WASBO
Spring Conference
Wisconsin Dells, WI

Understanding HVAC

MAY 17, 2024 | 9:40AM – 10:30AM

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Wikipedia defines Facility Management (FM) as…

"…an interdisciplinary business function that coordinates space, infrastructure, people and organization."

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We define Facility Management as...

"An ideal facility manager must have Aristotle's logic and Solomon's wisdom, a priest's discretion and a gambler's poker face, a lawyer's shrewdness and a marketing director's charm, a gladiator's courage, a marathon runner's perseverance and a sprinter's speed, a leatherneck's toughness and a dancer's agility, lots of good luck and 30 hours per day."

- Unknown

HVAC 101

Module 1: *What is HVACR?*

Module 2: *Terminology & Slang*

Module 3: *Basic Sciences*

Module 4: *Air Conditioning / Basic Small Tonnage*

Module 5: *Air Conditioning / Basic Large Tonnage*

Module 6: *Air flow Types and Systems*

Module 7: *Commercial System Applications*

Module 8: *Support Components & Control Systems*

Module 9: *Heating Systems*

Module 10: *Focusing on the Customer*

Language of HVACR

A building climate is determined by three functions:
Heating, Ventilation, and Air Conditioning (HVAC)

THE MECHANICAL SERVICES FAMILY

Heating

Ventilation

Air

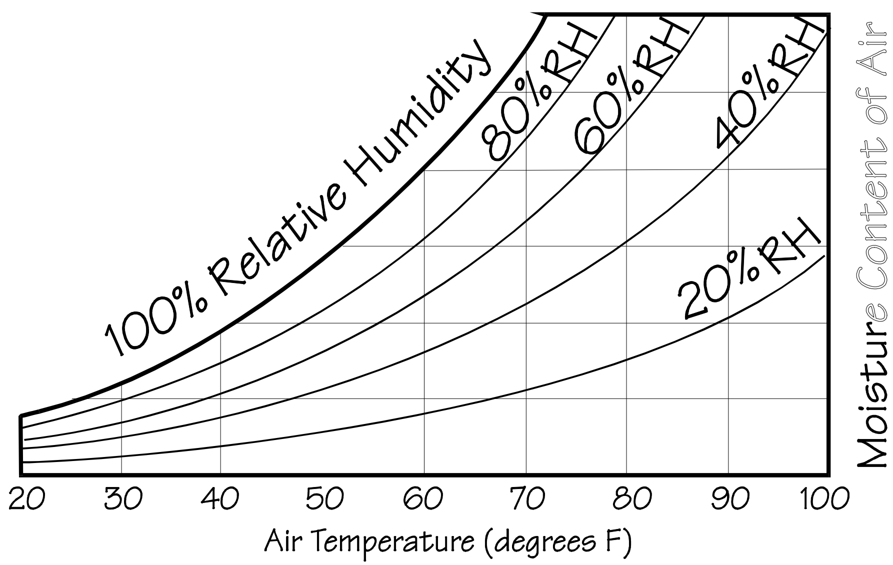
Conditioning

Refrigeration

Language of HVACR

- Measurable Parameters
  - Temperature (Dry Bulb/ Wet Bulb)
  - Pressure
  - Humidity
  - Indoor Air Quality (CO, CO2, odor, VOC's, particulate, etc.)
  - Ventilation Air – Outdoor Fresh Air %
  - Air Changes/Air Flow (CFM)
  - kWh/ft^2, BTU/ft^2
    - British Thermal Unit (Btu) = Heat required to raise 1 lb of water 1 degree F
    - Ton of Cooling = Heat required to melt 2000 lb of ice in 24 hours (12,000 Btu/hr)
  - $/$ft^2$

Psychrometric Chart



HVAC System Goals

There may be a great deal of complexity surrounding mechanical systems, but the goal is easy to understand

- Regulate temperature and humidity
- Circulate appropriate volumes of fresh air
- Filter contaminants from air
- Be unobtrusive and quiet
- Operate efficiently and economically

Considerations During Design

- Budget tolerance of School Board
- Amount of addition vs. size of existing building
- Available floor to ceiling height
- Building footprint, single-story with a sprawling footprint

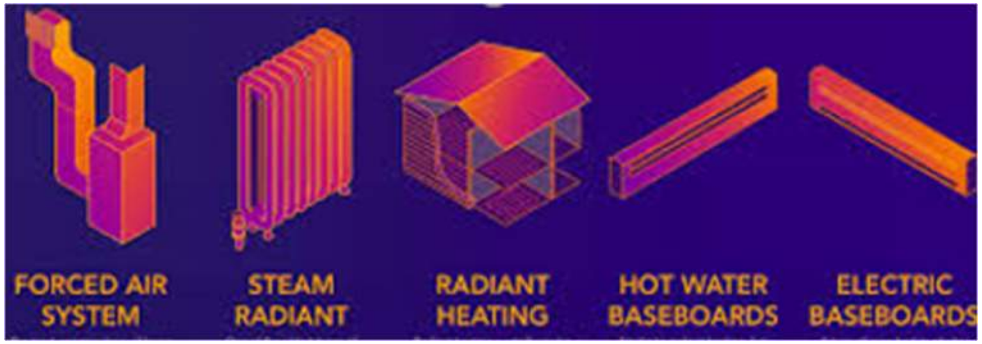
Students in well-maintained facilities score 11% higher on standardized tests

A study of the District of Columbia school system found, after controlling for other variables such as a student's socioeconomic status, that students' standardized achievement scores were lower in schools with poor building conditions. Students in school buildings in poor condition had achievement that was 6% below schools in fair condition and 11% below schools in excellent condition. (Edwards, 1991)

Similarly, Hines' (1996) study of large, urban high schools in Virginia also found a relationship between building condition and student achievement. Indeed, Hines found that student achievement was as much as 11 percentile points lower in substandard buildings as compared to above-standard buildings.

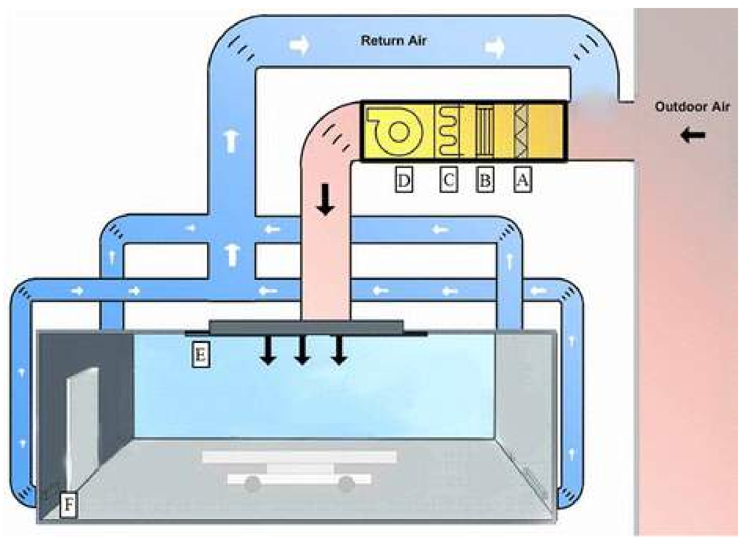
Heating Systems

- Buildings may use gas boilers, electric heating coils or even geothermal sources of heat with water steam or air as the transfer medium
- The system consists of piping and ductwork to move heated fluid or heated air into different parts of the building
- Equipment for heating systems are usually located in a central mechanical room



Ventilation

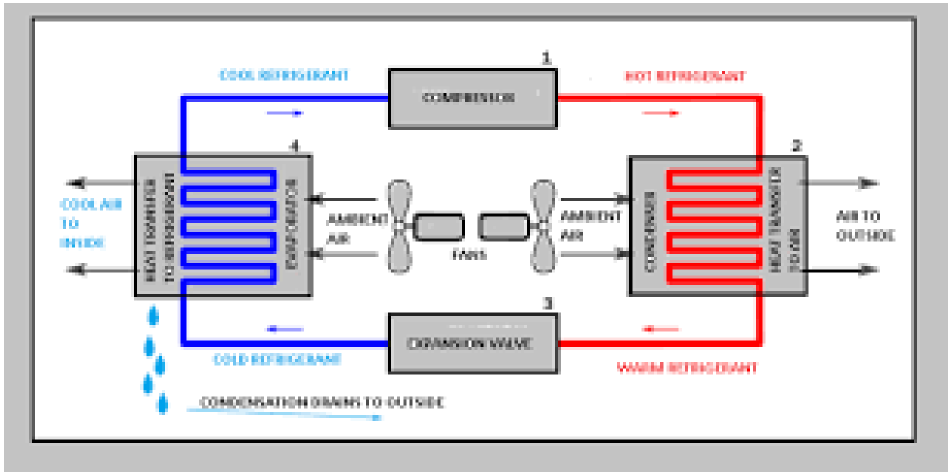
- Ventilation refers to the changing of air in any space
- Ventilation includes both the exchange of air to the outside as well as circulation of air within the building
- Proper ventilation is one of the most important factors for maintaining acceptable indoor air quality in buildings



Air Conditioning

An air conditioning system provides heating, cooling, ventilation, and humidity control for all or part of a building.

Air conditioning simply "conditions air" to whatever temperature is required.



