Economizers: Design, Performance, and Commissioning Issues

Economizer Physics

Instructor:

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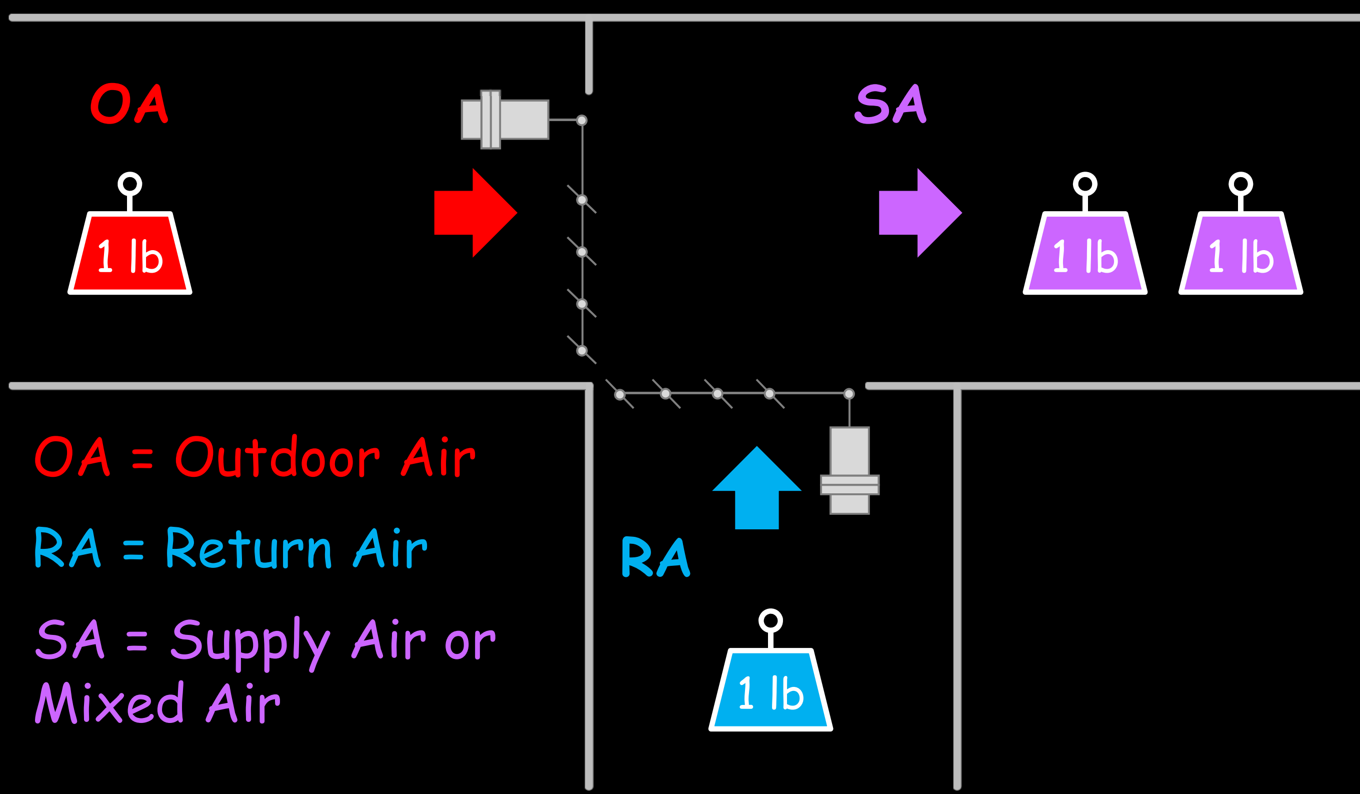
What's In This Module?

