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

Building Science

Adventures In Building Science

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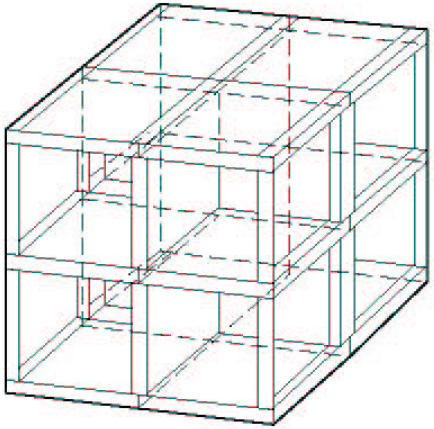


Figure 2.11
Three Dimensional Multi-Layer Multi-Cell Analogue

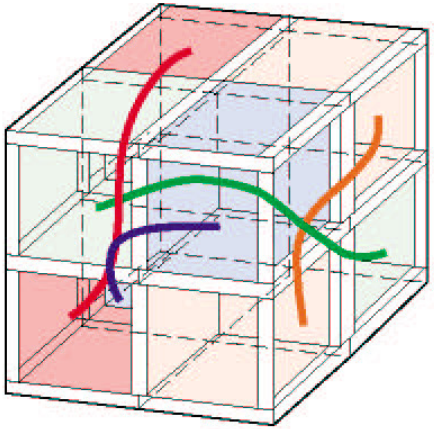
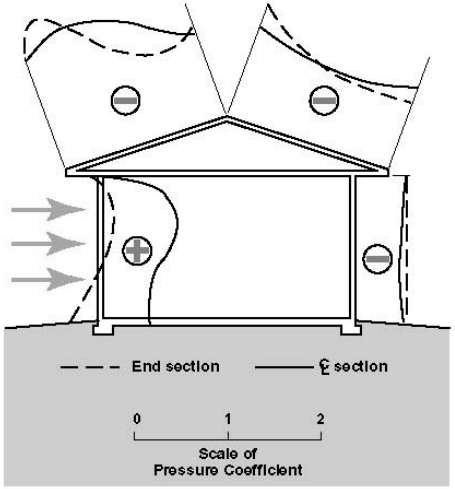


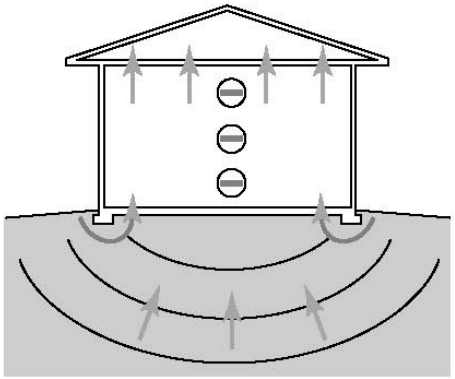
Figure 2.12
Three Dimensional Multi-Layer Multi-Cell Non-Contiguous Analogue