WORKING OF AIR-CONDITIONER

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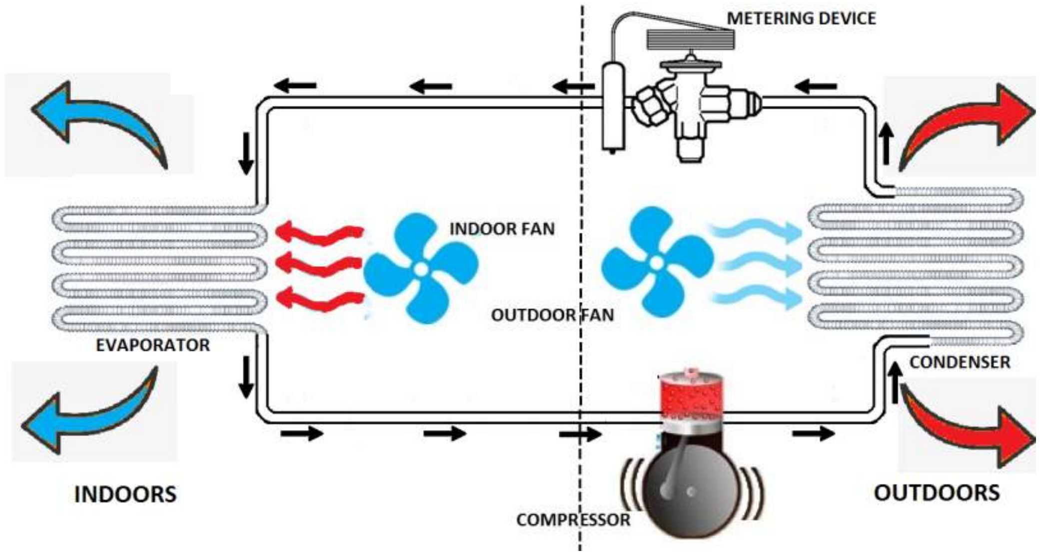
Air Conditioning System

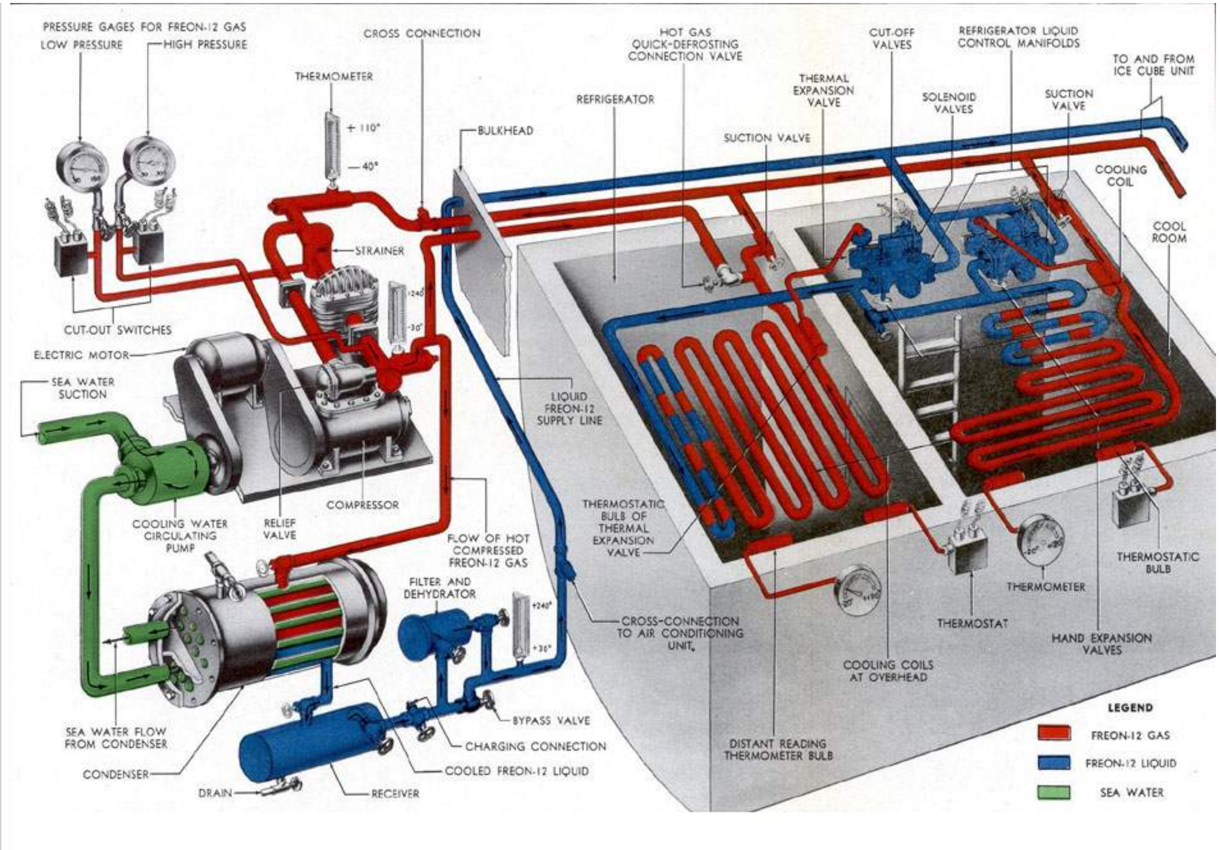
There are four main components to an Air Conditioning System

- Compressor – the pump used to move the refrigerant through the system
- Condenser - reduces refrigerants to their liquid form by the removal of heat
- Metering Device – controls the amount of refrigerant to the evaporator
- Evaporator – absorbs the heat from the space we are trying to cool



Refrigeration Systems

Refrigeration systems are mainly used to store food and other perishables at low temperatures in order to prevent bacteria, yeasts and molds from growing



Types of Commercial Systems

Common HVAC Systems:

- Rooftop Units, AHUs (Packaged Units)
- Heat Pumps (Air & Water Source)
- Boilers (Hot Water & Steam)
- Chillers (Air Cooled, Water Cooled, Glycol Cooled)
- Cooling Towers
- Heaters (Gas fired, Electric, Hot Water, Infra-Red etc.)
- Fans and Ventilation

Types of Commercial Systems

Most commercial buildings have Packaged Rooftop Units

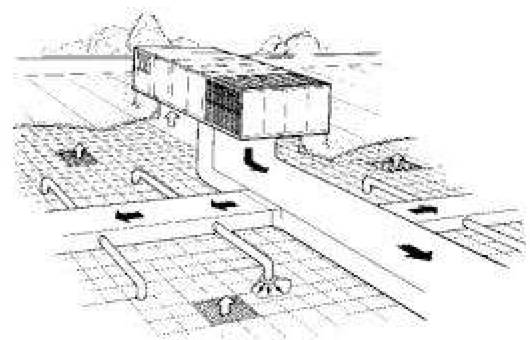
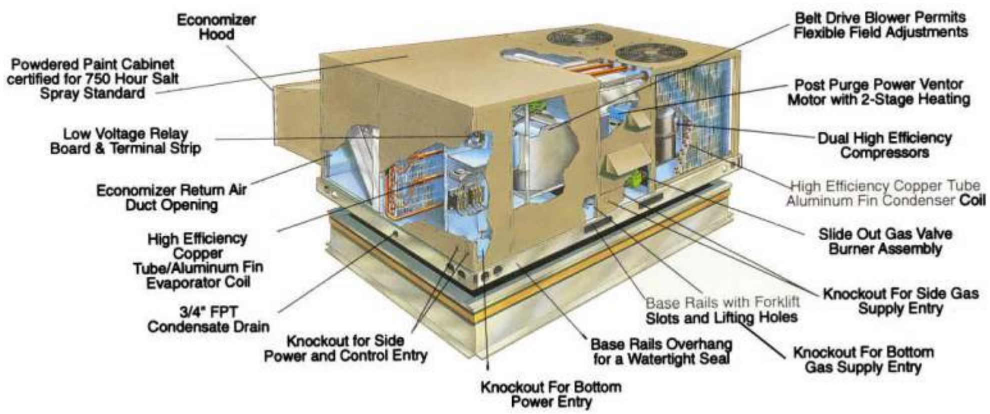


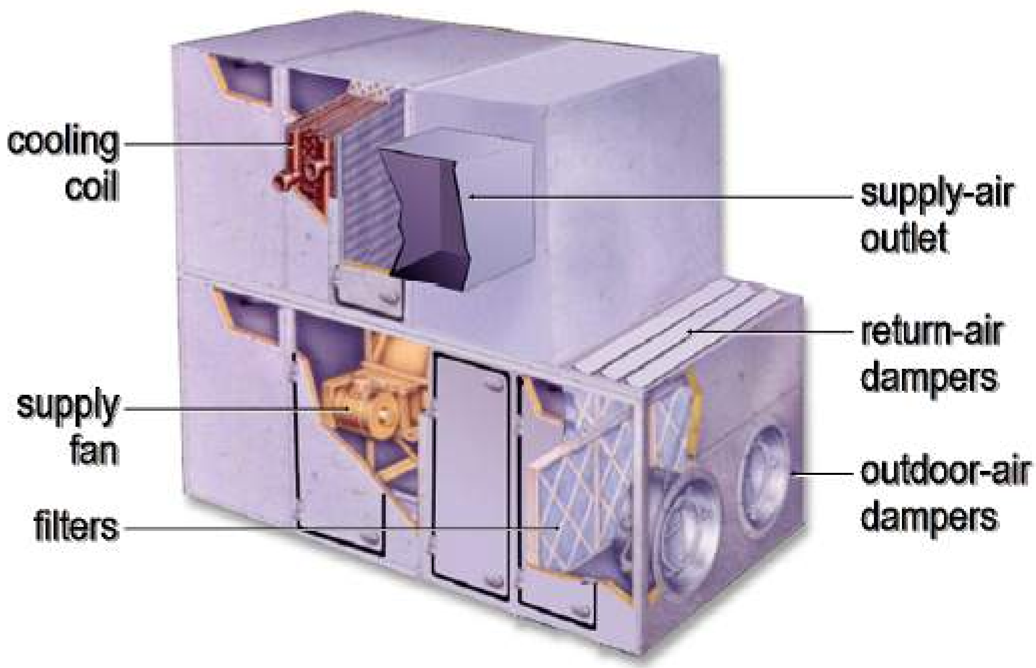
FIGURE 5.13 Typical rooftop installation of the single-zone system. (Lennox)



