

# Practical Approaches to Residential Ventilation for Improved Durability and Indoor Air Quality

by

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Building Science Consortium  
USDOE Building America Program

for

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Providing **durability** for  
little or no incremental  
cost is a goal of the  
***Building America*** program



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**Durability** and maintenance cost are direct functions of:

- **Moisture**
- **Heat**
- **Ultra-violet light**

Of these three, **Moisture** is the most significant



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## **Durability** can be insured with respect to moisture by:

- **Providing a building envelope design that can dry should it get wet**
- **Preventing excessive pressurization and depressurization of occupied spaces and cavities**
- **Installing controlled mechanical ventilation systems**



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# Purposes of mechanical ventilation

1. Point-source ventilation - Remove Pollutants
  - exhaust fans: kitchen, bath, laundry
2. Whole-building ventilation - Dilute Pollutants
  - supply, exhaust, or balanced fans distributing to all rooms

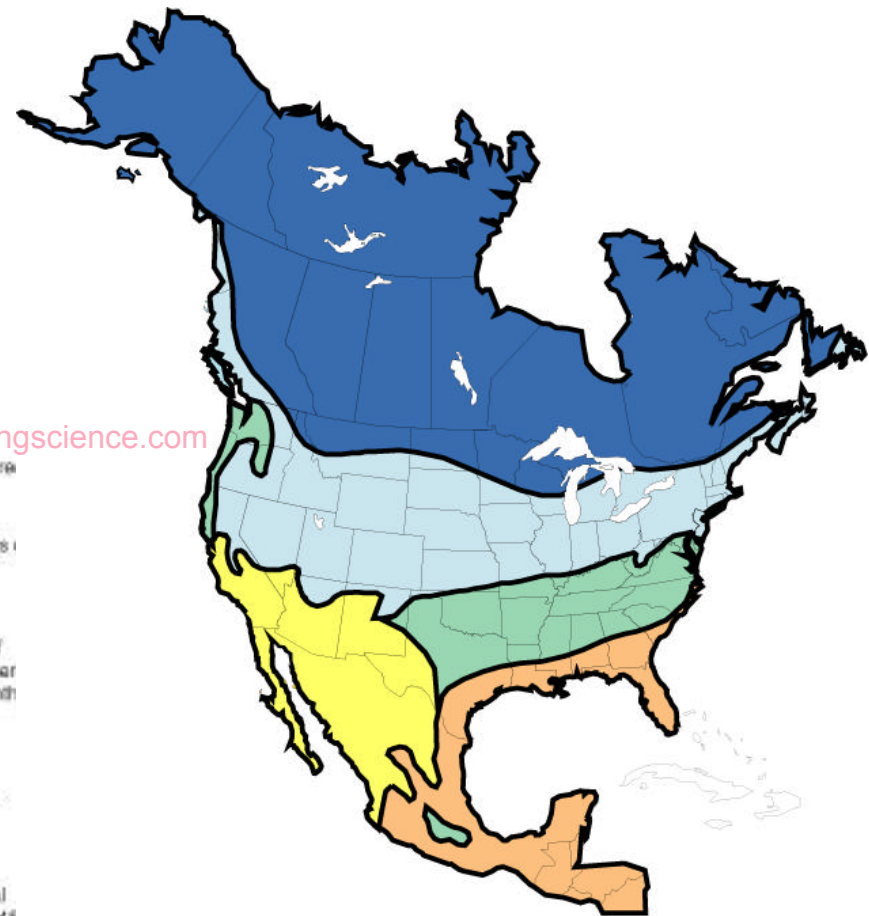


# Climate Specific Design Solutions

## Legend

<b>Severe-Cold</b>	A severe cold climate is defined as a region with approximately 8,000 heating degree days or more.
<b>Cold</b>	A cold climate is defined as a region with approximately 4,500 heating degree days or less than approximately 8,000 heating degree days.
<b>Mixed-Humid</b>	A mixed-humid climate is defined as a region that receives more than 20 inches of annual precipitation, has approximately 4,500 heating degree days or less and where the monthly average outdoor temperature drops below 45°F during the winter month.
<b>Hot-Humid</b>	A hot-humid climate is defined as a region that receives more than 20 inches of annual precipitation and where the monthly average outdoor temperature remains above 45°F throughout the year.
<b>Hot-Dry/Mixed-Dry</b>	A hot-dry climate is defined as a region that receives less than 20 inches of annual precipitation and where the monthly average outdoor temperature remains above 45°F throughout the year. A mixed-dry climate is defined as a region that receives less than 20 inches of annual precipitation, has approximately 4,500 heating degree days or less and where the monthly average outdoor temperature drops below 45°F during the winter months.

