Mechanical Systems
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Cooling System To Make It Cold
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Dehumidification System To Make It Dry
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Cooling System To Make It Cold
Dehumidification System To Make It Dry
Heating System To Make It Warm
Mechanical Systems
Cooling System To Make It Cold
Dehumidification System To Make It Dry
Heating System To Make It Warm
Energy Recovery System To Keep It Cold and Dry and Warm and Comfortable
Mechanical Systems
Cooling System To Make It Cold
Dehumidification System To Make It Dry
Heating System To Make It Warm
Energy Recovery System To Keep It Cold and Dry and Warm and Comfortable
Distribution System To Make It Uniform
Mechanical Systems
Cooling System To Make It Cold
Dehumidification System To Make It Dry
Heating System To Make It Warm
Energy Recovery System To Keep It Cold and Dry and Warm and Comfortable
Distribution System To Make It Uniform
Range Hoods Are A Special Kind of Hell
Don’t Try to Combine Them……
**Cooling System** makes it cold

**Dehumidification System** makes it dry

**Heating System** makes it warm

**ERV** keeps it cold and dry and warm and comfortable

**Distribution System** makes it uniform
Build Tight - Ventilate Right
Build Tight - Ventilate Right
How Tight?
What’s Right?
Air Barrier Metrics

Material  0.02 l/(s-m2) @ 75 Pa
Assembly   0.20 l/(s-m2) @ 75 Pa
Enclosure  2.00 l/(s-m2) @ 75 Pa

0.25 cfm/ft2 @ 50 Pa
<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Getting rid of big holes</td>
<td>3 ach@50</td>
</tr>
<tr>
<td>Getting rid of smaller holes</td>
<td>1.5 ach@50</td>
</tr>
<tr>
<td>Getting German</td>
<td>0.6 ach@50</td>
</tr>
</tbody>
</table>
Best

As Tight as Possible - with -
Balanced Ventilation
Energy Recovery
Distribution and Mixing
Source Control - Spot exhaust ventilation
  Filtration
Material selection
Worst

Leaky - with – Nothing
Spot Ventilation in Bathroom/Kitchen
Exhaust Ventilation – with – No Distribution and No Mixing
Three Types of Controlled Ventilation Systems

Exhaust Ventilation
Supply Ventilation
Balanced Ventilation
Induced exfiltration
Motorized damper

Outside Air
Ventilation Rates Are Based on Odor Control
Ventilation Rates Are Based on Odor Control
Health Science Basis for Ventilation Rates is Extremely Limited
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Almost Nothing Cited Applies to Housing
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Almost Nothing Cited Applies to Housing
The Applicable Studies Focus on Dampness
Figure 1: Minimum ventilating rate history.
Figure 2: Odor acceptance.
House

2,000 ft\(^2\)
3 bedrooms
8 ft. ceiling
Volume: 16,000 ft\(^3\)

\[\begin{array}{cc}
.35 \text{ ach} & 93 \text{ cfm} \\
.30 \text{ ach} & 80 \text{ cfm} \\
.25 \text{ ach} & 67 \text{ cfm} \\
.20 \text{ ach} & 53 \text{ cfm} \\
.15 \text{ ach} & 40 \text{ cfm}
\end{array}\]
# House

- 2,000 ft²
- 3 bedrooms
- 8 ft. ceiling
- Volume: 16,000 ft³

## Ventilation Rates

| .35 ach | 93 cfm | 62 - 73 | 5 cfm/person | 20 cfm |
| .30 ach | 80 cfm | 62 - 89 | 10 cfm/person | 40 cfm |
| .25 ach | 67 cfm | 62.2 - 2010 | 15 cfm/person | 60 cfm |
| .20 ach | 53 cfm |  | .35 ach | 90 cfm |
| .15 ach | 40 cfm | 62.2 - 2013 | 7.5 cfm/person + 0.01 | 50 cfm |
|          |        |          | 7.5 cfm/person + 0.03 | 90 cfm |
Office

Occupant Density

15/1000 ft² (67 ft²/person) 62 - 89
15 cfm/person

5/1000 ft² (200 ft²/person) 62.1 - 2007
17 cfm/person

Correctional Facility Cell

Occupant Density

20/1000 ft² (48 ft²/person) 62.1 – 2007
10 cfm/person
C.P. Yaglou
Harvard School of Public Health
1936
1955

150 ft³ $\rightarrow$ 20 cfm/person

300 ft³ $\rightarrow$ 12 cfm/person
C.P. Yaglou
Harvard School of Public Health
1936
1955

150 ft³ → 20 cfm/person 18.75 ft² 106 occupants
300 ft³ → 12 cfm/person 37.5 ft² 53 occupants

Experiment

470 ft³ → 59 ft²
200 ft³ → 25 ft²
100 ft³ → 12 ft²
Aubin, D., Won, D.Y., Schleibinger, H., 2010
Formaldehyde sample concentration versus PFT measured outside air exchange rate over the test day

Formaldehyde concentration (µg/m³)

Outside air exchange rate over 24 h test day (ach)
ASHRAE Standard 62.2 calls for 7.5 cfm per person plus 0.03 cfm per square foot of conditioned area

Occupancy is deemed to be the number of bedrooms plus one
ASHRAE Standard 62.2 calls for 7.5 cfm per person plus 0.03 cfm per square foot of conditioned area

Occupancy is deemed to be the number of bedrooms plus one

Outcome is often bad – part load humidity problems, dryness problems, energy problems
IRC 2015 and 2018 calls for 7.5 cfm per person plus 0.01 cfm per square foot of conditioned area

Occupancy is deemed to be the number of bedrooms plus one
IRC 2021 and IMC 2021 calls for 7.5 cfm per person plus 0.01 cfm per square foot of conditioned area.