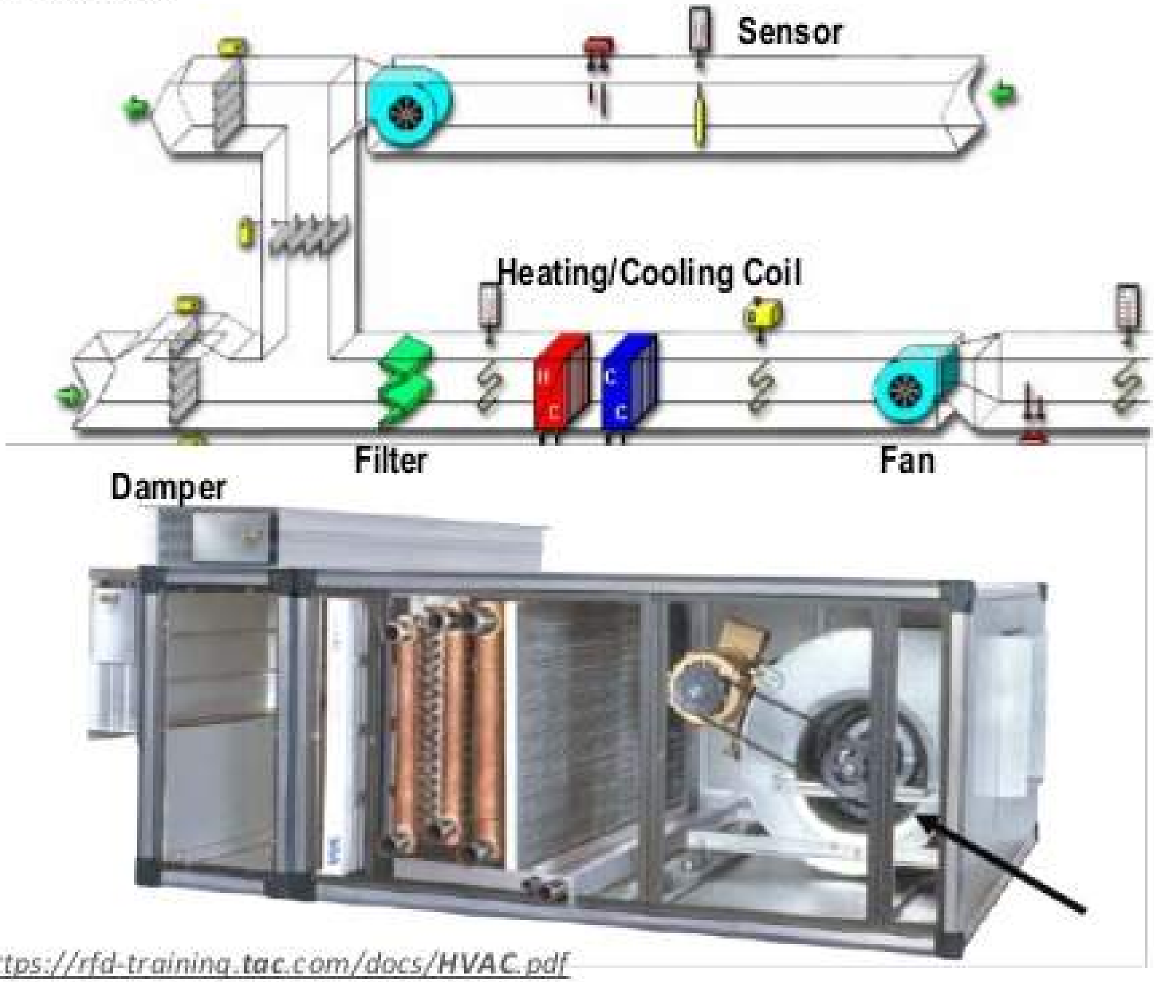
Types of Commercial Systems

Just as the compressor is the workhorse of an HVACR refrigeration system, the **Air Handling Unit** (**AHU**) is the heart of an HVACR air distribution and ventilation system.

Air Handling Unit



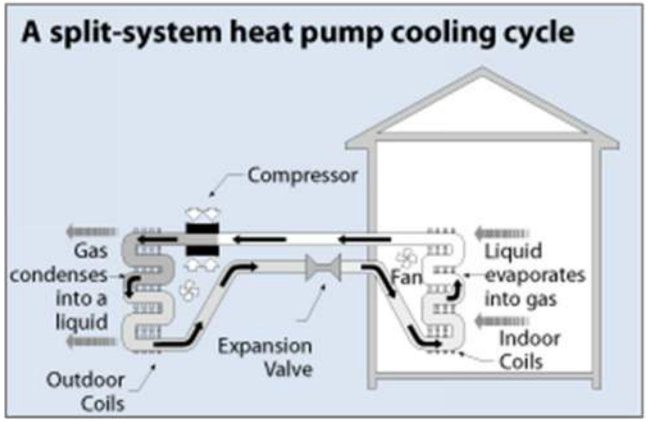
What's in an AHU?



:tures from https://rfd-training.tac.com/docs/HVAC.pdf

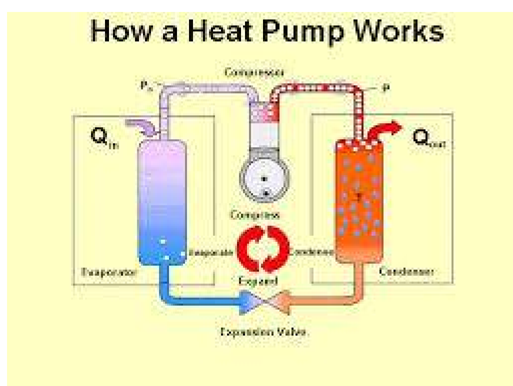
Types of Commercial Systems

Heat Pumps: Like a refrigerator working in reverse, a heat pump extracts the heat from the air (or water) and uses it for heating. The most common air-to-air heat pumps have the compressor and condenser in an outside unit. Then the refrigerant piping goes to an inside air handler unit which houses the expansion valve and the evaporator. System simplicity and low initial cost are the main benefit, while short life span (7 years is typical) and lack of control options are the principal drawbacks.



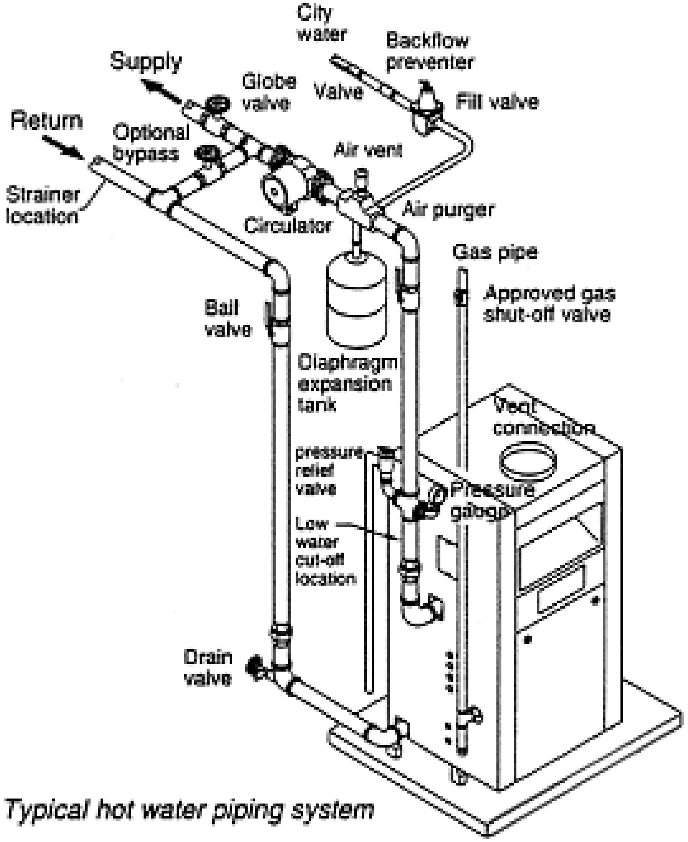
Types of Commercial Systems

Water Source Heat Pumps: Called a one pipe system, a single pipe carries water through the building which the individual water source heat pumps use for their heat source. This system requires a boiler to raise the loop water temperature and a cooling tower to lower the loop water temperature. Each zone has a dedicated water source heat pump that is located inside the building. This system is extremely energy efficient during those times of the year. The main drawback is probably all the compressors located throughout the interior, both for noise and maintenance.