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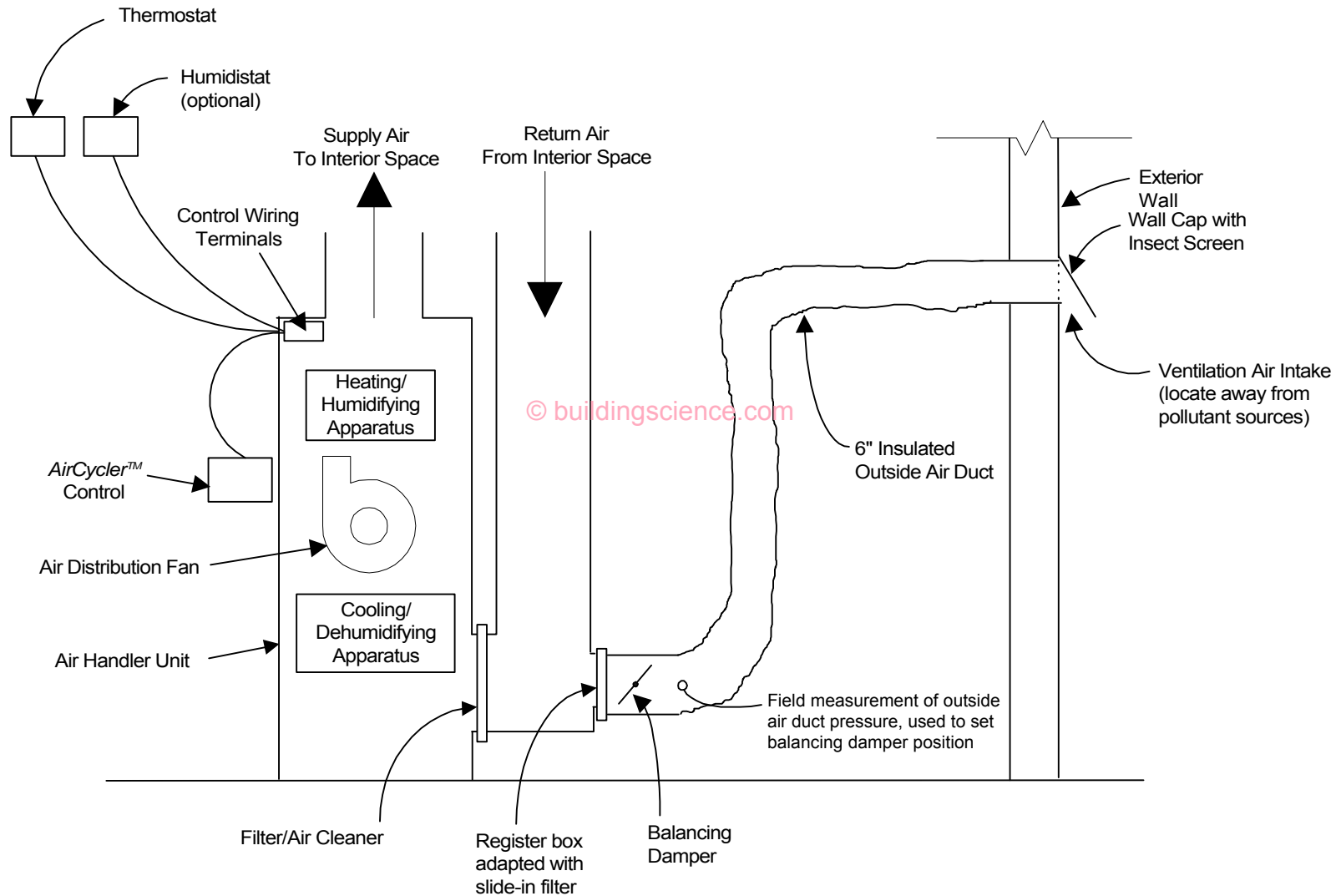


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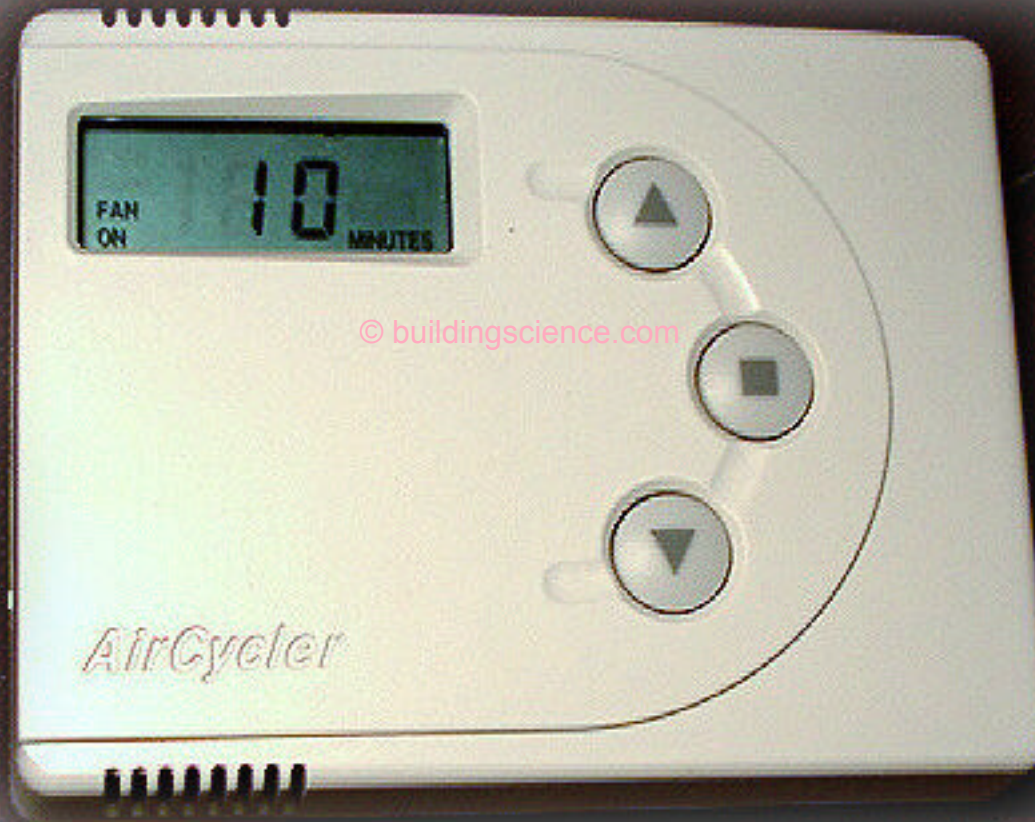
# Central-fan-integrated supply ventilation