Occupancy is deemed to be the number of bedrooms plus one.

Plus a 30 percent credit for balanced ventilation and distribution.
3 Bedroom House – 2,500 ft²
30 cfm plus 75 cfm
105 cfm
3 Bedroom House – 2,500 ft²
30 cfm plus 25 cfm
55 cfm
3 Bedroom House – 2,500 ft²
30 cfm plus 25 cfm
55 cfm
55 cfm x 0.7 = 38.5 cfm
The Cult of The Blower Door
Blower Door Can’t Get You The True ACH
On A Short Term Basis – Hour, Day, Week
Don’t Know Where The Holes Are
Don’t Know The Type of Holes
Don’t Know The Pressure Across The Holes
\[ ELA = C \times \frac{\text{Rate of flow}}{\sqrt{\text{Pressure difference}}} \]

\[ (\text{Meters})^2 = \frac{1}{780} \times \frac{\text{Litres per second}}{\sqrt{\text{Pascals}}} \]
Dilution Is Not The Solution To Indoor Pollution
Source Control
Dilution For People
Source Control For The Building
Relative Humidity (RH) %

- **Uncomfortably Dry**: 0 to 20%
- **Comfort Range**: 20% to 75%
- **Uncomfortably Wet**: 75% to 100%

Target Range:
- Winter: 0 to 20%
- Summer: 75% to 100%
Recommended Range of Relative Humidity
Above 25 percent during winter
Below 70 percent during summer
Kitchen Exhaust Hoods
Unconditioned make-up air 60 - 70% of hood exhaust
- Move cabinets farther apart.
- Hood wider than cook top and extended outboard past head space.
- Move hood up to provide headroom.
- Interlocked make-up air.
Clothes Dryers
Fireplaces
Approaches
Return air

Supply air

Dehumidifier

Bedroom

Heat exchange
ventilator

Bath

Kitchen

Exhaust air

Outside air

Exhaust air

Interlocked kitchen hood
make-up air
Stack Effect Flow Out (Exfiltration)

\[ P_{\text{inside}} \text{ drops with height slower than } P_{\text{outside}} \]

Stack Effect Flow In (Infiltration)

\[ P_{\text{outside}} \text{ drops with height faster than } P_{\text{inside}} \]
Reduced Individual Unit Stack Effect
Motorized damper — typically closed (connected to fire control system)

Smoke and hot gas vent

(3 1/2% of shaft or 3 ft² per elevator car)

Constant airflow regulator

Exhaust from elevator shaft
Ductwork and Air Handlers in Basements

- No air pressure differences result in a house with an air handler and ductwork located in a basement if there are no leaks in the supply ducts, the return ducts or the air handler and if the amount of air delivered to each room equals the amount removed.
Figure 3.13

Ductwork and Air Handlers in Vented Attics

- No air pressure differences result in a house with an air handler and ductwork located in a vented attic if there are no leaks in the supply ducts, the return ducts or the air handler and if the amount of air delivered to each room equals the amount removed.
Figure 3.15  
**Leaky Ductwork and Air Handlers in Vented Attics**

- Supply ductwork and air handler leakage is typically 20% or more of the flow through the system.
Duct Leakage Should Be Less Than 5% of Rated Flow As Tested By Pressurization To 25 Pascals
Note: Colored shading depicts the building’s thermal barrier and pressure boundary. The thermal barrier and pressure boundary enclose the conditioned space.
Figure 3.16

**Leaky Supply Ductwork in Vented Crawl Space**

- Air pressurization pattern with mechanical system ducts in the crawl space
Figure 3.14
**Leaky Ductwork and Air Handlers in Basements**
- Air pressurization patterns in a house with leaky ductwork in the basement
Figure 3.18

**Insufficient Return Air Paths**

- Pressurization of bedrooms often occurs if insufficient return pathways are provided; undercutting bedroom doors is usually insufficient; transfer grilles, jump ducts or fully ducted returns may be necessary to prevent pressurization of bedrooms.

- Master bedroom suites are often the most pressurized as they typically receive the most supply air.

- When bedrooms pressurized, common areas depressurize; this can have serious consequences when fireplaces are located in common areas and subsequently backdraft.
Grille located high in wall on bedroom side to avoid blockage by furniture.

Cavity is sealed tight, drywall glued to studs and plates on both sides.

Grille located low in wall on hallway side.