Types of Commercial Systems

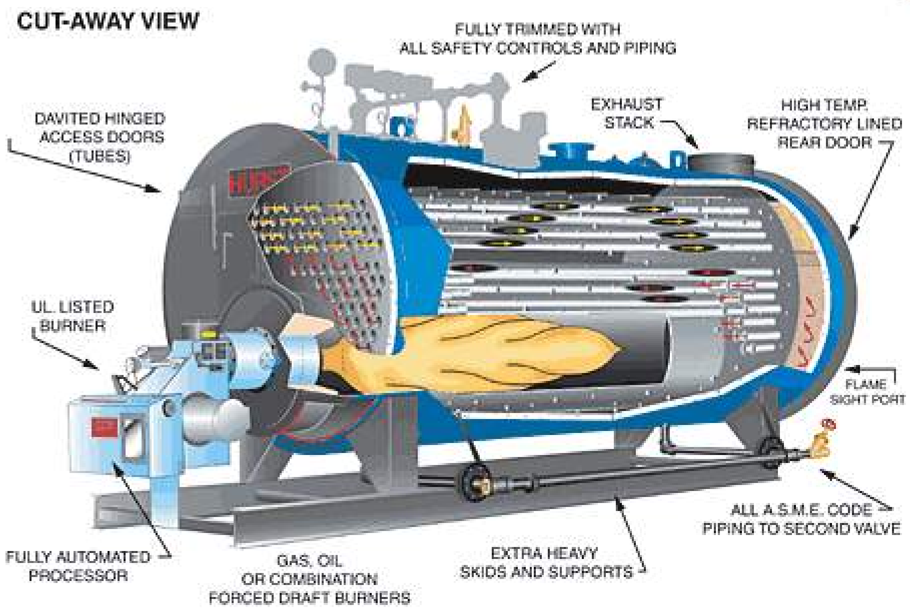
Boilers (Hot Water)



Typical hot water piping system

Types of Commercial Systems

Boilers (Steam)



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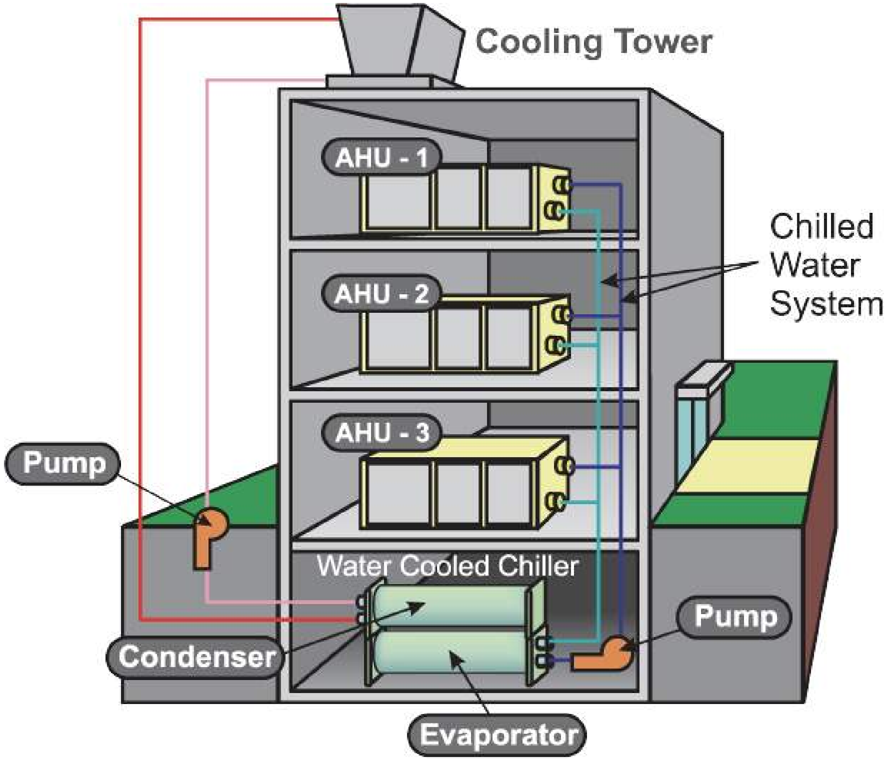
Types of Commercial Systems

Chillers - Typically Air & Water Cooled

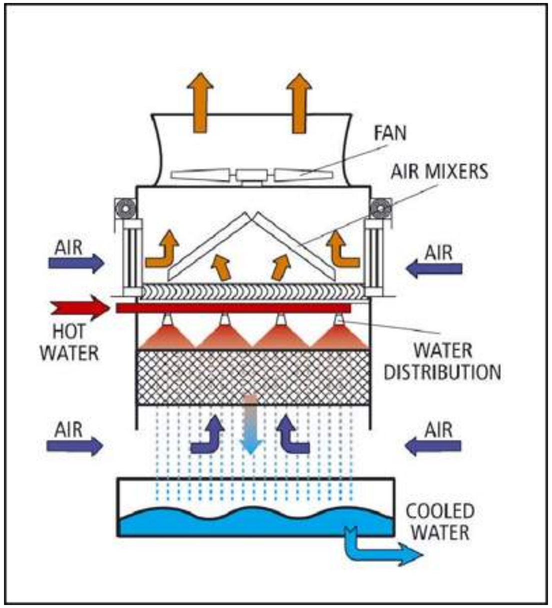


Types Of Commercial Systems

Chiller (Air Cooled) Air-cooled chillers are similar to water-cooled chillers. Both are refrigeration systems that are common in mechanical industries. They both use the same basic principles to generate cooling power, but they use different substances to cool the condensers. Air-cooled chillers do this with the use of air.

Types of Commercial Systems

Cooling Towers: *From Wikipedia*: Is a heat rejection device which extracts waste heat to the atmosphere through the cooling of a water stream to a lower temperature.



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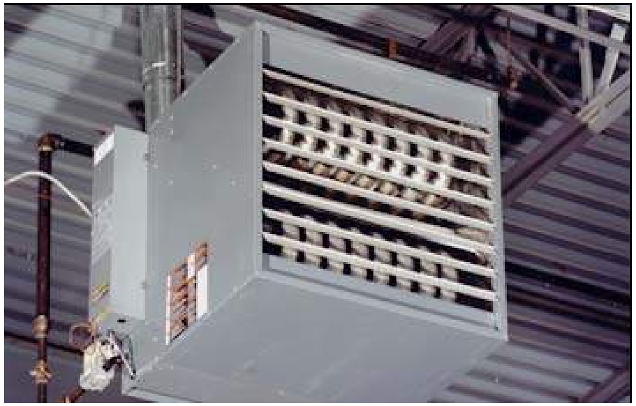
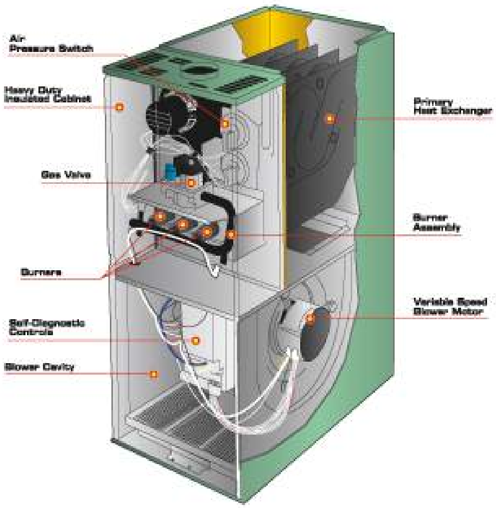
Types of Commercial Systems

Heaters

- Gas Fired Unit Heater
- Forced Air Furnace
- Infra-Red Heater



FURNACE GAS-HOT AIR



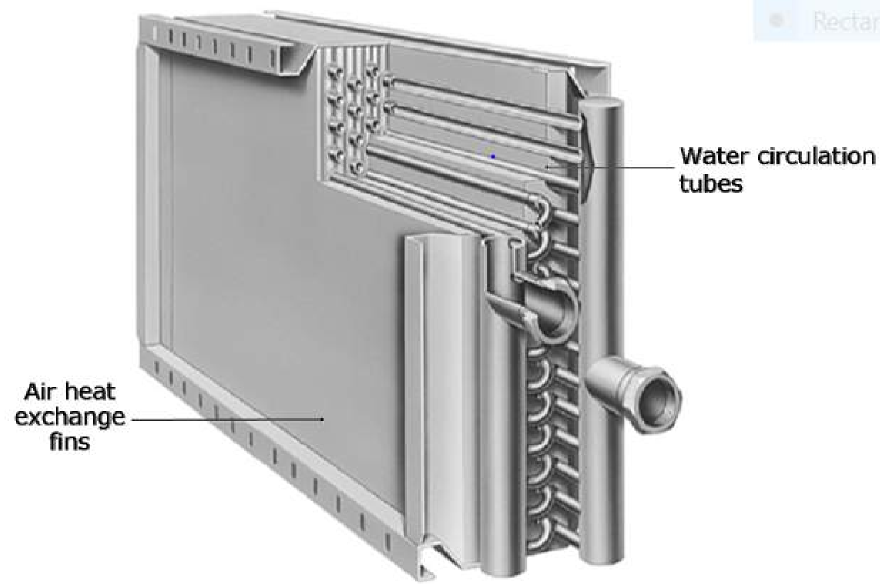
Types of Commercial Systems

Fans and Ventilation: The use of fans to ventilate a space for cooling and/or expulsion of indoor pollutants can be done in many ways. From a simple toilet exhaust fan to huge wall fans interconnected with wall louvers used for summer cooling, there are many ways to ventilate.

