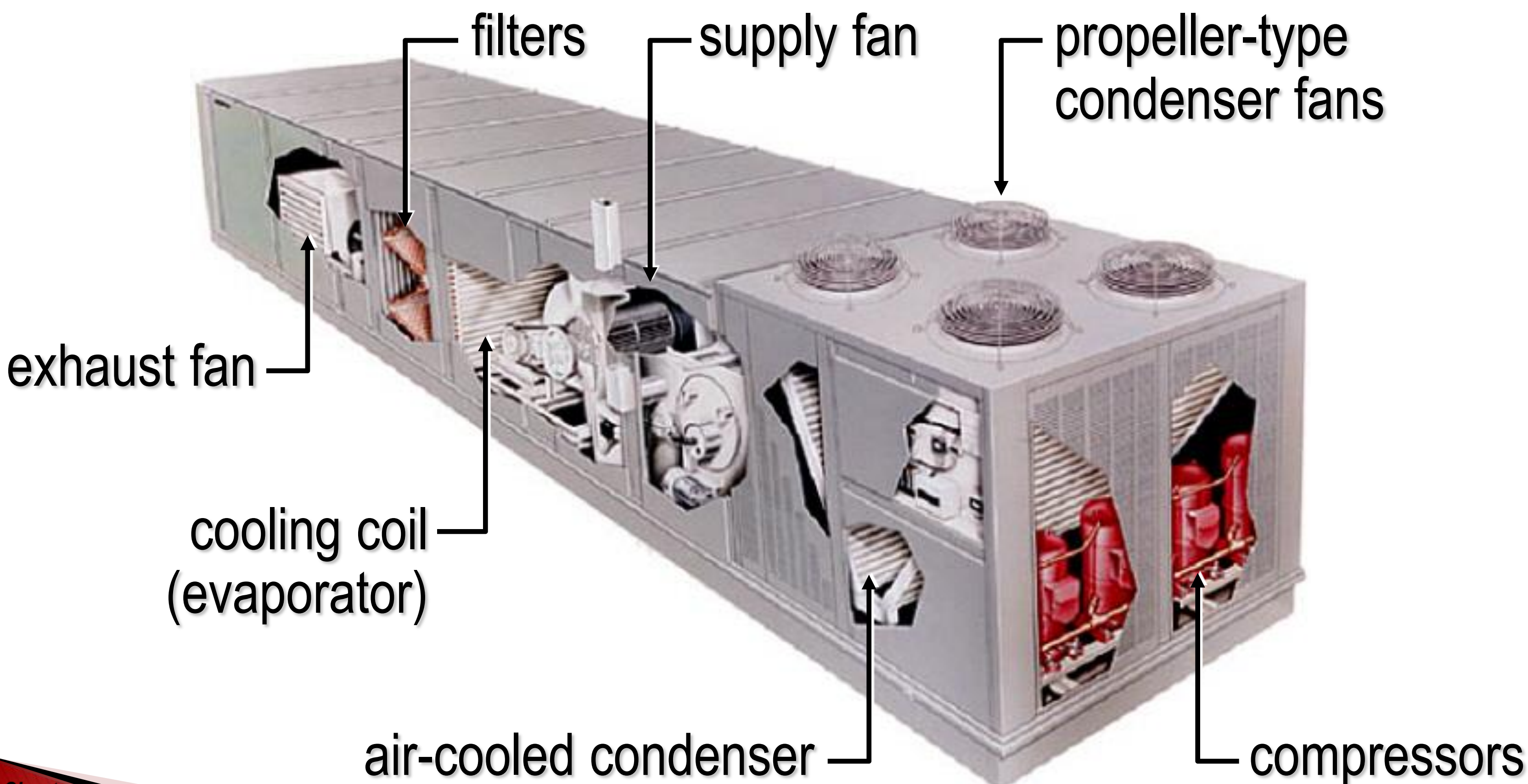


multiple zones, variable volume

DX Rooftop VAV System



Packaged Rooftop Air Conditioner