## Interior closet or basement configuration



# Ventilation Air Distribution and Mixing Control

Wires to low voltage terminals on central air handler unit





# Intermittent Operation

- Sizing
  - intermittent flow equals constant flow reduced by low background infiltration amount when blower is not on, all divided by duty cycle fraction

$$\dot{Q}_{in} = \frac{(\dot{Q}_{co}) - \left(\frac{I}{60} V (1 - f)\right)}{f}$$



# Intermittent Operation

- where,

$$f = \frac{t_{on}}{t_{on} + t_{off}} = \frac{t_{on}}{t_{total}}$$

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# Very cold climate ventilation and moisture control designs HDD > 8000

- 1<sup>st</sup> choice is continuously operating single-point exhaust with intermittent central-fan-integrated supply limited to 7% of AHU flow
- 2<sup>nd</sup> choice is continuously operating single-point exhaust with central fan recycling for distribution and mixing (sealed combustion space/DHW heating)
- 3<sup>rd</sup> choice is balanced heat recovery ventilation with central fan recycling for distribution, or fully ducted to all rooms



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**Builders** Pulte Home Corp.  
Centex Homes  
Town & Country Homes

**Location** Minneapolis, Minnesota

**Subdivisions** The Grove at Elm Creek  
Regatta  
Eden Prairie

**Climate** very cold

**No. Homes** 300+



### Ventilation systems

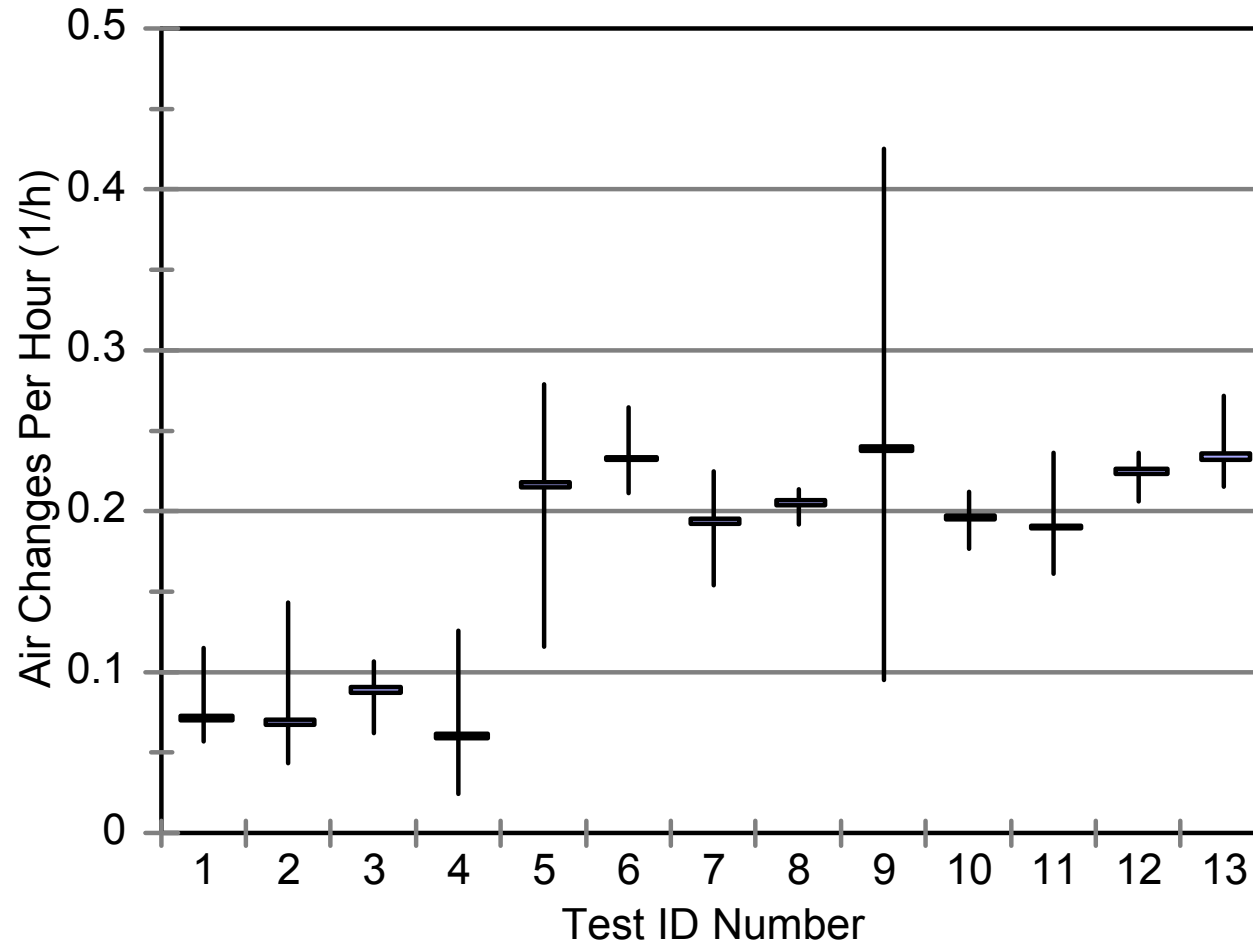
- Continuously operating single-point exhaust with central fan recycling for whole-house distribution and mixing, and with intermittent central-fan-integrated supply limited to 7% of AHU flow