Types of Commercial Systems

Heating and cooling coils or elements are normally included in a centralized AHU to provide temperature control for the distributed supply air. Larger AHUs utilize heat exchanger coils that can circulate hot water or steam from a central boiler for heating, and chilled water from a central chiller system for cooling.

Cooling or Heating Coil



Air Filters

With today's ever-increasing emphasis on indoor air quality, filtering has become an important factor in design and operation of the air distribution system.

Filter Selection is Critical

Filter Selection

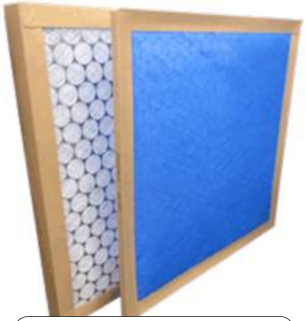
- Information off Label (or photo of label) if possible
- Efficiency
  - MERV/HEPA
- Size - H x W x D
  - Nominal vs Exact
- If Temperature >150F might need High Temperature

Common Standard Size
12x24
16x20
16x25
18x24
20x20
20x24
20x25
24x24

Filtration Basics

Filter Selection

- Filter Style
  - Disposable
  - Pleated
  - Panel
  - Rigid/Box
  - V-Cell
  - Bag/Pocket
  - HEPA
  - Carbon

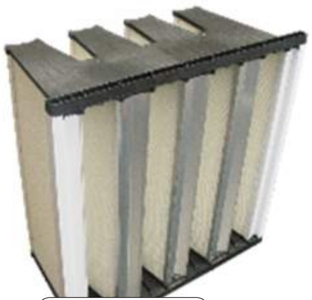


Disposable

Pleated

Panel

Rigid/ Box



V-Cell

Bag/ Pocket

Carbon

Understanding Filter language

What is a MERV rating?

Minimum Efficiency Reporting Values, or MERVs, report a filter's ability to capture larger particles between 0.3 and 10 microns.

•This value is helpful in comparing the performance of different filters

•The rating is derived from a test method developed by the American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) [see www.ashrae.org].

•The higher the MERV rating the better the filter is at trapping specific types of particle

Pleated Filters

Efficiency

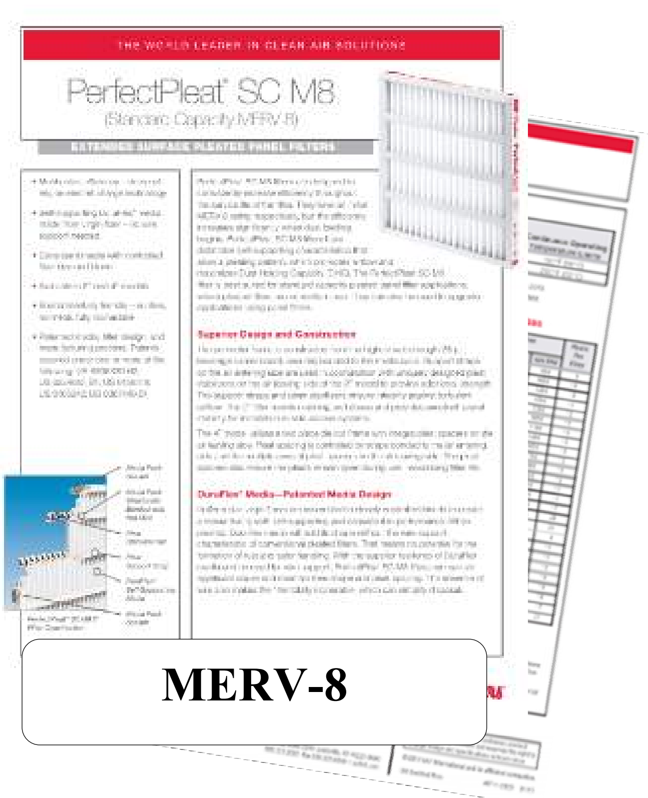
$ ΔP Eff 		
MERV 8 Pleated	**MERV 11 Pleated**	**MERV 13 Pleated**
Cost	Approx 20% more	Approx 50 – 75% more
SC 2” 500 FPM = 0.21”WG HC = 0.20”WG	SC = 0.33”WG HC = 0.31”WG	Only HC = 0.35”WG
MERV 8	MERV 11	MERV 13

Increasing Filter MERV Rating?

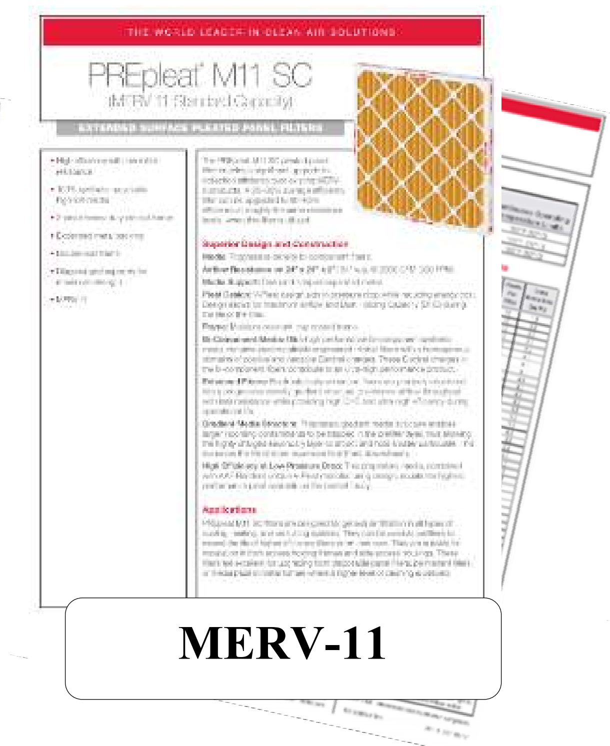
MERV	Performance (ASHRAE Std. 52.1) *Avg. Min. Composite Efficiency* E_1 (0.3µm- 1.0µm)	E_2 (1.0µm- 3.0µm)	E_1 (3.0µm- 10.0µm)	Application: Controlled Particulate — Size	Controlled Particulate — Example	Typical Application and Limitations
1	-	-	< 20%	> 10.0 µm	- Pollen - Dust Mites - Sanding Dust - Carper Fibers	Minimum filtration, Residential, window air-conditioners
2	-	-	< 20%			
3	-	-	< 20%			
4	-	-	< 20%			
5	-	-	20-35%	3.0-10.0 µm	- Mold and Spores - Cement Dust - Hair Spray - Powdered Milk	Standard commercial buildings, Industrial work places, Paint booth inlet air
6	-	-	35-50%			
7	-	-	50-70%			
8	-	-	> 70%			
9	-	< 50%	> 85%	1.0-3.0 µm	- Legionella - Lead Dust - Coal Dust - Auto Emissions	Better commercial buildings, Hospital laboratories
10	-	50-65%	> 85%			
11	-	65-80%	> 85%			
12	-	> 80%	> 90%			
13	< 75%	> 90%	> 90%	0.3-1.0 µm	- Bacteria - Most Tobacco Smoke - Cooking Oil - Droplet nuclei (sneezes)	Superior commercial, General surgery, Smoking lounges, Hospital inpatient care
14	75-85%	> 90%	> 90%			
15	85-95%	> 90%	> 90%			
16	> 95%	> 95%	> 95%			
17	-	-	-	< 0.3 µm	- Virus (unattached) - Sea salt - Radon progeny - Carbon Dust	Cleanrooms, Pharm. mfg., Radioactive materials, Carcinogenic materials
18	-	-	-			
19	-	-	-			
20	-	-	-			

Increasing Filter MERV Rating?

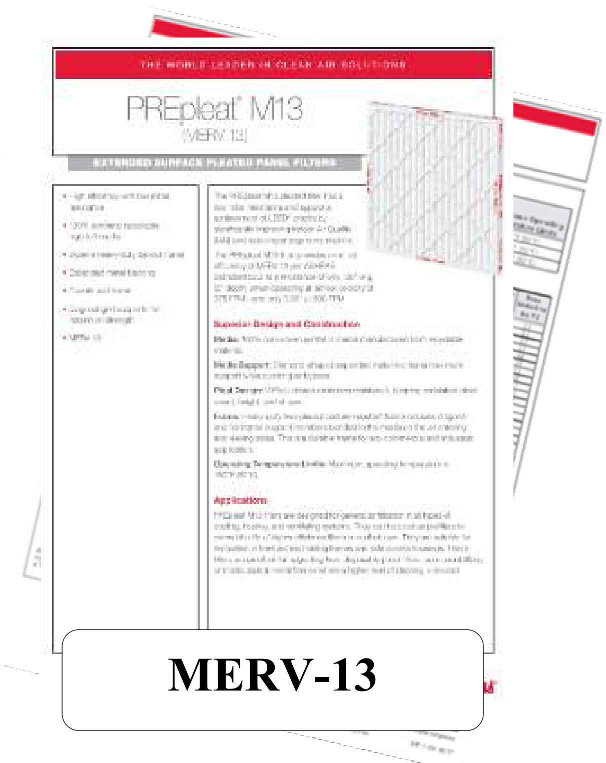
If we replace MERV-8 filters with MERV-11 or MERV-13, what would happen to unit performance? Are adjustments required?



