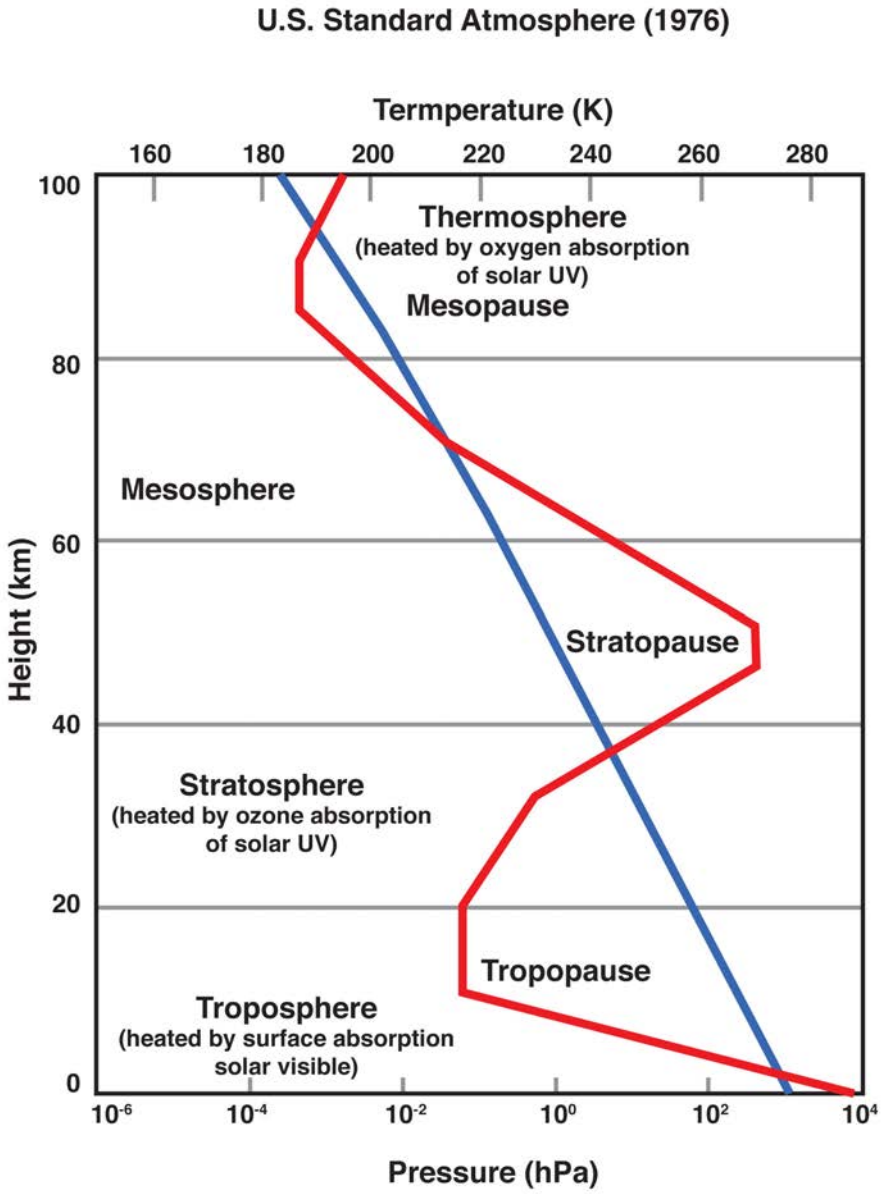
Joseph Lstiburek, Ph.D., P.Eng, ASHRAE Fellow

Building Science

Ventilation

www.buildingscience.com

Lapse Rate


U.S. Standard Atmosphere (1976)
Termperature (K)
160
180
200
220
240
260
280
100
80
60
40
20
0
Height (km)
Thermosphere
(heated by oxygen absorption
of solar UV)
Mesopause
Mesosphere
Stratopause
Stratosphere
(heated by ozone absorption
of solar UV)
Tropopause
Troposphere
(heated by surface absorption
solar visible)
10^{-6}
10^{-4}
10^{-2}
10^{0}
10^{2}
10^{4}
Pressure (hPa)

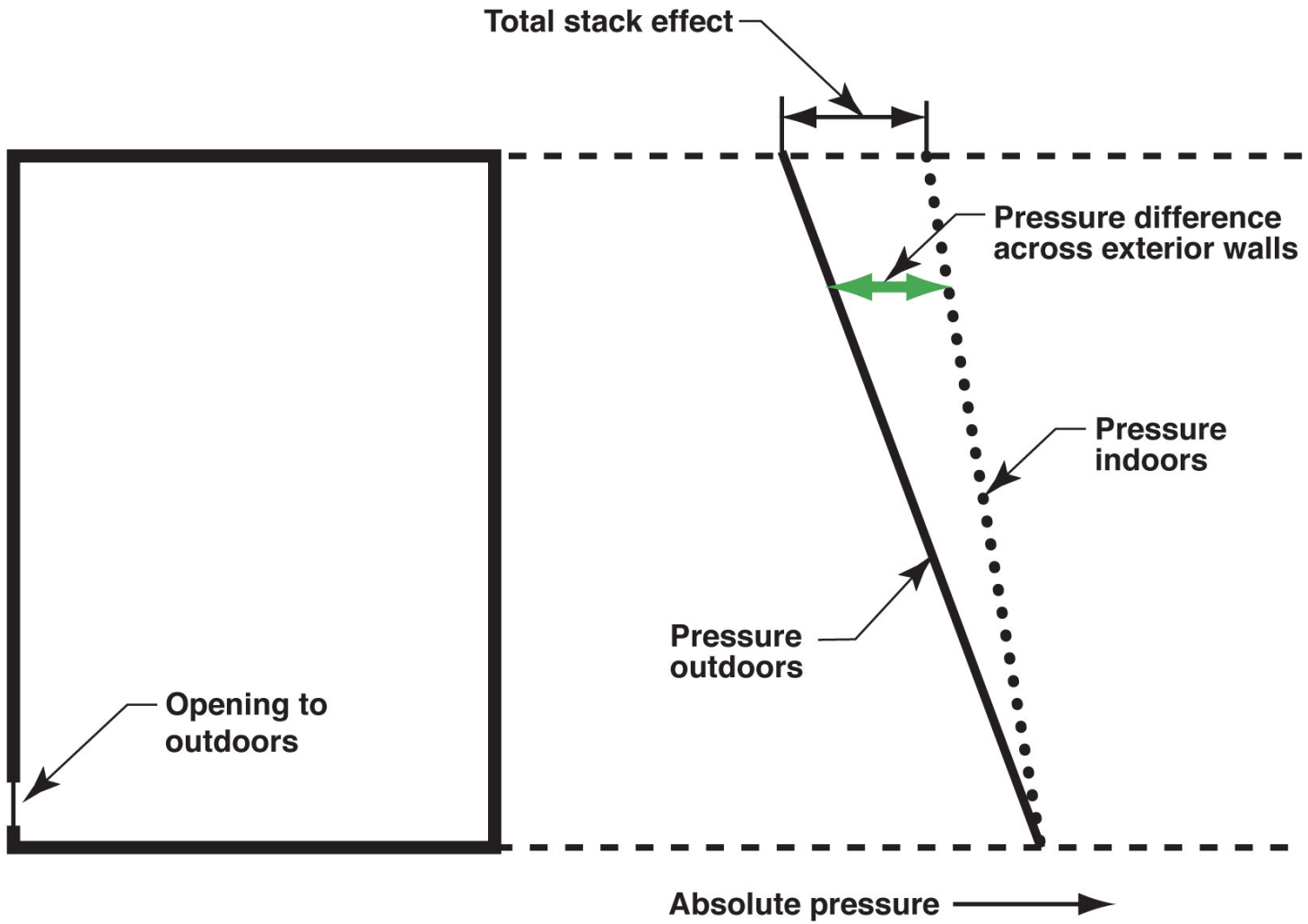


Figure 11.1: Building with no internal separations with opening at the bottom (Adapted from G.O. Handegord, 1998)

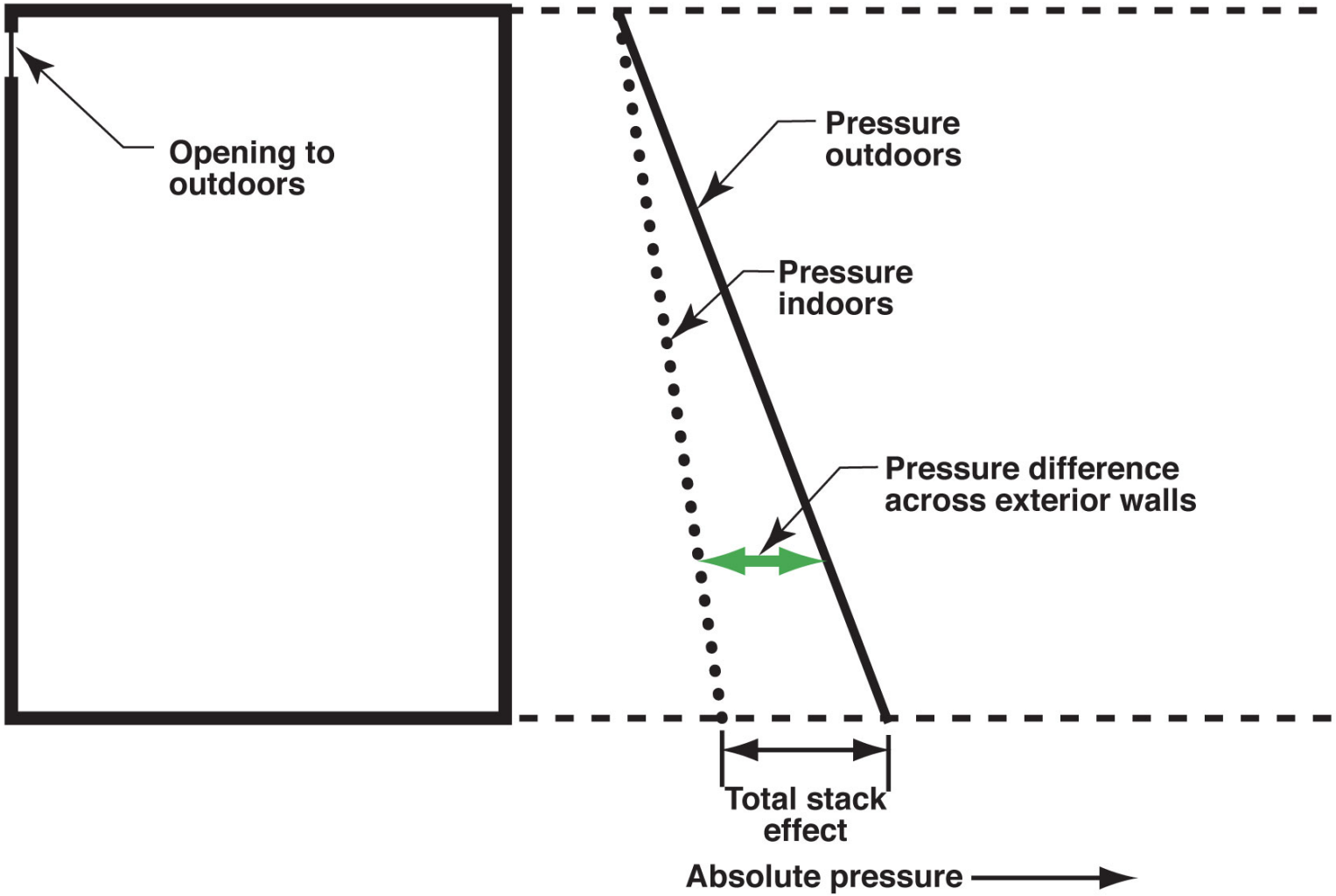


Figure 11.2: Building with no internal separations with opening at the top (Adapted from G.O. Handegord, 1998)

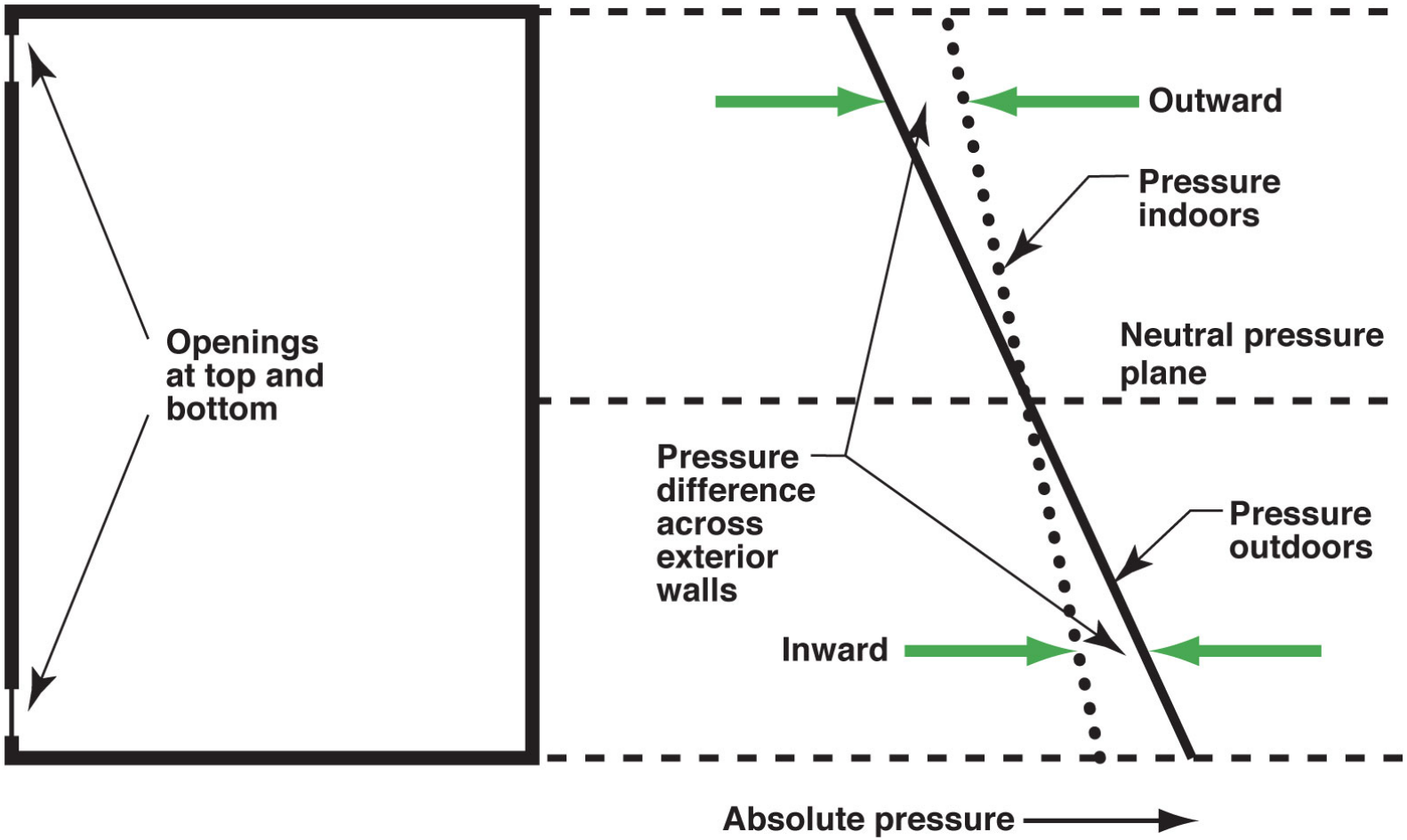


Figure 11.3: Building with no internal separations with openings at top and bottom (Adapted from G.O. Handegord, 1998)

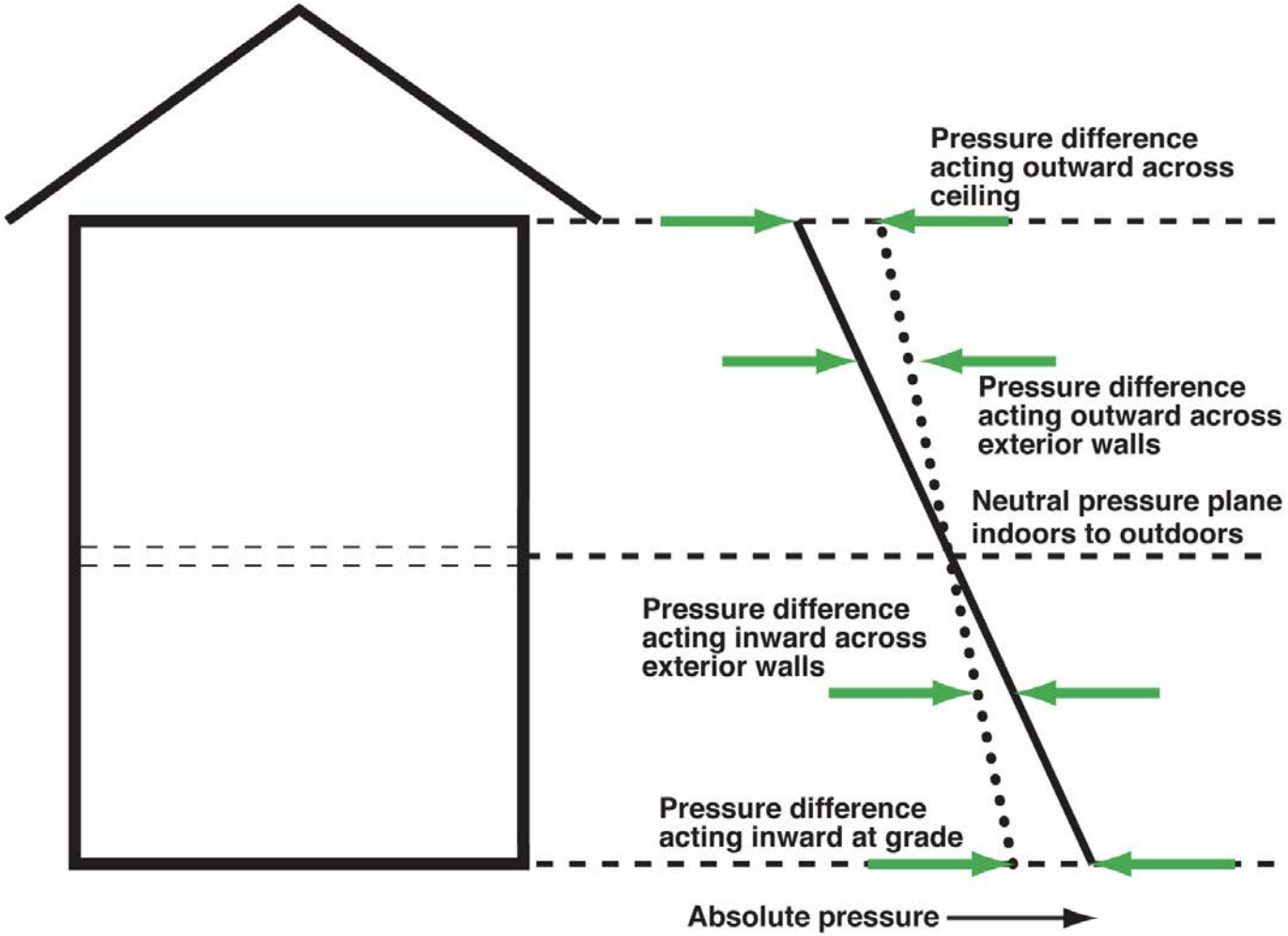
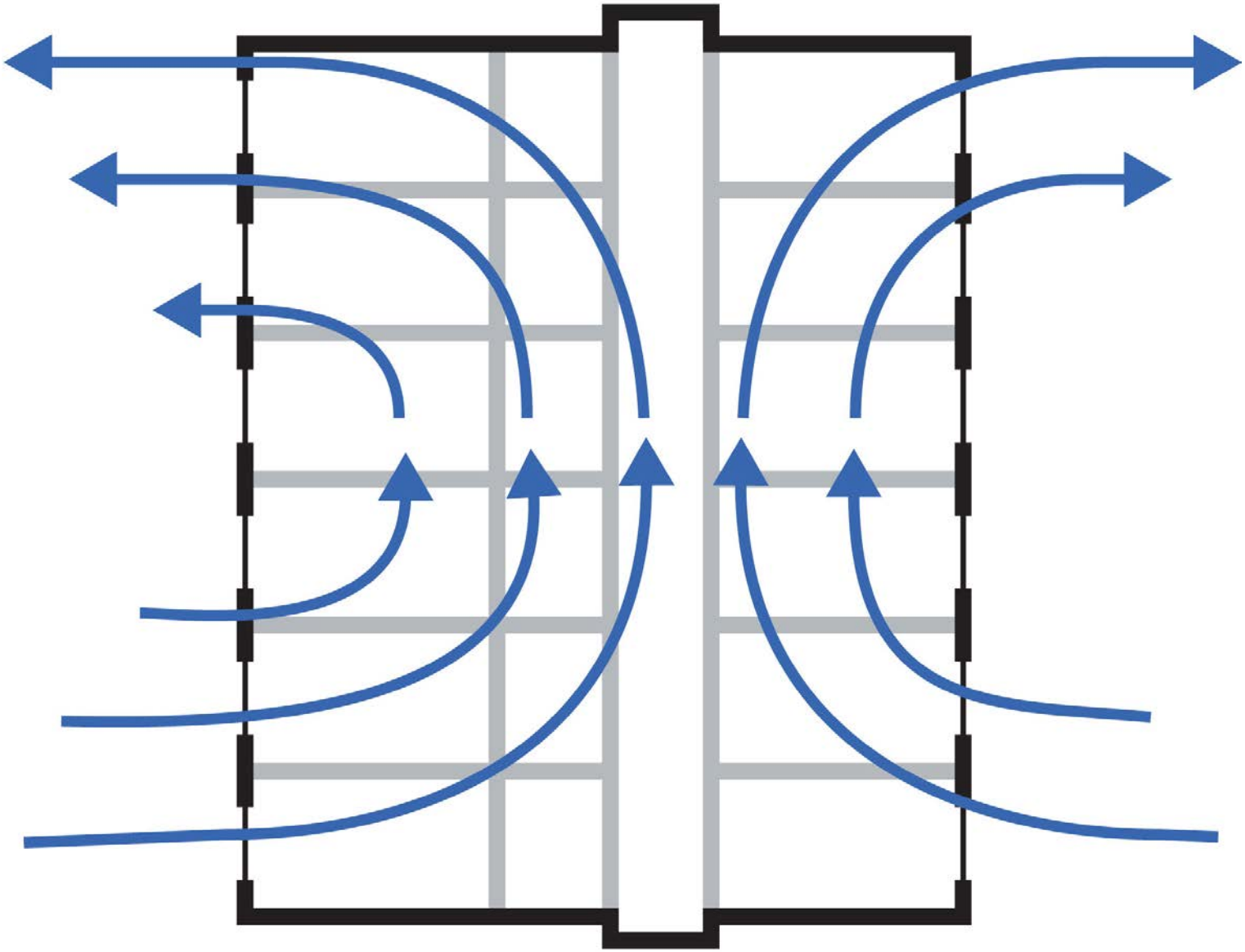
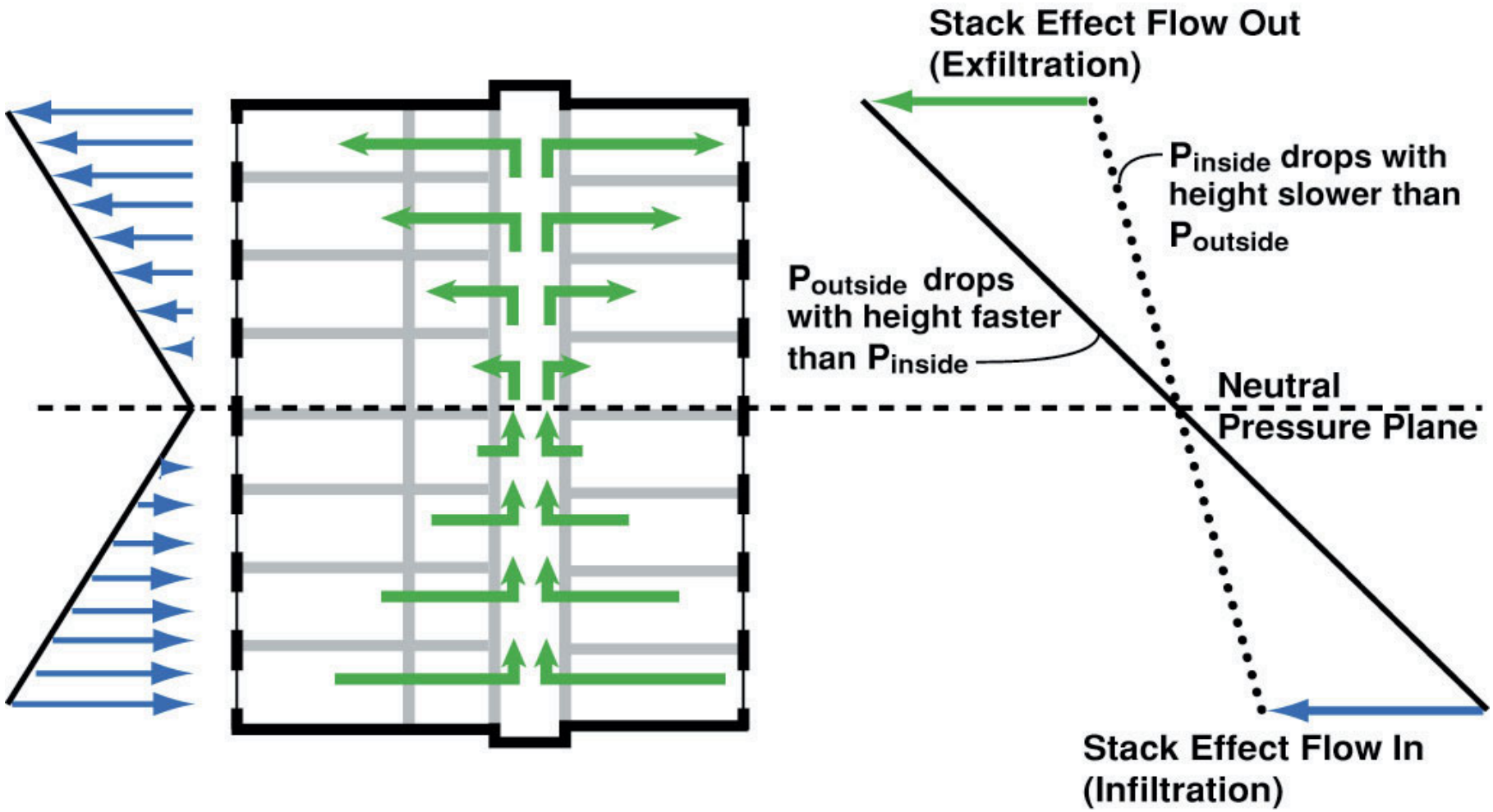


Figure 11.4: Basic two storey house with vented attic (Adapted from G.O. Handegord, 1998)


POMPIERS NO. 3




Stack Effect Flow Out
(Exfiltration)
Pinside drops with
height slower than
Poutside
Poutside drops
with height faster
than Pinside
Neutral
Pressure Plane
Stack Effect Flow In
(Infiltration)