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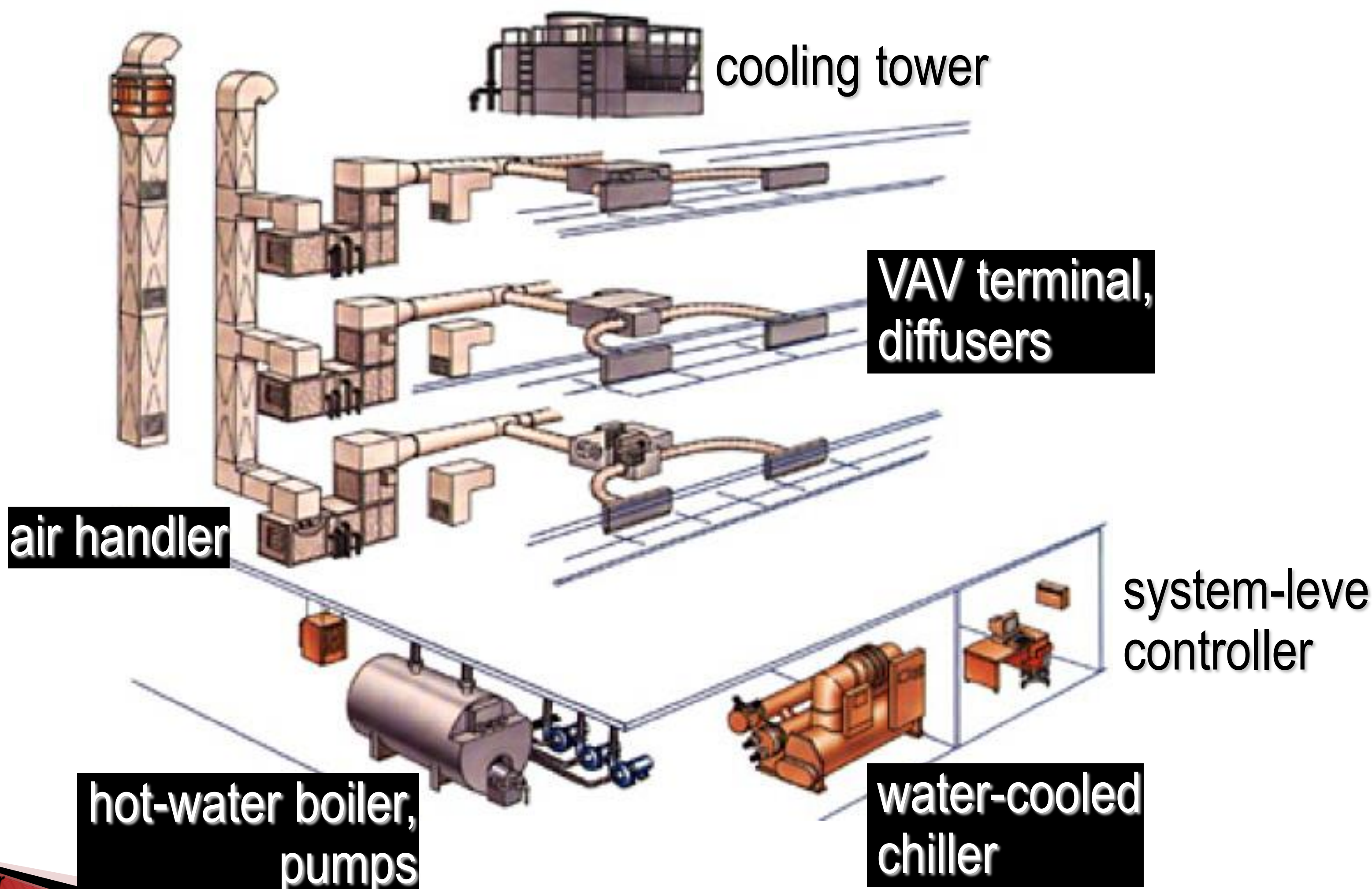
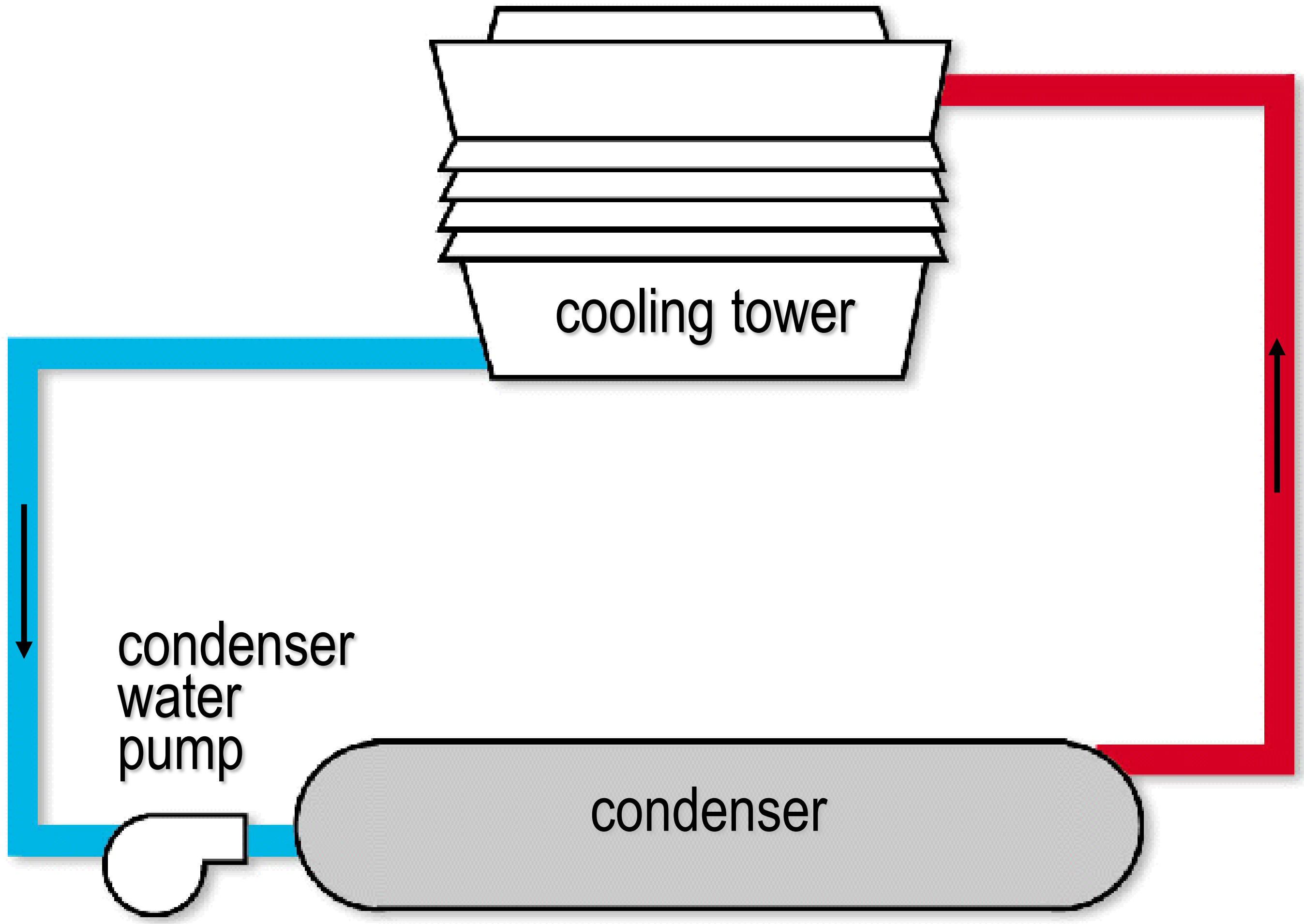
multiple zones, variable volume