MERV-8



MERV-11



MERV-13


THE RELATIVE SIZE
OF PARTICLES
From the COVID-19 pandemic to the U.S. West Coast wildfires, some of the biggest threats now are also the most microscopic.
A particle needs to be 10 microns (µm) or less before it can be inhaled into your respiratory tract. But just how small are these specks?
Here's a look at the relative sizes of some familiar particles ›
HUMAN HAIR 50-180µm ›
FOR SCALE
FINE BEACH SAND 90µm ›
GRAIN OF SALT 60µm ›
WHITE BLOOD CELL 25µm ›
GRAIN OF POLLEN 15µm ›
DUST PARTICLE (PM10) <10µm ›
RED BLOOD CELL 7-8µm ›
RESPIRATORY DROPLETS 5-10µm ›
DUST PARTICLE (PM2.5) 2.5µm ›
BACTERIUM 1-3µm ›
WILDFIRE SMOKE 0.4-0.7µm ›
CORONAVIRUS 0.1-0.5µm ›
T4 BACTERIOPHAGE 0.225µm ›
ZIKA VIRUS 0.045µm ›
Pollen can trigger allergic reactions and hay fever—which 1 in 5 Americans experience every year.
The visibility limits for what the naked eye can see hovers around 10-40µm.
Respiratory droplets have the potential to carry smaller particles within them, such as dust or coronavirus.
Wildfire smoke can persist in the air for several days, and even months.

Installation

Damage / Improper Installation

Installation (Bypass of Dirty Air)

Damage/Improper Installation

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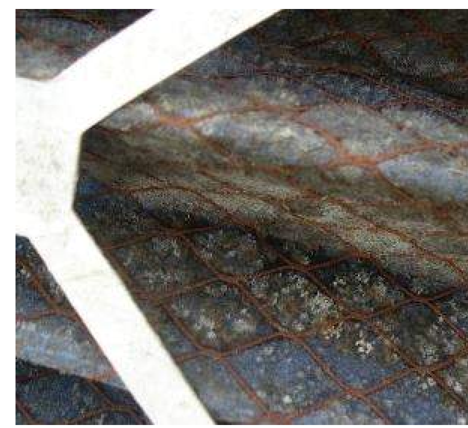
Environment

Microbial Growth/Moisture



Is the Correct Filter Enough?

Other factors that can affect the quality of the air

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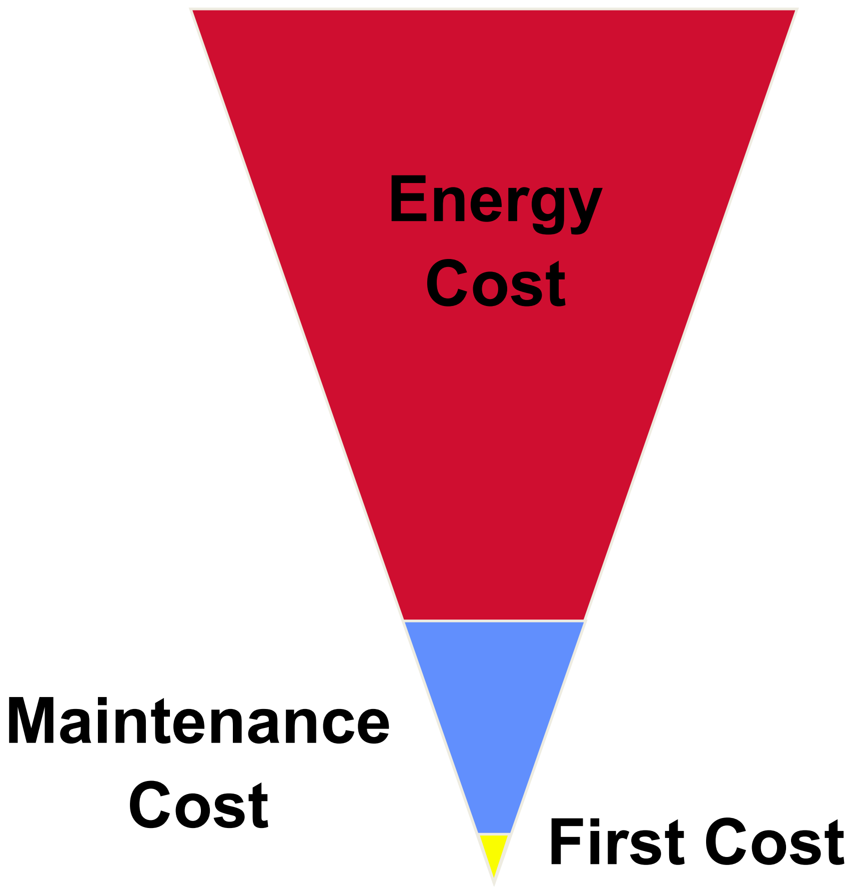
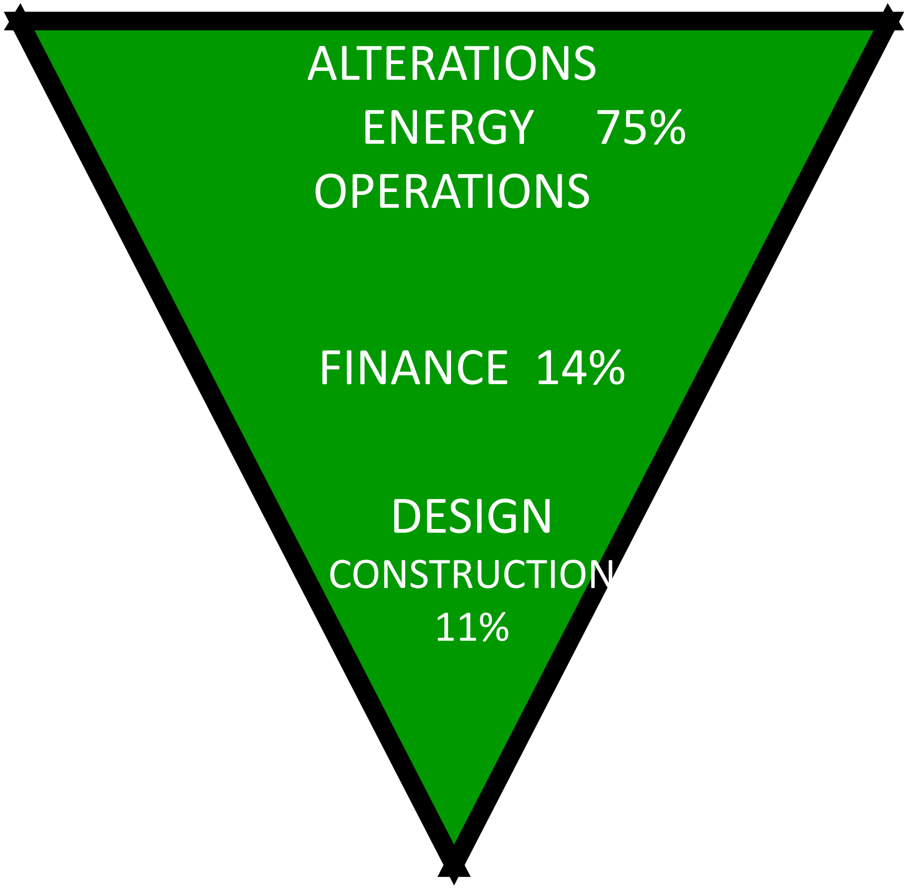
Energy Systems Total Cost of Ownership



Life Cycle Cost of a Building



Benefits Of Planned Maintenance

Energy Savings

The beginning of energy savings starts with proper maintenance.

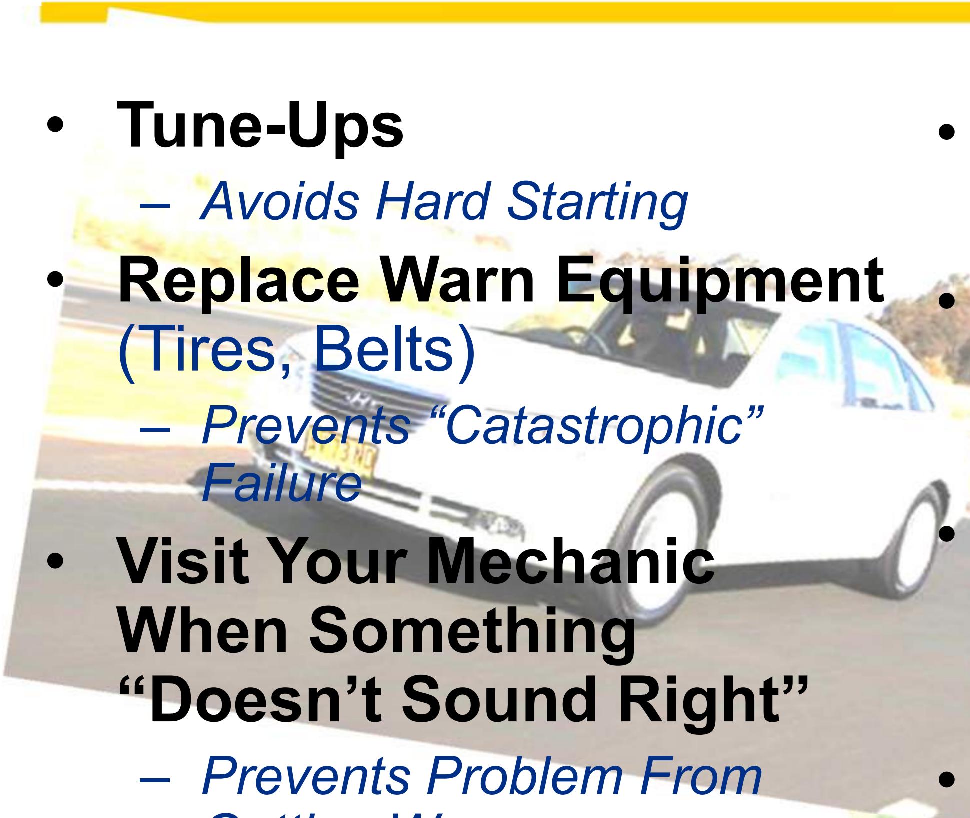
Industry experience demonstrates the following savings from planned maintenance activities:

