

# Economizers: Design, Performance, and Commissioning Issues

Economizer Physics



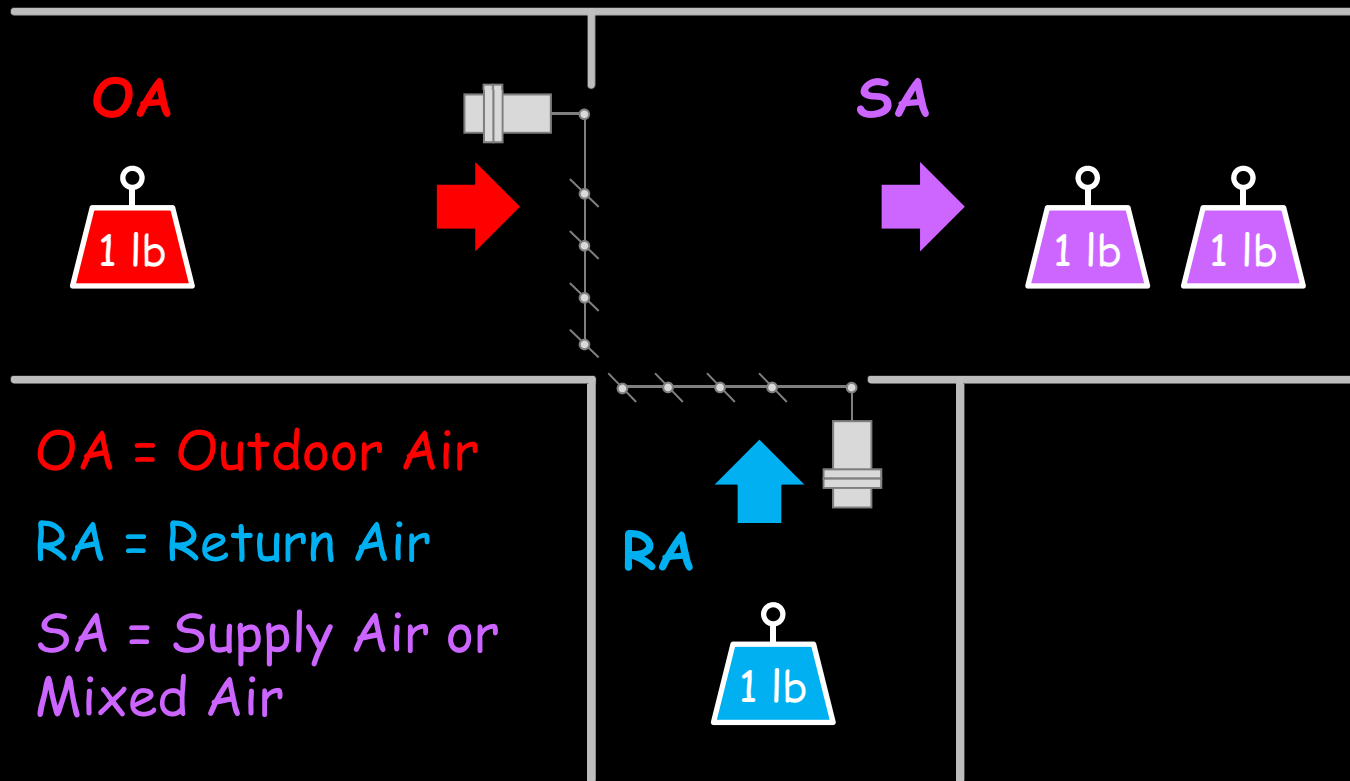
Instructor:

- David Sellers
- Senior Engineer
- Facility Dynamics Engineering
- February 6, 2018