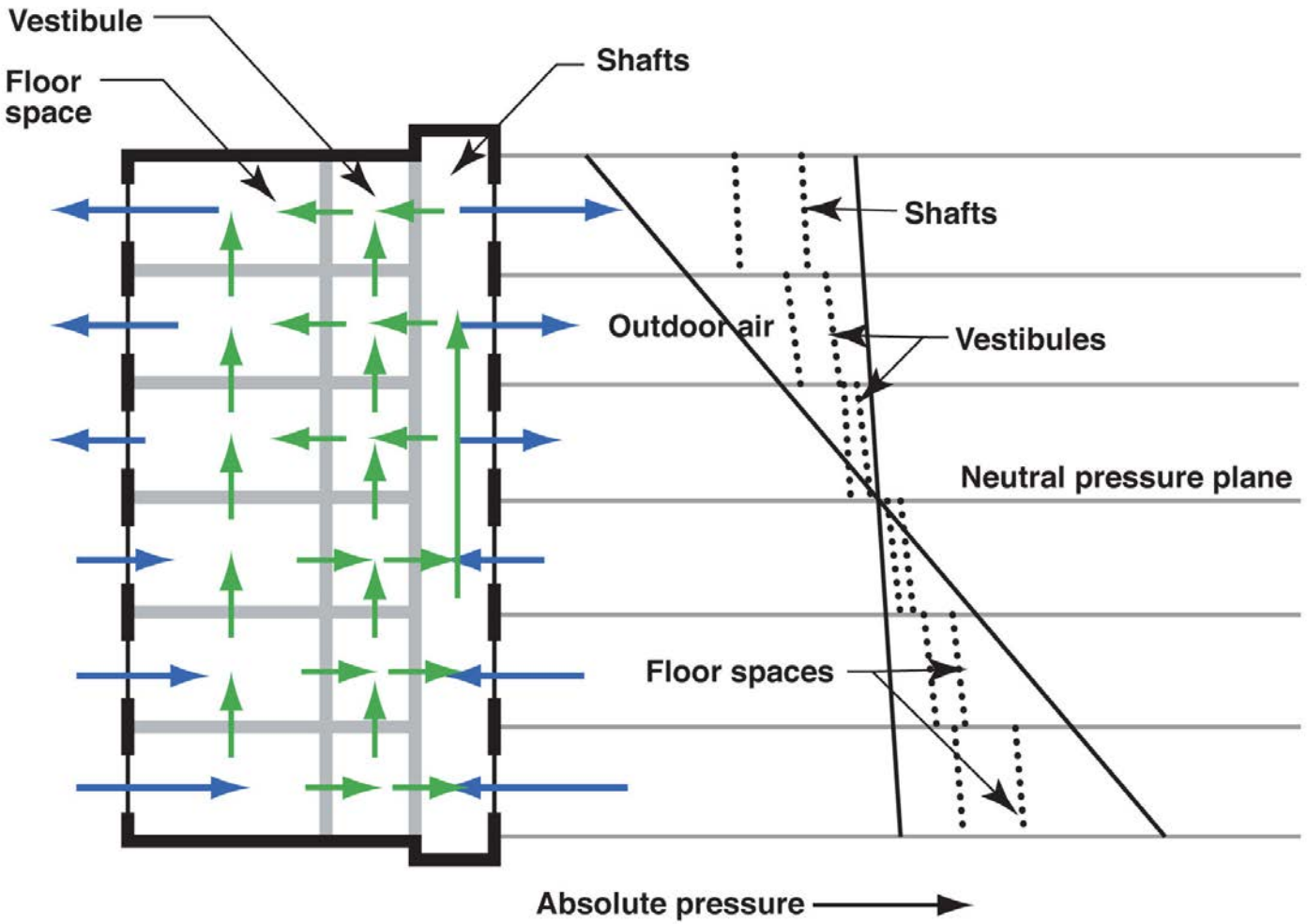


Figure 11.8: Stack effect pressures in high rise office building (Adapted from G.O. Handegord, 1998)

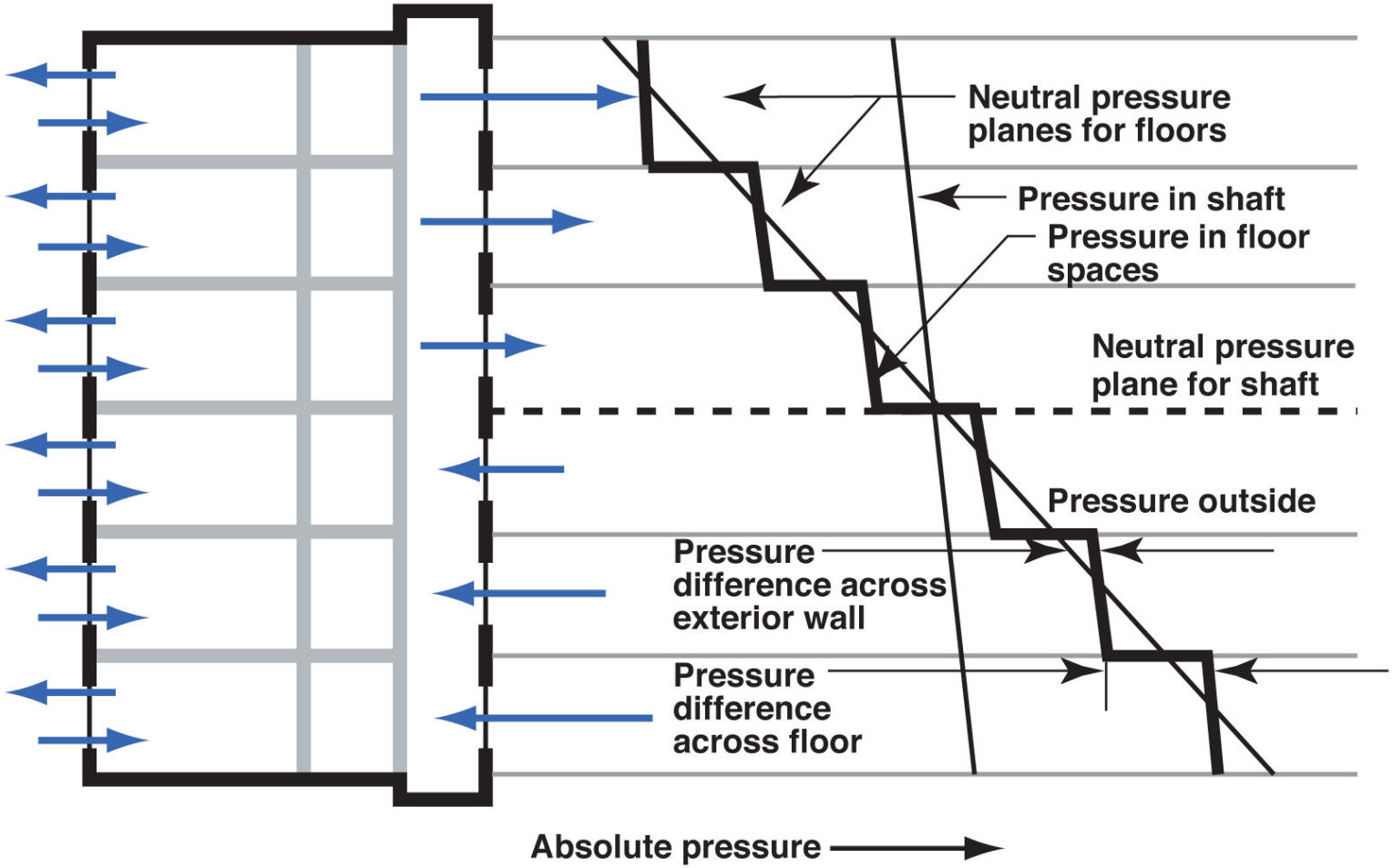


Figure 11.9: Multi-storey building with floor spaces isolated from vertical shafts (Adapted from G.O. Handegord, 1998)

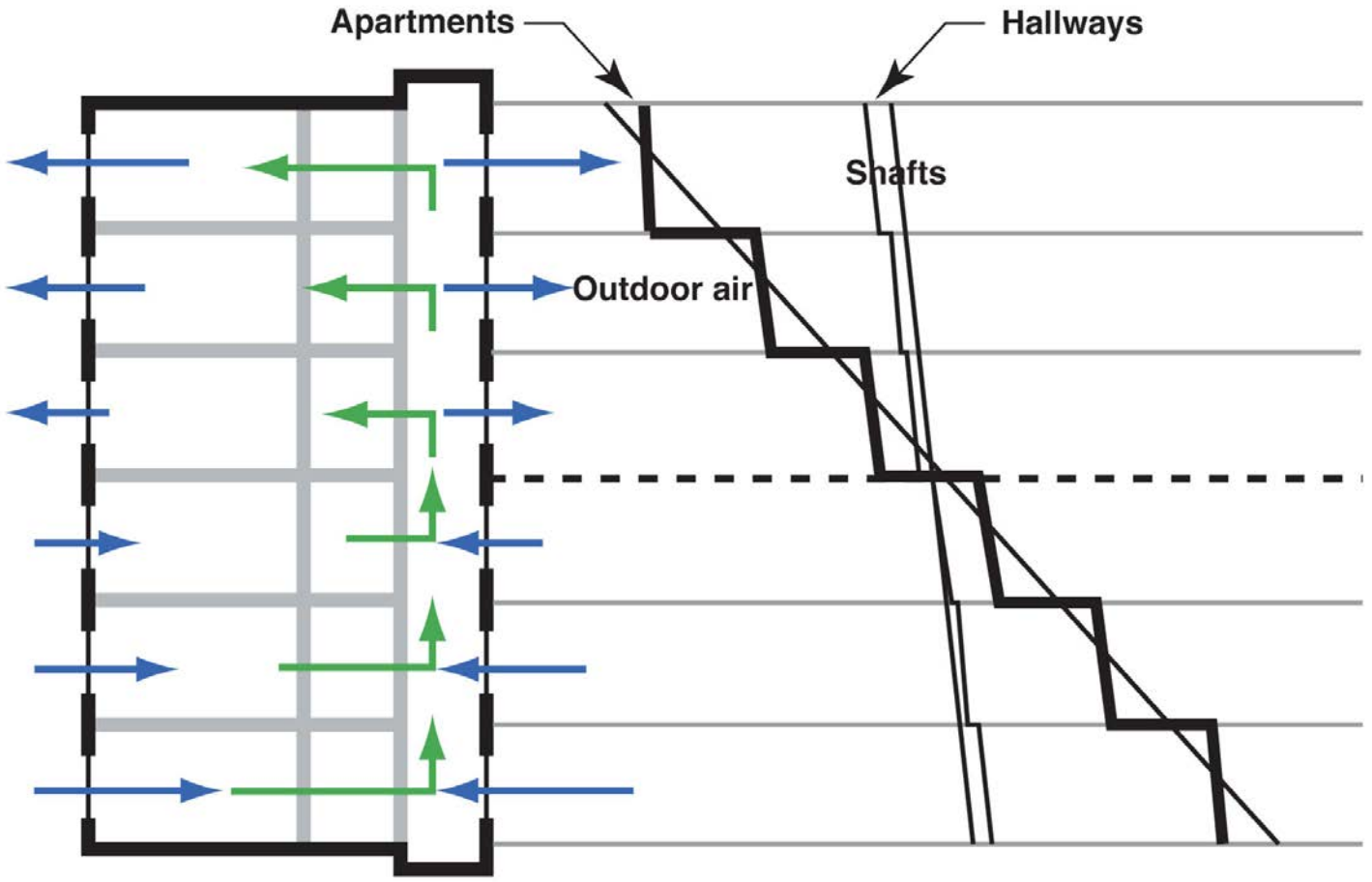
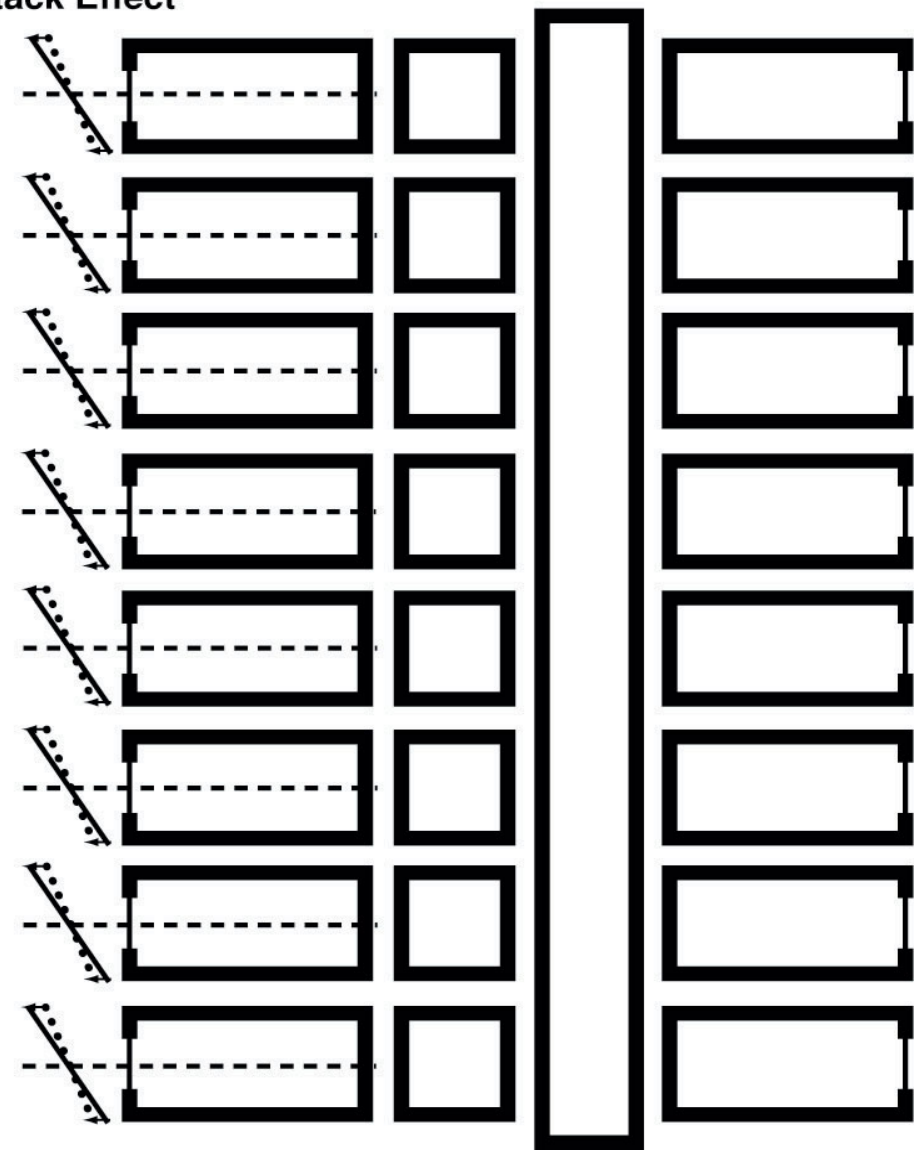
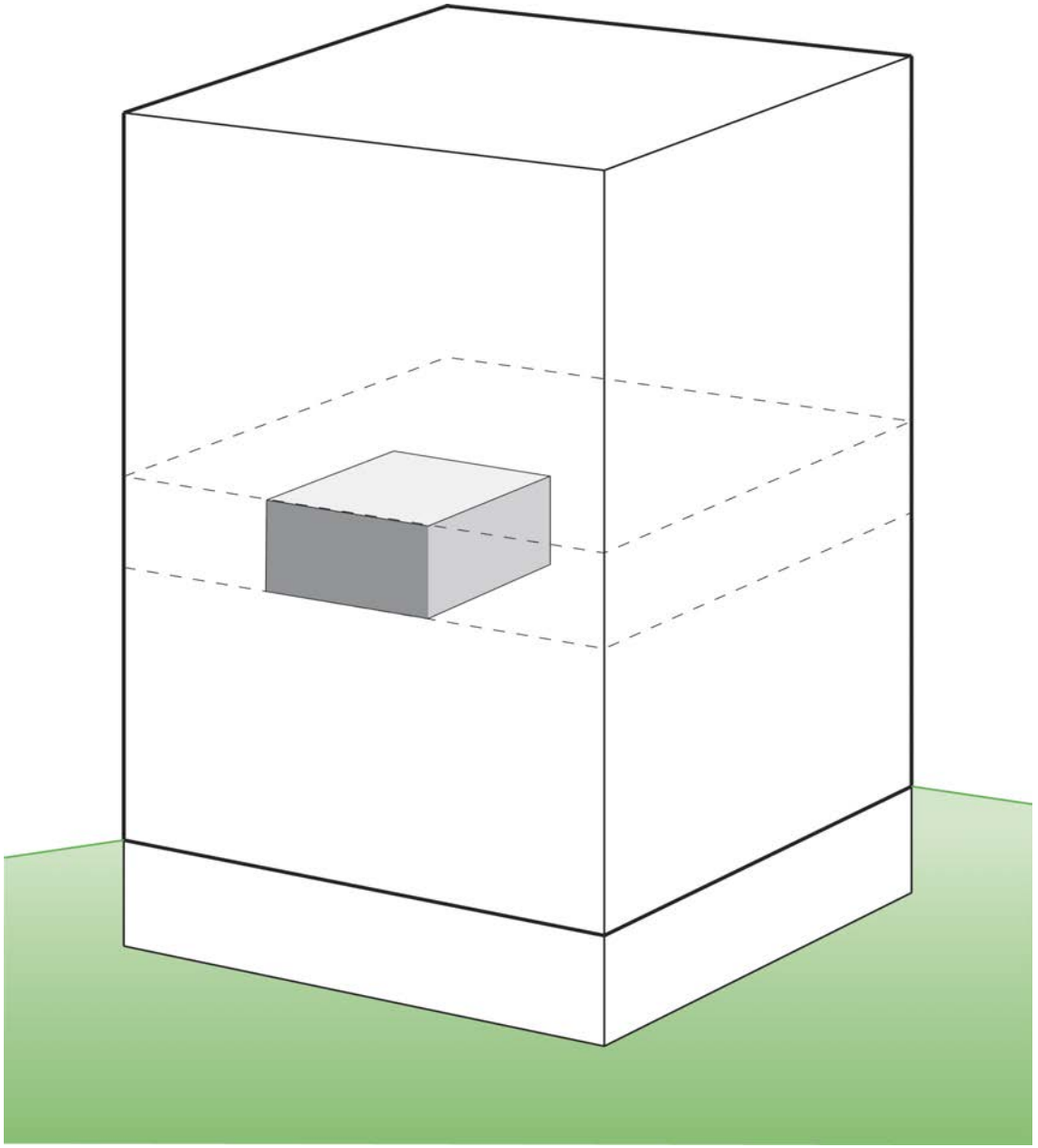


Figure 11.12: Apartment building with tighter apartment entry doors (Adapted from G.O. Handegord, 1998)

Reduced Individual Unit Stack Effect





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
	0.35 cfm/ft2 @ 50 Pa
	0.25 cfm/ft2 @ 50 Pa
	0.15 cfm/ft2 @ 50 Pa

Getting rid of big holes	3 ach@50
Getting rid of smaller holes	1.5 ach@50
Getting German	0.6 ach@50

As Tight as Possible - with -

Balanced Ventilation

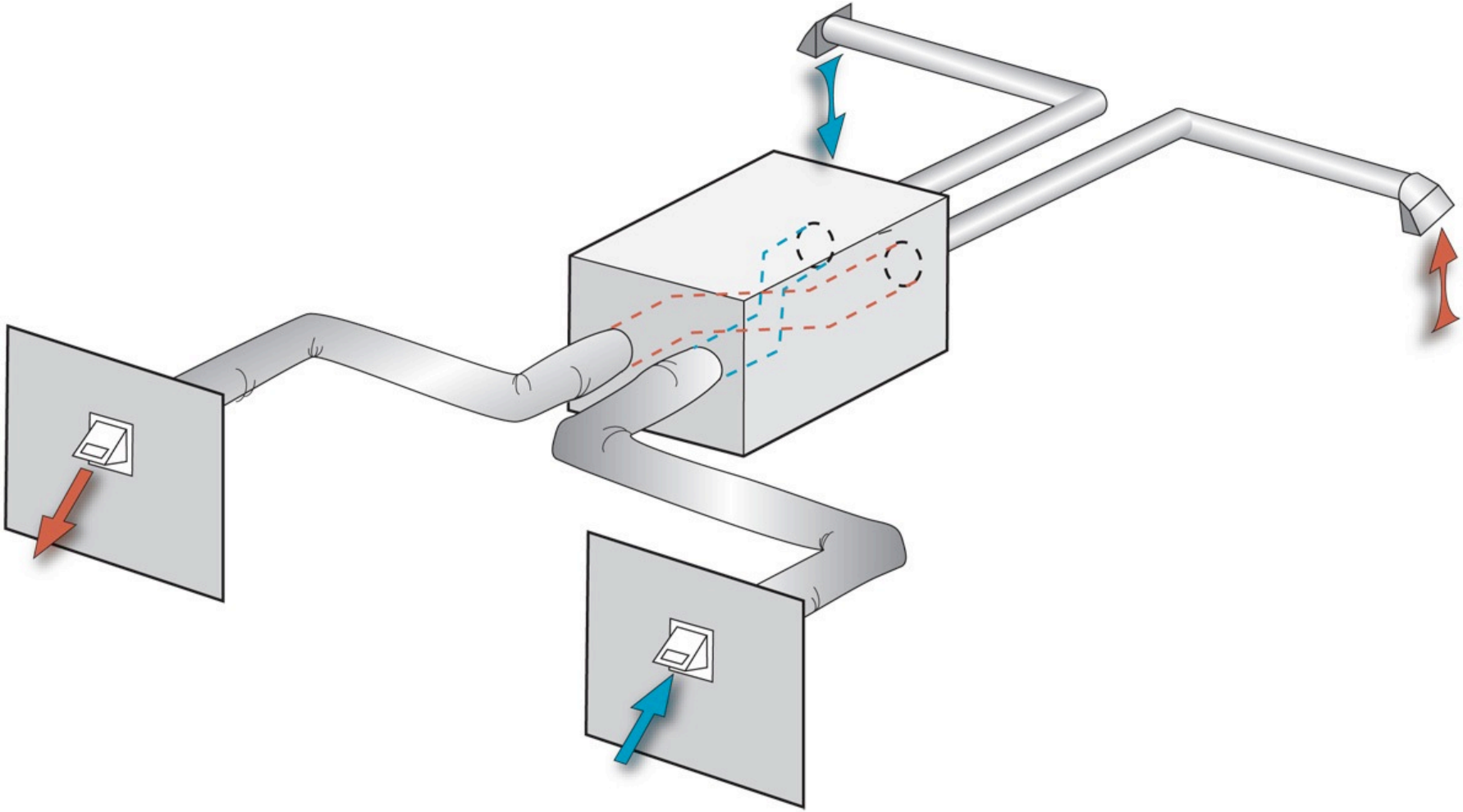
Distribution

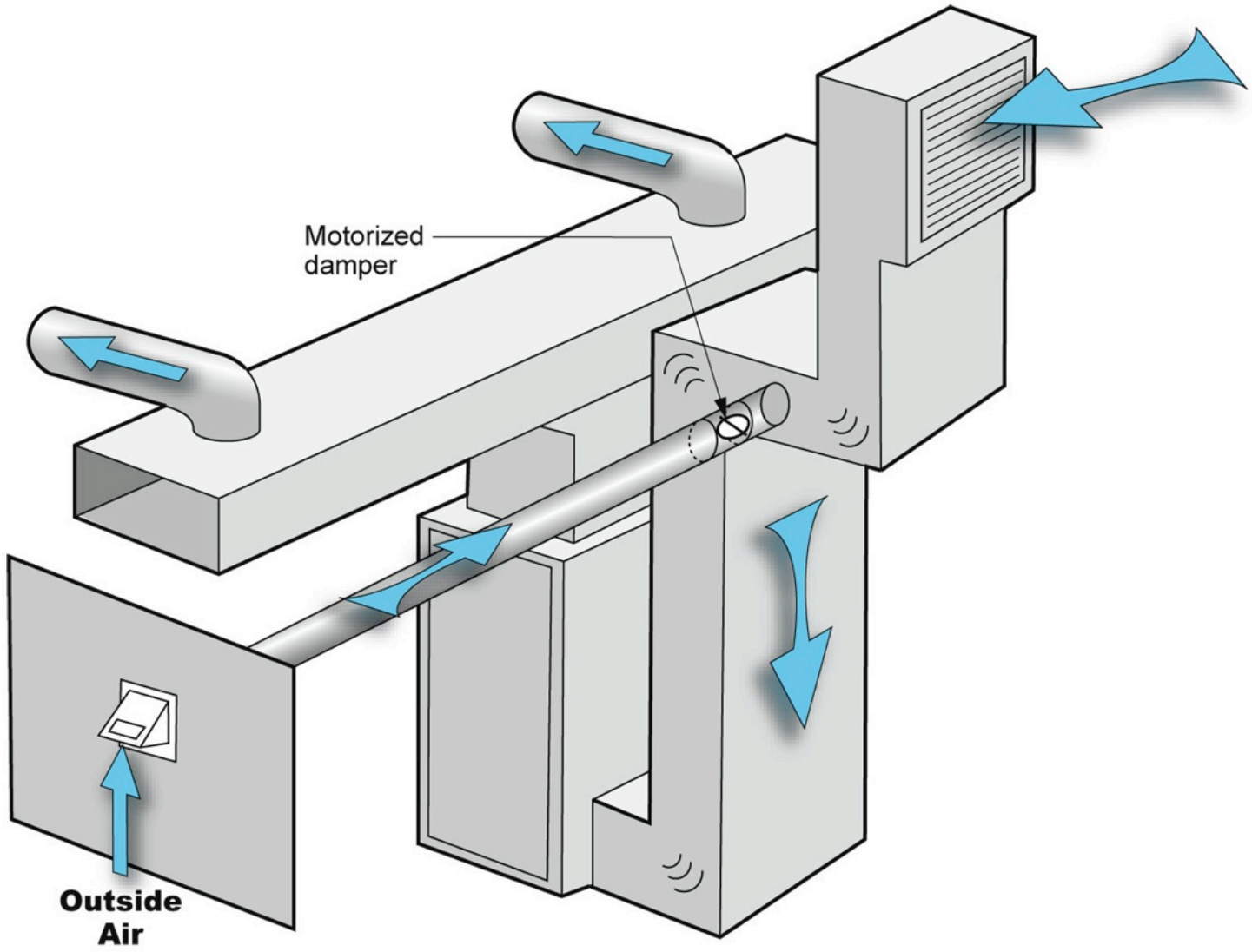
Source Control - Spot exhaust ventilation