Central Chilled-Water VAV System

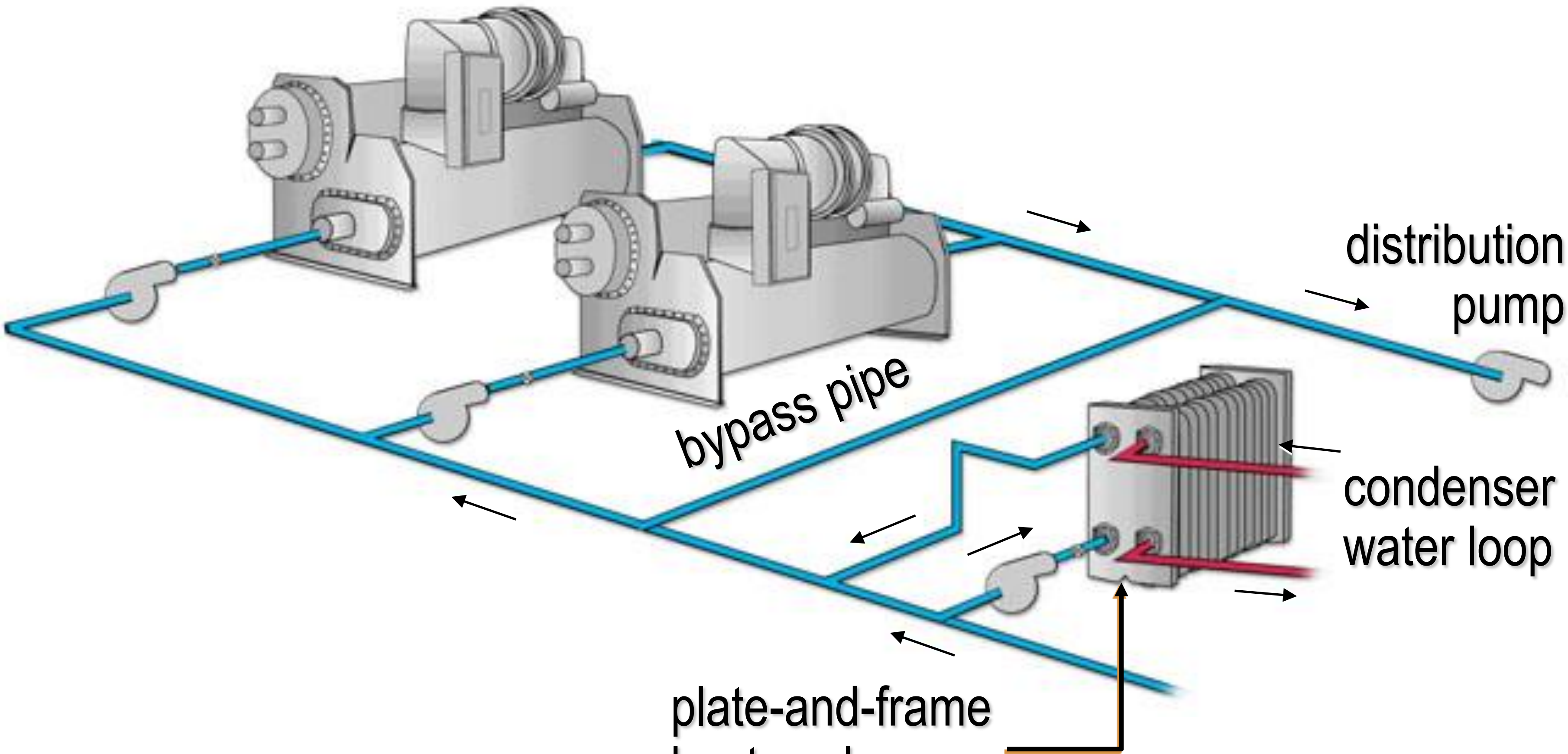


Condensing Temperature Control

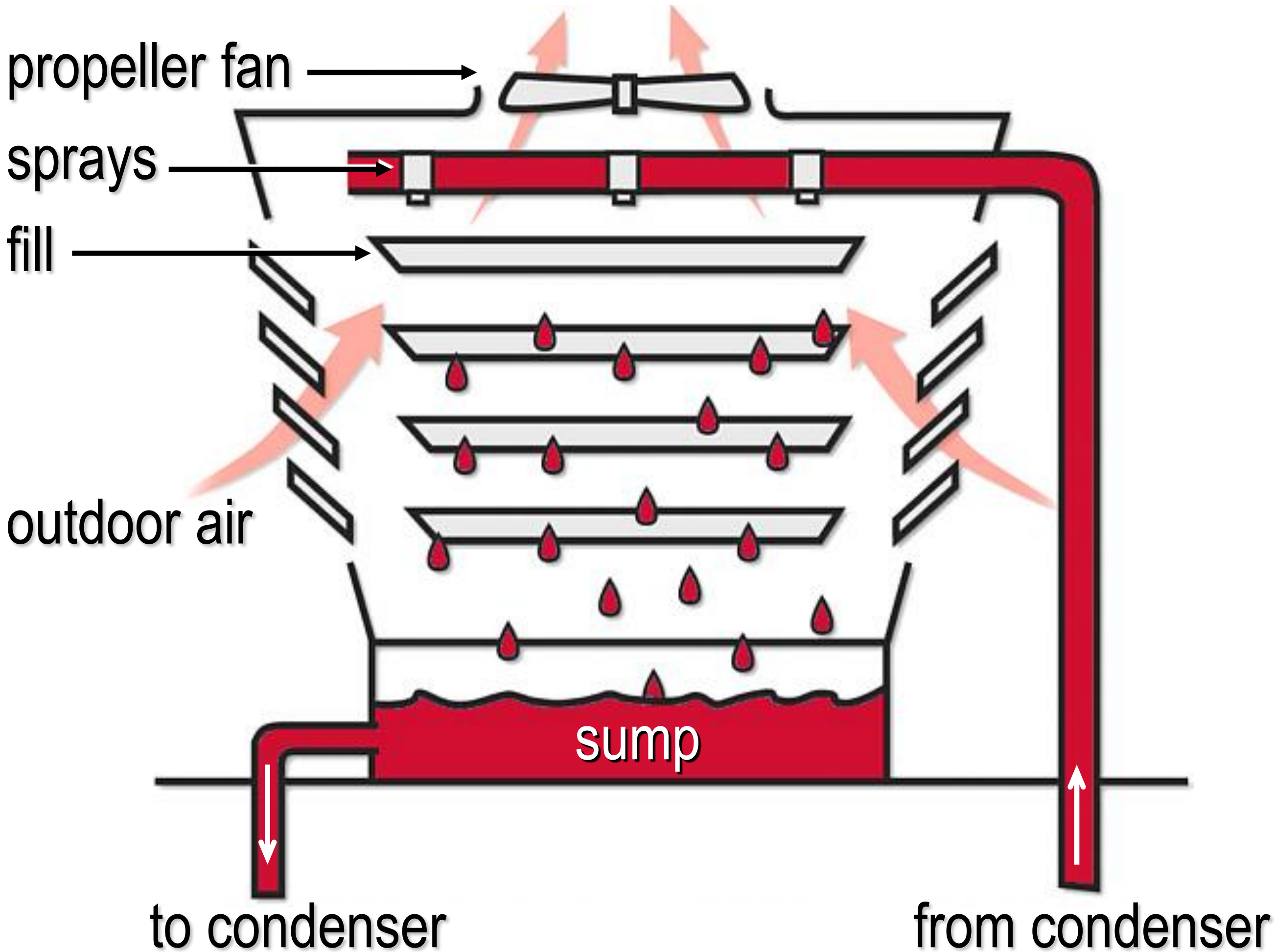


waterside economizer

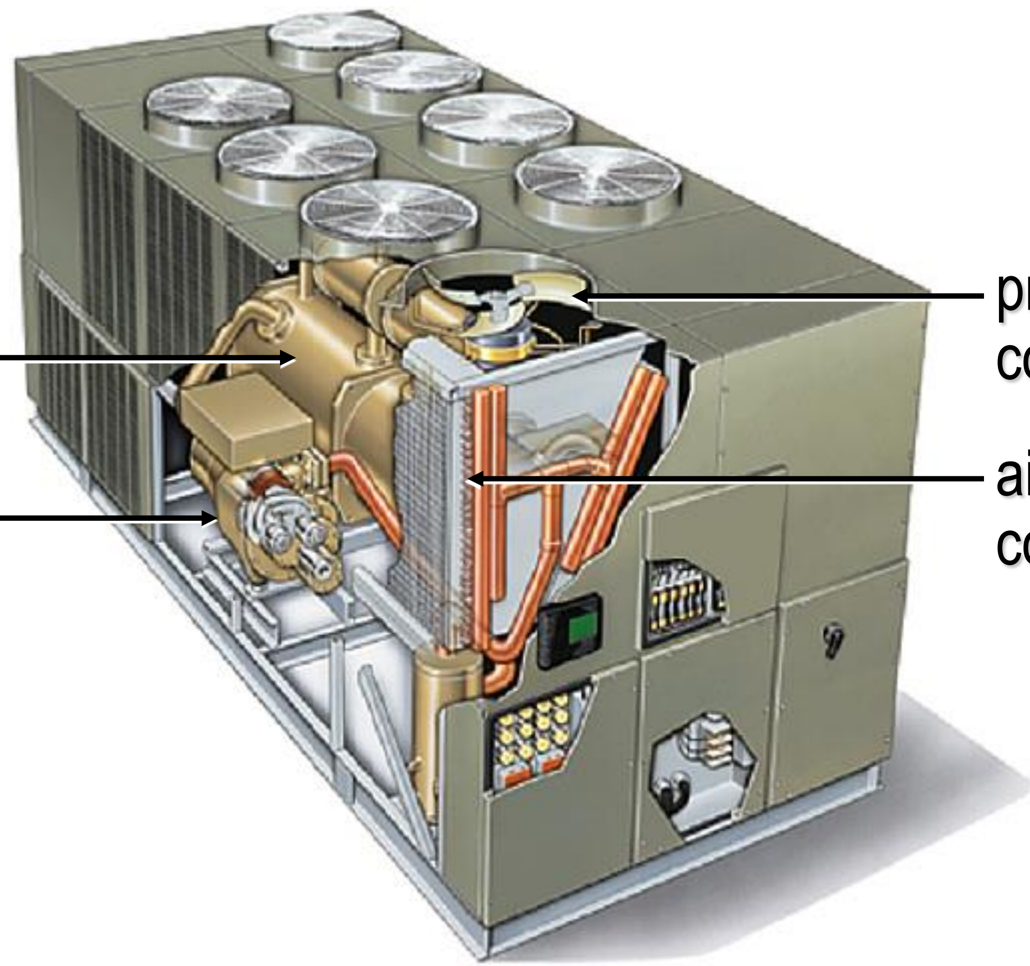
Plate-and-Frame Heat Exchanger



Cooling Tower



Packaged Air-Cooled Chiller



Energy Saving Control Sequences

- Scheduled Start – Stop of HVAC systems based on time
- Unoccupied Setback temperature (winter) and Setup (summer)
- Optimized Start – Stop of HVAC system based on both indoor temperature and outdoor temperature. Time varies depending on deviation

Energy Saving Control Sequences

- Chilled Water Temperature Reset is upward adjustment of supply water at less than full load (Be careful, you must still dehumidify if outdoor dew point is high) based on ambient temperature, return water temperature, or building load.
- Cooling Tower Water Reset is downward adjustment of sump temperature as outdoor wet bulb temperature decreases (there is a low limit not to go below)

Energy Saving Control Sequences

- Supply Air Temperature Reset is upward adjustment of discharge air when the load is less than full load (Be careful, you must still dehumidify if outdoor dew point is high)
- Supply Static Pressure Reset is downward adjustment of SP set point when the load on a VAV system is not 100%

Energy Saving Control Sequences

- Outside Air Economizer is using cooler air to supply to the space load at times of the year when available. Can be dry bulb or enthalpy based switchover point. Cooling without mechanical refrigeration
- Demand Limiting of Electrical usage demand is unloading air handlers, chillers, package rooftops, lighting to stay below a preset KW limit

Energy Saving Control Sequences

- Demand Control Ventilation changes the CFM of outside air flow in response to an input from a CO2 monitor to increase the OSA if on the high side and visa versa. When applied to a VAV system, VAV box position is also necessary. Outside air flow measurement is required
- Outside air control – closed during unoccupied hours and morning warm up or cool down

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Energy Saving Control Sequences

- Hot water reset of boilers (be careful, older boilers have a low limit of ~150 degree to prevent flue gas condensation)
- Hot air temperature reset
- Morning cool down ventilation brings in outside air for an hour or so before start time to pre cool the building in the summer without mechanical refrigeration

Energy Saving Control Sequences

- The ability to control the temperature range of the space sensor located in the room (cooling can be 75 to 78 degrees and heating can be 67 to 70 degrees) regardless of the set point shown on the sensor
- Separate cooling and heating set point by at least 5 degrees (required by Std 90.1)

Energy Saving Control Sequences