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# Minneapolis ventilation study



# Cold climate ventilation and moisture control designs

4500<HDD<8000

- 10 cfm/person design
  - 1<sup>st</sup> choice is central-fan-integrated supply limited to 10% of AHU flow
- 20 cfm/person design
  - 1<sup>st</sup> choice is continuously operating single-point exhaust with intermittent central-fan-integrated supply limited to 10% of AHU flow
  - 2<sup>nd</sup> choice is continuously operating single-point exhaust with central fan recycling for distribution and mixing (sealed combustion space/DHW heating)



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**Builder** Sturbridge Construction  
**Subdivision** Prairie Crossing  
**Location** Grayslake, Illinois  
**Climate** cold  
**No. Homes** 350



### Ventilation systems

- In 1996, started with low-cost blending supply system
  - separate inline fan, no filter, 2 pickups, 1 supply
  - complaints: fan noise and cold basement
- In 1997, changed to central-fan-integrated supply with fan recycling
  - 6" insulated OA duct to AHU return, with balancing damper
  - 7% outside air fraction, minimum 33% duty cycle
  - filtration by AHU filter
  - builder provides customer education
  - no complaints after over 3 years



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**Builder** Town & Country Homes  
**Subdivision** Centennial Crossing  
**Location** Vernon Hills, Illinois  
**Climate** cold  
**No. Homes** 191



### Ventilation system

- Central-fan-integrated supply with fan recycling
  - 6" insulated OA duct to AHU return, with balancing damper
  - 7% outside air fraction, minimum 33% duty cycle
  - filtration by AHU filter
  - no complaints after over three years



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# Monitored Runtime Data

## Centennial Crossing, Lot 22

	Cool ON	Heat ON	Fan Recycling	
	(%)	(%)	Vent ON (%)	Cost (\$)
Apr (27-30)	0	12	12	0.24
May	1	2	15	3.06
Jun	7	1	10	2.05
Jul	10	0	12	2.58
Aug	10	0	13	2.72
Sep	5	0	15	2.96
Oct	0	4	15	3.07
Nov	0	13	10	1.99
Dec	0	20	6	1.31
Jan	0	31	3	0.60
Feb	0	23	5	0.95
Mar (1-9)	0	25	4	0.23

**Notes:** Fan recycling control set for 25 min OFF, 6 min ON (19% duty cycle)

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# Monitored Runtime Data

Centennial Crossing, Lot 176

	Cool ON (%)	Heat ON (%)	Fan Recycling Vent ON (%)	Cost (\$)
<b>Aug</b>	21	0	17	3.52
<b>Sep</b>	10	0	21	4.24
<b>Oct</b>	0	5	20	4.12
<b>Nov</b>	0	15	12	2.33
<b>Dec</b>	0	27	6	1.35
<b>Jan</b>	0	35	3	0.54
<b>Feb</b>	0	24	5	1.00

**Notes:** Fan recycling control set for 20 min OFF, 8 min ON (29% duty cycle)

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# Monitored Runtime Data

Centennial Crossing, Lot 179

	Cool ON (%)	Heat ON (%)	Fan Recycling Vent ON (%)	Cost (\$)
<b>Oct</b>	0	5	24	4.97
<b>Nov</b>	0	15	14	2.81
<b>Dec</b>	0	25	9	1.81
<b>Jan</b>	0	34	3	0.68
<b>Feb</b>	0	26	6	1.18
<b>Mar (1-8)</b>	0	31	3	0.17