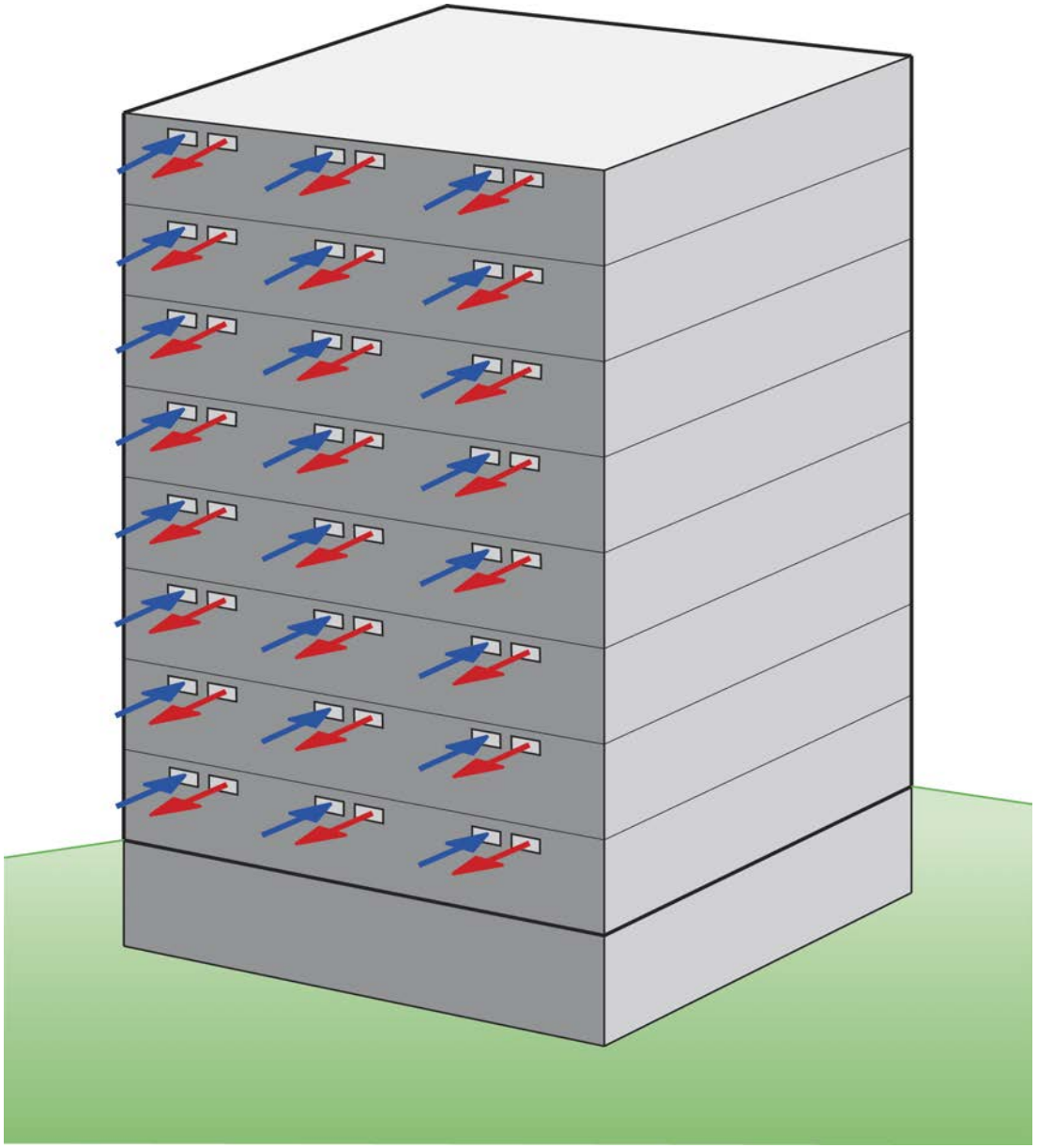
Filtration

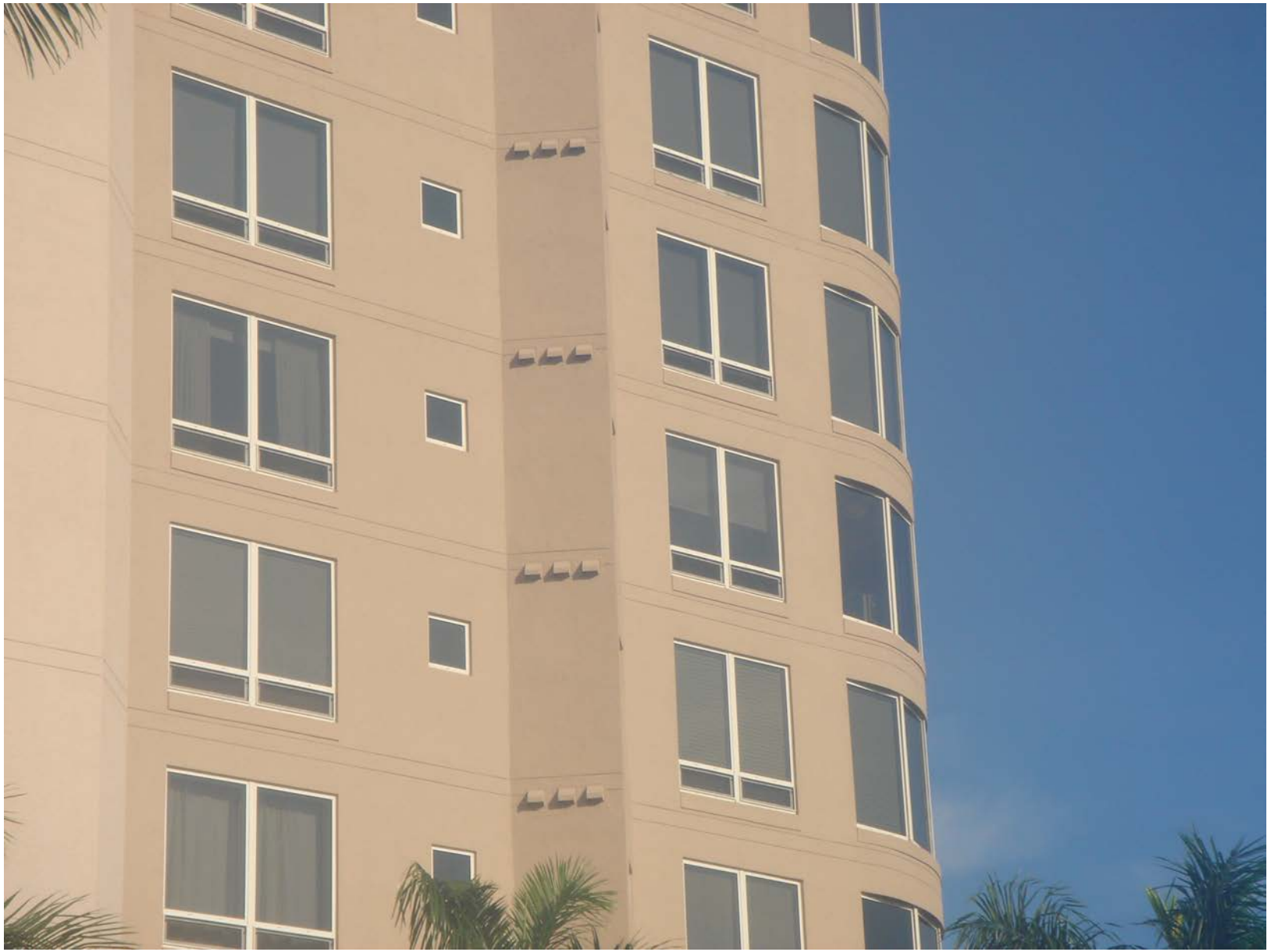
Material selection

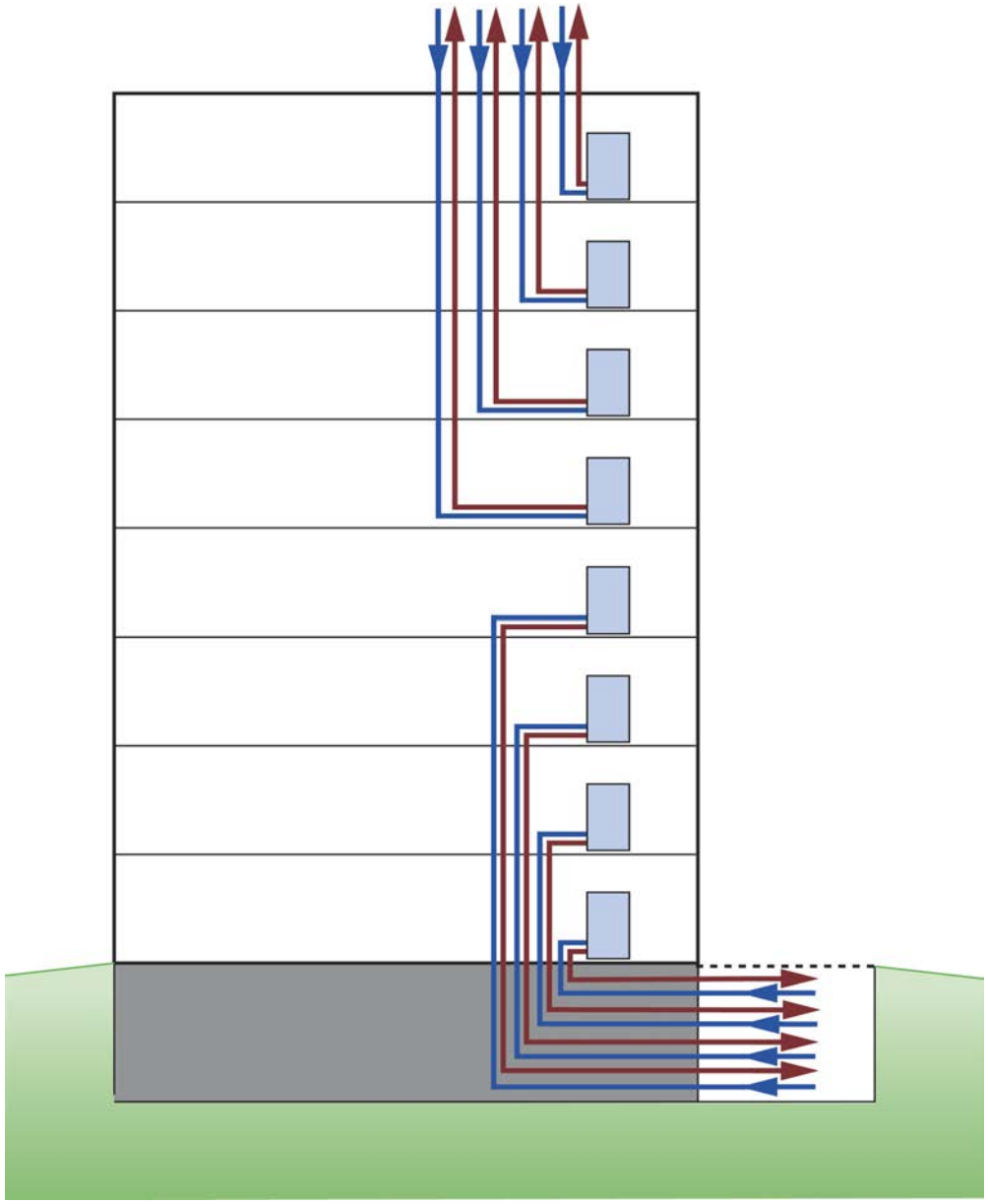
Energy Recovery

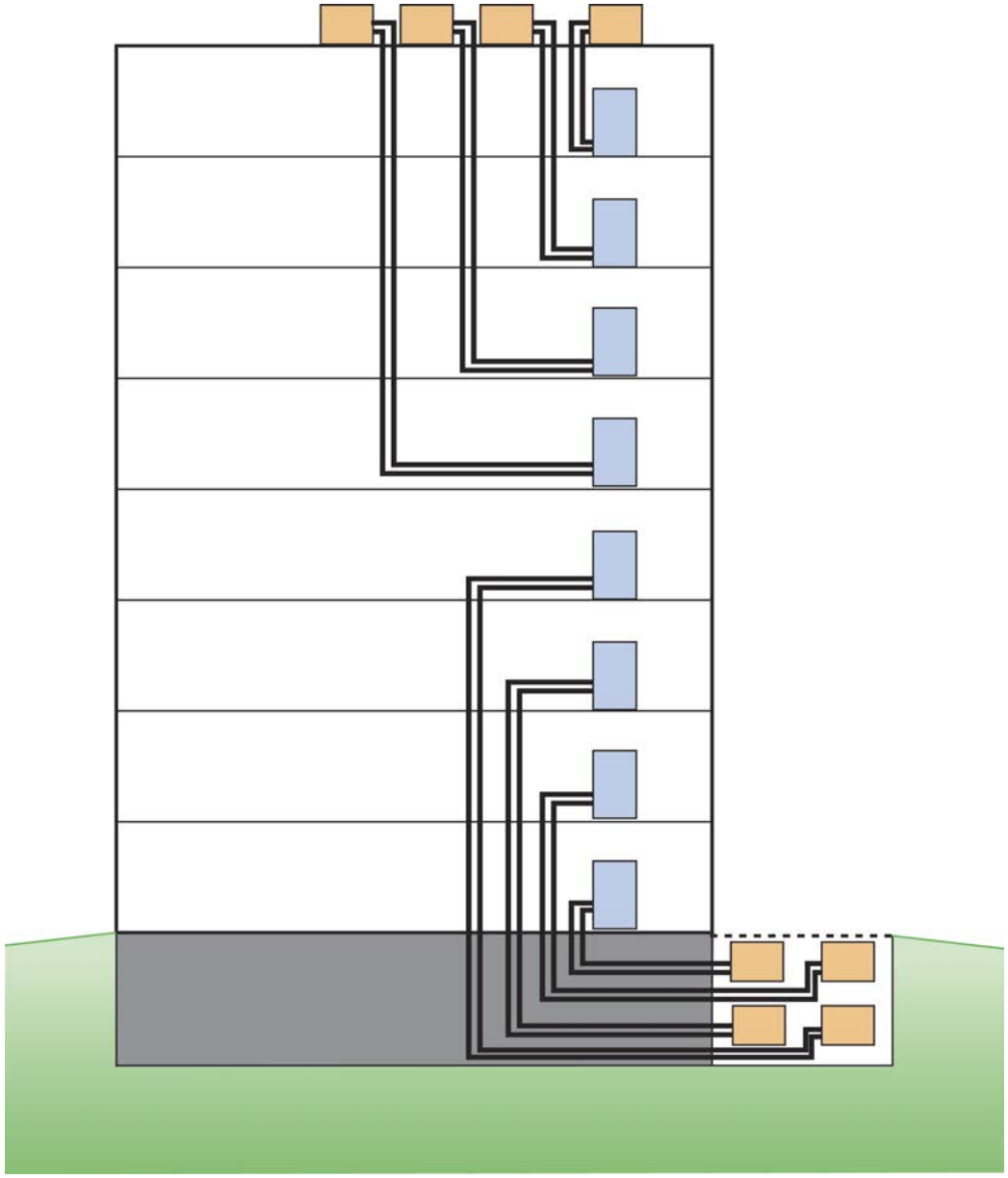


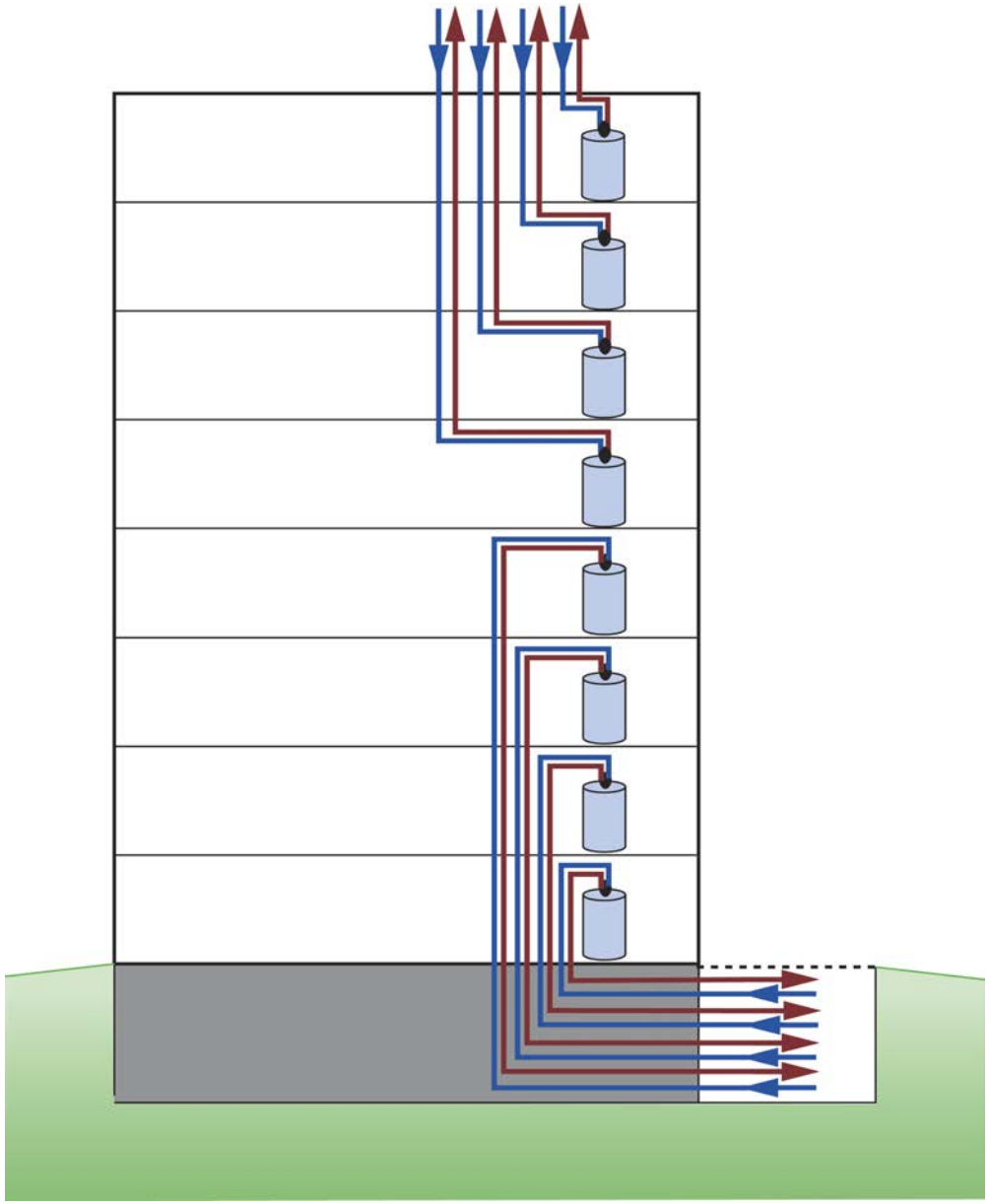

Motorized
damper
Outside
Air











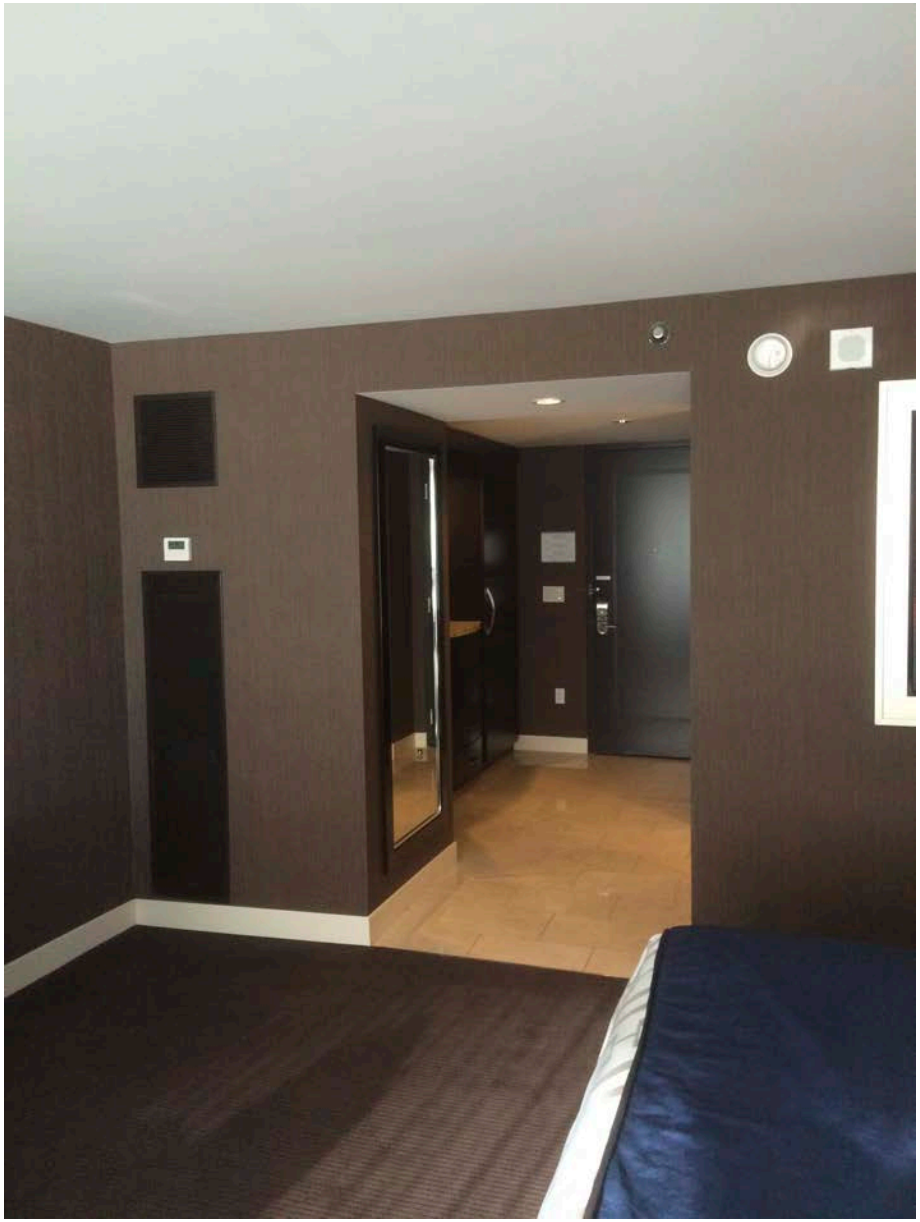

HOT WATER

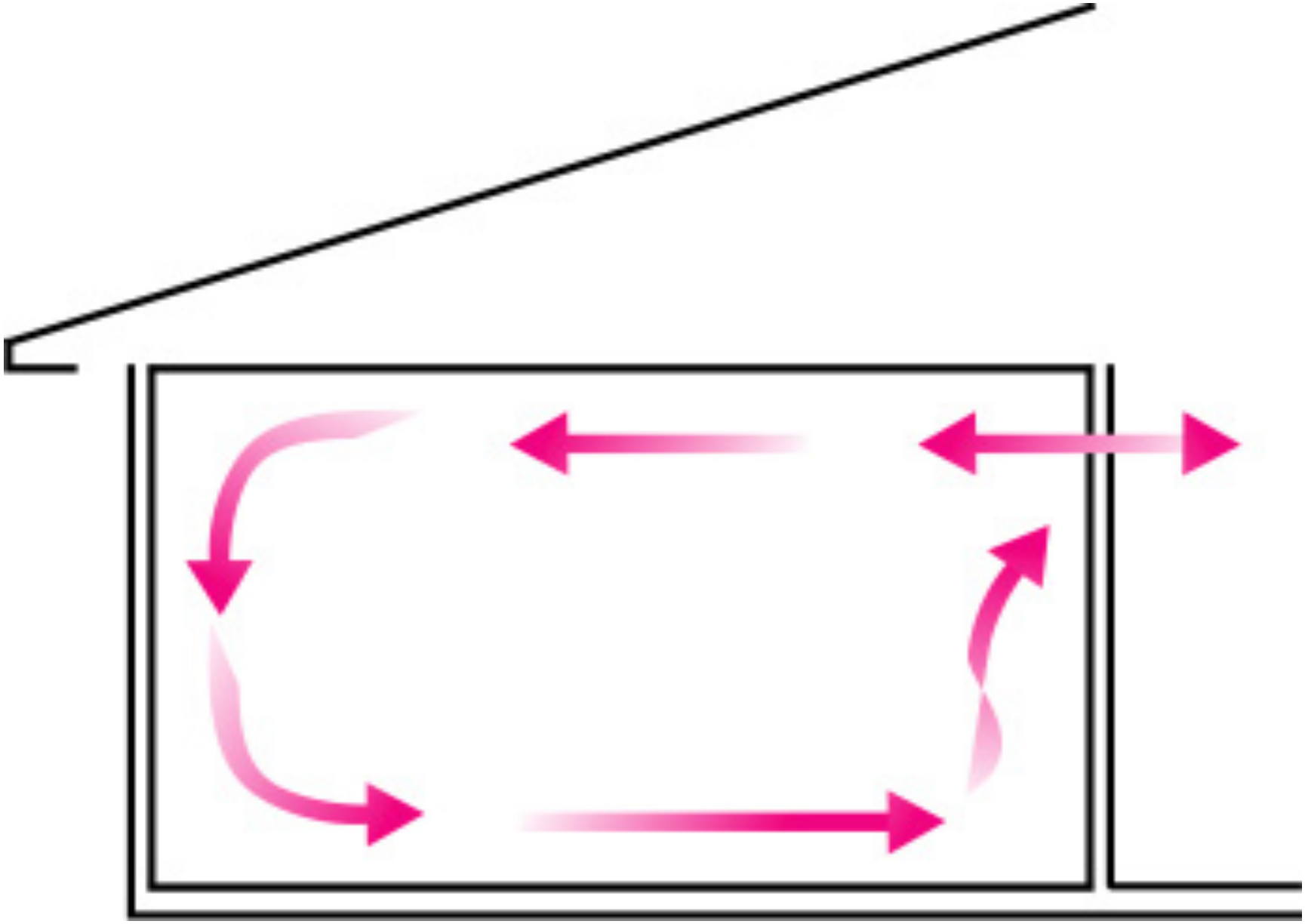

YORK
YORK

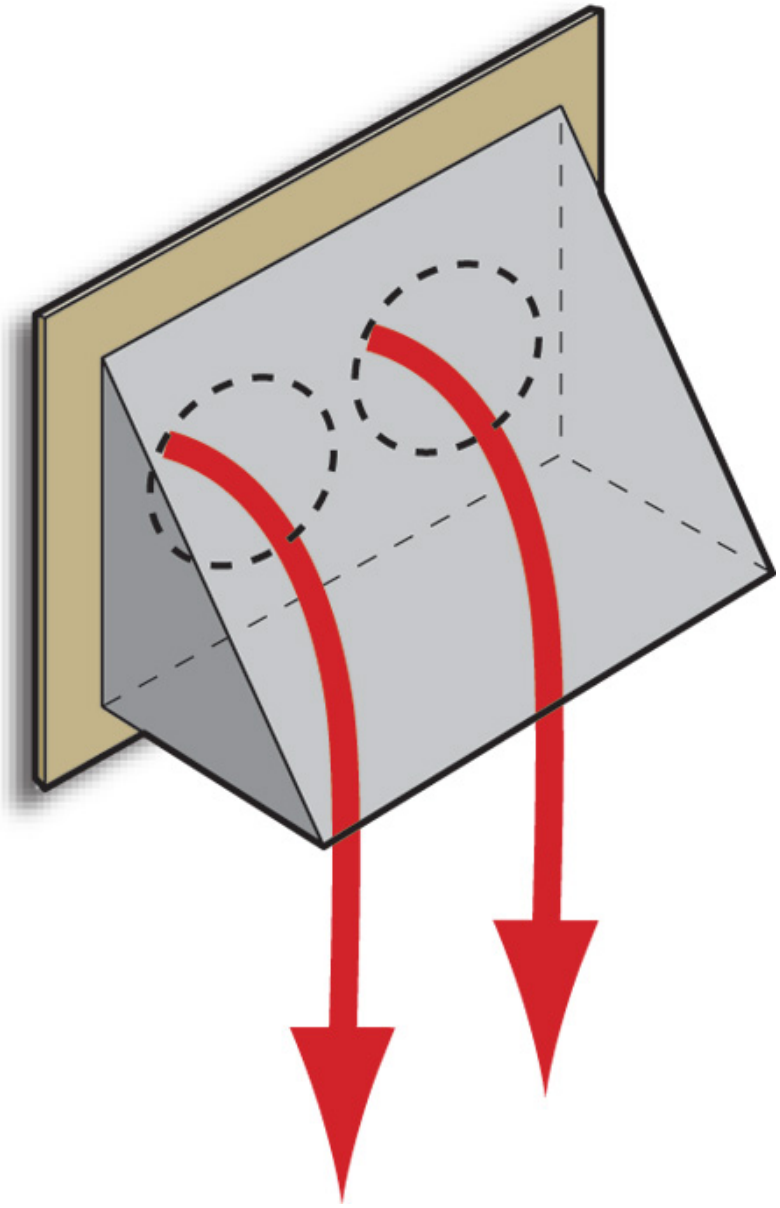

Goodman
Goodman

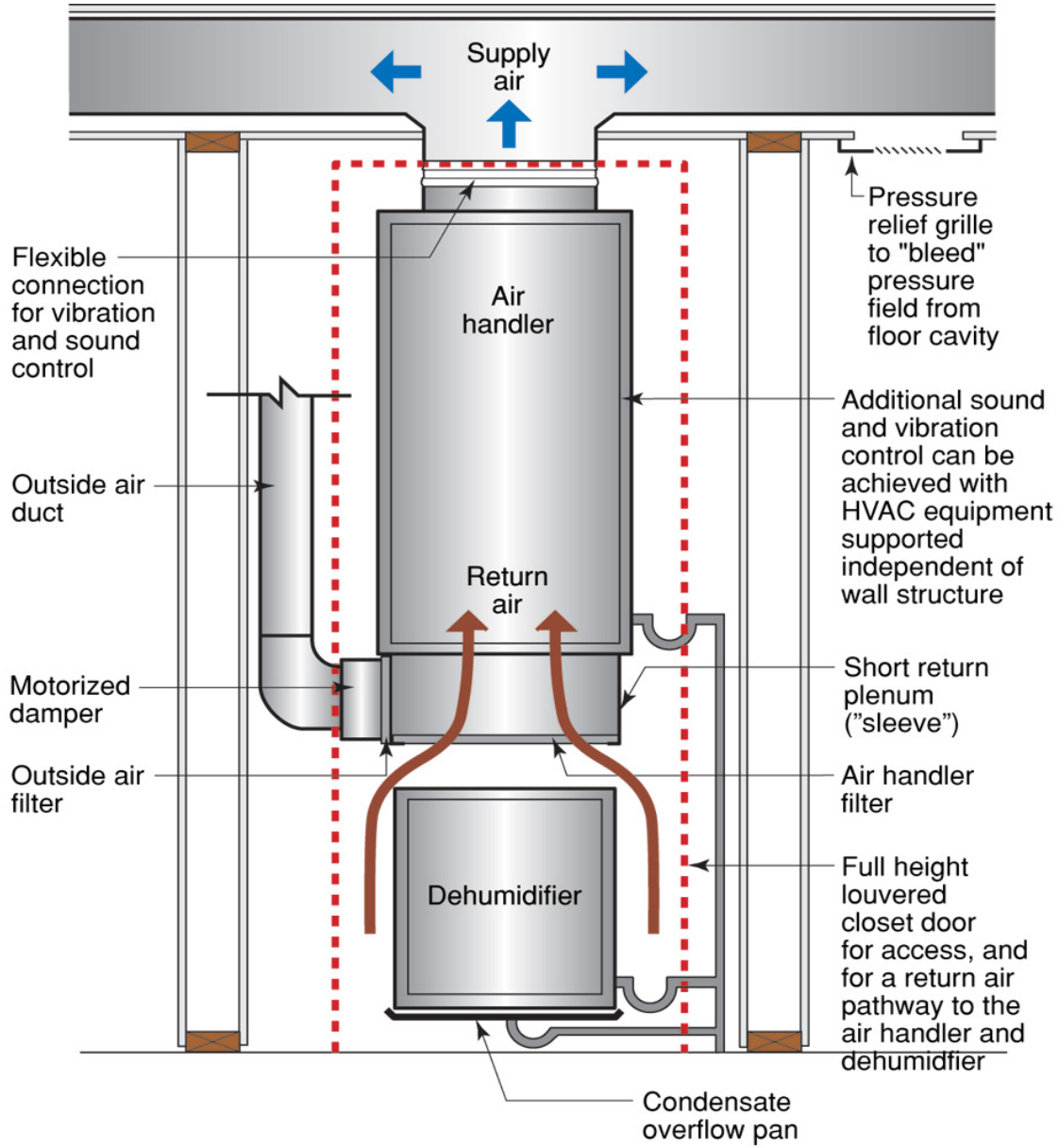

EASTERN
ANJAC FASHION BLDG
Carrier


A.O. Smith
EnergySaver
ENERGUIDE
8.23.09

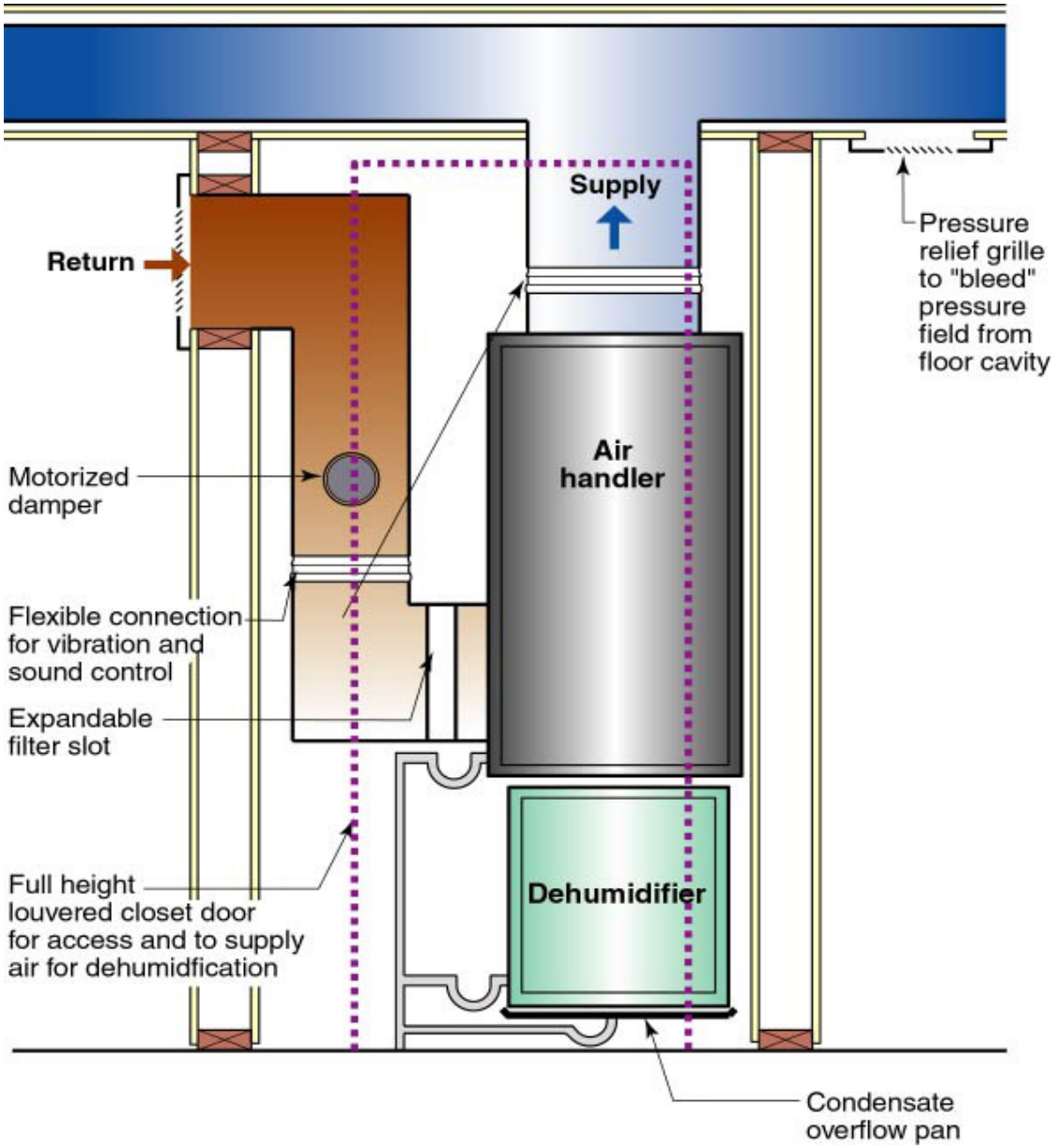




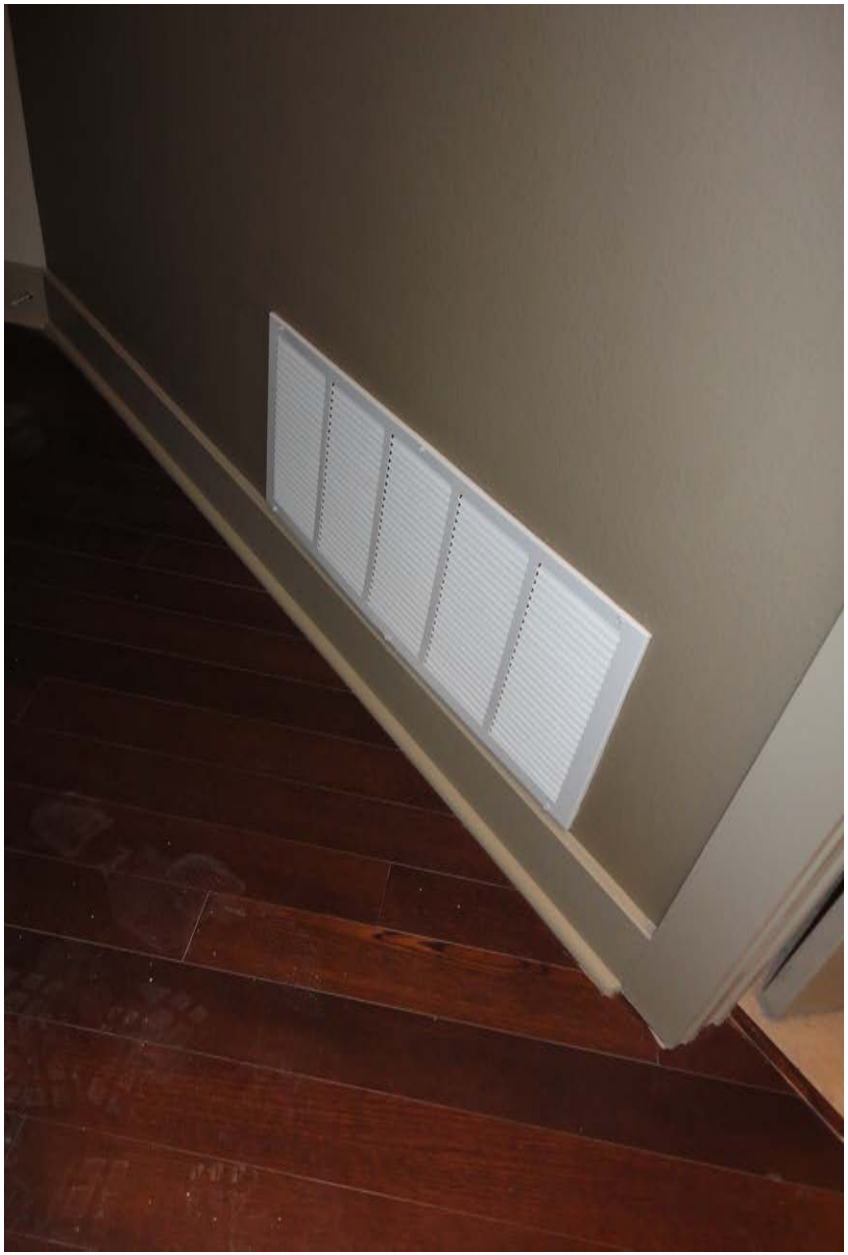



Supply air
Pressure relief grille to "bleed" pressure field from floor cavity
Flexible connection for vibration and sound control
Air handler
Additional sound and vibration control can be achieved with HVAC equipment supported independent of wall structure
Outside air duct
Return air
Short return plenum ("sleeve")