5% - 15%	**Cleaning Coils**
8% - 10%	**Re-Alignment of Belts**
10% - 15%	**Replacing Dirty Filters**
12% - 15%	**Proper burner efficiency**
7% - 9%	**Removing Soot from Burners**
20% - 25%	**Operating Sequence Adjustments**

Source: DEPARTMENT of ENERGY

Regular Car Maintenance

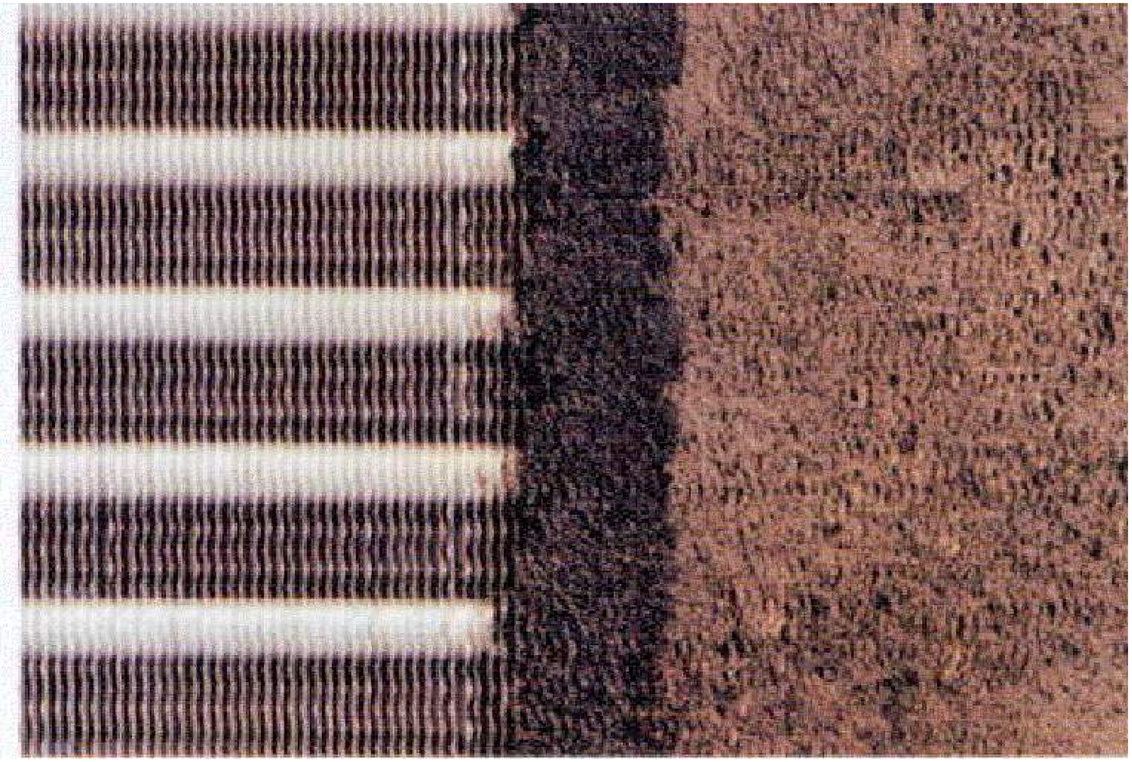
- **Tune-Ups**
  - *Avoids Hard Starting*
- **Replace Warn Equipment** (Tires, Belts)
  - *Prevents "Catastrophic" Failure*
- **Visit Your Mechanic When Something "Doesn't Sound Right"**
  - *Prevents Problem From Getting Worse*
  - *Prevents You From Being Stranded*
- **Check & Change the Oil**
  - *Protects The Engine*
- **Check The Tire Pressure**
  - *Improves Performance & Mileage*
- **Wash To Remove Road Salt**
  - *Prevents Rust*
- **Safety & Emissions Inspection**
  - *Keeps Your Car "Legal"*



What is the cost of Preventative Maintenance?

- **Fact:** Fuel costs continue to rise.
- **Fact:** Energy consumption is greatly increased with dirty coils and dirty filters.
- **Fact:** Proper preventative maintenance can provide energy savings more than the maintenance cost itself.
- **Fact:** Energy costs will only increase.
- **Fact:** The most basic maintenance procedures provide the best cost savings.

How Clean are your Coils and Filters?



Condenser Coils

- **Dirty condenser coils can cost as much as 1/3 more to operate than well maintained coils.**
- **Dirty coils provide inadequate heat transfer, causing higher discharge pressures, leading to increased electricity use and reduced capacity of the unit.**
- **Elevated pressure and temperature can lead to compressor lubricant breakdown, acid formation and ultimate equipment failure.**

Condenser Coils

Progressive Effects of Scale On Air Cooled Condenser

Thickness of Scale in Inches	% Loss of Heat Transfer
.000	0
.006 Human Hair	16%
.012 Index Card	20%
.024	27%
.036 Paper Clip	33%

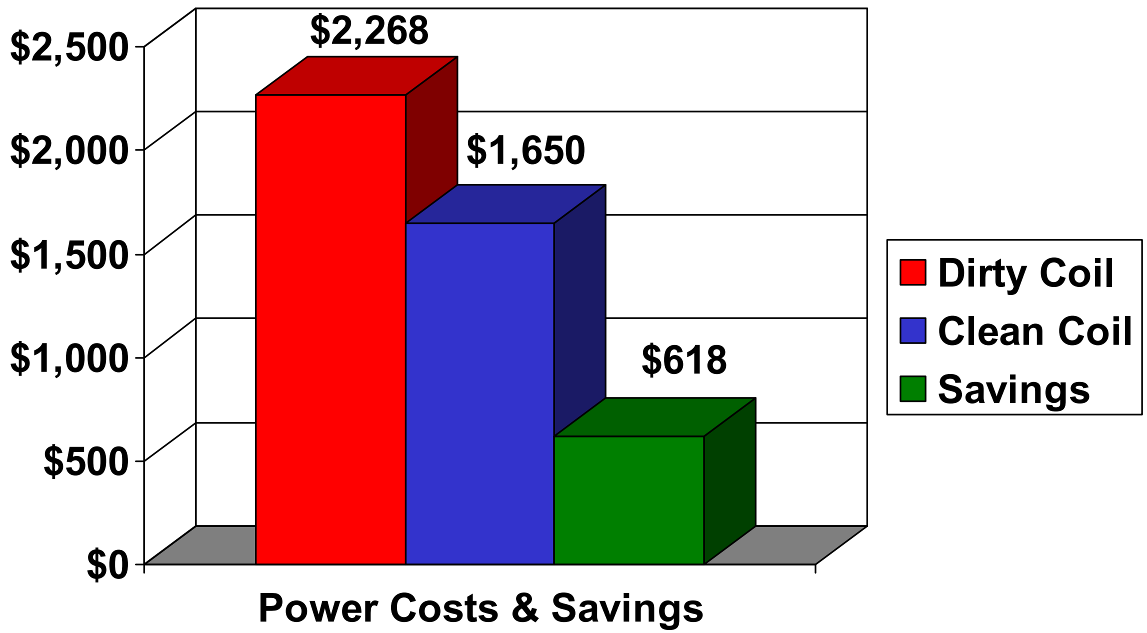
Particle Settling Rate

Distance 8 Feet

10 Microns – 6.8 Minutes
1 Micron – 58 Minutes
0.1 Micron – 37.7 Hours

Condenser Coils

A typical 10-ton air conditioning system operating for an average cooling season of 1,500 hours



If you multiply your total building tonnage by $62, you can see the savings

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V-Belts

- **Proper tensioning** of V-belts is the single most important factor necessary for long, efficient and acceptable belt operation.

- **Too little tension** results in slippage, causing rapid belt and sheave wear, and loss of productivity.

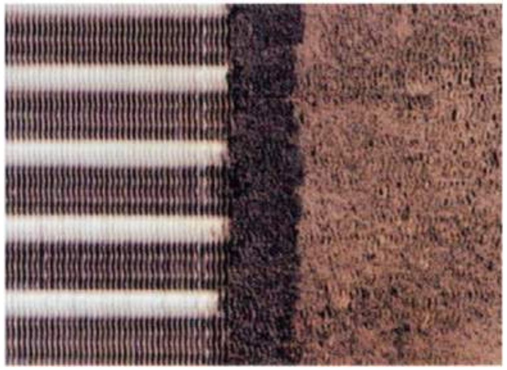
- **Too much tension** puts excessive stress on belts, bearings and shafts, reducing energy.