- The Physics of the Mixed Air Plenum
- Useful Mixed Air Plenum Relationships

Conservation of Mass in a Mixed Air Plenum



OA = Outdoor Air

RA = Return Air

SA = Supply Air or Mixed Air

Conservation of Mass in a Mixed Air Plenum

$$\dot{m}_{OutdoorAir} + \dot{m}_{ReturnAir} = \dot{m}_{MixedAir}$$

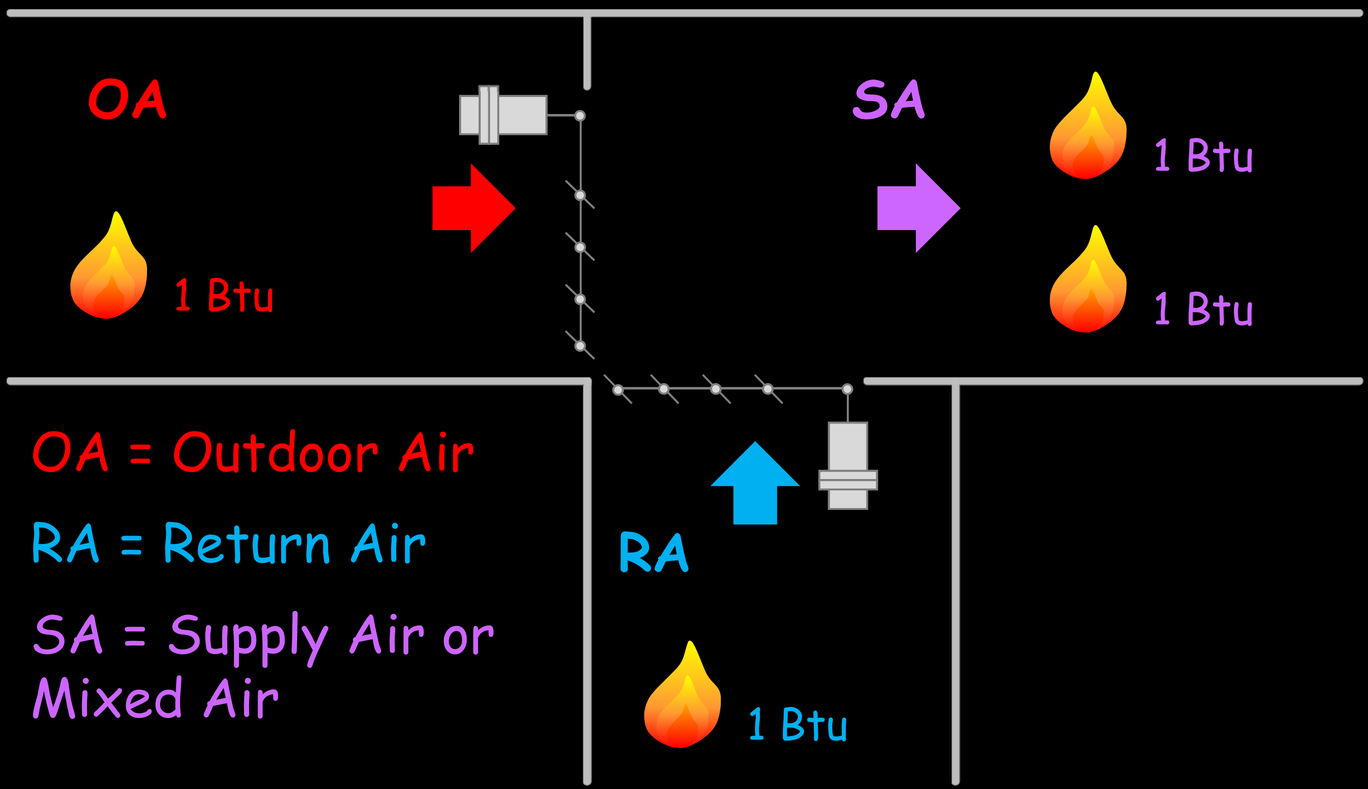
Where:

$\dot{m}_{OutdoorAir}$ = Mass flow rate for outdoor air in consistent units

$\dot{m}_{ReturnAir}$ = Mass flow rate for return air in consistent units

$\dot{m}_{MixedAir}$ = Mass flow rate for mixed air in consistent units

Conservation of Energy in a Mixed Air Plenum



OA = Outdoor Air

RA = Return Air

SA = Supply Air or Mixed Air

This is the first law of thermodynamics

Conservation of Energy in a Mixed Air Plenum

If any system undergoes a process in which energy is added or removed from it (in the form of work or heat), none of the energy added is destroyed with-in the system and none of the energy removed is created with-in the system