- Maintenance based on time usage for air filter changes, grease bearing, check belt tension, clean coils, tighten electrical connections, check control system valves and actuators
- Maintenance based a system parameter like air filter pressure differential alarm or cooling tower pool filter

Energy Saving Control Sequences

- Alarms with levels based on the degree of severity
- Data Logs by sensor/unit/system
- Lighting control or interface

Energy Saving Control Sequences

- Remember, we are in the comfort business so it is always a delicate balance between saving energy and keeping our customers happy
- If you are upgrading an existing building with a new control system, be prepared to fix some exist HVAC unit issues

New Control Features

- Auto Commissioning Software
- Web Based communication
- Enterprise Servers for multisite owners
- Resetting of HVAC System Level components for lowest system energy usage
- Graphic Programming vs line by line code writing

New Control Features

- Central Plant Optimization by looking at total Plant KW/Ton with real time inputs from chillers, pumps, towers.
- Graphics from many standard library files

Where the Energy Goes

- HVAC
- Compressor, Fans, Pumps, Boilers, Cooling Towers

Loads

- Lighting
- Overhead, Task, Emergency, Outdoor, Parking lot, Parking Garage
- Indoor Lighting – T12 – 40 Watt, T8 – 32 Watt, T5 – 28 Watt, LED is the lowest

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Loads

- Elevators
- PC or Plug Loads
- Office Equipment
- Parking Garage Ventilation

Loads

- Service Hot Water
- Electric or Gas water heaters
- Storage or Instantaneous
- Circulation pumps

Loads

- On Site Kitchen or Food Service
- Vending Machines
- Ice Melting
- Fountains

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Loads

- Industrial Process
- Warehouse
- On Site Water and or Waste Water Treatment Plant

Loads

- Electric Motors – can be the largest single user of power in your facility
- http://www1.eere.energy.gov/industry is a good source of industry motor data

Induction Motors

- Stator windings are powered and induce current into the rotor causing the opposite magnet field
- Requires rotor bars to carry this induced current
- No slip rings or brushes required
- Operate at less than the synchronous speed

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KW Power

- $P(\text{kW}) = \sqrt{3} \times PF \times I(\text{A}) \times V_{L-L}(\text{V}) / 1000$
- Example:
- KW = 1.73 x 0.87 x 59A x 460V / 1000
- KW = 40.84
- Nameplate from a 50 HP 460/3 motor
- One HP = 746 watts
- 40849 w / 746 w = 54.74 Hp

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Power Factor Correction

- Used on induction only motors if a penalty is accessed for low power factor (such as less than 0.85)
- Install power factor correction capacitors on your system to raise the power factor due to all the induction motors
- Capacitor has a power factor greater than one