Motorized damper
Outside air filter
Air handler filter
Dehumidifier
Full height louvered closet door for access, and for a return air pathway to the air handler and dehumidfier
Condensate overflow pan

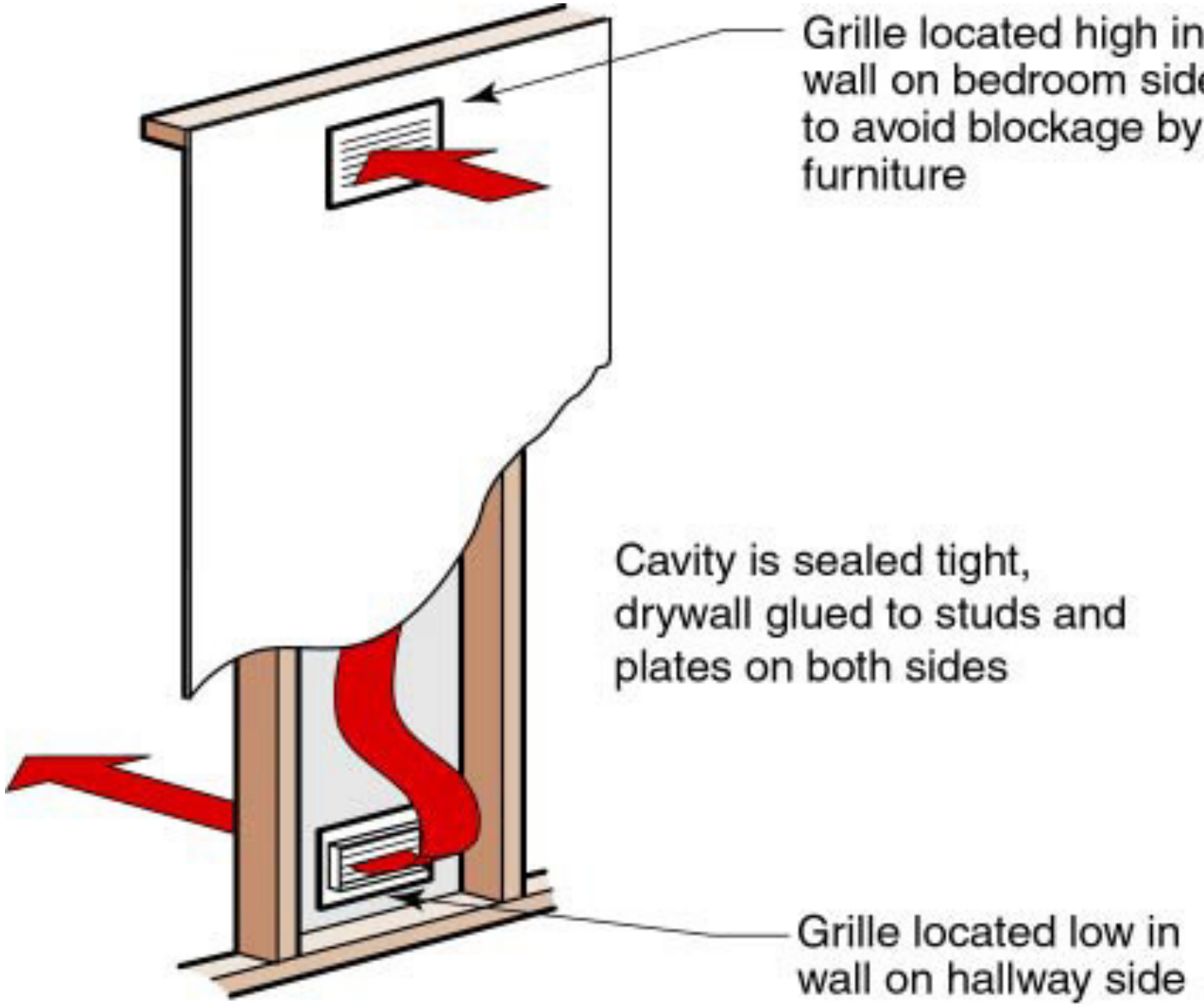

Carrier

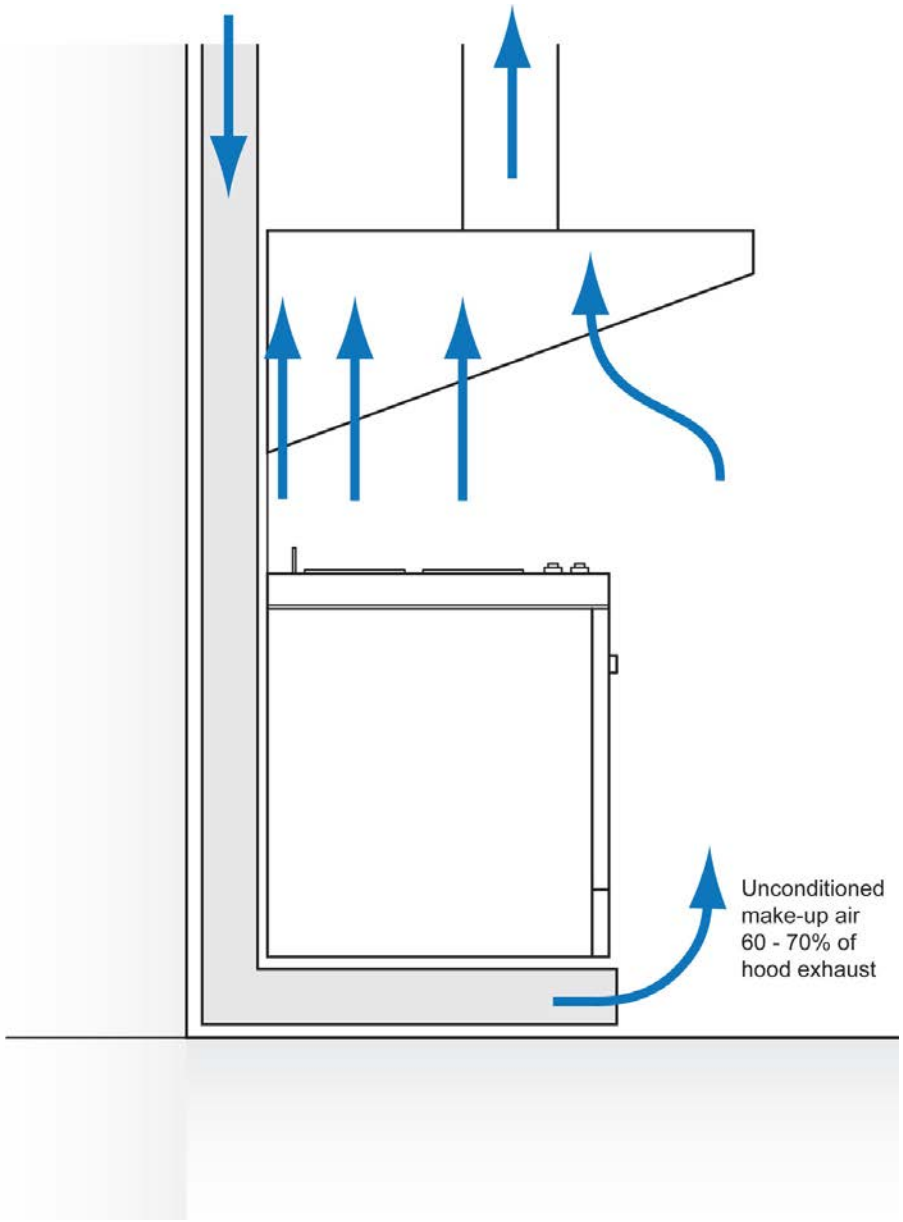

Supply
Return
Pressure relief grille to "bleed" pressure field from floor cavity
Air handler
Motorized damper
Flexible connection for vibration and sound control
Expandable filter slot
Dehumidifier
Full height louvered closet door for access and to supply air for dehumidfication
Condensate overflow pan

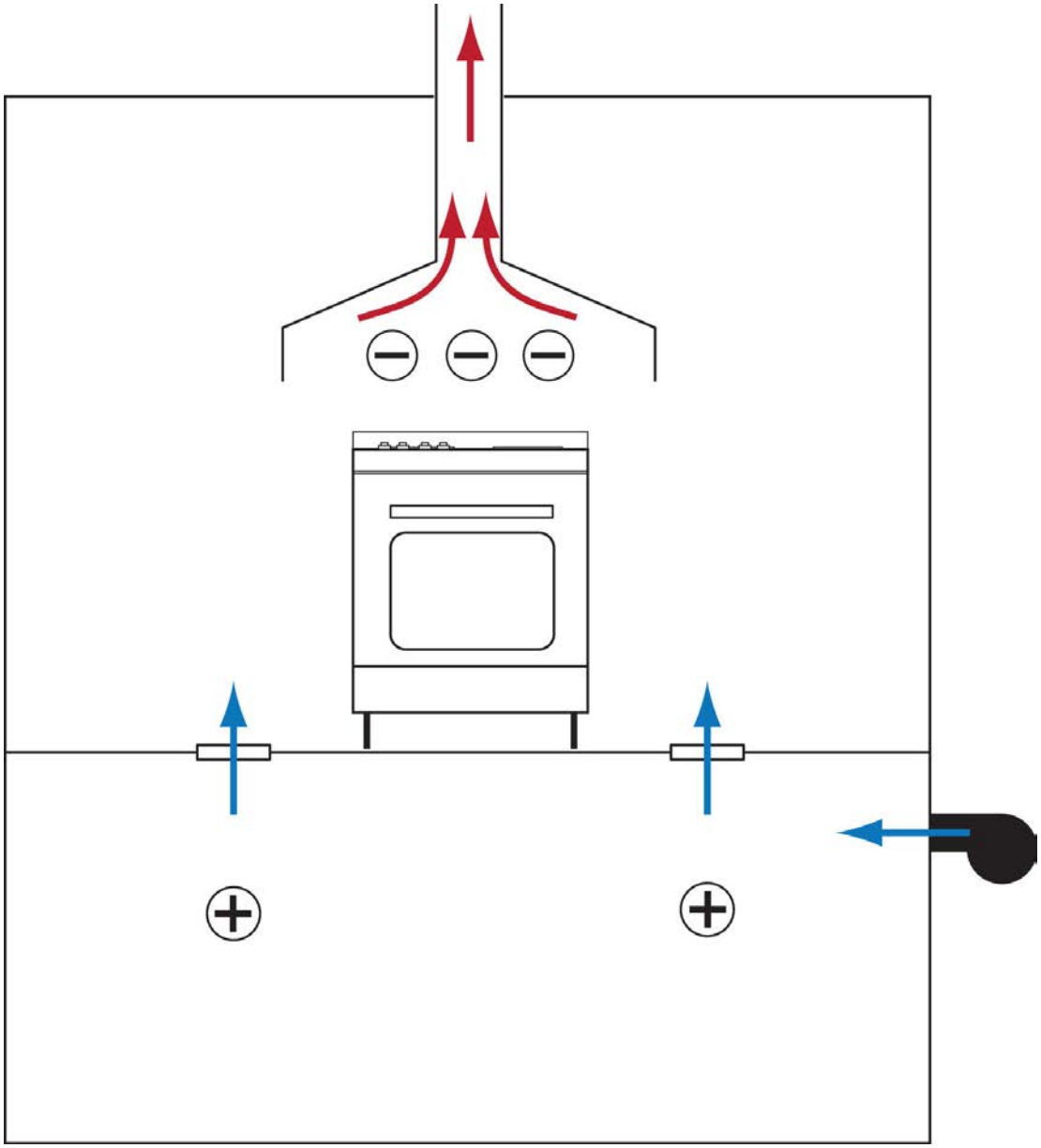

MAXIMUM

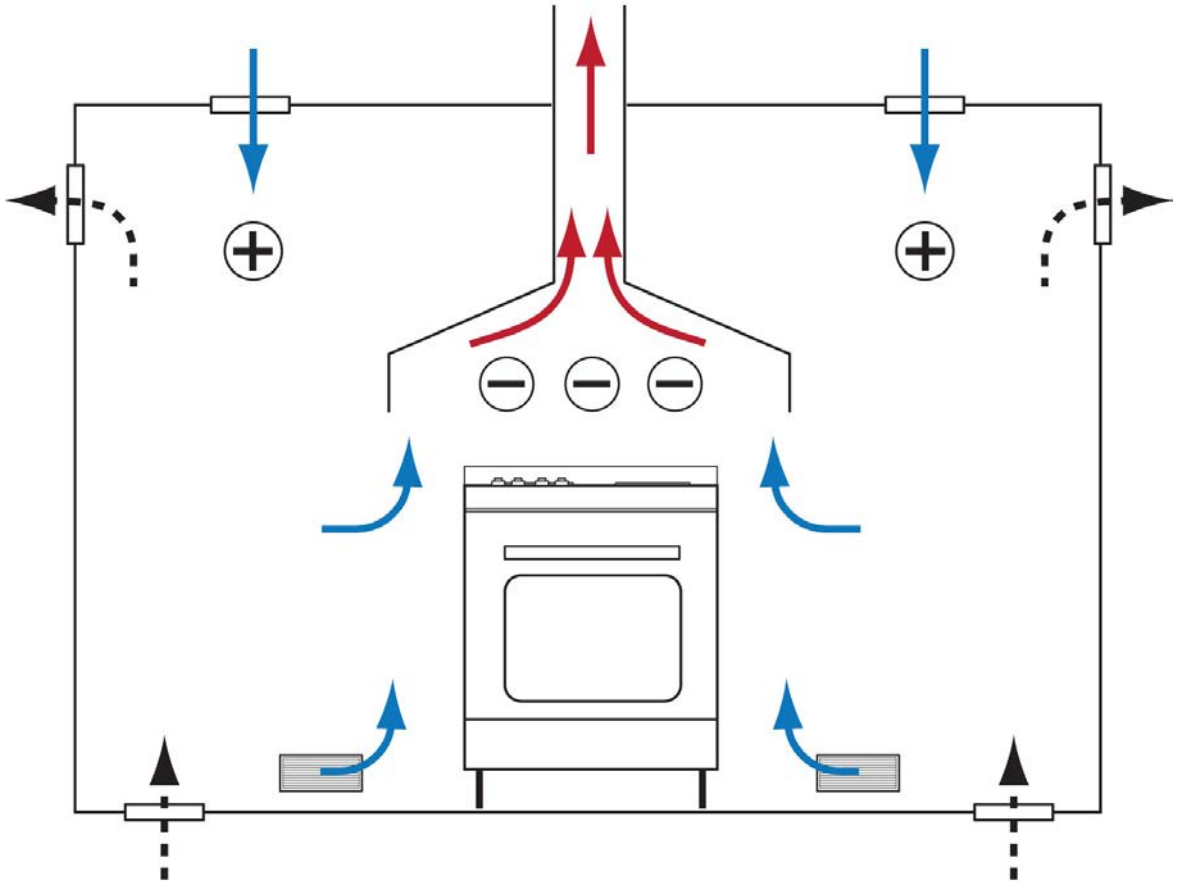


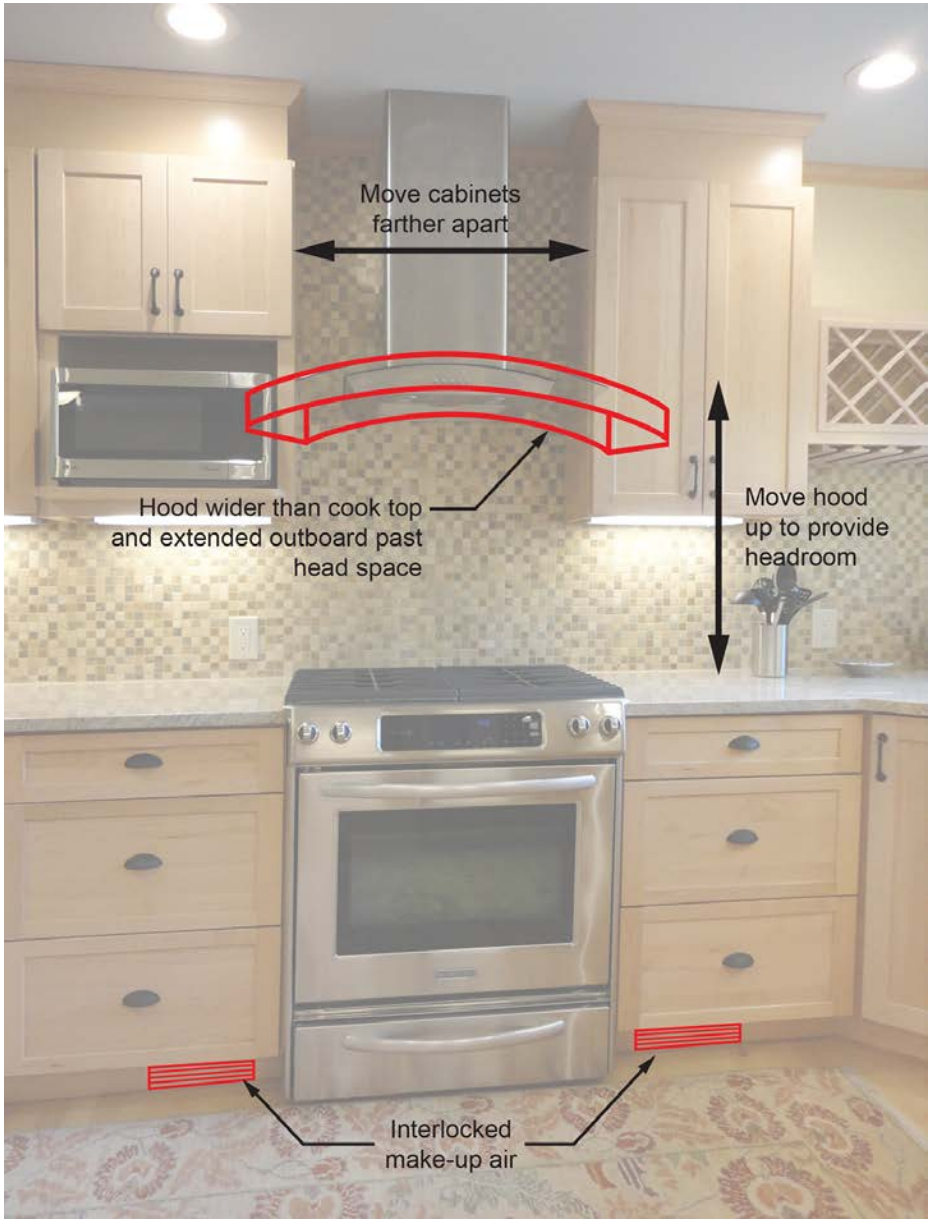

OCT 3 2001

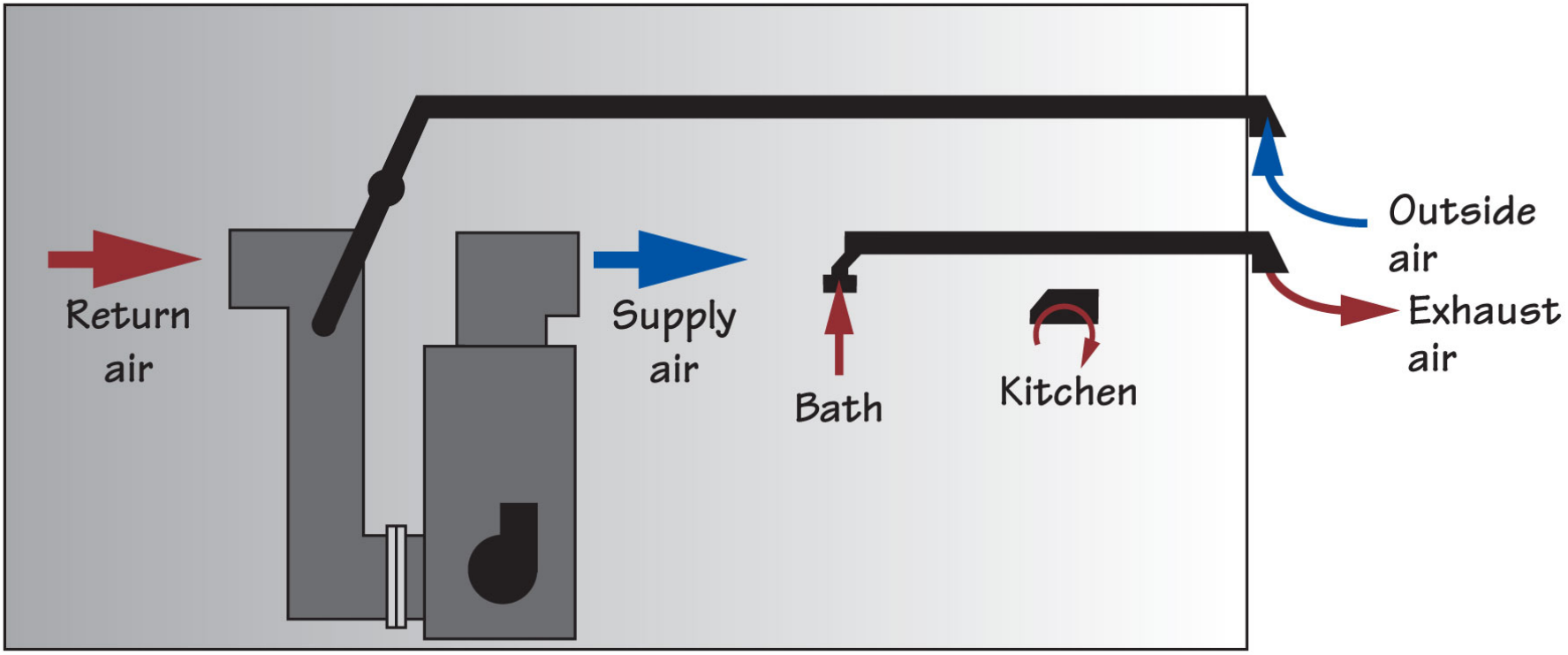

Grille located high in wall on bedroom side to avoid blockage by furniture
Cavity is sealed tight, drywall glued to studs and plates on both sides
Grille located low in wall on hallway side

