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
Durability and Disaster Mitigation In Wood-Frame Housing Conference
Madison, Wisconsin
08 November 2000
Providing durability for little or no incremental cost is a goal of the Building America program.
Durability and maintenance cost are direct functions of:

- Moisture
- Heat
- Ultra-violet light

Of these three, Moisture is the most significant
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
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

Severe-Cold
A severe cold climate is defined as a region with approximately 8,000 heating degree days.

Cold
A cold climate is defined as a region with approximately 4,500 heating degree days or less than approximately 8,000 heating degree days.

Mixed-Humid
A mixed-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.

Hot-Humid
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.

Hot-Dry/Mixed-Dry
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.

November 2000

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Central-fan-integrated supply ventilation
Interior closet or basement configuration

Thermostat
Humidistat (optional)
Control Wiring Terminals
Supply Air To Interior Space
Return Air From Interior Space

AirCycler™ Control
Air Distribution Fan
Air Handler Unit

Cooling/Dehumidifying Apparatus
Heating/Humidifying Apparatus

Filter/Air Cleaner
Register box adapted with slide-in filter
Balancing Damper

Field measurement of outside air duct pressure, used to set balancing damper position

Exterior Wall Wall Cap with Insect Screen
Ventilation Air Intake (locate away from pollutant sources)

6” Insulated Outside Air Duct

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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,

\[ f = \frac{t_{on}}{t_{on} + t_{off}} = \frac{t_{on}}{t_{total}} \]
Very cold climate
ventilation and moisture control designs
HDD > 8000

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

Air Changes Per Hour (1/h)

Test ID Number
Cold climate ventilation and moisture control designs
4500<HDD<8000

• 10 cfm/person design
  – 1\textsuperscript{st} choice is central-fan-integrated supply limited to 10% of AHU flow

• 20 cfm/person design
  – 1\textsuperscript{st} choice is continuously operating single-point exhaust with intermittent central-fan-integrated supply limited to 10% of AHU flow
  – 2\textsuperscript{nd} choice is continuously operating single-point exhaust with central fan recycling for distribution and mixing (sealed combustion space/DHW heating)
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
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
# Monitored Runtime Data

## Centennial Crossing, Lot 22

<table>
<thead>
<tr>
<th></th>
<th>Cool ON (%)</th>
<th>Heat ON (%)</th>
<th>Fan Recycling Vent ON (%)</th>
<th>Cost ($)</th>
</tr>
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<td>0</td>
<td>12</td>
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<td>0.24</td>
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<td>15</td>
<td>3.06</td>
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<td>Jun</td>
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<td>0</td>
<td>13</td>
<td>2.72</td>
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<tr>
<td>Sep</td>
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<td>0</td>
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<td>3.07</td>
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<td>Mar (1-9)</td>
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**Notes:** Fan recycling control set for 25 min OFF, 6 min ON (19% duty cycle)
Monitored Runtime Data

Centennial Crossing, Lot 176

<table>
<thead>
<tr>
<th></th>
<th>Cool ON (%)</th>
<th>Heat ON (%)</th>
<th>Fan Recycling Vent ON (%)</th>
<th>Cost ($)</th>
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</thead>
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**Notes:** Fan recycling control set for 20 min OFF, 8 min ON (29% duty cycle)
# Monitored Runtime Data

**Centennial Crossing, Lot 179**

<table>
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<th></th>
<th>Cool ON (%)</th>
<th>Heat ON (%)</th>
<th>Fan Recycling Vent ON (%)</th>
<th>Cost ($)</th>
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</tbody>
</table>

**Notes:** Fan recycling control set for 20 OFF 10 ON (33% duty cycle)
Mixed climate ventilation and moisture control designs
HDD<4500

• 10 cfm/person design
  – 1\textsuperscript{st} choice is central-fan-integrated supply limited to 13% of AHU flow

• 20 cfm/person design
  – 1\textsuperscript{st} choice is continuously operating exhaust with intermittent central-fan-integrated supply limited to 13% of AHU flow
Builder: The Lee Group/Braemar Urban Ventures
Subdivision: Village Green
Location: Los Angeles, California
No. Homes: 186

Ventilation system

- Specified single-point exhaust with central fan recycling for whole-house distribution and mixing
Hot-dry climate ventilation designs
>45 F, <20” rain

• 1st choice is central-fan-integrated supply limited to 15% of air handler flow

• 2nd choice is central-fan-integrated supply with continuously operating single-point exhaust (sealed combustion if in conditioned space)
Central-fan-integrated supply ventilation
Unvented-cathedralized attic configuration

Supply Air
Gypsum Ceiling
Central Return Box
Return Grille and Filter
Circular Filter (cut from blank and friction fit)
Balancing Damper Above

AirCycler™
Control

Heating Coil
Cooling Coil

Main Return Duct
Outside Air Duct
6" Insulated Flex-duct

Wall Cap
Gable End Wall

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Central-fan-integrated supply ventilation
Outside air duct (filtered) connected to return filter grille pan
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
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
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
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
Builder  
Subdivisions  
Location  
Climate  
No. Homes  
Ventilation system

Artistic Homes  
Mirabella, Tuscany, Desert Springs  
Albuquerque, NM  
mixed-dry  
15 (will soon be 800/yr)

- 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
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
Central-fan-integrated supply ventilation
Hot-humid climate interior mechanical closet configuration

- Thermostat
- Humidistat (optional)
- Control Wiring Terminals
- Supply Air To Interior Space
- Humidifying Apparatus
- Central Fan (blower)
- Air Handler Unit
- Wall Cap with Insect Screen
- Exterior Wall
- Ventilation Air Intake (locate away from pollutant sources)
- 6" Insulated Outside Air Duct (slope up for first 4’)
- Field measurement of outside air duct pressure, used to set balancing damper position
- Return Air From Interior Space
- Balancing Damper
- 40 pint/day dehumidifier
- Duct extension at air handler return (open at bottom)
- AirCycler® Control
- Heating/Dehumidifying Apparatus

Building Science Corporation
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