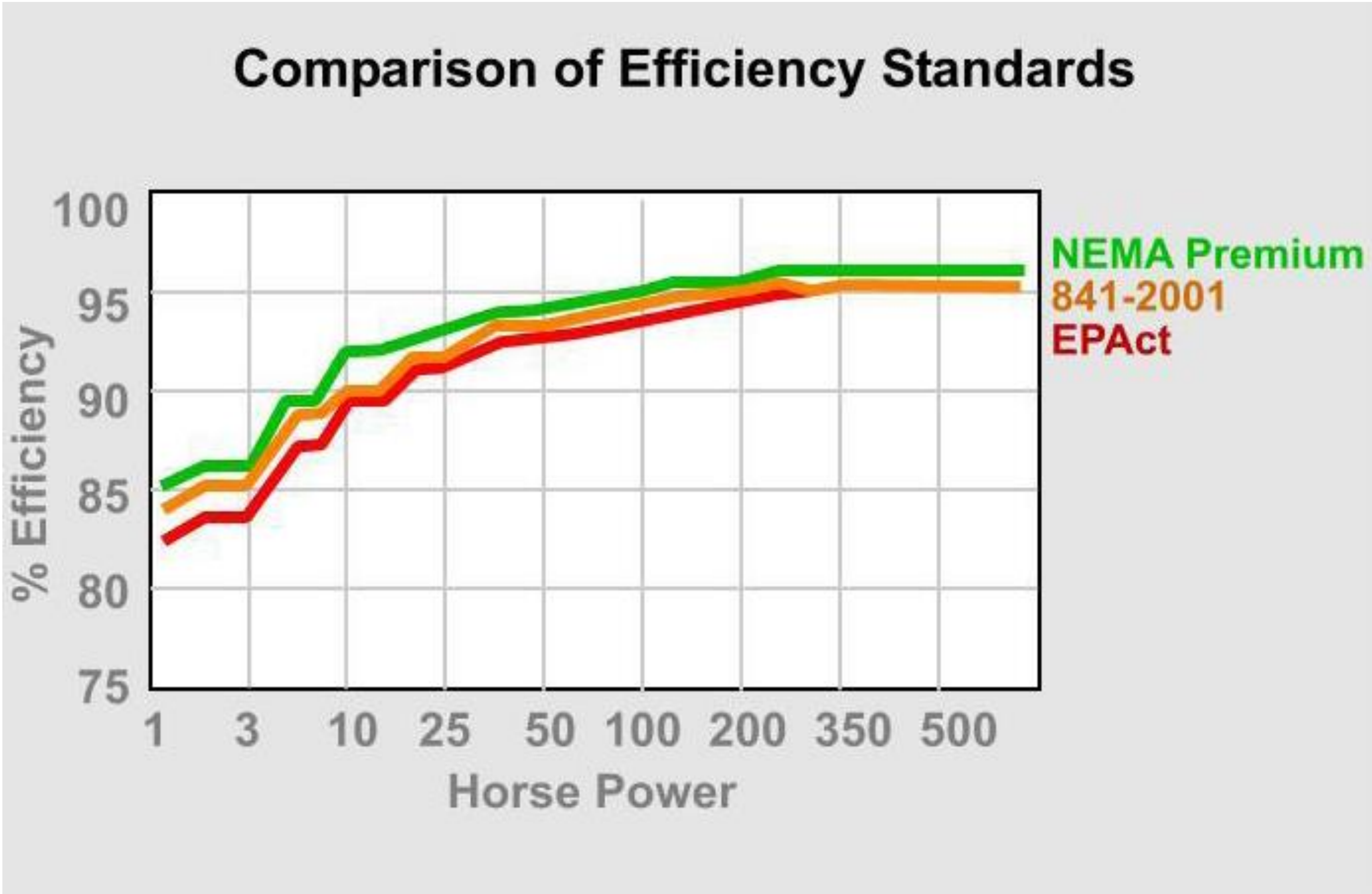
Power Factor Correction

- Available as an switch gear device that can sense when and how much capacitance to add or subtract, via contactor, as needed
- Can add at the motor, at a MCC, or at the main service entrance

Efficiency vs Load

- Motors are most efficient when they operate close to their rated load (75% or higher, measured in amperes).

Motor Efficiency Standards



2015 Small Motor Legislation

- D. O. E. Standard for ¼ hp to 3 hp
- Effective March of 2105
- All have Class F insulation material
- Better Aluminum in rotor bars
- Run Capacitor in all single phase motors

High Efficiency Motors

- Steel with better magnetic qualities
- More copper in the windings to reduce electrical losses
- Better bearings
- Better cooling fans
- Thinner core laminations (stator and rotor) to reduce Eddy currents
- Better quality insulation coatings (wire and laminations)
- Better quality lubrication

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ECM Motors

- Electrically Commutated Motor
- Have permanent magnets imbedded in the rotor, so induction is not needed
- Stator windings still rotate to produce repulsion but with half the power
- VFD on the end of the motor makes variable speed possible
- Max of 1 HP for now

Heating and Cooling Loads

- Many industry software available
- Must know envelope details, lighting loads, people density, ventilation rate, PC and other internal loads
- Is the existing system "right" sized

Energy Modeling

- Manual Method – use the std ratings of an HVAC unit to compare the existing usage and the reduction in usage with a proposed new, higher efficiency unit.
- Used for Level 1

Economic and Payback

- EER = Energy Efficiency Ratio = BTUH/Watts
- EER = 12 = 60,000 BTUH/5000 Watts
- EER = 3.413 x COP (Coefficient of Performance) Dimensionless
- EER is usually Unitary Equipment
- Kw/Ton = Kilowatts/12,000 BTUH or 1 Ton of Refrigeration
- Kw/Ton = 600 Kw/ 1000 Tons = 0.6 Kw/Ton
- Kw/Ton is usually Chillers
- Kw/Ton = 12/EER

Economic Example

- Existing 5 Ton Pkg Heat Pump, 9 SEER Cooling and 2.5 COP Heating Rating
- Cooling: 5 Tons is 60,000Btuh/9 SEER = 6.66KW
- 6.66KW x 2000 hrs/yr = 13,320 KWH
- 13,320 KWH x $0.05 = $666/yr
- Demand: Cooling 6 months, 6.66KW x $4/KW x 6 = $160/yr
- Total electric cost: $666 + $160 = $826/yr

Economic Example continued

- Heating: 2.5 COP, 40,000 Btuh Heat
- 40,000 Btuh/3.415 = 11.7 KW
- 11.7KW/ 2.5 COP = 4.68 KW input to Heat Pump
- 4.68 KW x 2000 hrs/yr = 9360 KWH
- 9360 KWH x $.05 / KWH = $468/ yr
- 4.68 KW x $4/Kw x 4 months = $75/ yr
- Total Heating Electric Cost = $468 + $75 = $543/ yr
- Heating and cooling combined $826 + $543 = $1369/ yr Total

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Economic Example Continued

- New 5 Ton Heat Pump, 14 SEER , 3.5 COP replacement
- Cooling: 5 Tons or 60,000 Btuh
- 60,000 Btuh / 14 SEER = 4.28 KW
- Cooling 6 months: 4.28 KW x 2000 hrs = 8560 KWH
- 8560 KWH x $.05 = $428/ Yr
- Demand: 4.28 KW x $4/kw x 6 = $103/ Yr
- Total cooling cost: $428 + $103 = $531/ Yr

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Economic Example Continued

- Heating: 3.5 COP, 40,000 Btuh
- 40,000 Btuh/ 3.415 = 11.7 KW
- 11.7 Kw / 3.5 COP = 3.3 KW input to heat pump
- 3.3 KW x 2000 hrs/yr = 6600 KWH
- 6600KWH x $.05 = $330/ yr
- Demand for 4 months: 3.3 KW x $4/KW x 4 = $53/ yr
- Total Heating Cost: $330 + $53 = $383/ yr
- Total Heating & Cooling Cost: $531 + $383 = $914/ yr

Economic Example Continued

- Old 9 SEER Unit : $1369/ yr
- New 14 SEER Unit: $914/ yr
- Difference: $ 455/ yr
- New Unit Cost Approx: $3,000
- Payback: Cost/Savings/yr = $3000/$455 = 6.5 yrs

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Energy Modeling

- Computer Simulation – industry standard software or utility proved software to simulate total energy usage or partial energy usage. Will also do payback period if you have accurate installed costs.
- Software most commonly used – Carrier HAP, DOE II or Plus, E quest, or Trane Trace

Energy Modeling

- Accurately predict energy usage as the building loads change on an annual basis
- Be accurate with building input – size, wall, window, roof type
- Be accurate with utility input – some programs get rates direct from the various utilities