Herman Stoever,
Engineering Thermodynamics

This is the first law of thermodynamics

Conservation of Energy in a Mixed Air Plenum

$$Q + u_1 + \frac{p_1 v_1}{J} + \frac{z_1}{J} + \frac{V_1^2}{2gJ} = \frac{W}{J} + u_2 + \frac{p_2 v_2}{J} + \frac{z_2}{J} + \frac{V_2^2}{2gJ}$$

Where:

Q = Heat in Btu/lb

W = Shaft work, ft-lb/lb

u = Internal energy, Btu/lb

pv = Flow work; pressure in lb/ft^2 x specific volume in ft^3/lb, ft-lb/lb

J = Mechanical equivalent of heat; 778 ft-lb/Btu

V = Velocity in feet per second

g = gravitational constant, 32 ft/sec/sec

This is the first law of thermodynamics stated mathematically

Conservation of Energy in a Mixed Air Plenum

If any system undergoes a process in which energy is added or removed from it (in the form of work or heat), none of the energy added is destroyed with-in the system and none of the energy removed is created with-in the system, therefore:

Herman Stoever,
Engineering Thermodynamics

$$\%_{OutdoorAir} = \frac{\left(t_{MixedAir} - t_{ReturnAir}\right)}{\left(t_{OutdoorAir} - t_{ReturnAir}\right)}$$