# 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



# Conservation of Mass in a Mixed Air Plenum

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

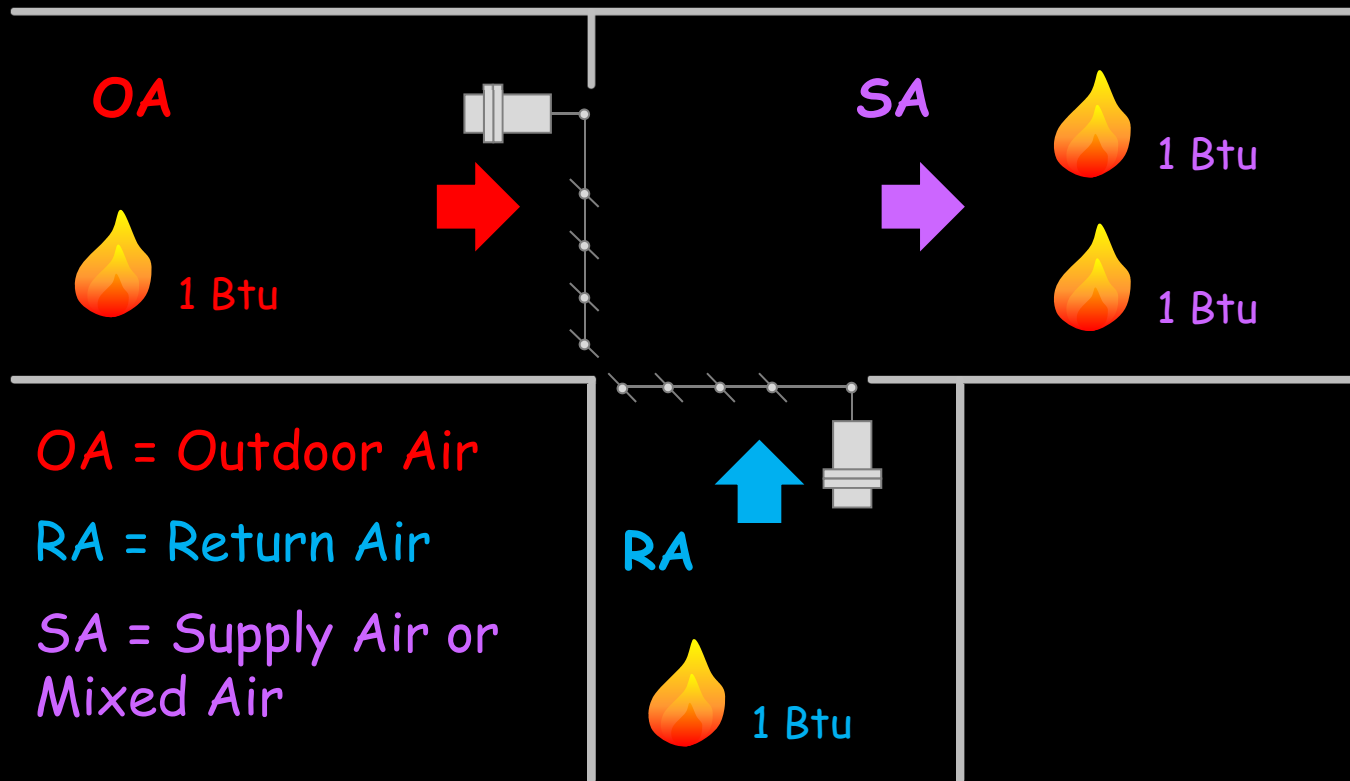
Where:

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

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

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

# Conservation of Energy in a Mixed Air Plenum



*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

$p v$  = Flow work; pressure in lb/ft<sup>2</sup> × specific volume in ft<sup>3</sup>/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 within the system and none of the energy removed is created within the system, therefore:*

*Herman Stoever,  
Engineering Thermodynamics*

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

*This is the first law of thermodynamics*



# Conservation of Energy in a Mixed Air Plenum

- Sidney Harris Cartoon Here

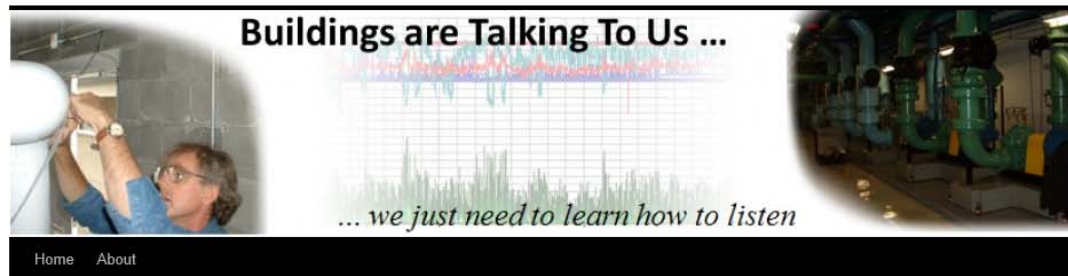
# Conservation of Energy in a Mixed Air Plenum

If you really want to know about the miracle visit

<http://tinyurl.com/MixedAirPlenumPhysics>

## A Field Perspective on Engineering

Engineering lessons from the field



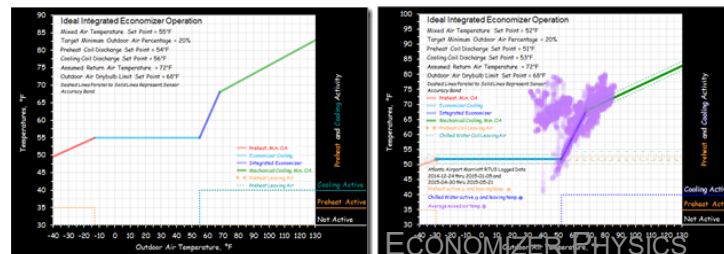
← Using Scatter Plots to Assess Building Performance—Part 7

Economizers—The Physics of Linkage Systems →

### Economizers—The Physics of a Mixed Air Plenum

Posted on September 22, 2015

I've been working on a post that shows how a scatter plot technique can be used to assess the performance of an HVAC airside economizer. It's based on comparing a plot of outdoor air temperature vs. mixed air temperature for a perfect economizer (left) with that same information taken from data loggers or control system trends for an operating system (right).



#### Archives

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#### Categories

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#### 01 - Commissioning Resources

- Building Commissioning Association
- California Commissioning Collaborative
- Control System Design Guide
- Functional Testing Checklist Tool and Test Directory
- Functional Testing Guide
- Functional Testing Guide Package Download
- HVAC Load Dynamics
- MCC Powers Damper Sizing Application Engineering Bulletin AE-24
- MCC Powers Valve Sizing Application Engineering Bulletin

# 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 ( $t_{MixedAir} = 32^\circ\text{F}$ ), 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.

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

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.

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

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

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

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

# 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