**Notes:** Fan recycling control set for 20 OFF 10 ON (33% duty cycle)

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# Mixed climate ventilation and moisture control designs

HDD<4500

- 10 cfm/person design
  - 1<sup>st</sup> choice is central-fan-integrated supply limited to 13% of AHU flow
- 20 cfm/person design
  - 1<sup>st</sup> choice is continuously operating exhaust with intermittent central-fan-integrated supply limited to 13% of AHU flow



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**Builder** The Lee Group/Braemar Urban Ventures  
**Subdivision** Village Green  
**Location** Los Angeles, California  
**Climate** mixed-dry  
**No. Homes** 186



Ventilation system

- Specified single-point exhaust with central fan recycling for whole-house distribution and mixing



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# Hot-dry climate ventilation designs

>45 F, <20" rain

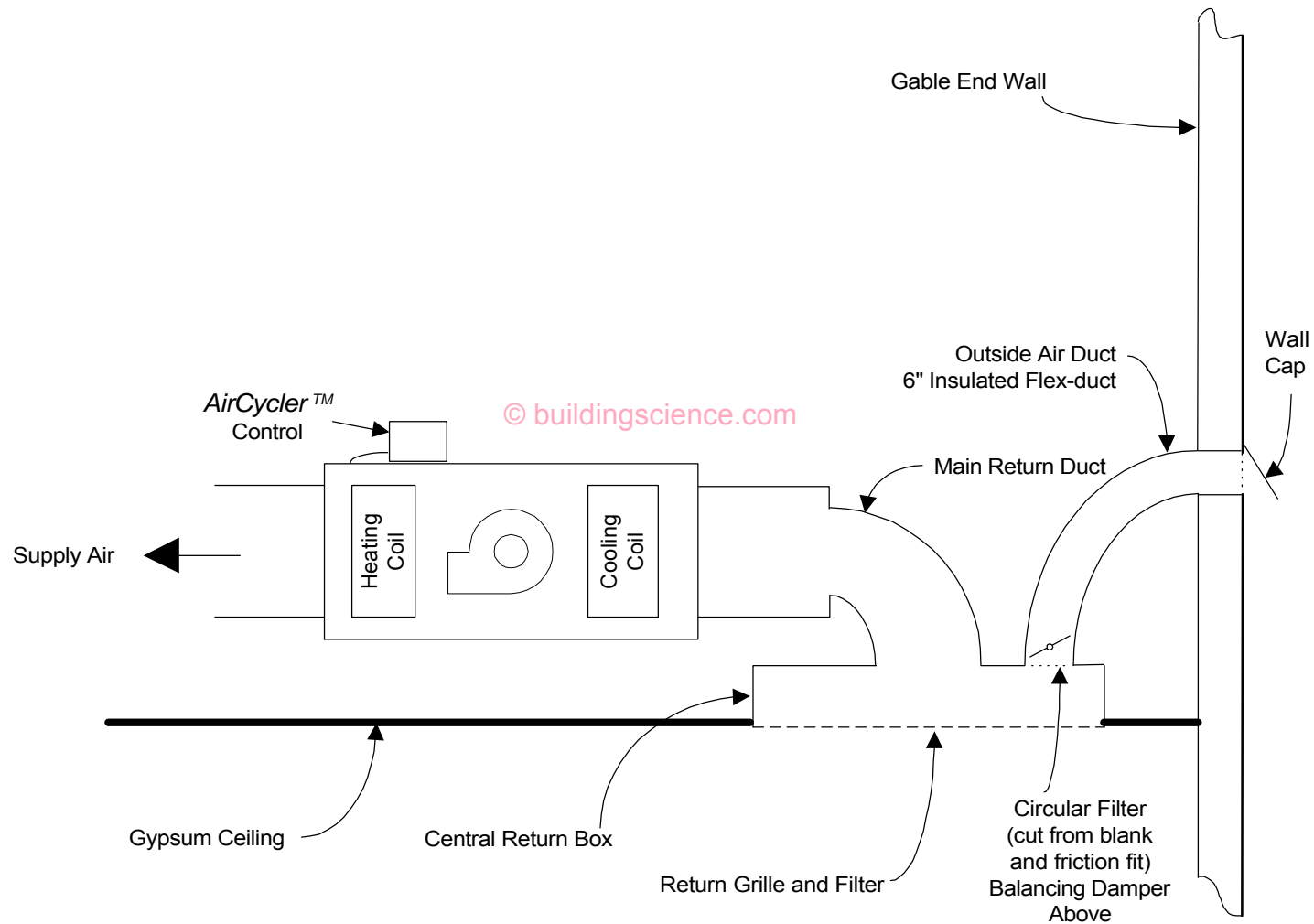
- 1<sup>st</sup> choice is central-fan-integrated supply limited to 15% of air handler flow
- 2<sup>nd</sup> choice is central-fan-integrated supply with continuously operating single-point exhaust (sealed combustion if in conditioned space)