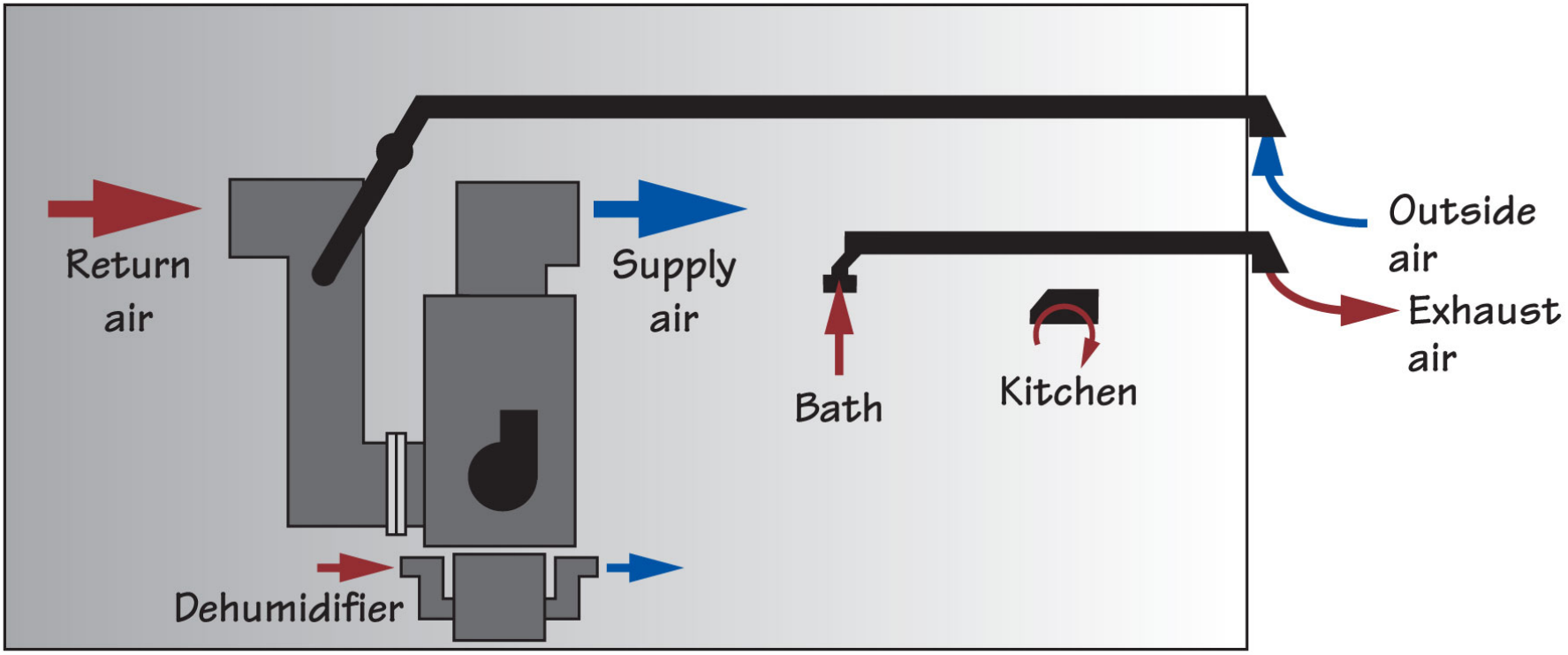

Unconditioned
make-up air
60 - 70% of
hood exhaust

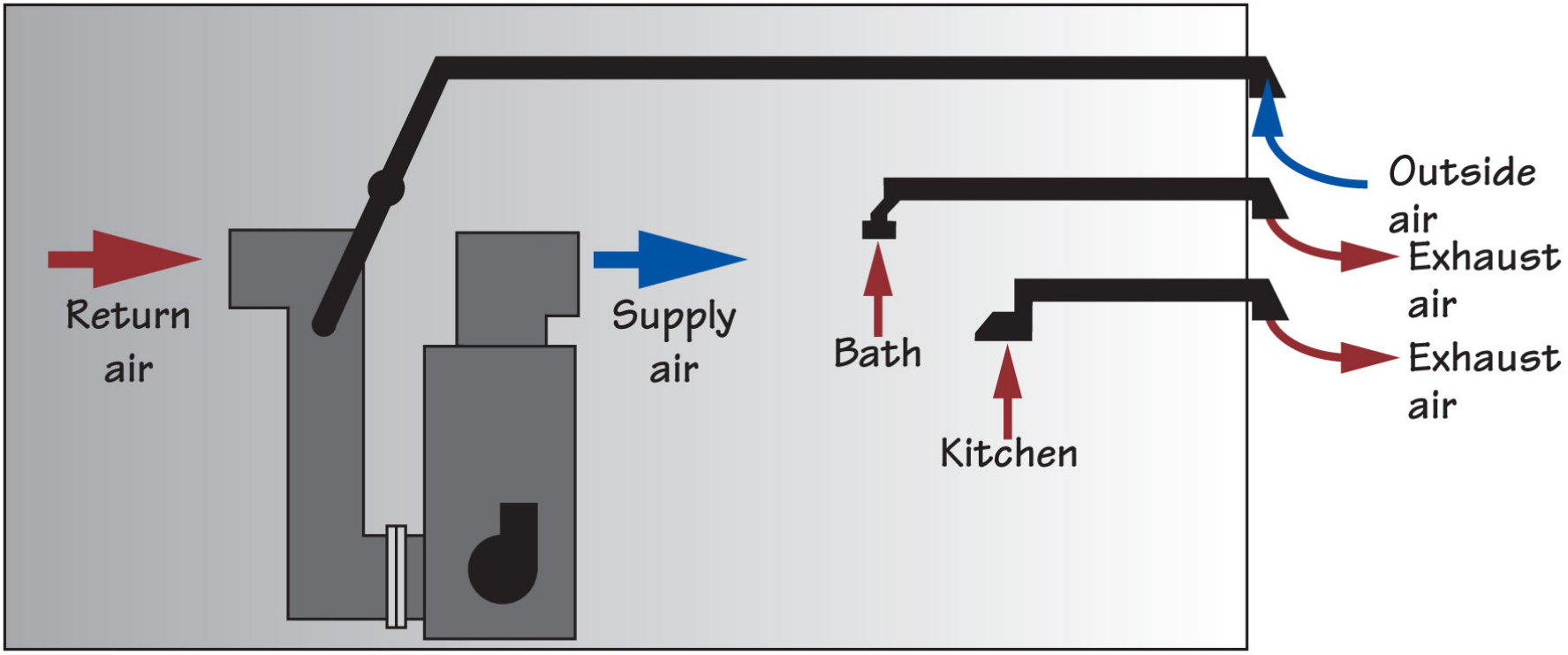


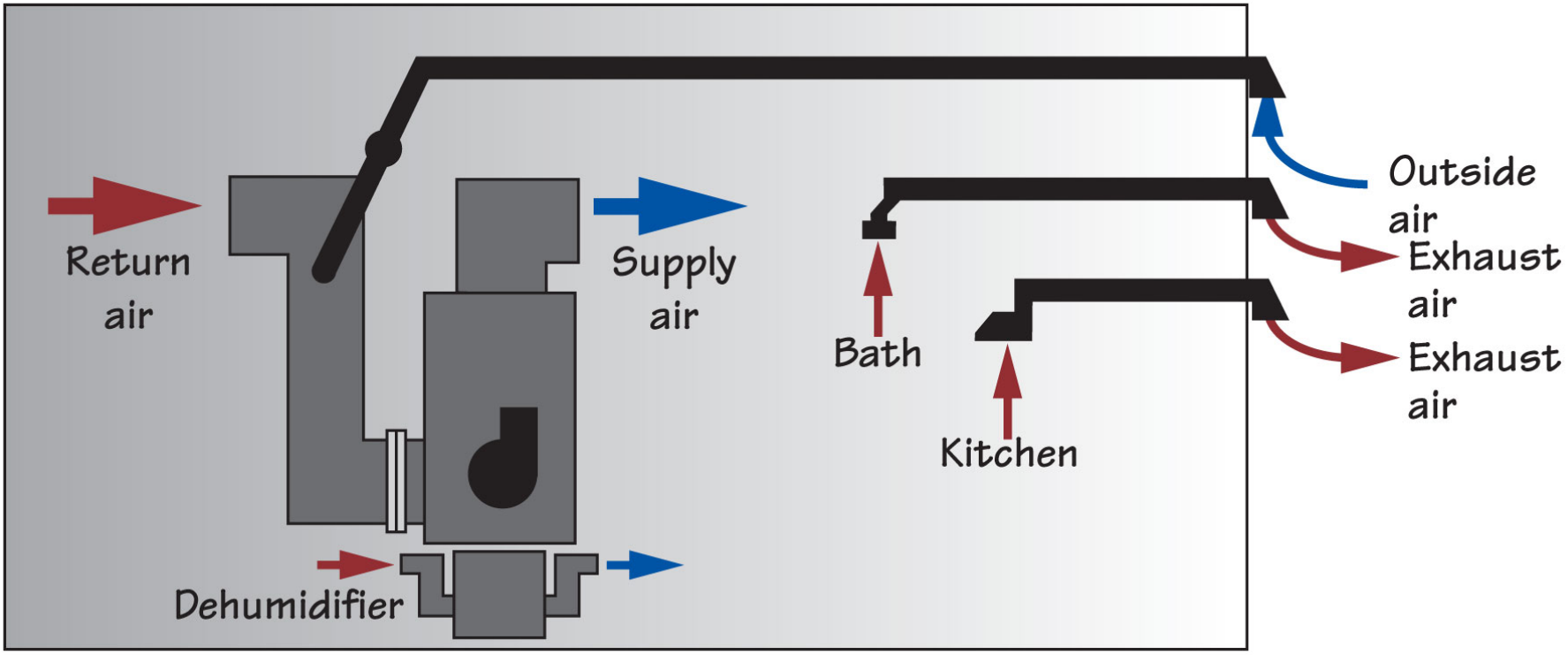


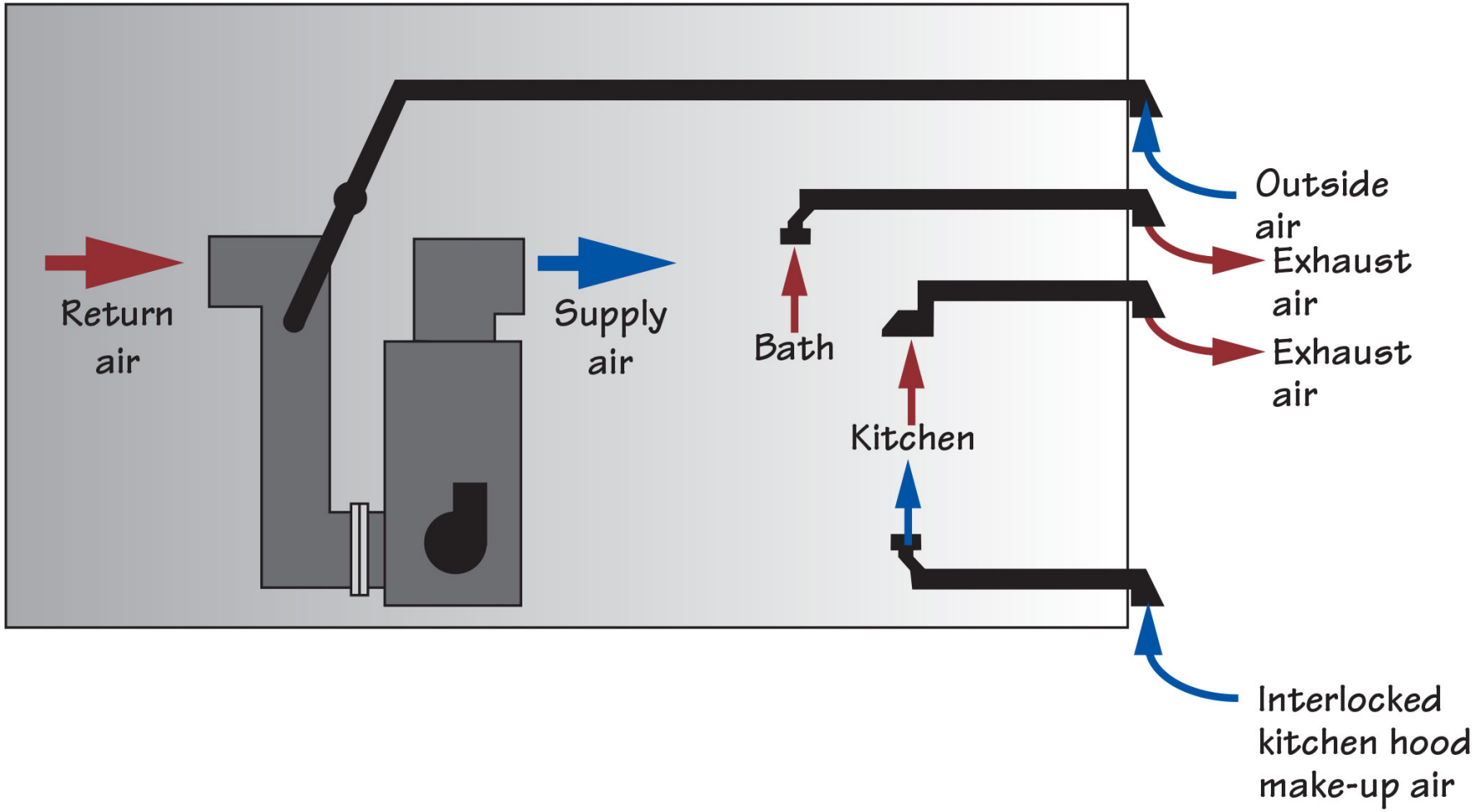

Move cabinets
farther apart
Hood wider than cook top
and extended outboard past
head space
Move hood
up to provide
headroom
Interlocked
make-up air

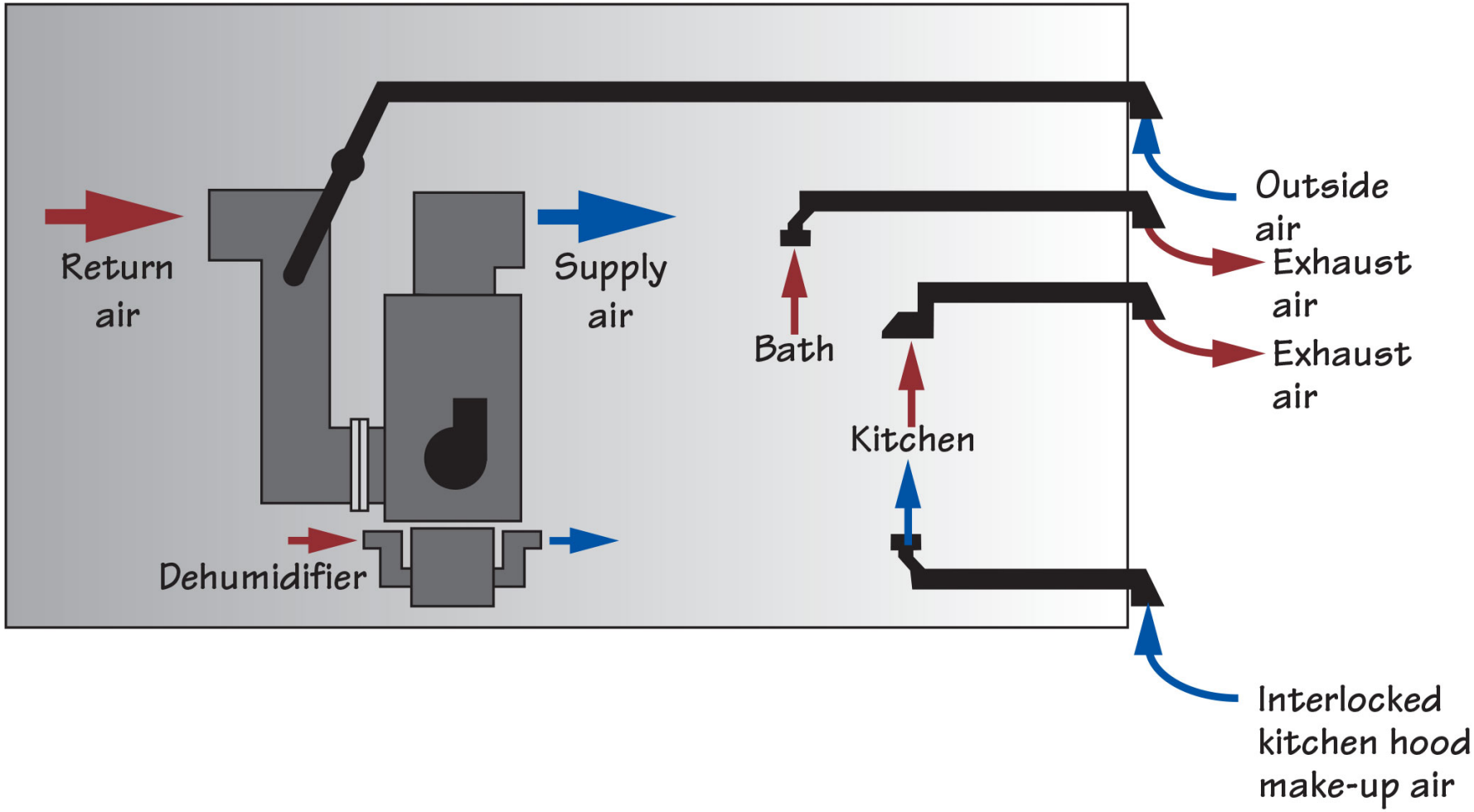

Return
air
Supply
air
Bath
Kitchen
Outside
air
Exhaust
air

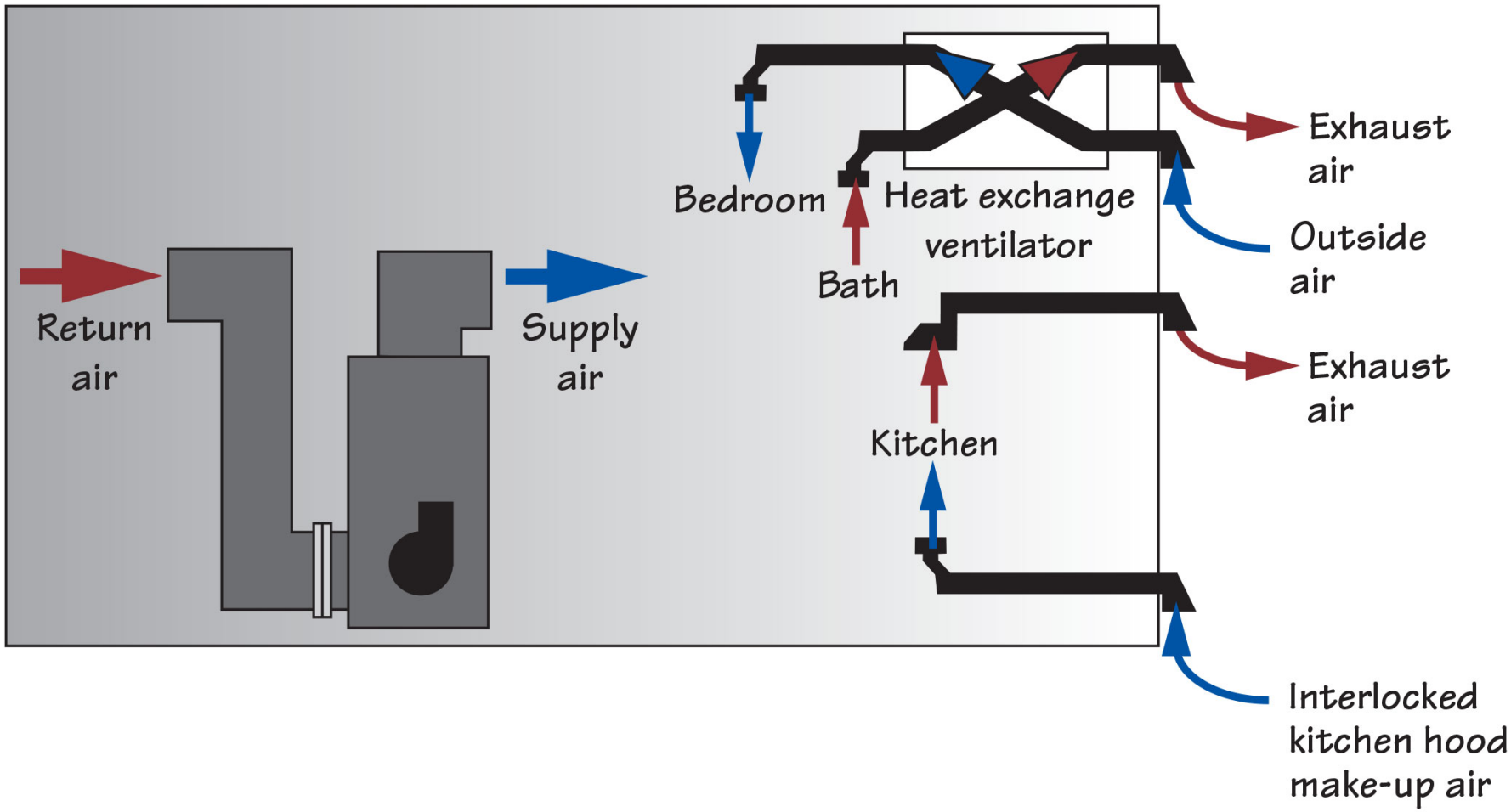

Return
air
Supply
air
Outside
air
Exhaust
air
Bath
Kitchen
Dehumidifier

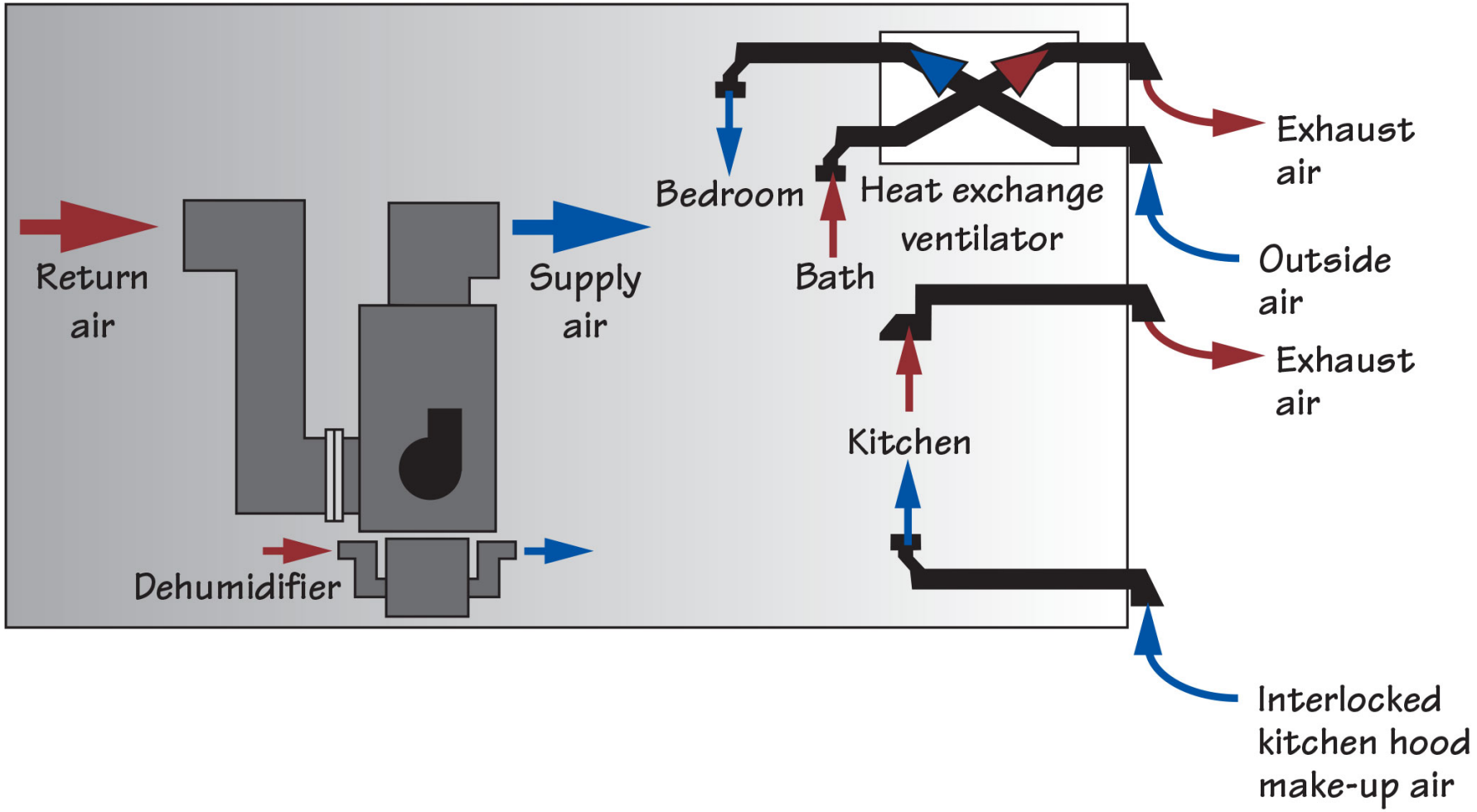

Return air
Supply air
Bath
Kitchen
Outside air
Exhaust air
Exhaust air

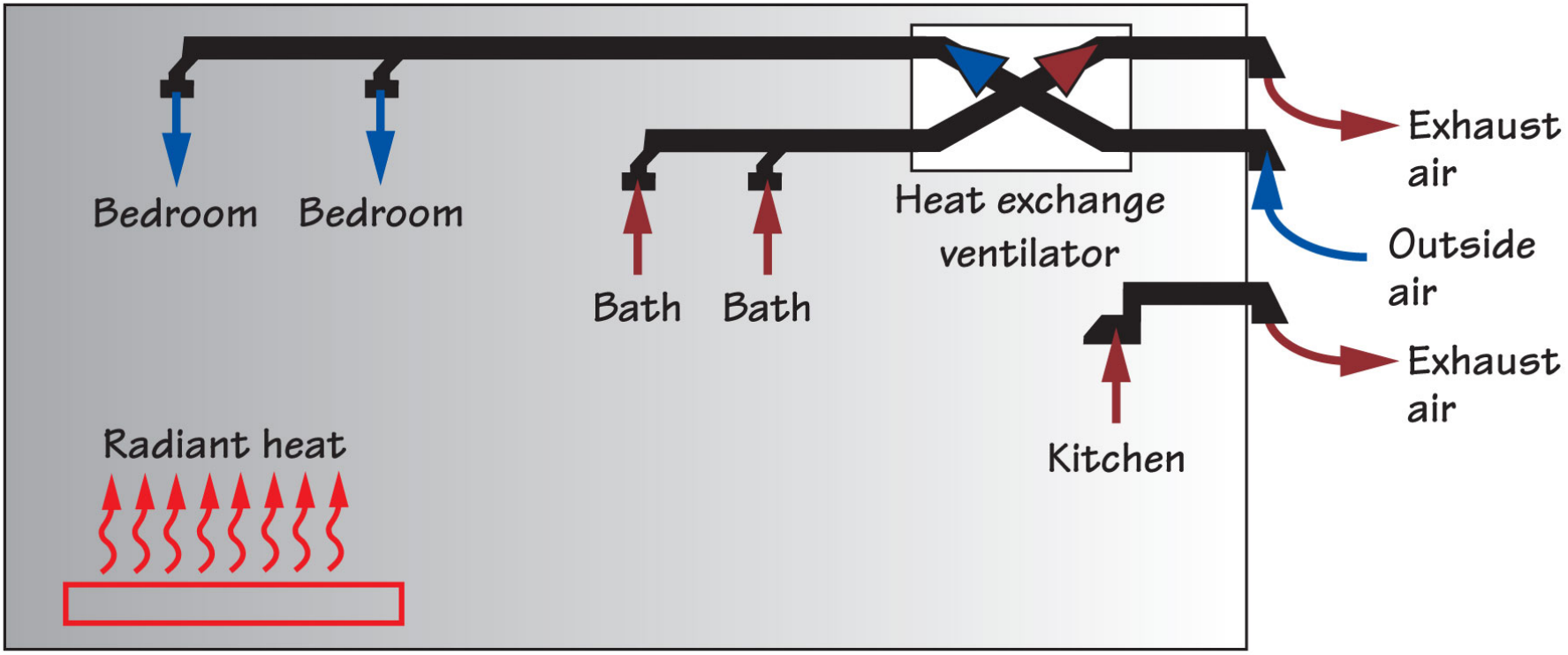

Return air
Supply air
Outside air
Exhaust air
Exhaust air
Bath
Kitchen
Dehumidifier