Energy Consumption

- Your HVAC equipment is responsible for 40% of your school's energy costs.
- **80% of that energy consumption is due to the system overcoming static pressure across the filter bank.**
- Filters that provide good efficiency with low pressure drop are ideal.
- Well managed filter changes save energy.

Equipment Neglect – What to look for and what to do with it

- Dirty air filters
- Faulty drive belts
- Dirty motors
- Burnt contact points
- Refrigerant leaks
- Plugged drains
- Trash on roof
- Missing/loose panels



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Equipment Neglect / Poor Installation

ASHRAE Handbook Life Cycle Costs

Equipment Type	Years	Equipment Type	Years
Air Conditioning Units		**Coils**	
Window Units	10	DX, Water, or Steam	20
Residential Units	15	Electric	15
Commercial Through the Wall	15	**Heat Exchangers**	
Computer Room Units	15	Shell-and-Tube	24
Water-Cooled Package	15	**Reciprocating Compressors**	20
Heat Pumps		**Package Chillers**	
Residential Air-to-Air	10	Reciprocating	20
Commercial Air-to-Air	15	Centrifugal	23
Commercial Water-to-Air	19	Absorption	23
Rooftop Air Conditioners		**Cooling Towers**	
Single-zone	15	Galvanized Metal	20
Multizone	15	Wood	20
Boilers, Hot Water (Steam)		Ceramic	34
Steel Water-Tube	24(30)	**Air-Cooled Condensers**	20
Steel Fire-Tube	25(25)	**Evaporative Condensers**	20
Cast Iron	35(30)	**Insulation**	
Electric	15	Molded	20
Burners	21	Blanket	24
Furnaces		**Pumps**	
Gas or Oil-Fired	18	Base-Mounted	20
Unit Heaters		Pipe-Mounted	10
Gas or Electric	13	Sump and Well	10
Hot Water or Steam	20	Condensate	15
Radiant Heaters		**Reciprocating Engines**	20
Electric	10	**Steam Turbines**	30
Hot Water or Steam	25	**Electric Motors**	18
Air Terminals		**Motor Starters**	17
Diffusers, Grills, and Registers	27	**Electric Transformers**	30
Induction and Fan-coil units	20	**Controls**	
Air-Washers	17	Pneumatic	20
Duct Work	30	Electric, or Electronic	15

HVAC Components

Component failure rates will depend largely on the owner’s proactive approach with planned maintenance versus breakdown repair only. A good planned maintenance program can add 20% or more life to existing equipment. No planned maintenance can deduct 20-30% from typical unit life expectancy.

HVAC Component Typical Life Expectancy	Typical Failure Rate Expectancy
Compressors	Typically 5-15 year range for failures. Most manufacturers warranty 1-5 years only.
Condenser Fan Motors	Starts after 3-5 years.
Blower Motor	Rarely fail in the first 10 years.
Blower Wheels	Rarely fail themselves; are typically replaced due to shaft or bearing failures.
Contactors	Typical wear item. Replace every few years.
Bearings	Typical wear item. Life span is 1-10 years.
Relays	Typical wear item. Replace every few years.
Thermostats	Low maintenance item. Failure rate is minimal. More subject to damage by occupant.
Timers	Typical life span 5-10 years.
Fan Blades	High wear item. Typically replaced with condenser fan motors after 3-5 years.
Condensers	Normally last unit life except for severe hail damage.
Evaporators	Normally last unit life unless filters are not changed regularly.
Heat Exchangers	Failure typically starts at 10 years due to rust and cracks. Note: newer units have thinner metal.
Gas Valves	Failures begin at 5-10 year range.
Igniters	Typical wear item. Should be replaced every few years.
Gas Regulators	Failures begin at 5-10 year range.
Actuators	Failures begin at 5-10 year range.
Circuit Boards	No-maintenance item. Failures are normally due to other component failures.

Health & Safety Awareness

Safety Training:

Practice it because of things like this…

Safety Training (Cont.)

And this…

■

Safety Training (cont.)

Yes, and this…

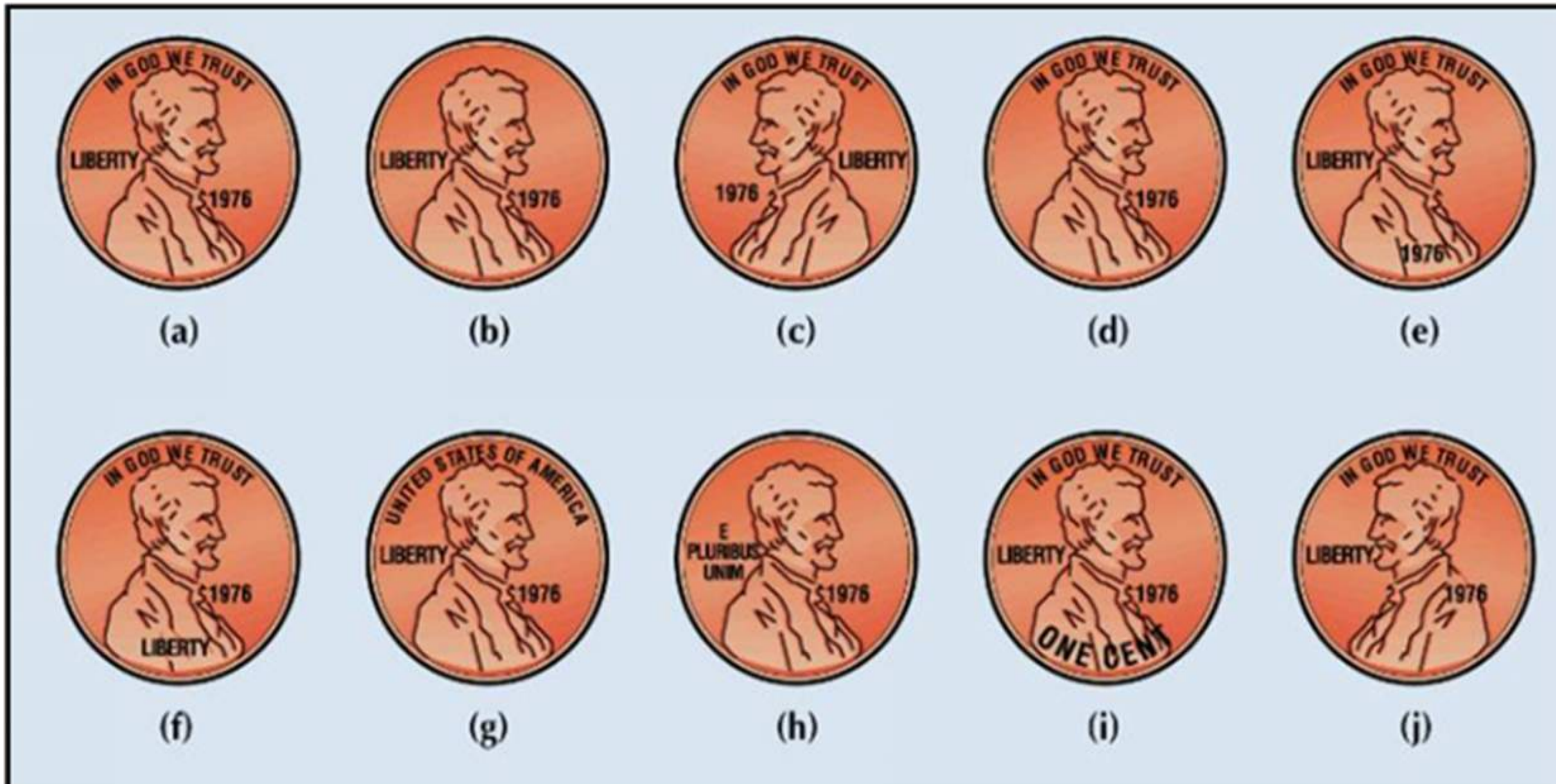
Safety Awareness

"I am going to be working in the following areas- my PPE includes Safety Glasses, ear protection, gloves, and work boots"

- "Do I require any other items or is there clothing such as badge lanyard or jewelry that should not be worn?"
- "What procedures should I follow related to security, signing in and who to contact?"
- "Are any aspects of Health & Safety covered at that time?"

Inspecting Equipment Accurately is Very Important

Know what you’re looking at!



Working On Equipment – The Safety Factor

- Identifying equipment that may be difficult to access
- What obstacles could be out there?
  - Landscaping
  - Snow, ice
  - Animals (ex: Snakes, Bees, Wasps, Insects etc.)
  - Skylights
  - Garbage or other debris
  - Height of first step
  - Properly secured to the building

HVAC Equipment – The Safety Factor

Safety issues: What to look for and why

- Roof access conditions
- Hard to get to access
- Poor lighting
- Skylights
- Overhead Obstacles
- Trip Hazards
- Walkways
- Wet slippery floors
- Hazardous Areas (chemicals present)
- Over Head Work (workers working above you)
- Opening Units? De-energizing electrical
- Surrounding Environment, noise, weather

Time for Questions?

Thank you for meeting us today!

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