List of Energy Conserving Measures

- Cooling
- Energy Recovery
- Heating
- Building Envelope
- Ventilation
- Lighting

Cooling System Efficiency Improvements

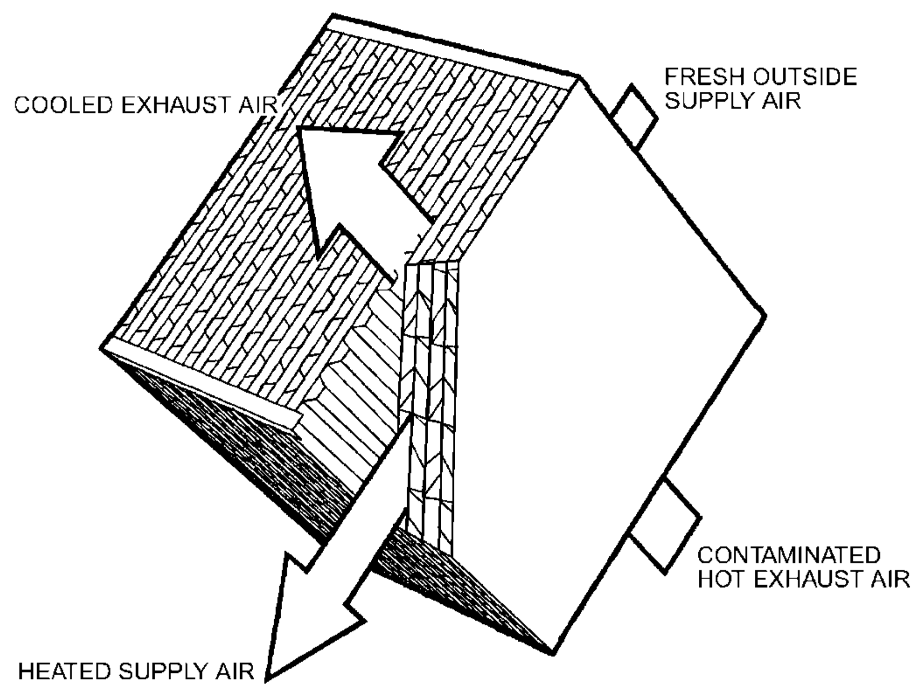
- System scheduling via programmable thermostat or EMS
- Proper amount of outside ventilation air – not too much – close OSA in unoccupied times – add CO2 sensors to demand control the amount of OSA
- Airside Economizer for free cooling in fall, winter, and spring
- Waterside economizer for free cooling on chilled water systems in the fall, winter and spring with cooling tower
- Supply Air Temperature reset upward when the load is reduced
- Chilled Water temperature reset upward when the load is reduced

Cooling System Efficiency Improvements

- Install Heat or Energy Recovery devices between exhaust airstream and outside airstream – be careful of wheels with leakage
- Convert constant volume airside and waterside systems to variable volume systems with VFD (variable fan drive)
- Convert constant speed chillers to VFD chillers
- Install new high efficiency equipment at replacement time or when payback can be justified
- Improve system and equipment maintenance – air filters, strainers, annual inspection, grease bearings, pumps, cooling towers, clean coils, leaks, clean tubes

Heat Recovery Systems *(cont.)*

- Exchanger
  - Incoming outside air is heated by warm exhaust air
  - Exchange is made through a heat conductive metal
  - Low efficiency
  - No cross-contamination



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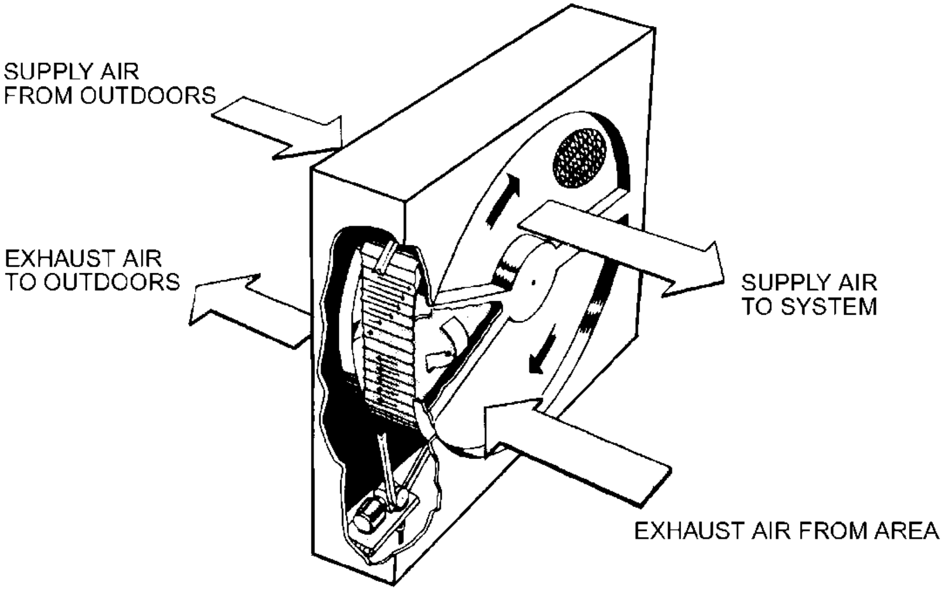
78

Energy Recovery Systems

- Heat Wheel
  - A desiccant material (like silica) absorbs heat (sensible and latent) in exhaust air and transfers it to outside air
  - Risk of contamination
  - Space limitations
  - Good efficiency
  - Freeze-thaw cycle