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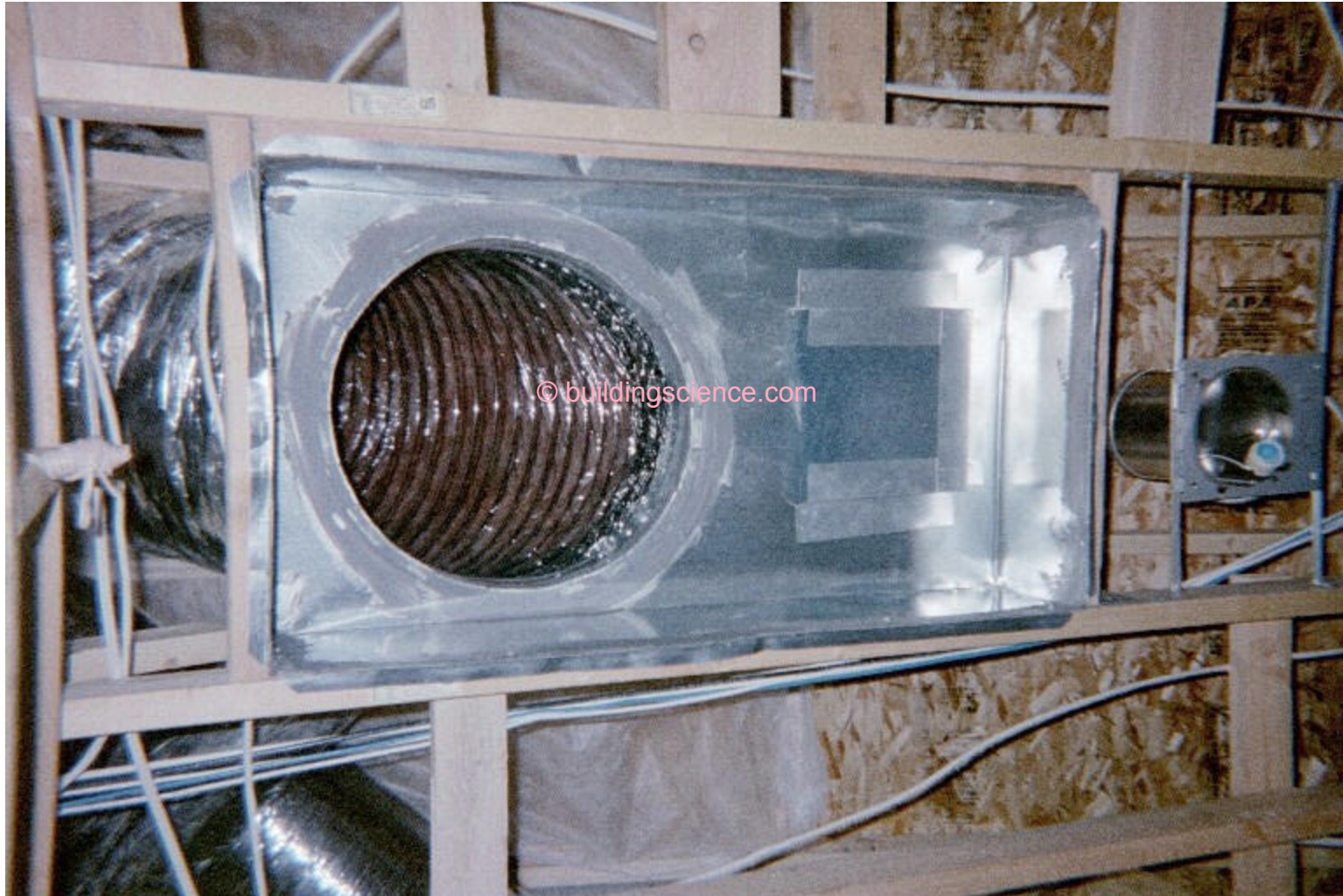
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# Central-fan-integrated supply ventilation Unvented-cathedralized attic configuration



# Central-fan-integrated supply ventilation

## Outside air duct (filtered) connected to return filter grille pan



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**Builder** Pulte Home Corporation  
**Subdivisions:** Angel Park (2), Cypress Pointe (116),  
Crown Ridge (105), Arbor View (88),  
Stallion Mountain (760)  
**Location** Las Vegas, Nevada  
**Climate** hot-dry  
**No. Homes** over 1000