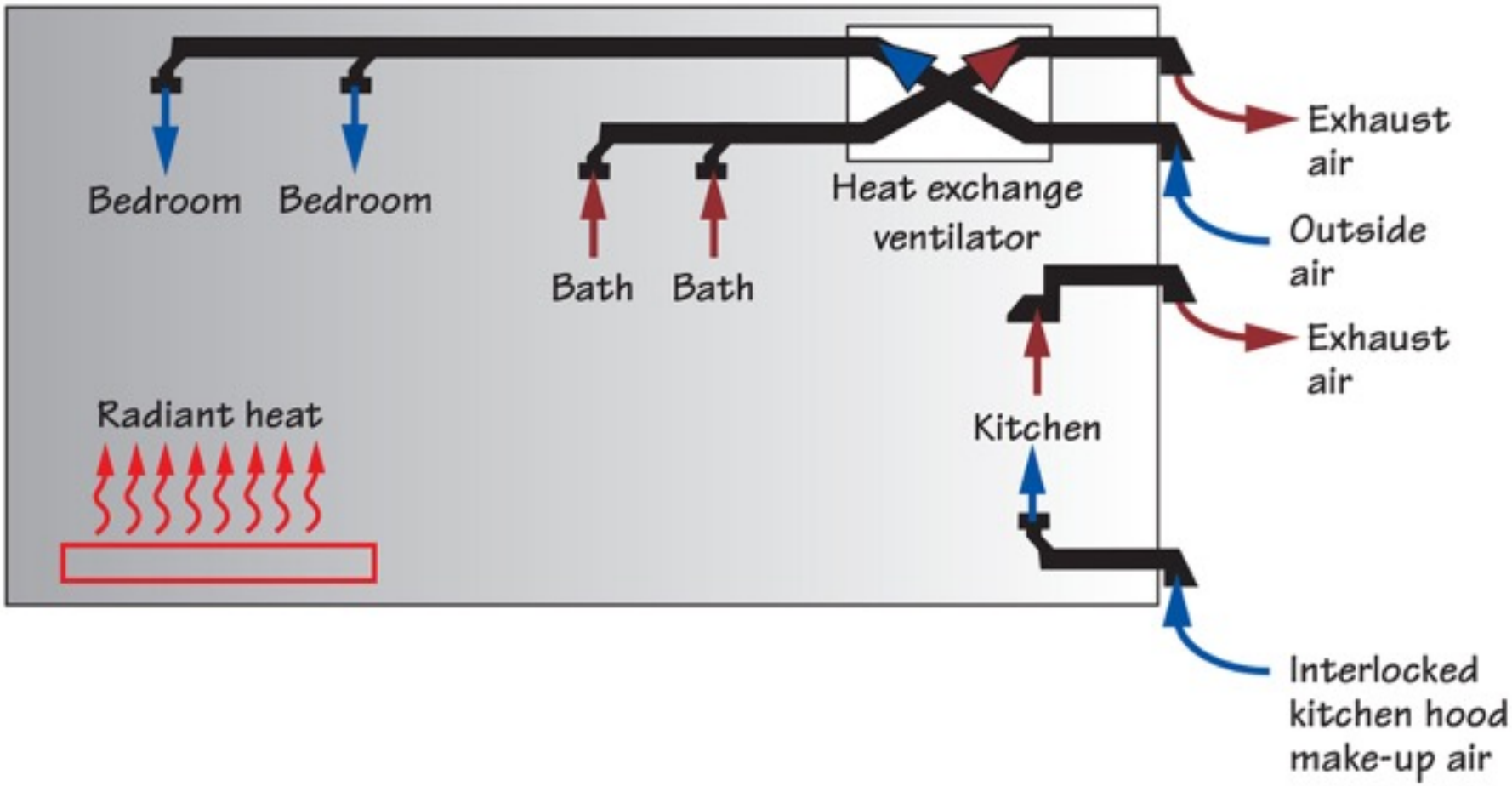

Return air
Supply air
Bath
Kitchen
Outside air
Exhaust air
Exhaust air
Interlocked kitchen hood make-up air

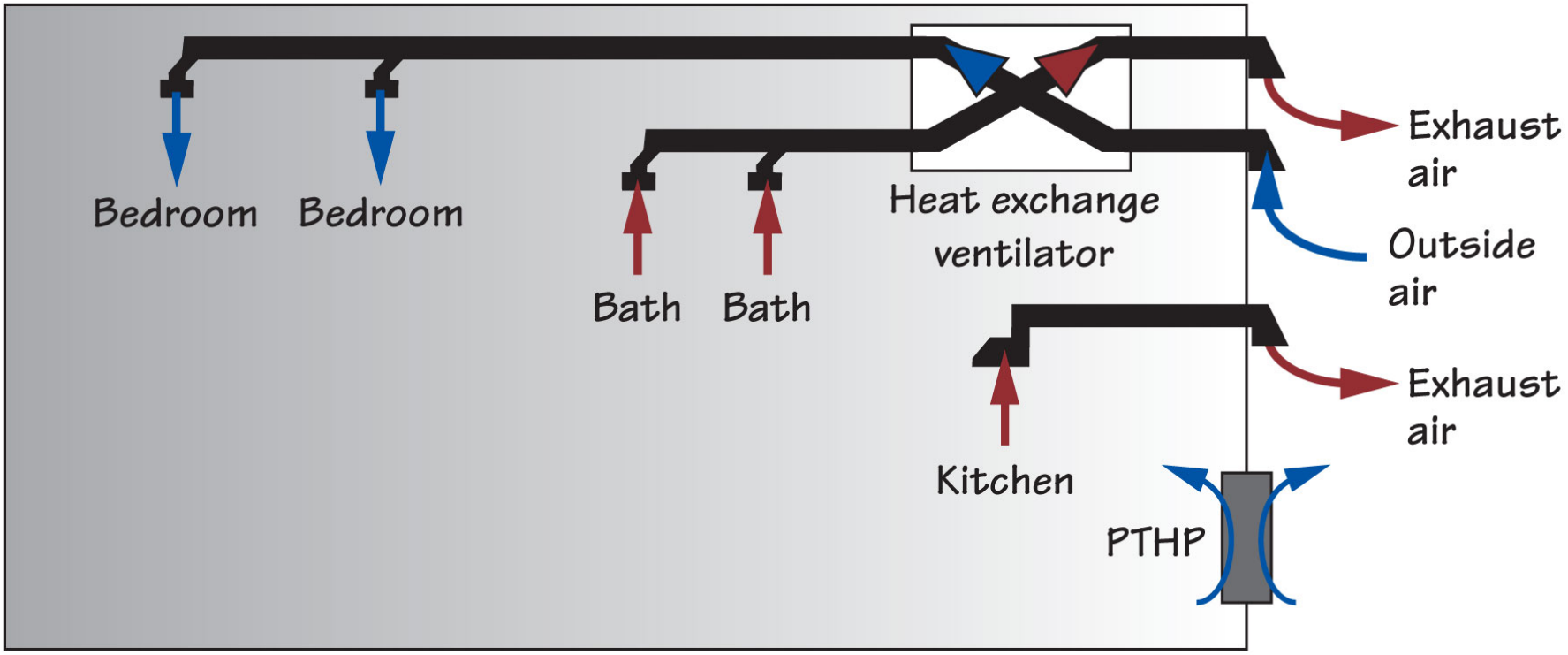

Return air
Supply air
Dehumidifier
Bath
Kitchen
Outside air
Exhaust air
Exhaust air
Interlocked kitchen hood make-up air

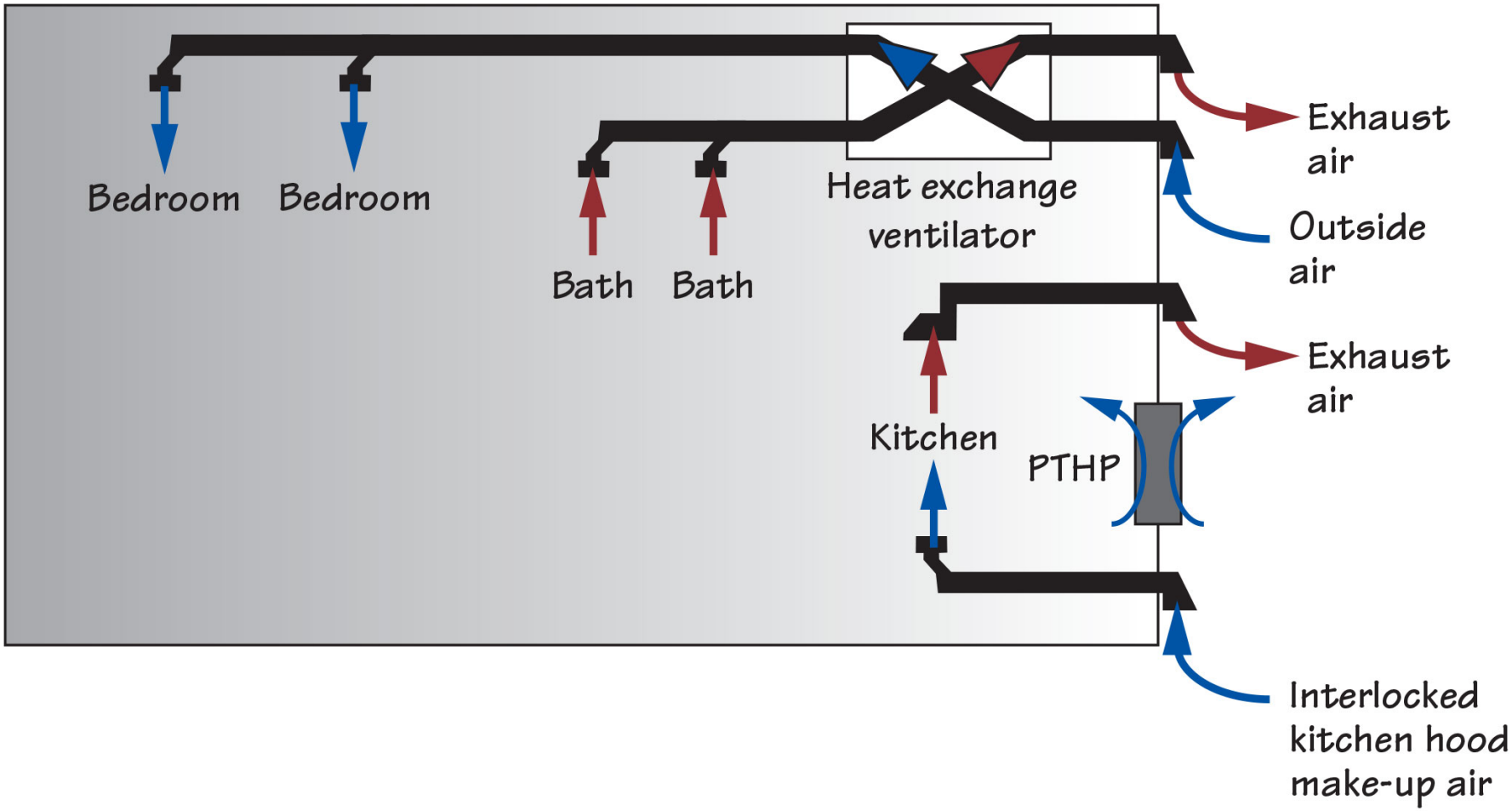

Return air
Supply air
Bedroom
Bath
Heat exchange ventilator
Exhaust air
Outside air
Exhaust air
Kitchen
Interlocked kitchen hood make-up air

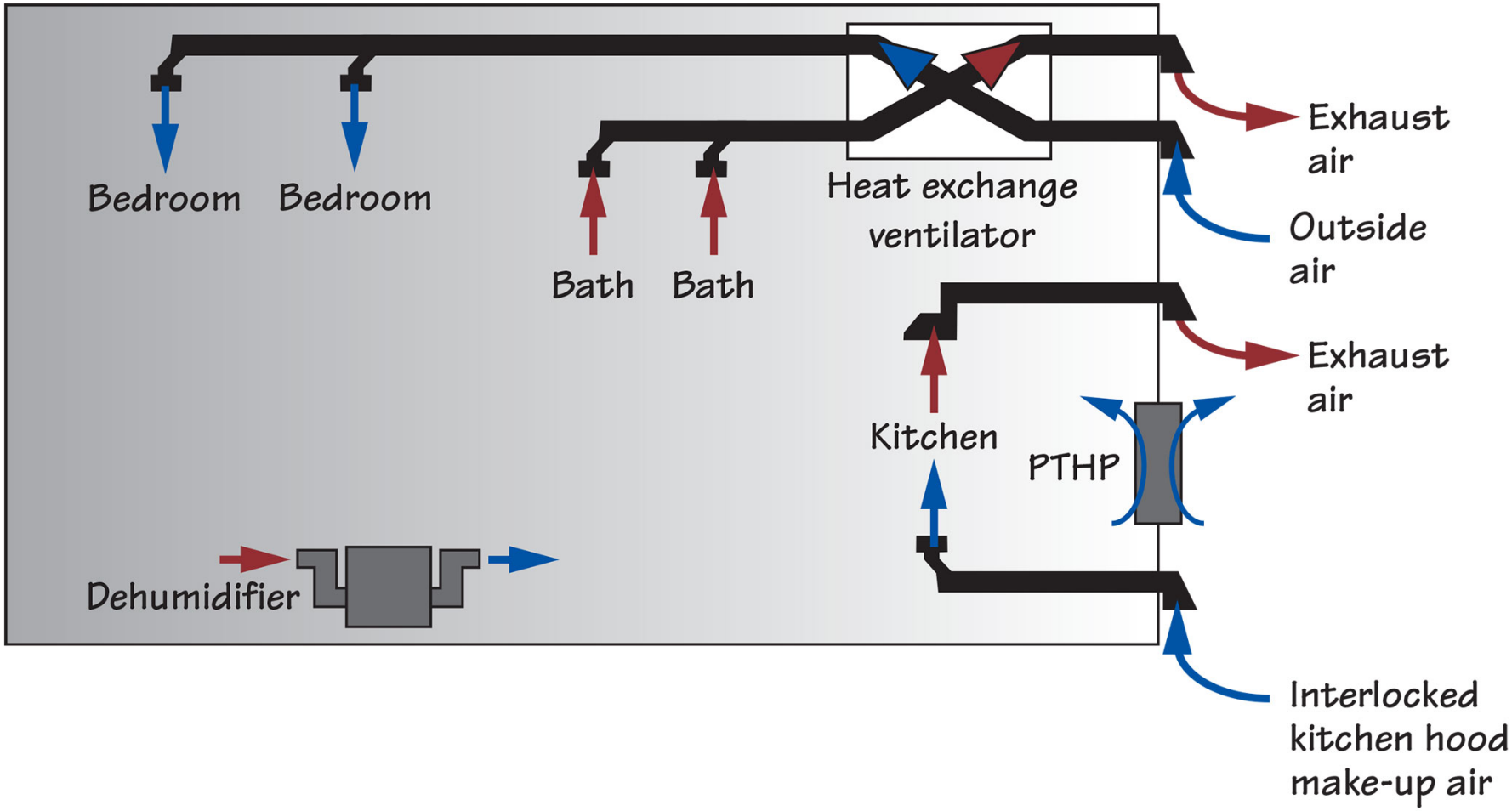

Return air
Supply air
Dehumidifier
Bedroom
Bath
Heat exchange ventilator
Exhaust air
Outside air
Exhaust air
Kitchen
Interlocked kitchen hood make-up air


Bedroom
Bedroom
Bath
Bath
Heat exchange
ventilator
Exhaust
air
Outside
air
Exhaust
air
Kitchen
Radiant heat


Bedroom
Bedroom
Bath
Bath
Heat exchange ventilator
Exhaust air
Outside air
Exhaust air
Kitchen
Radiant heat
Interlocked kitchen hood make-up air


Bedroom
Bedroom
Bath
Bath
Heat exchange
ventilator
Exhaust
air
Outside
air
Exhaust
air
Kitchen
PTHP


Bedroom
Bedroom
Bath
Bath
Heat exchange ventilator
Exhaust air
Outside air
Exhaust air
Kitchen
PTHP
Interlocked kitchen hood make-up air


Bedroom
Bedroom
Bath
Bath
Heat exchange ventilator
Exhaust air
Outside air
Exhaust air
Kitchen
PTHP
Dehumidifier
Interlocked kitchen hood make-up air