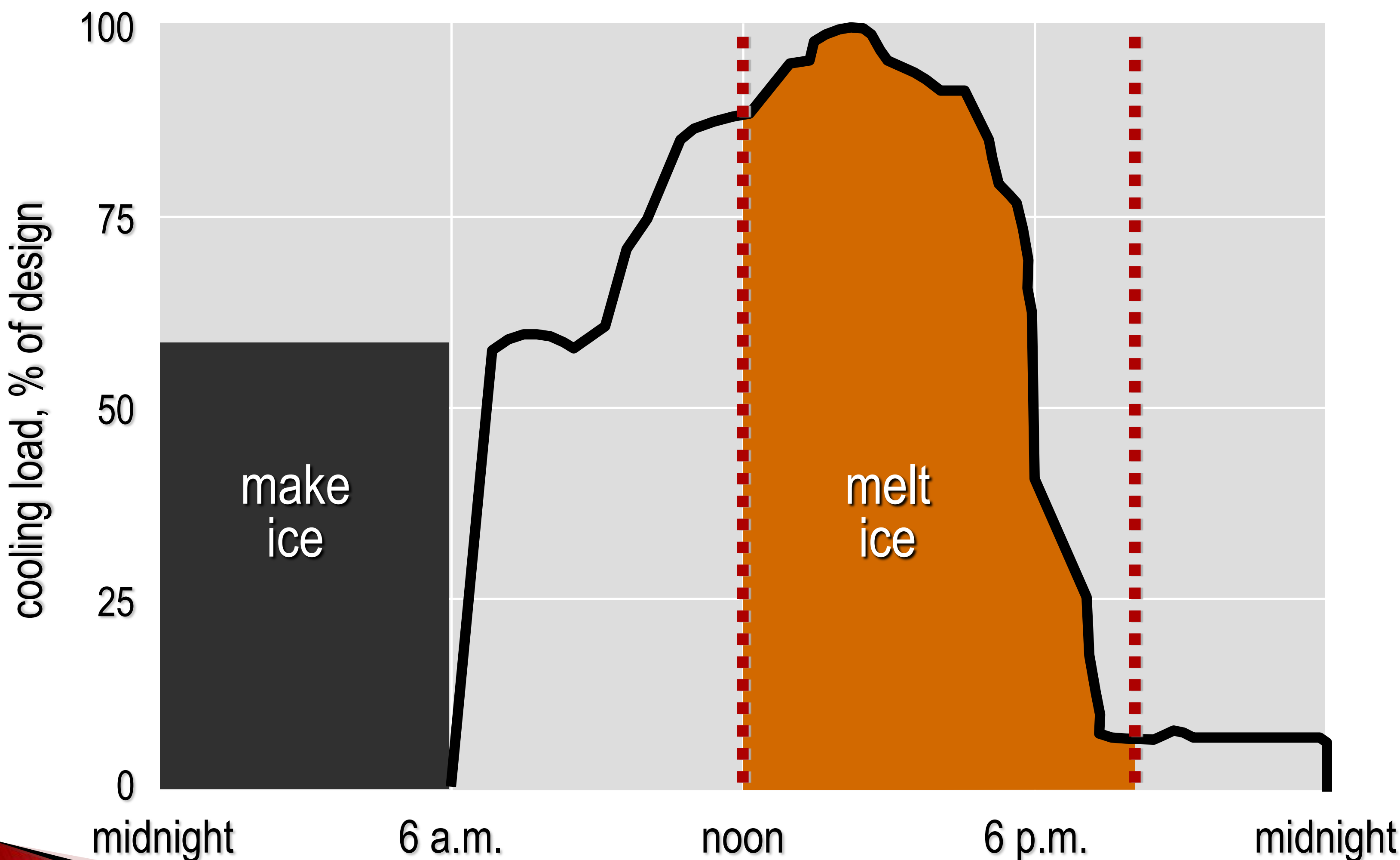
Cooling System Efficiency Improvements

- Install chilled water or ice storage, off peak, thermal storage system
- Reduce cooling load with building envelope improvements
- Install occupancy sensors in room/zone for HVAC/lighting usage
- Run only the number of chillers that are needed
- Control System maintenance/check out

Building Envelope Efficiency Improvements

- Reduce cooling load with building envelope improvements

On-Peak Cooling with Ice



Heating System Efficiency Improvements

- Schedule System
- Proper amount of Ventilation Air
- Do a combustion test annually with gas fired devices
- For larger boiler, add combustion analyzer controls to the burner
- Hot Water Temperature reset downward (be careful)
- Replace boiler with higher efficiency or condensing boiler
- Steam trap maintenance program with temperature measure

Heating System Efficiency Improvements

- Lower steam pressure at boiler if not needed in system
- Operate the correct number of boilers
- Maintenance – air filters, strainers, pumps, leaks, clean boiler tubes and other parts inside the boiler

New Construction/Major Renovation

- Select highest efficiency equipment possible.
- Use ASHRAE Std 90.1 – 2013 as a guideline.
- Consider chilled beam, radiant heating/cooling, underfloor air distribution, ground source heat pump.
- Use Dedicated Outdoor Air System make up approach.
- Use high delta temperature on chilled water and condenser water systems.
- Use ECM motors if 1 HP and less.

Ventilation

- A controlled process where we bring outside air into an occupied space or building for the purpose of diluting the internal pollutants generated by the building materials and the people occupying the space, to provide an acceptable indoor environment.

Conditioning of Outdoor Air

- Can be done at each air handler, fan coil, or DX unit provide the capacity can meet all three design conditions – heating, cooling and de humidification
- Can be done at one central dedicated outside air make up unit that filters, heats, cools, de humidifies, reheats if needed and is then ducted to each terminal unit

Dedicated Outdoor Air Unit

- Pre conditions the air so each terminal unit just has to sensibly heat or cool the room air.
- Great way to do heat or energy recovery since all the air is in one or a few locations

Demand Control Ventilation

- As HVAC engineers design around increased ventilation rates and building energy performance, various strategies and designs have emerged.
- One of these designs is **demand control ventilation (DCV)**, which is categorized as a dilution method (one of the two methods specified by ASHRAE 62.1).

Demand Control Ventilation

- Most commonly used with room CO_2 sensors
- Can be used with room occupancy sensors
- Can also be used with card access/card reader systems
- By lowering the outside air CFM, energy and cost savings can be huge

Demand Control Ventilation

- Required by ASHRAE Standard 90.1 –2013, Building Energy Efficiency, whenever the people density in a zone is greater than 25 people/1000 sq ft
- This is an example where a different standard, ASHRAE 90.1, overrides ASHRAE Std 62.1 – 2013