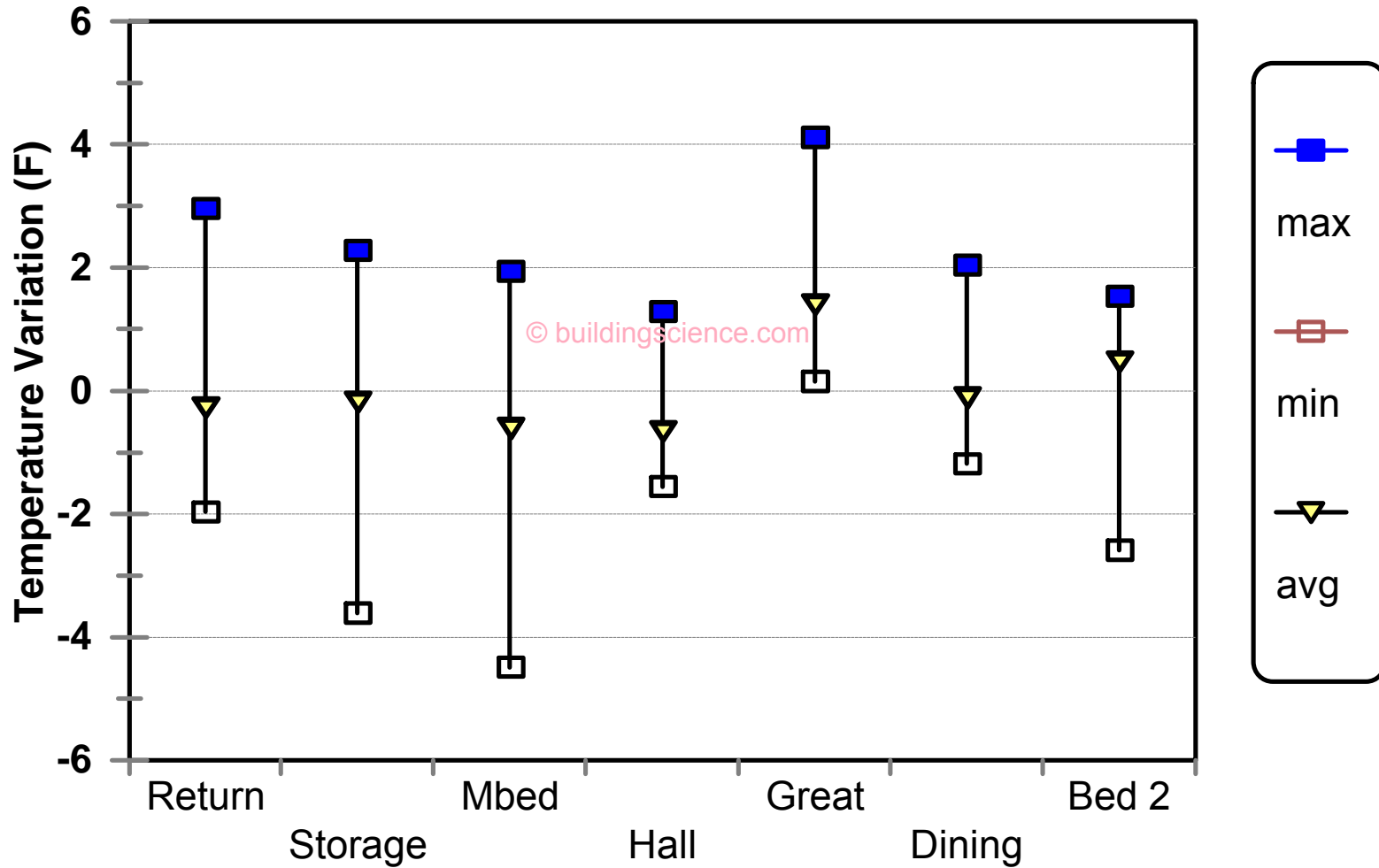


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Lot 6  
Arbor View

# Indoor temperature variation from the house average



**Builder** Watt Homes  
**Subdivision** Four Seasons  
**Location** Las Vegas, Nevada  
**Climate** hot-dry  
**No. Homes** 106



### Ventilation system

- Central-fan-integrated supply with fan recycling
  - 5" insulated OA duct to AHU return, with balancing damper
  - 7% outside air fraction, minimum 33% duty cycle
  - washable filter behind central return filter grille
  - no complaints after over 3 years



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**Builder** Pulte Home Corporation  
**Subdivision** Arroyo Ridge  
**Location** Tucson, Arizona  
**Climate** hot-dry  
**No. Homes** 2



### Ventilation system

- Central-fan-integrated supply with fan recycling
  - 6" insulated OA duct to AHU return, with balancing damper
  - 7% outside air fraction, minimum 33% duty cycle
  - washable filter behind central return filter grille
  - no complaints or concerns after over 2 years



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**Builder** Pulte Home Corporation  
**Subdivision** Retreat at the Bluffs  
**Location** Tucson, Arizona  
**Climate** hot-dry  
**No. Homes** 156



### Ventilation system

- Single-point exhaust
  - upgraded fan in laundry room, wall switch
  - complaints: fan noise, lack of filtration and distribution
- Changed to central-fan-integrated supply on following project:  
Spanish Trails



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**Builder** Artistic Homes  
**Subdivisions** Mirabella, Tuscany,  
Desert Springs  
**Location** Albuquerque, NM  
**Climate** mixed-dry  
**No. Homes** 15 (will soon be 800/yr)



### Ventilation system

- Central-fan-integrated supply with fan recycling
  - 6" insulated OA duct to AHU return, with balancing damper
  - 7% outside air fraction, minimum 33% duty cycle
  - filtration by AHU filter
  - no complaints after three months