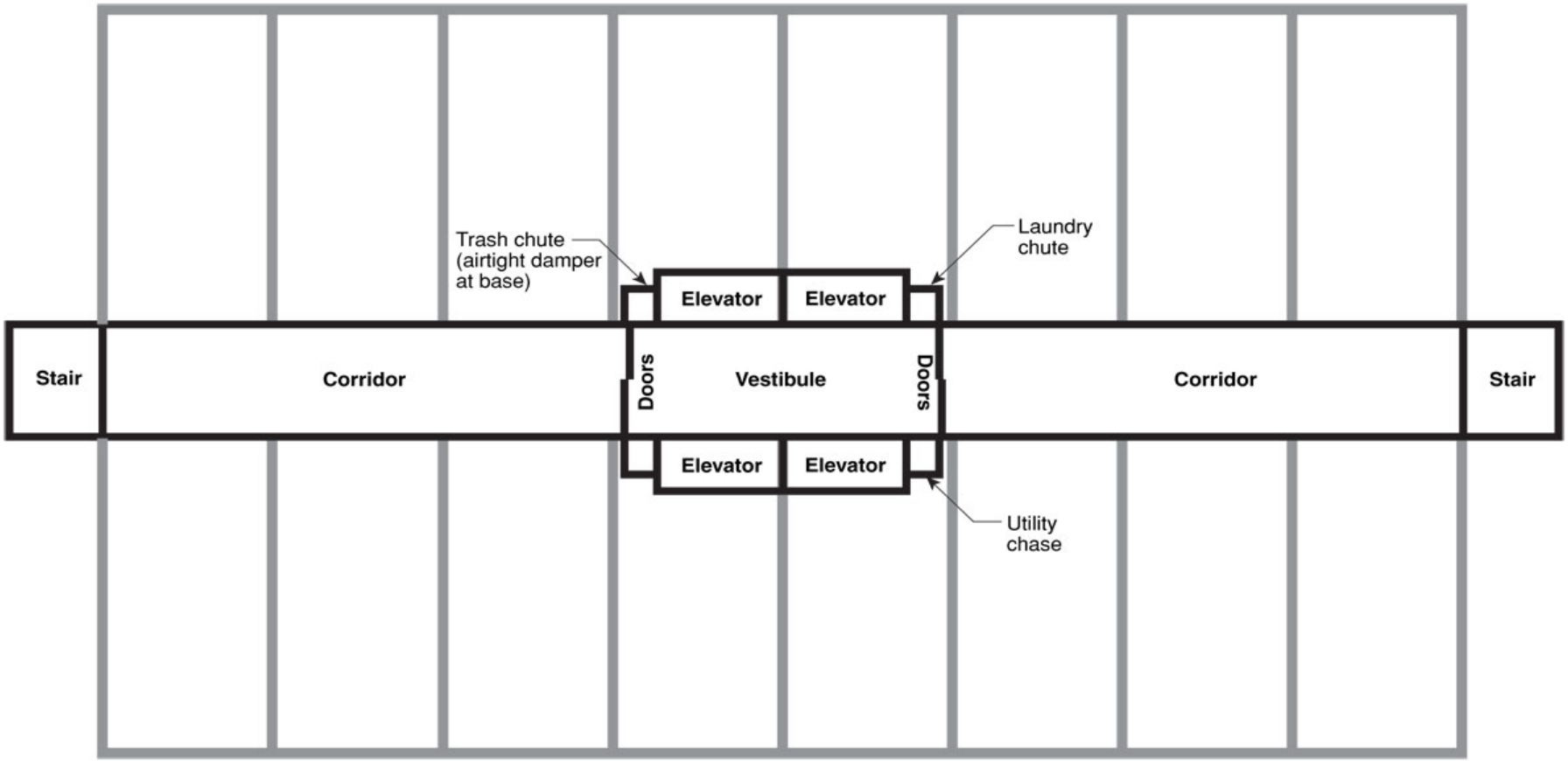

ASKO
ASKO
ENERGUIDE
209

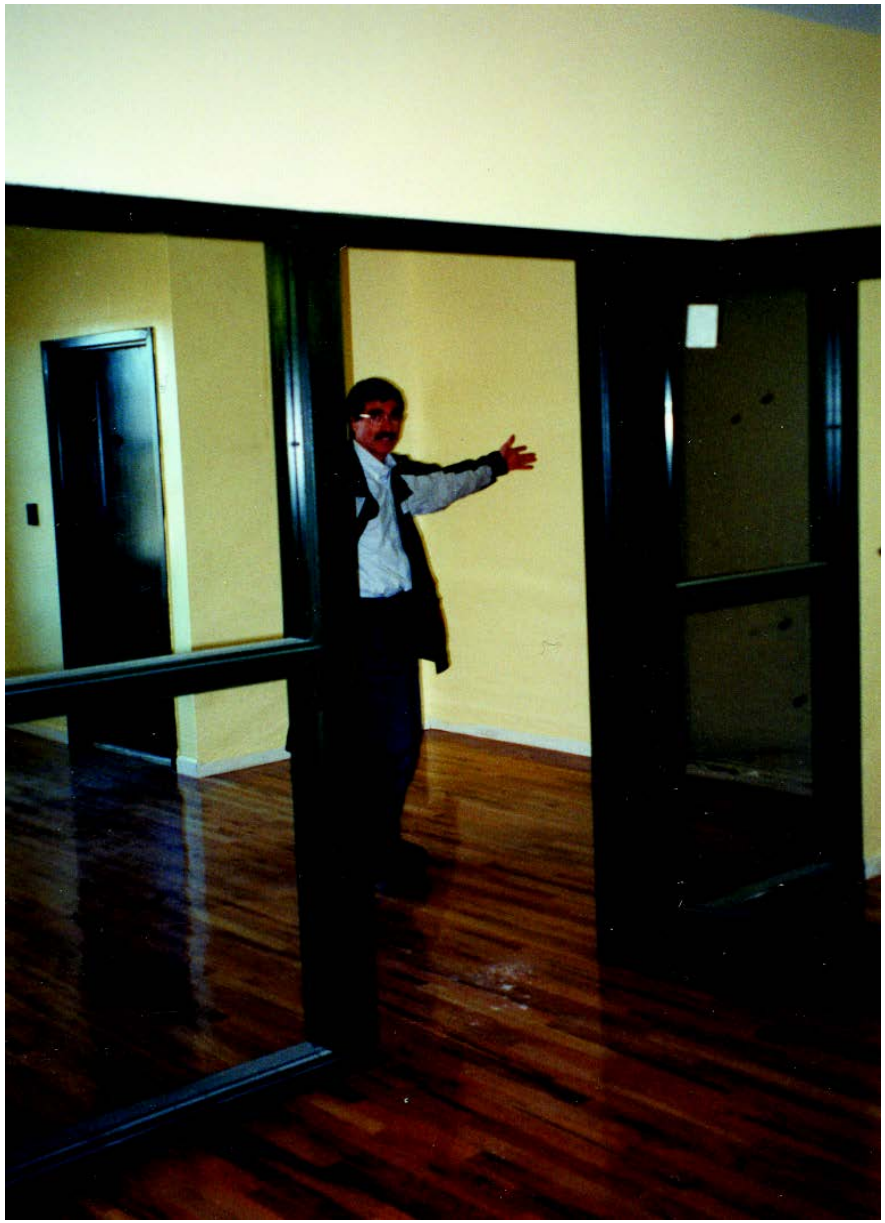

FHP
Heating And Air Conditioning

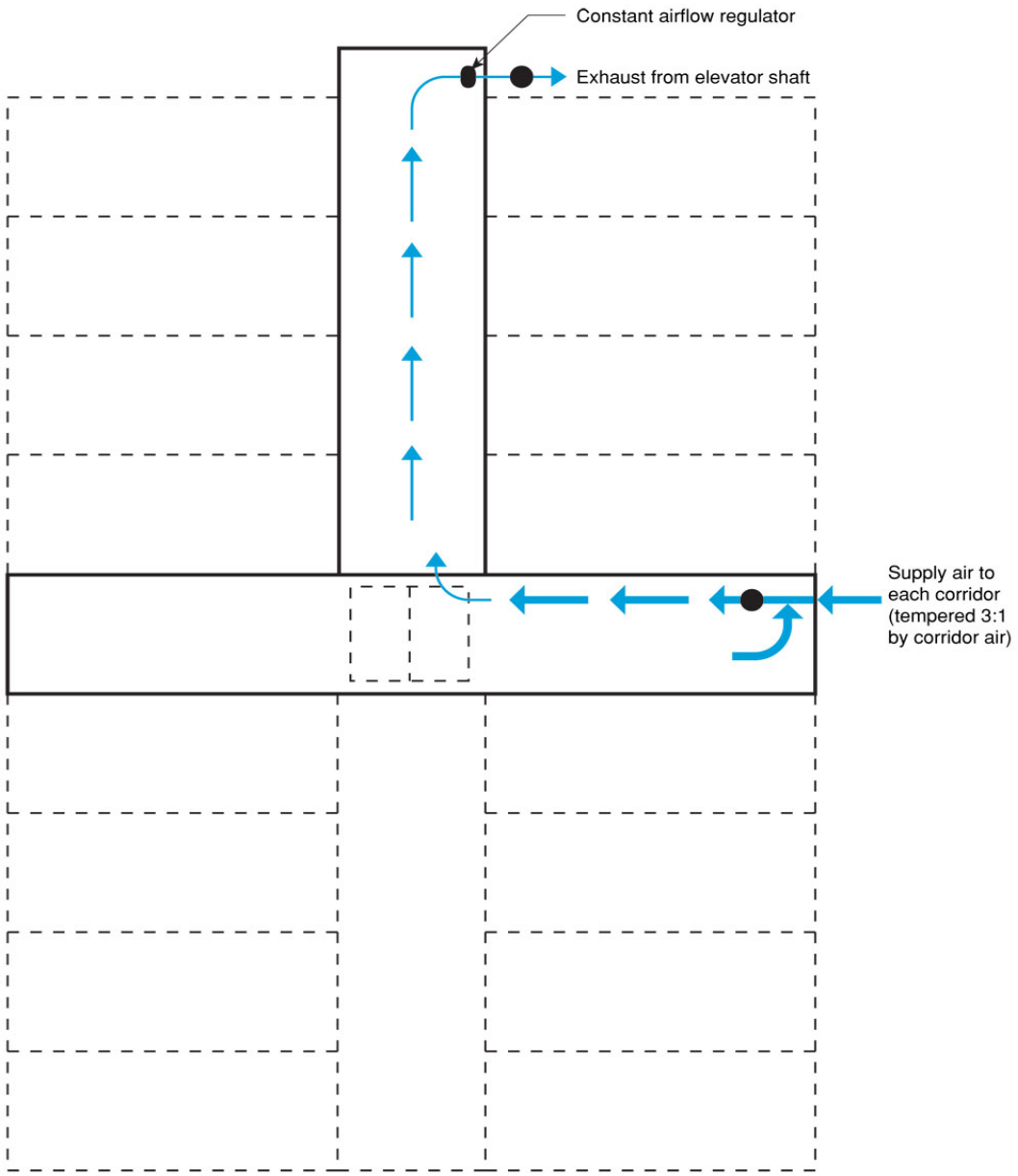

ENERGYGUIDE

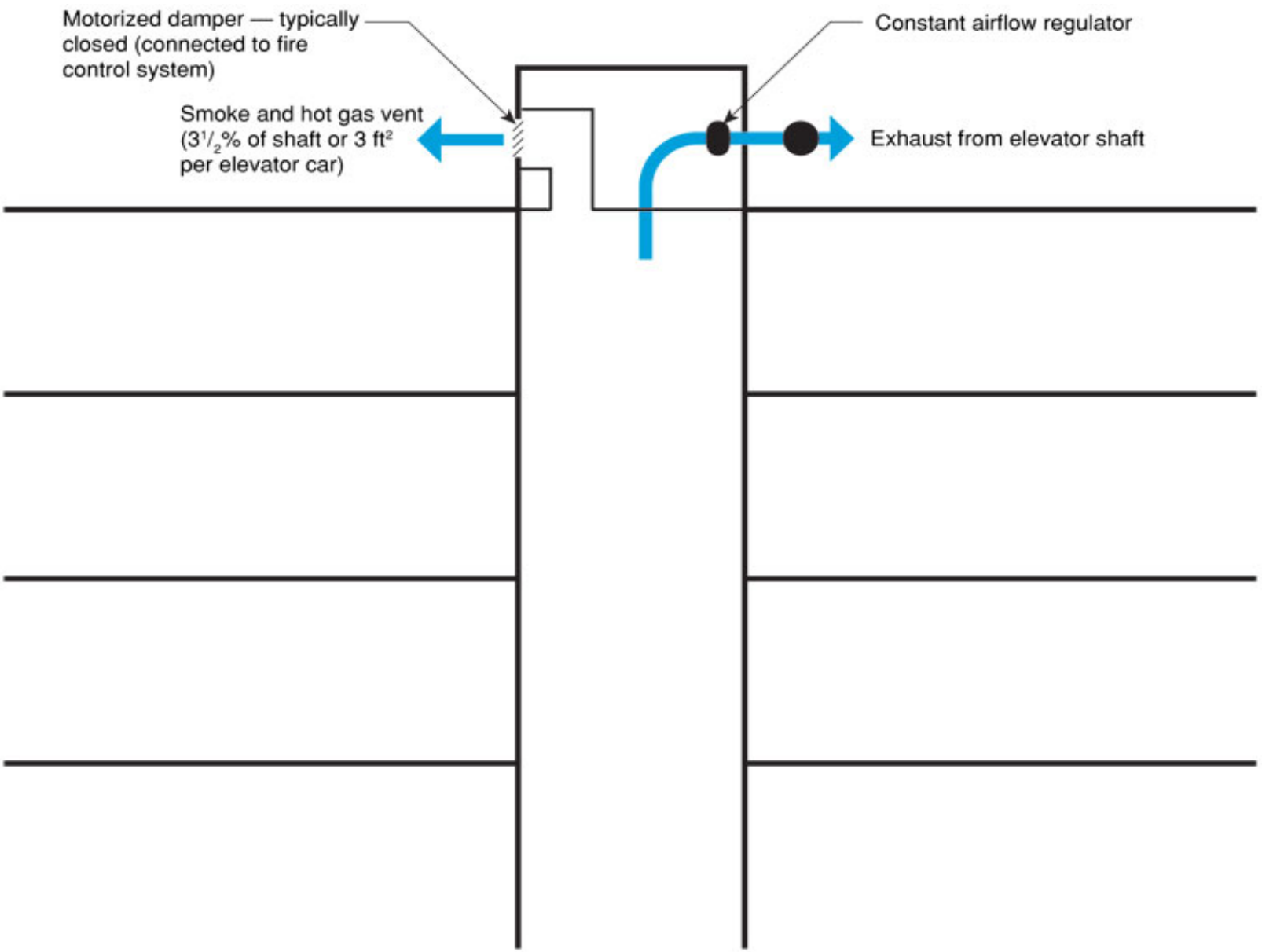

Rheem
EverKleen
ENERGYGUIDE
DANGER

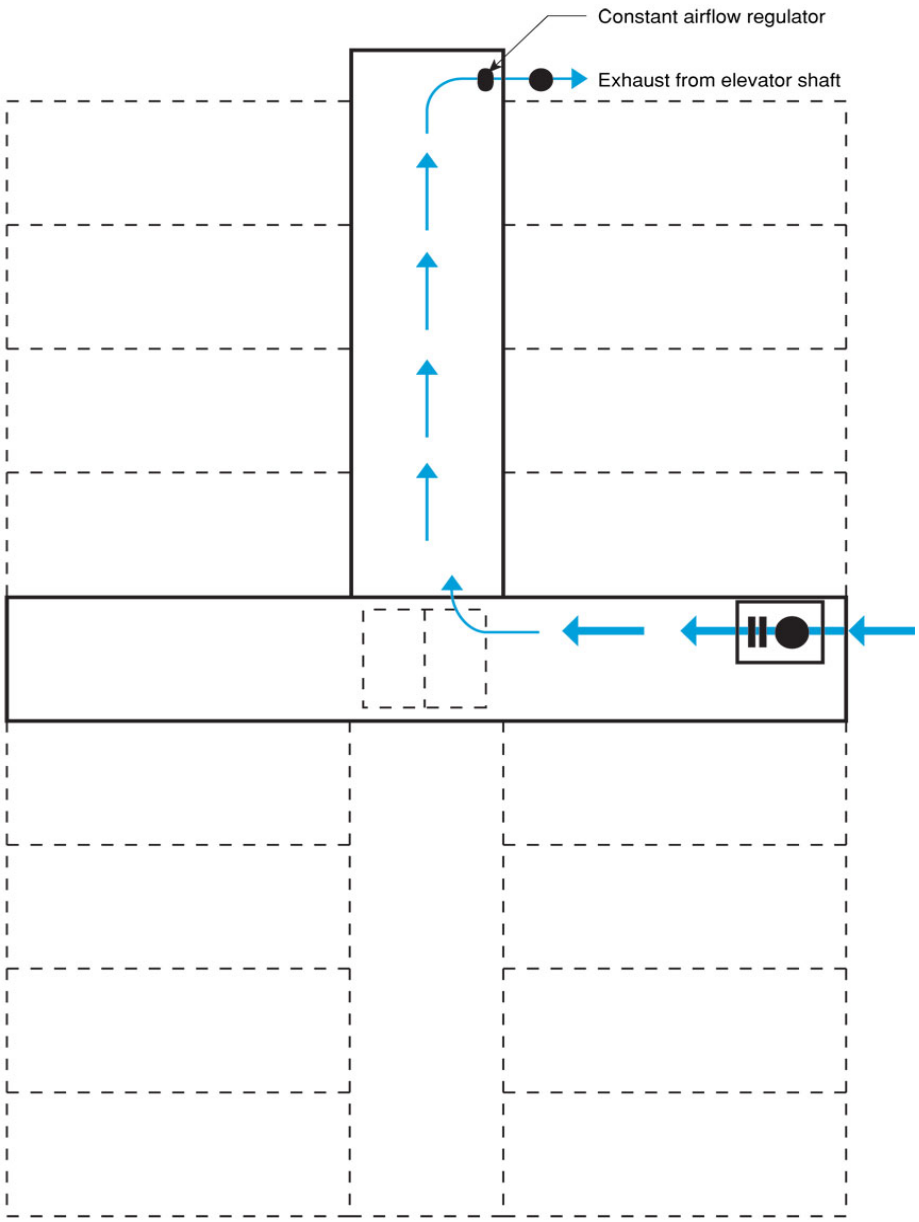

BOSTON
UNIVERSITY

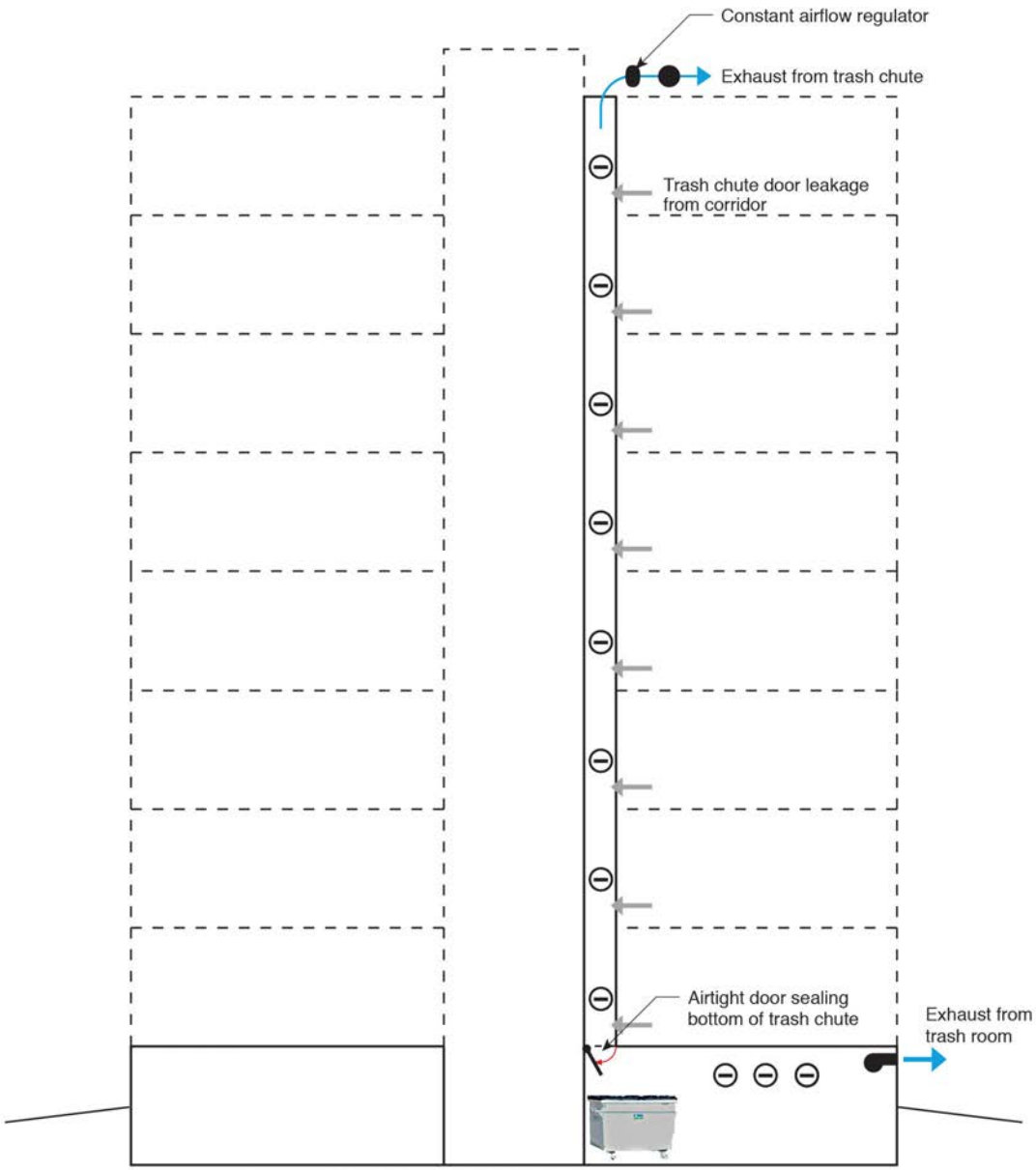

Trash chute
(airtight damper
at base)
Laundry
chute
Elevator
Elevator
Stair
Corridor
Doors
Vestibule
Doors
Corridor
Stair
Elevator
Elevator
Utility
chase

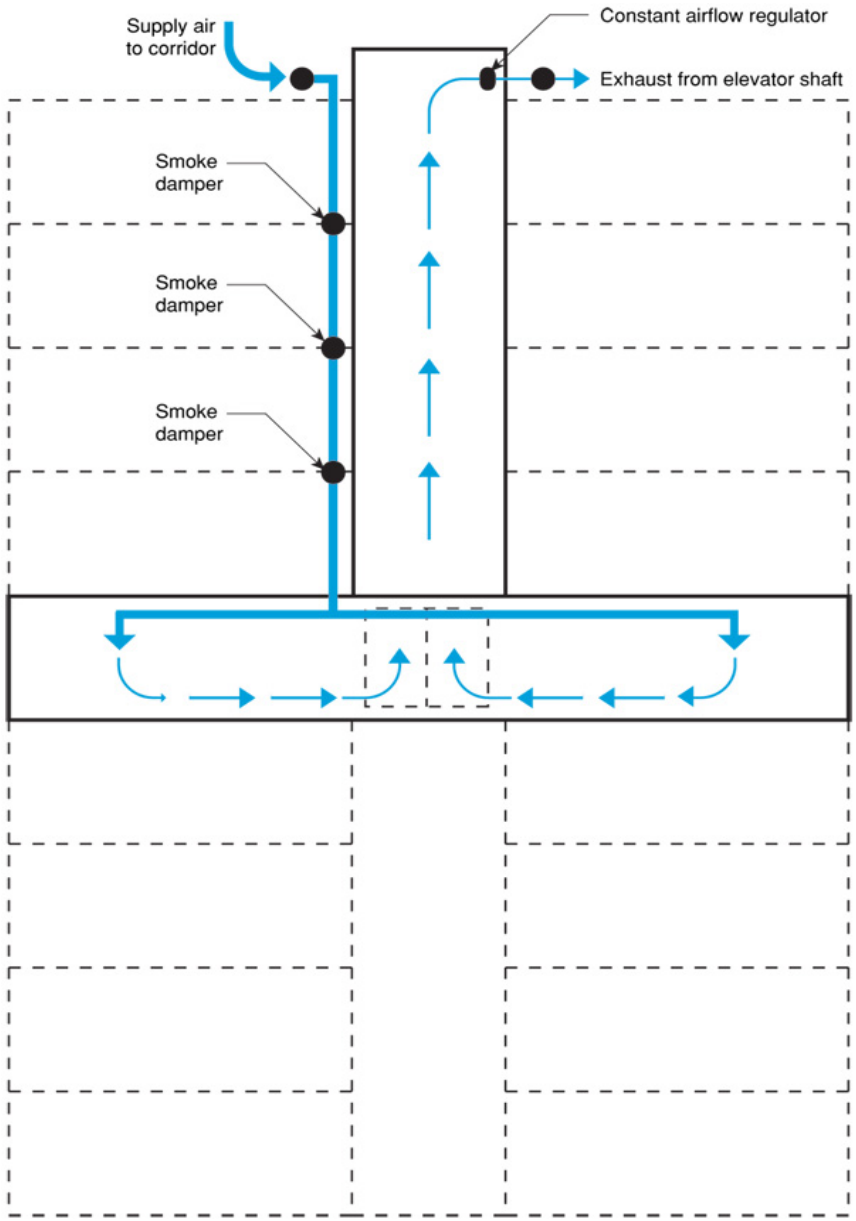


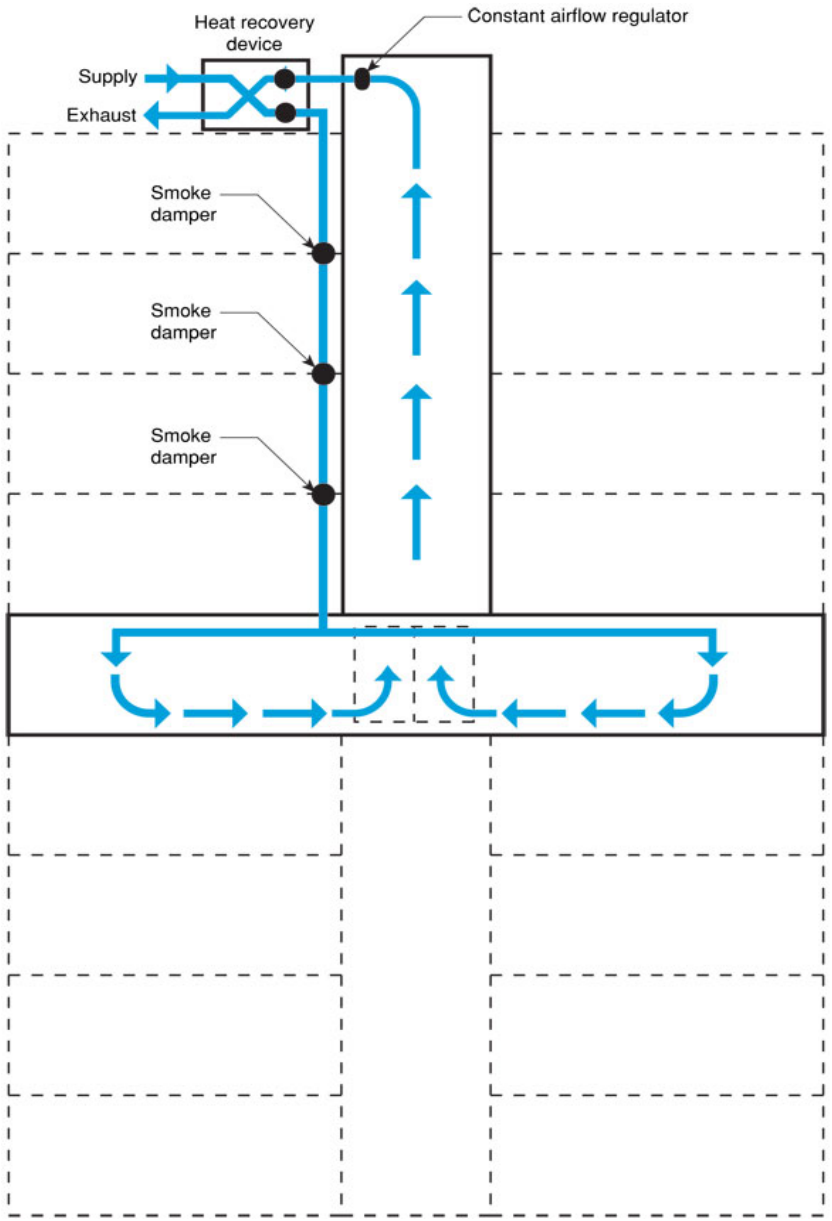

Constant airflow regulator
Exhaust from elevator shaft
Supply air to each corridor (tempered 3:1 by corridor air)

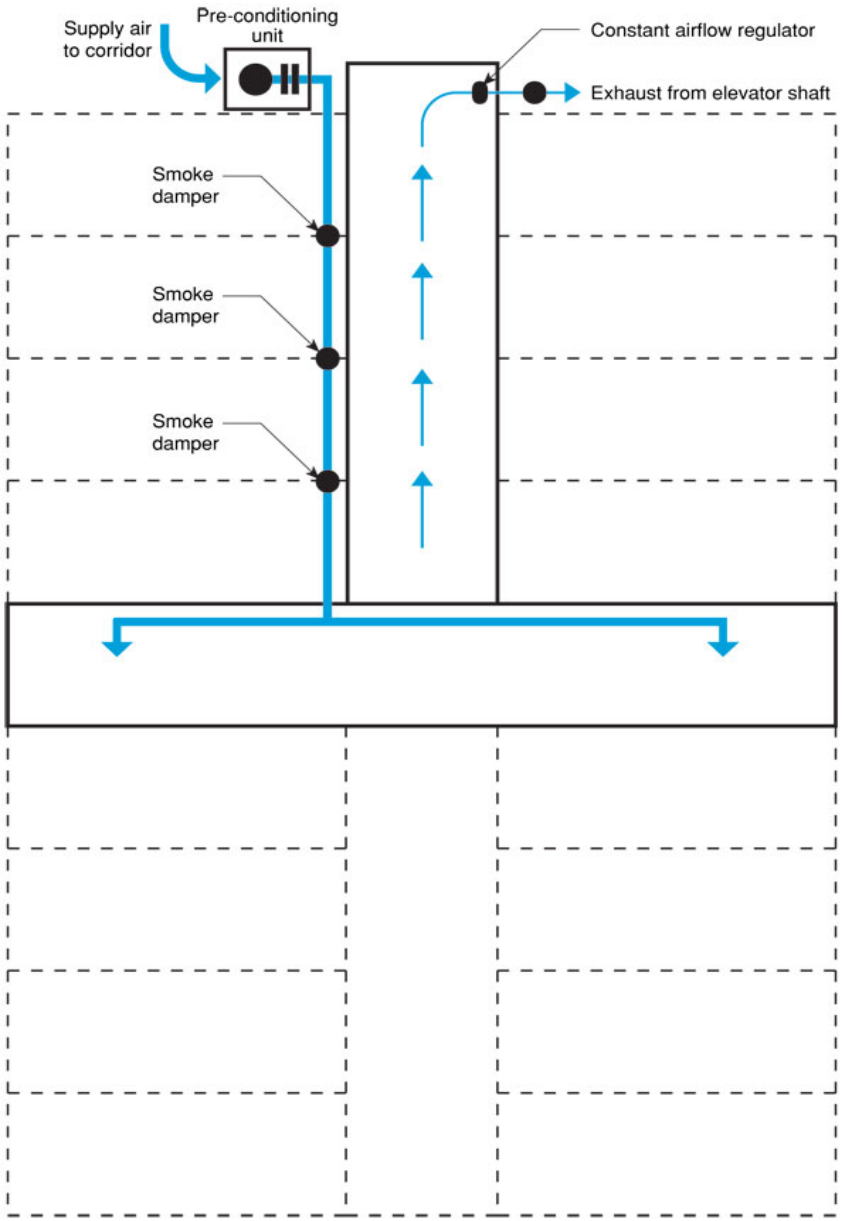

Motorized damper — typically closed (connected to fire control system)
Constant airflow regulator
Smoke and hot gas vent (3 1/2% of shaft or 3 ft² per elevator car)
Exhaust from elevator shaft

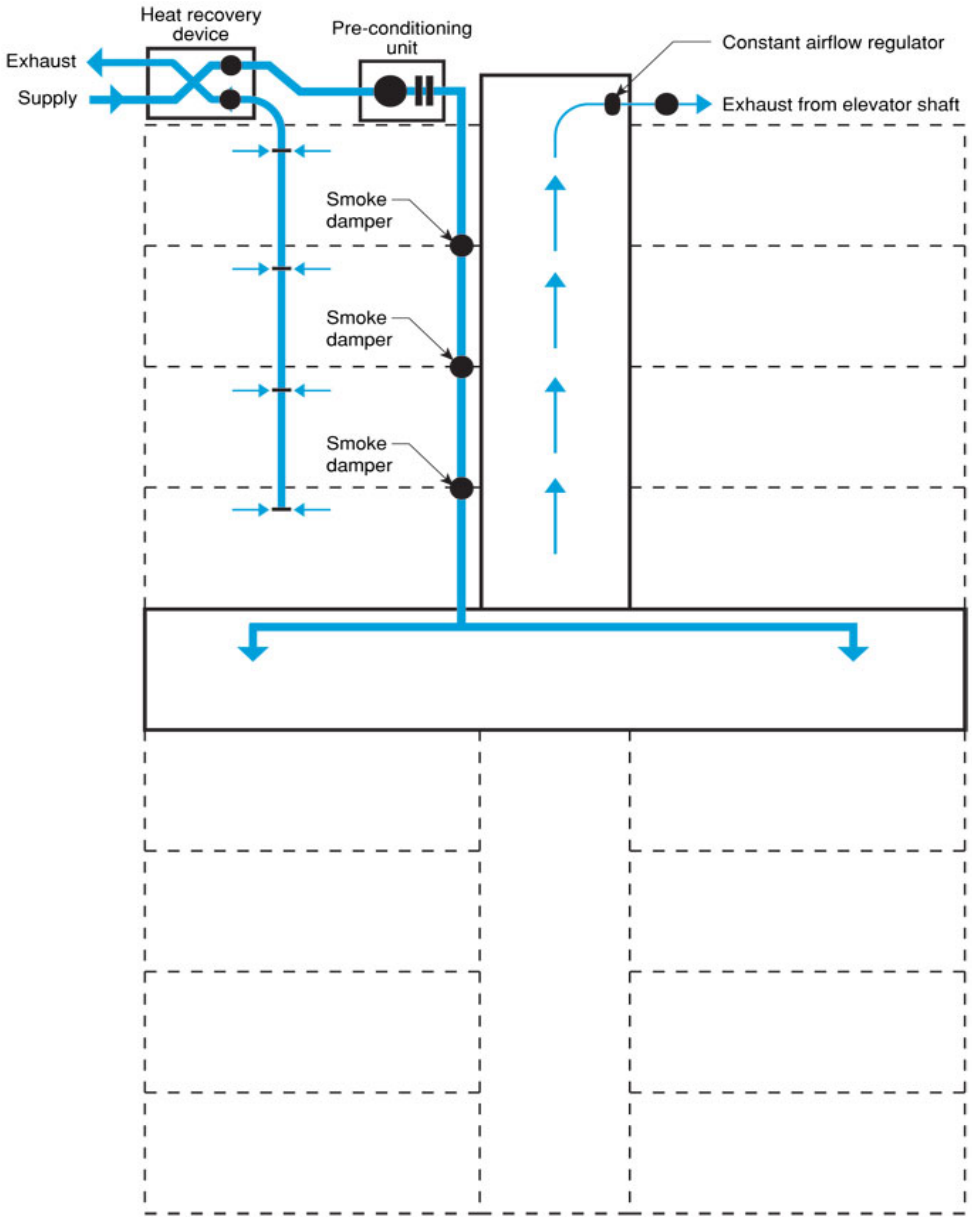

Constant airflow regulator
Exhaust from elevator shaft


Constant airflow regulator
Exhaust from trash chute
Trash chute door leakage from corridor
Airtight door sealing bottom of trash chute
Exhaust from trash room