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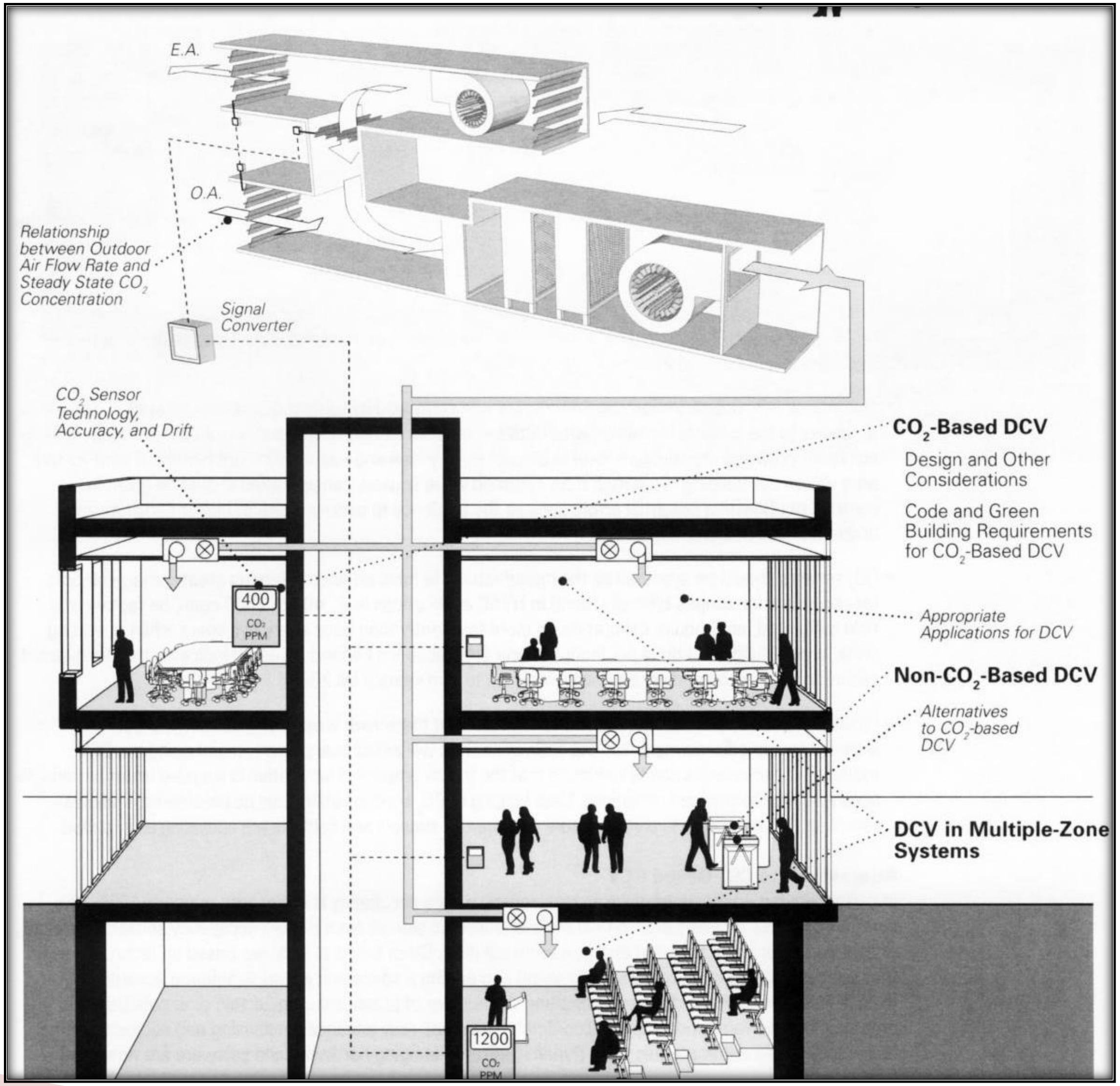
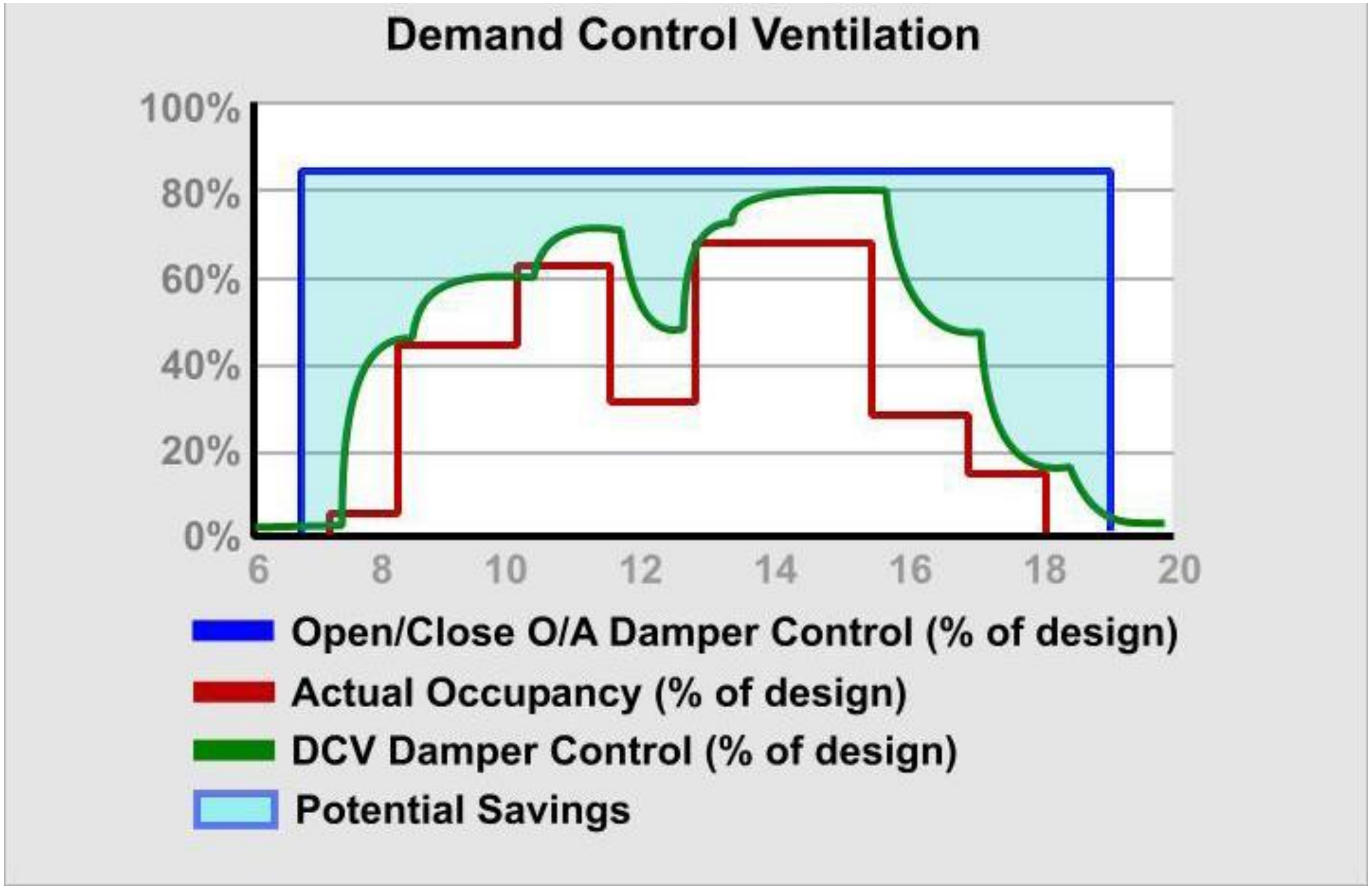
Demand Control Ventilation



DCV Savings


Demand Control Ventilation
100%
80%
60%
40%
20%
0%
6
8
10
12
14
16
18
20
Open/Close O/A Damper Control (% of design)
Actual Occupancy (% of design)
DCV Damper Control (% of design)
Potential Savings

Energy Usage Index

- Measured in thousands of BTUH per square foot per year
- Can be compared to similar occupancy buildings in North America
- May see shown as EUI

EUI

- Office Bldg – 50 to 65 Kbtuh/sq ft/yr
- Small Retail – 100 to 120 “
- Schools – 70 to 90 “
- Fast Food – 250 to 400 “
- Lodging – 75 to 100 “

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EUI

- Big Box Store – 60 to 100 Kbtuh/sq ft/yr
- Grocery Store – 200 to 350 “
- Hospital/HealthCare – 200 to 300 “
- Office Warehouse –
- Source – ASHRAE Advanced Energy Design Guides for 30% and 50% improvement
- Free at ASHRAE. Org – must register

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Checklist for Energy Audit

- Breakdown all the steps into a large Excel spreadsheet
- Can add or delete items as job requires.
- Sample attached

Final Report

- List all the items in the existing building – HVAC, Lighting, SWH, PC or plug loads
- Level One is usually only a few pages
- Level Two is more complex and may include the results of energy modeling
- Level Three is very complex and expensive.
- Include photos

Final Report

- Include any data logging outputs if they were done
- List any safety issues you discovered on the site
- Include building floor plans if used
- Suggest Measurement & Verification on large impact ECM – before and after
- List time and date of site visit

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Final Report

- Compare the building being audited to a national average for similar occupancy.
- Include our energy audit checklist if you feel it will be helpful

Final Report

- If your building has a number of non functional systems, a complete retro commissioning maybe required before any high efficiency improvements can be done

Credits for Seminar

- Trane Air Conditioning Clinic Series
- ASHRAE Standards, AEDG
- Mitsubishi Electric