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# Hot-humid climate ventilation and moisture control designs >45 F, >20" rain

- Central-fan-integrated supply with fan recycling, damper, and dehumidifier
  - air handler unit in conditioned space closet, placed on platform high enough to place dehumidifier underneath
  - dehumidifier controlled by dehumidistat in conditioned space
  - normal thermostat driven cycling of air handler, and fan recycling, distributes both ventilation air and dry air to whole house



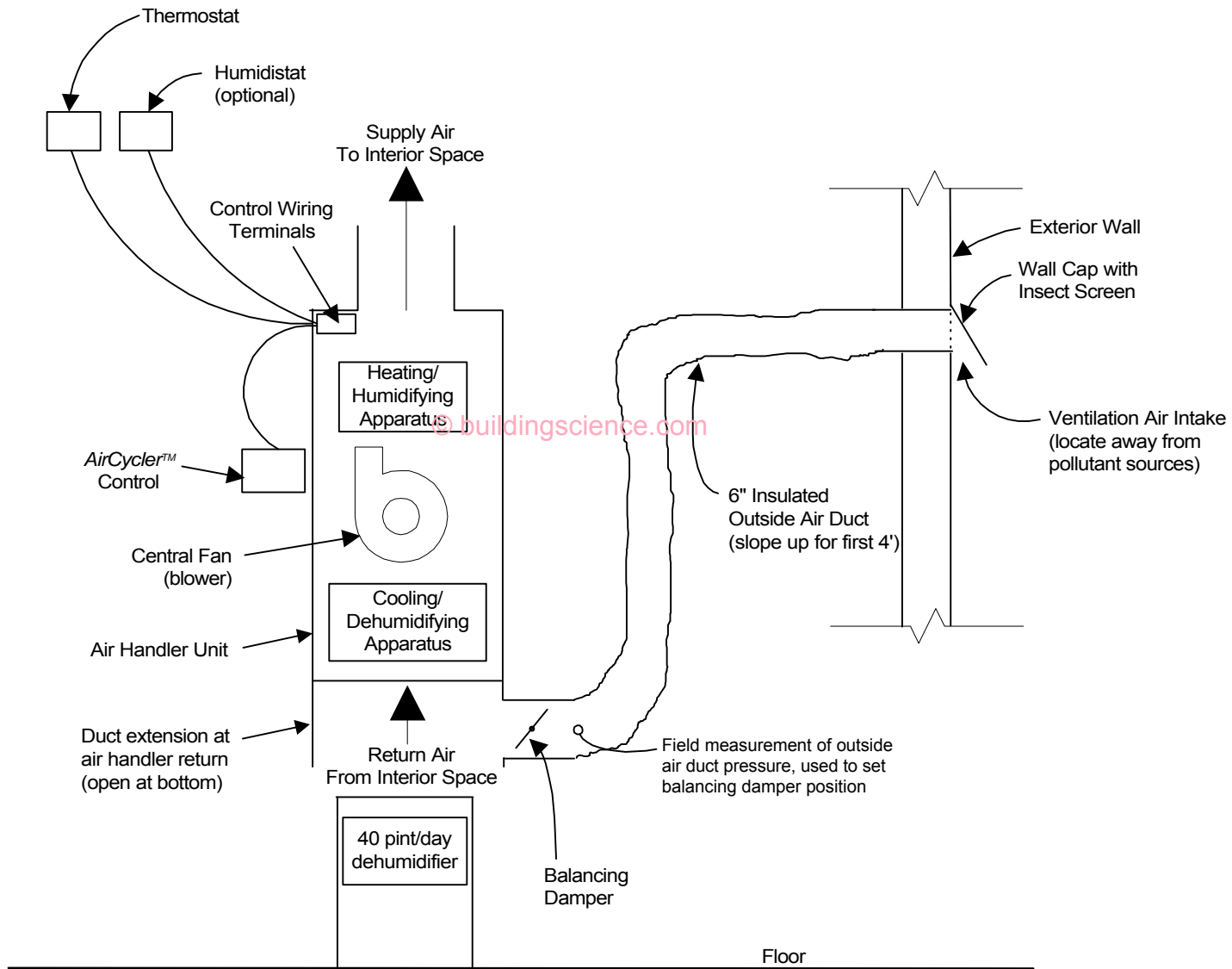
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# Central-fan-integrated supply ventilation

## Hot-humid climate interior mechanical closet configuration





**Builder** Pulte Home Corporation  
**Subdivision** East Hampton  
**Location** Jacksonville, Florida  
**Climate** hot-humid  
**No. Homes** 2



### Ventilation system

- Central-fan-integrated supply with fan recycling
  - 6" insulated OA duct to AHU return, balancing damper
  - 7% outside air fraction, minimum 33% duty cycle
  - filtration at air handler unit
  - no complaints or concerns after over 6 months

### Additional moisture control system

- 40 pint per day dehumidifier under air handler unit, with central fan recycling for whole-house distribution and mixing



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