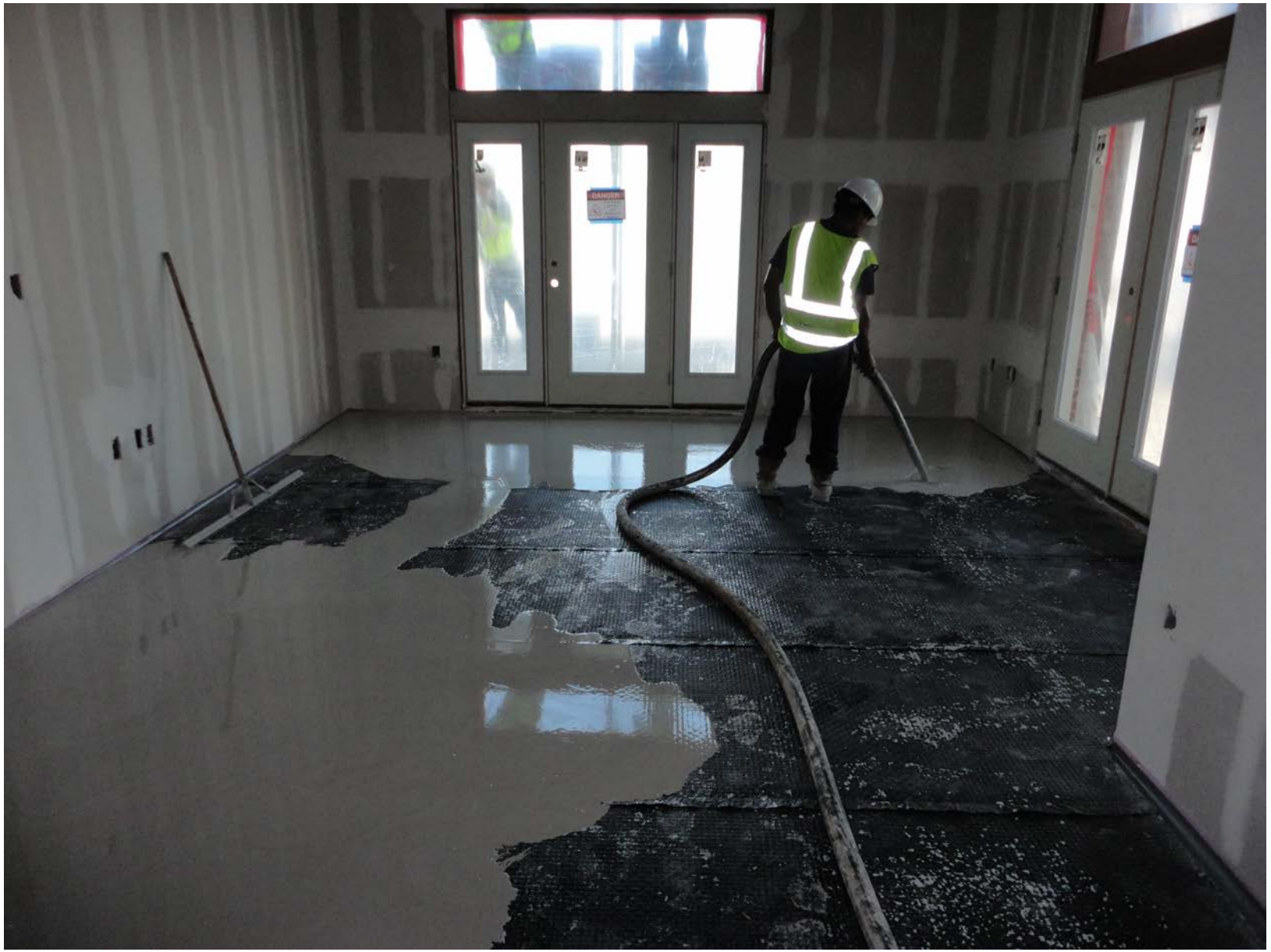

Supply air
to corridor
Constant airflow regulator
Exhaust from elevator shaft
Smoke
damper
Smoke
damper
Smoke
damper

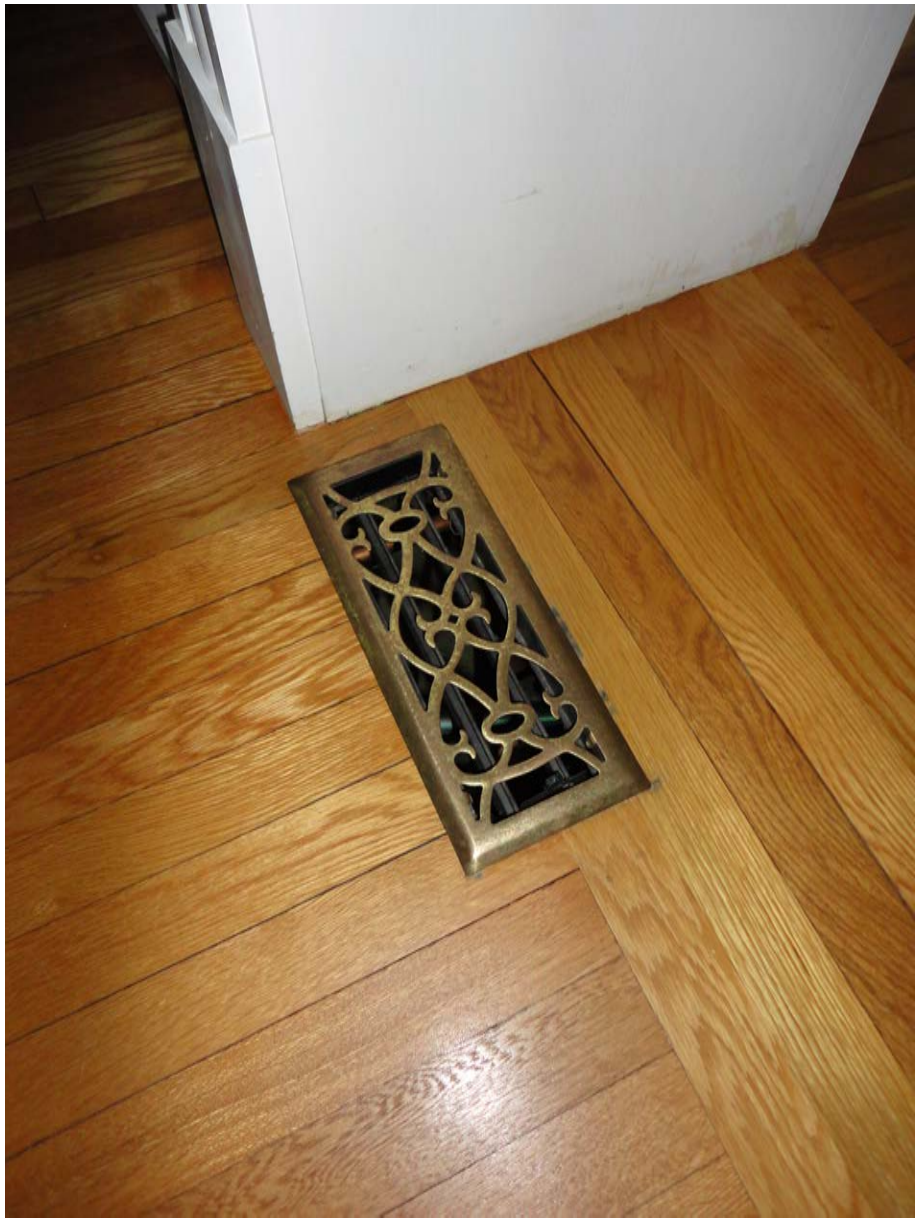

Heat recovery device
Constant airflow regulator
Supply
Exhaust
Smoke damper
Smoke damper
Smoke damper


Supply air
to corridor
Pre-conditioning
unit
Constant airflow regulator
Exhaust from elevator shaft
Smoke
damper
Smoke
damper
Smoke
damper


Heat recovery device
Pre-conditioning unit
Exhaust
Supply
Constant airflow regulator
Exhaust from elevator shaft
Smoke damper
Smoke damper
Smoke damper


EXIT


DANGER



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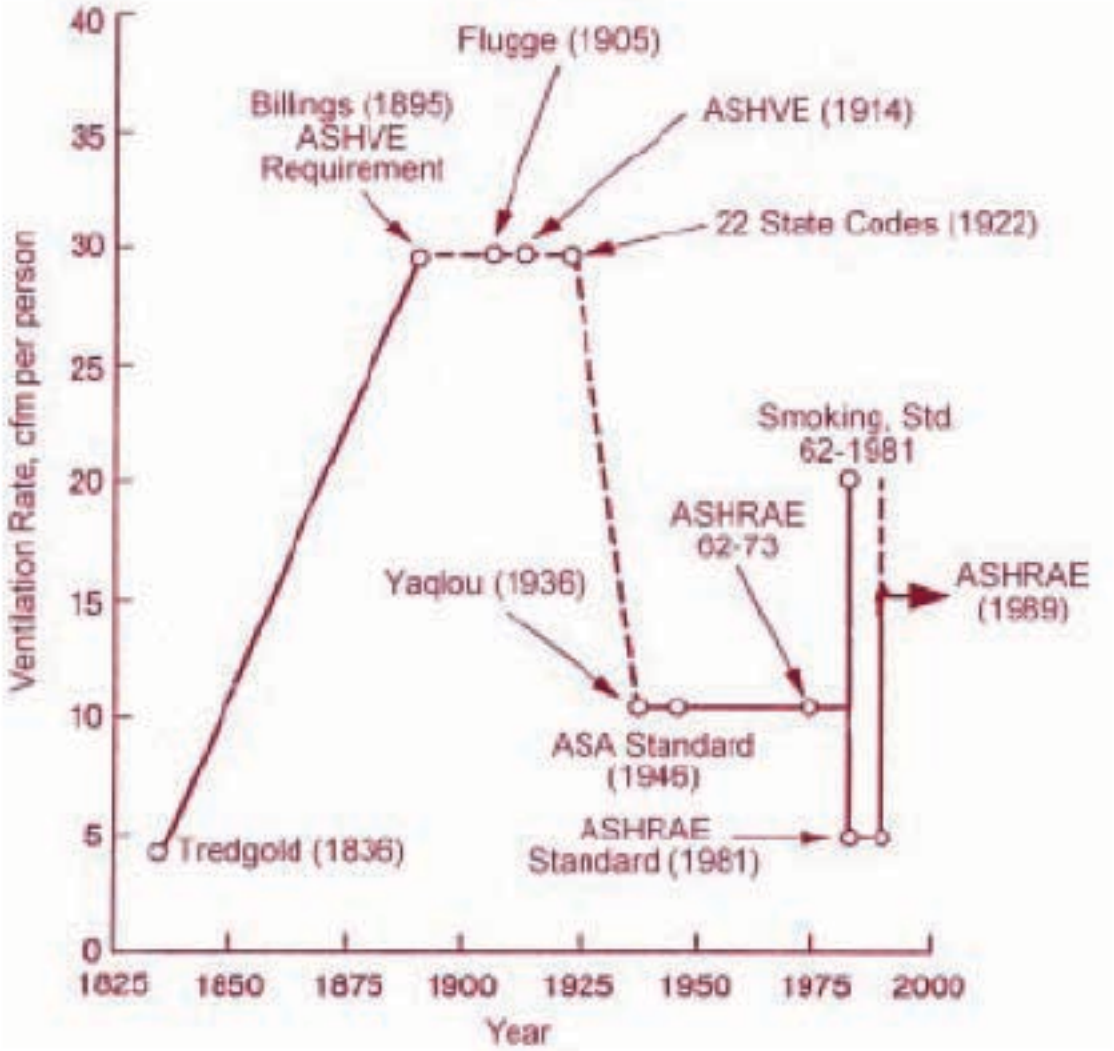

Figure 1: Minimum ventilating rate history.

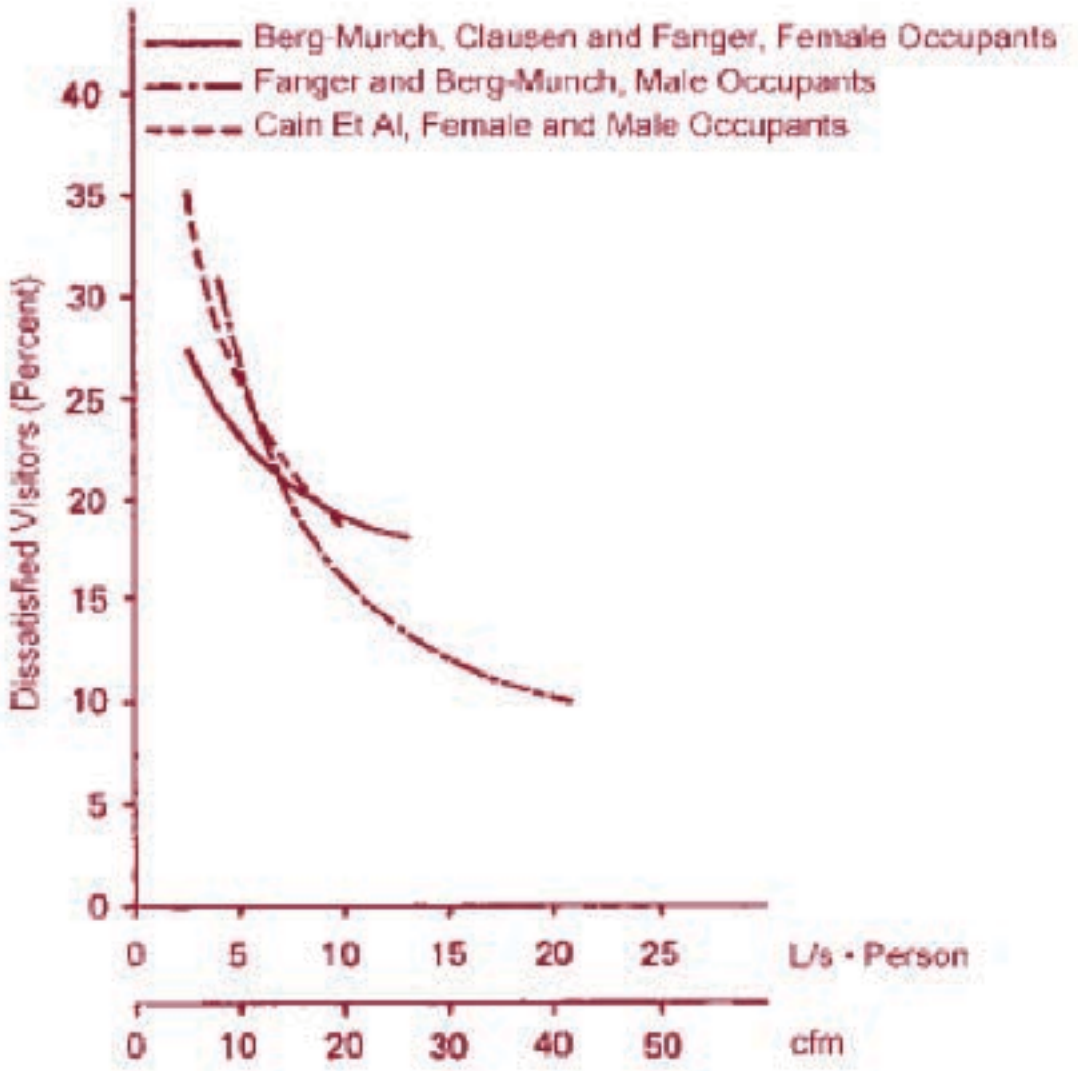

Figure 2: Odor acceptance.

House

2,000 ft^2

3 bedrooms

8 ft. ceiling
Volume: 16,000 ft^3

.35 ach	93 cfm
.30 ach	80 cfm
.25 ach	67 cfm
.20 ach	53 cfm
.15 ach	40 cfm

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3 bedrooms
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Ventilation Rates

62 - 73	5 cfm/person	20 cfm
	10 cfm/person	40 cfm
62 - 89	15 cfm/person	60 cfm
	.35 ach	90 cfm
62.2 - 2010	7.5 cfm/person + 0.01	50 cfm
62.2 - 2013	7.5 cfm/person + 0.03	90 cfm

Office

Occupant Density

15/1000 ft^2 (67 ft^2/person) 15 cfm/person	62 - 89
5/1000 ft^2 (200 ft^2/person) 17 cfm/person	62.1 - 2007

Correctional Facility Cell

Occupant Density

20/1000 ft^2 (48 ft^2/person) 10 cfm/person	62.1 – 2007

C.P. Yaglou

Harvard School of Public Health
1936
1955

150 ft^3  20 cfm/person

300 ft^3  12 cfm/person

C.P. Yaglou

Harvard School of Public Health
1936
1955

150 ft^3 → 20 cfm/person 18.75 ft^2 106 occupants

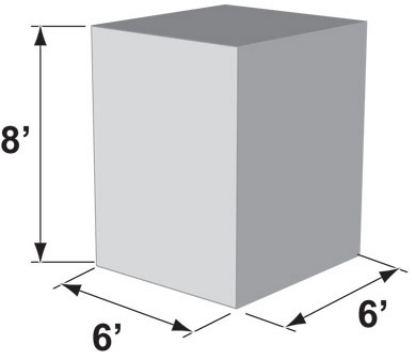
300 ft^3 → 12 cfm/person 37.5 ft^2 53 occupants

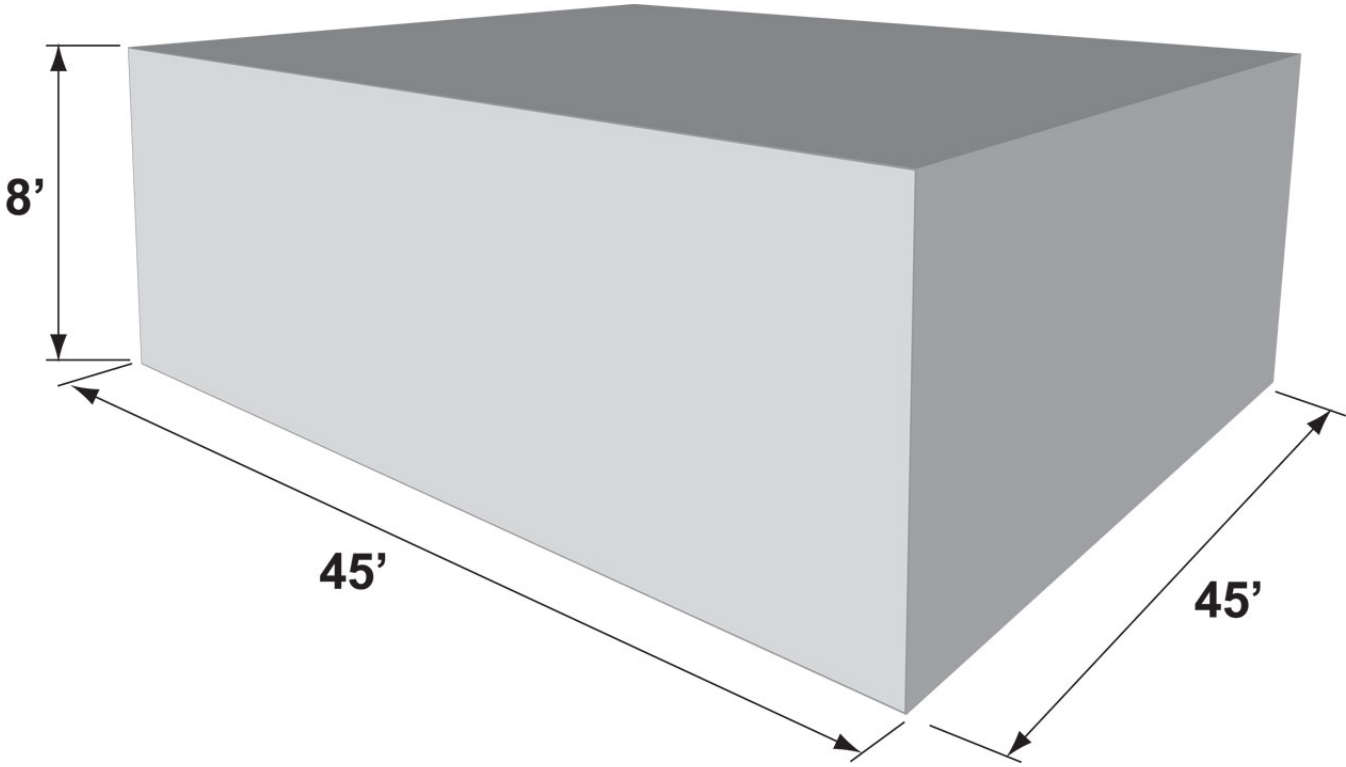
Experiment

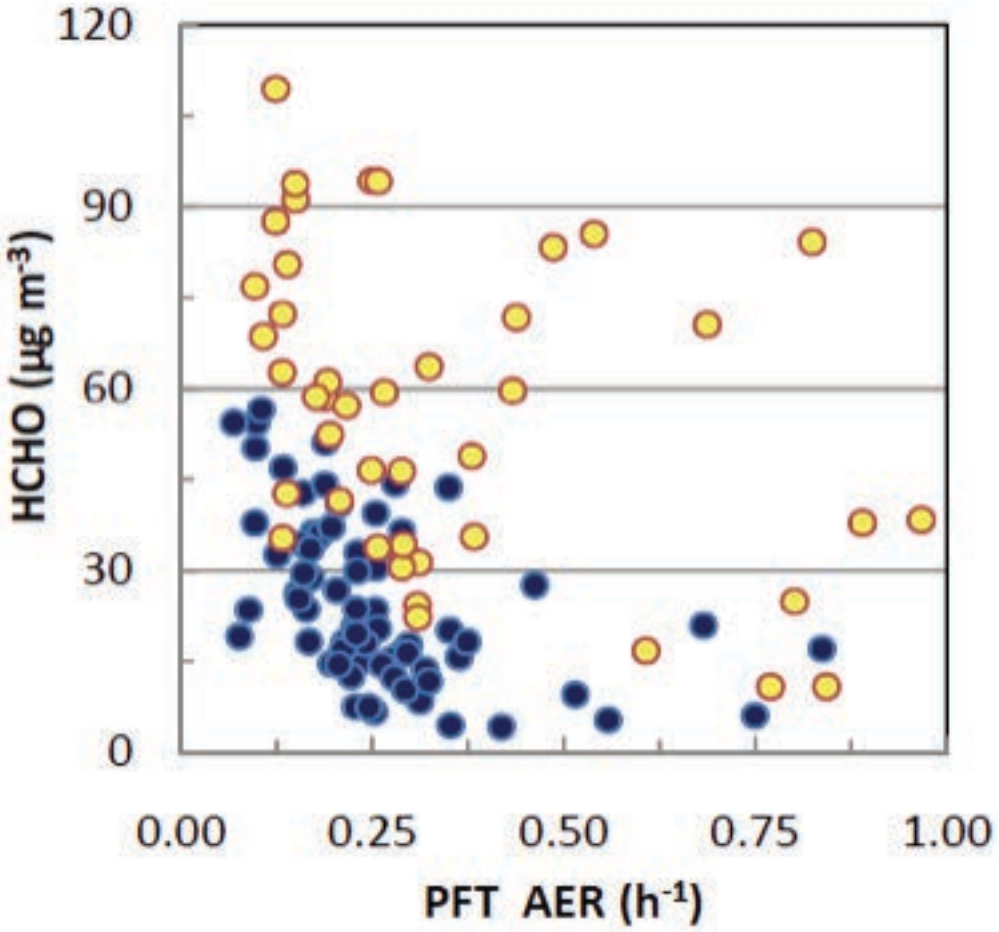
470 ft^3 → 59 ft^2

200 ft^3 → 25 ft^2

100 ft^3 → 12 ft^2


8’
6’
6’


8’
45’
45’



Aubin, D., Won, D.Y., Schleibinger, H., 2010

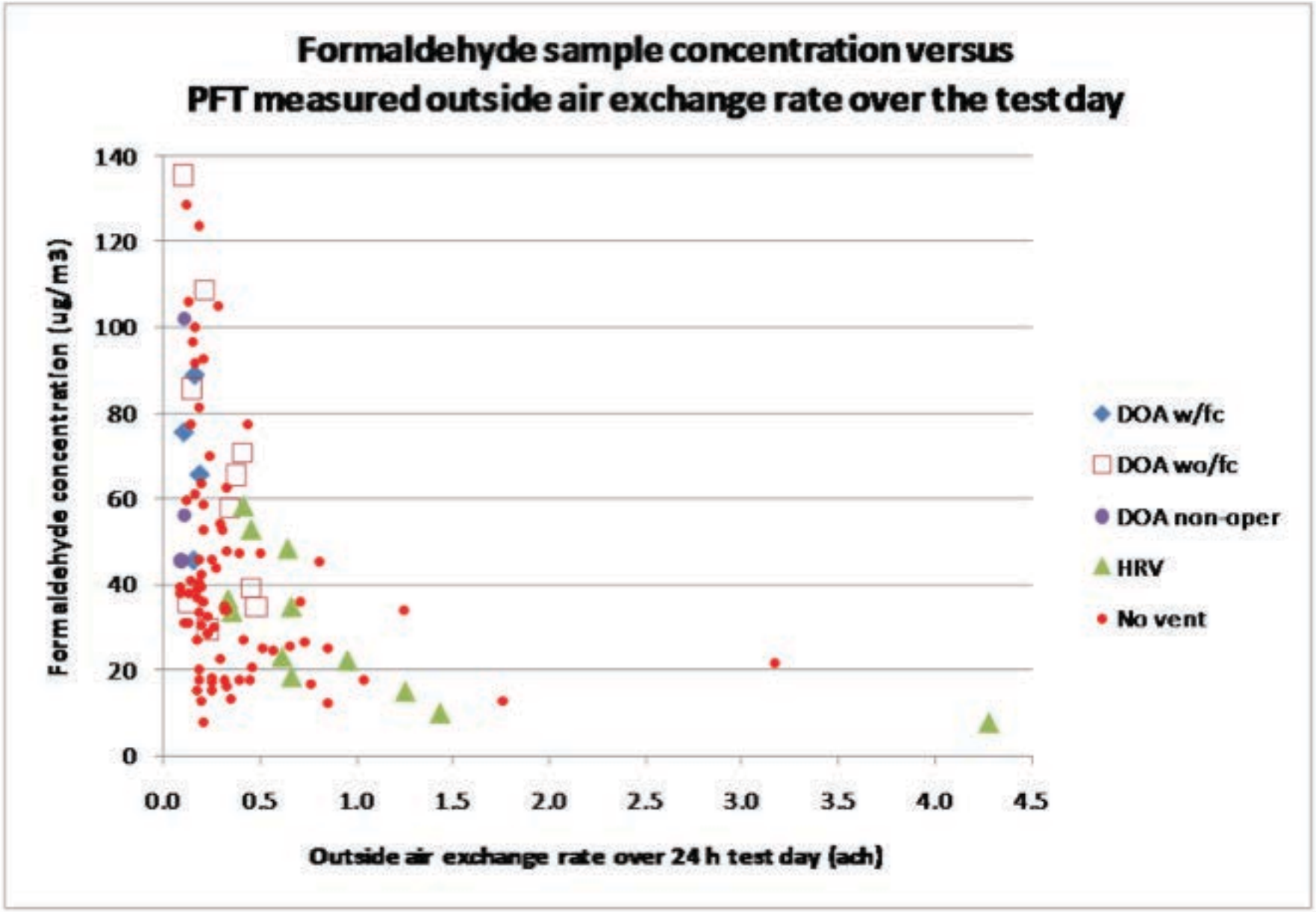

Formaldehyde sample concentration versus
PFT measured outside air exchange rate over the test day
Formaldehyde concentration (ug/m3)
140
120
100
80
60
40
20
0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
Outside air exchange rate over 24 h test day (ach)
DOA w/fc
DOA wo/fc
DOA non-oper
HRV
No vent

Table 1. Summary of the air changes rates measured during the winter 2009-10 season in Quebec City

Method	ACH (h^{-1})	ACH standard deviation (h^{-1})	number of measurements
SF_6 tracer decay	0.27	0.12	77
perflurocarbon tracer	0.32	0.22	37
blower door at 50 Pa	4.16	2.64	63