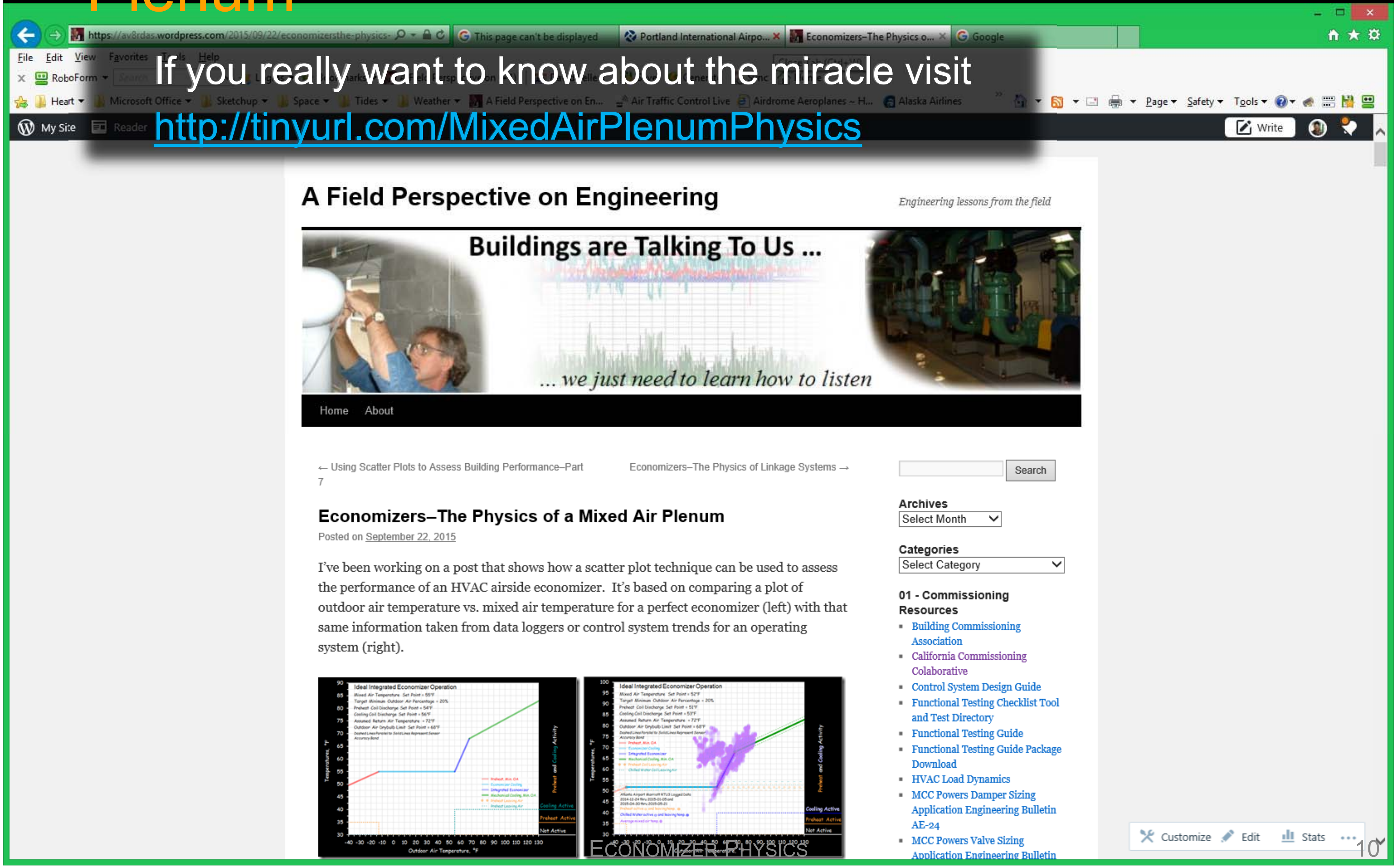
This is the first law of thermodynamics

Conservation of Energy in a Mixed Air Plenum

- Sidney Harris Cartoon Here

Conservation of Energy in a Mixed Air Plenum

If you really want to know about the miracle visit
http://tinyurl.com/MixedAirPlenumPhysics



A Few Other Useful Relationships

OAT to Produce Freezing Mixed Air

If you wanted to determine the outdoor air temperature ($t_{OutdoorAir_{Mix32}}$) that would cause the mixed air temperature to drop to freezing ($t_{MixedAir} = 32°F$), given a return temperature $t_{ReturnAir}$) and an outdoor air percentage ($\%_{OutdoorAir}$):

$$\%_{OutdoorAir} = \frac{(32 - t_{ReturnAir})}{(t_{OutdoorAir_{Mix32}} - t_{ReturnAir})}$$

$$\%_{OutdoorAir} = \frac{(32 - t_{ReturnAir})}{(t_{OutdoorAir_{Mix32}} - t_{ReturnAir})}$$

$$\%_{OutdoorAir} \times (t_{OutdoorAir_{Mix32}} - t_{ReturnAir}) = (32 - t_{ReturnAir})$$

$$(t_{OutdoorAir_{Mix32}} - t_{ReturnAir}) = \frac{(32 - t_{ReturnAir})}{\%_{OutdoorAir}}$$

$$t_{OutdoorAir_{Mix32}} = \left[\frac{(32 - t_{ReturnAir})}{\%_{OutdoorAir}}\right] + t_{ReturnAir}$$

A Few Other Useful Relationships
OAT to Produce a Specific Mixed Air Temperature

If you want to know how cold it would have to get outside, given a system's return temperature and minimum outdoor air percentage, before the mixed air temperature would drop below the design mixed air temperature and preheat would be required, this variation is what you need.

$$t_{OutdoorAir} = \left[\frac{\left(t_{MixedAir_{Design}} - t_{ReturnAir} \right)}{\%_{OutdoorAir}} \right] + t_{ReturnAir}$$

Where $t_{MixedAir_{Design}}$ is the design mixed air temperature for the system.

A Few Other Useful Relationships

Mixed Air Temperature Given an OA%, OAT, and RAT

If you want to determine the mixed air temperature ($t_{MixedAir}$) created by a particular outdoor air percentage ($\%_{OutdoorAir}$), outdoor air temperature ($t_{OutdoorAir}$), and return air temperature ($t_{ReturnAir}$), then you need this variation of the equation.

$$\%_{OutdoorAir} = \frac{\left(t_{MixedAir} - t_{ReturnAir}\right)}{\left(t_{OutdoorAir} - t_{ReturnAir}\right)}$$

$$\%_{OutdoorAir} \times \left(t_{OutdoorAir} - t_{ReturnAir}\right) = \left(t_{MixedAir} - t_{ReturnAir}\right)$$

$$\left(t_{MixedAir} - t_{ReturnAir}\right) = \%_{OutdoorAir} \times \left(t_{OutdoorAir} - t_{ReturnAir}\right)$$

$$t_{MixedAir} = \left[\%_{OutdoorAir} \times \left(t_{OutdoorAir} - t_{ReturnAir}\right)\right] + t_{ReturnAir}$$

Bottom Lines

- Fundamental physical relationships can be used to describe our HVAC processes
  - Frequently, the complexity can be reduced by making appropriate simplifying assumptions and substitutions
  - A simplifying *assumption* is different from a simplifying *substitution*