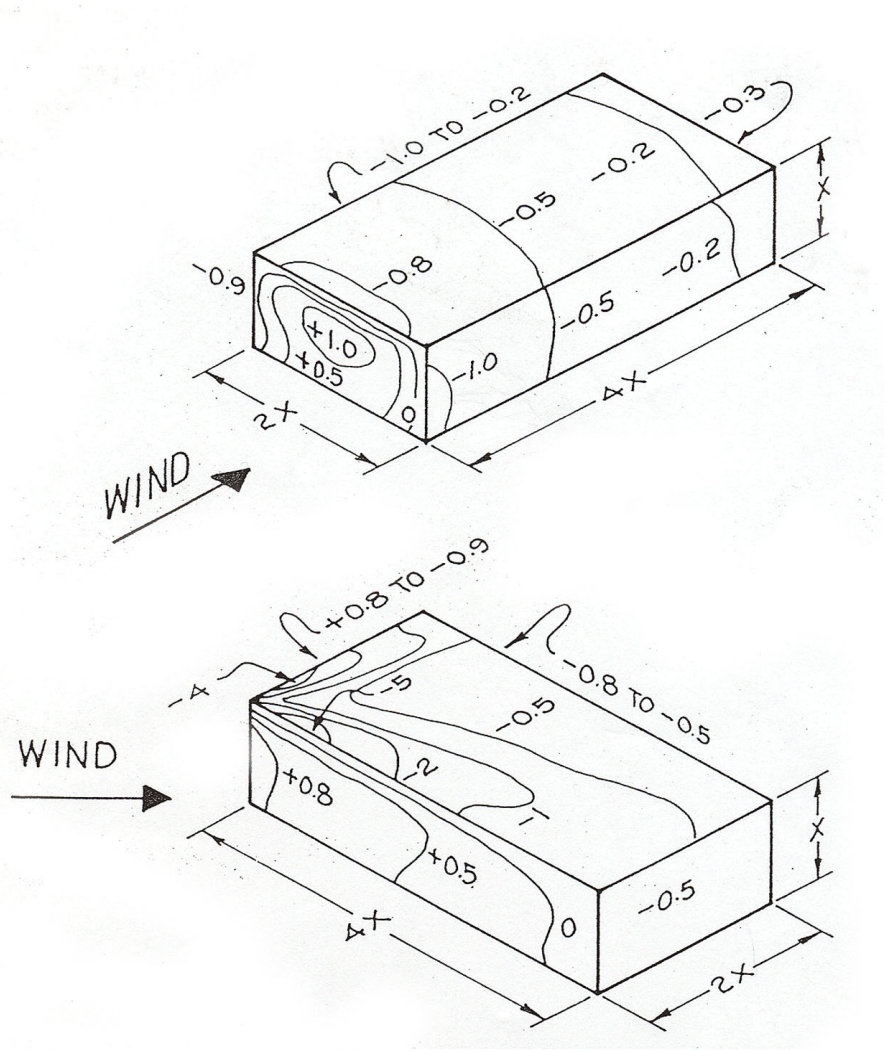
Figure 3.1
Exterior Air Pressure Field
(from Hutcheon & Handegord, 1983)



Distribution of pressures (+) and suctions (-) on a house with a low-sloped roof with wind perpendicular to eave

Figure 3.2
Exterior Air Pressure Field Extending Below Grade





Pressure coefficients on walls and roof of rectangular buildings without parapets.

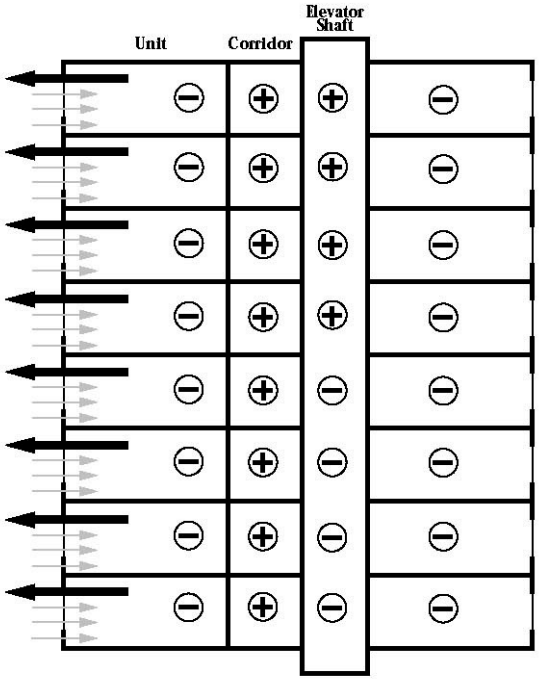


Figure 3.3
Interior Air Pressure Field

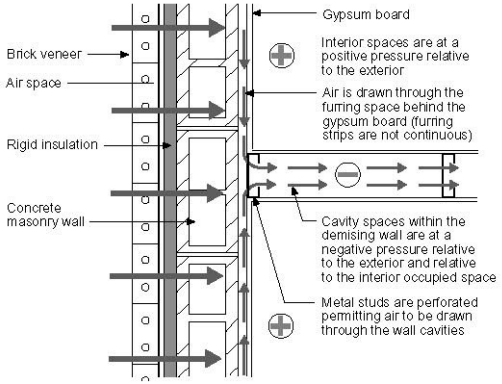


Figure 3.4
Interstitial Air Pressure Field

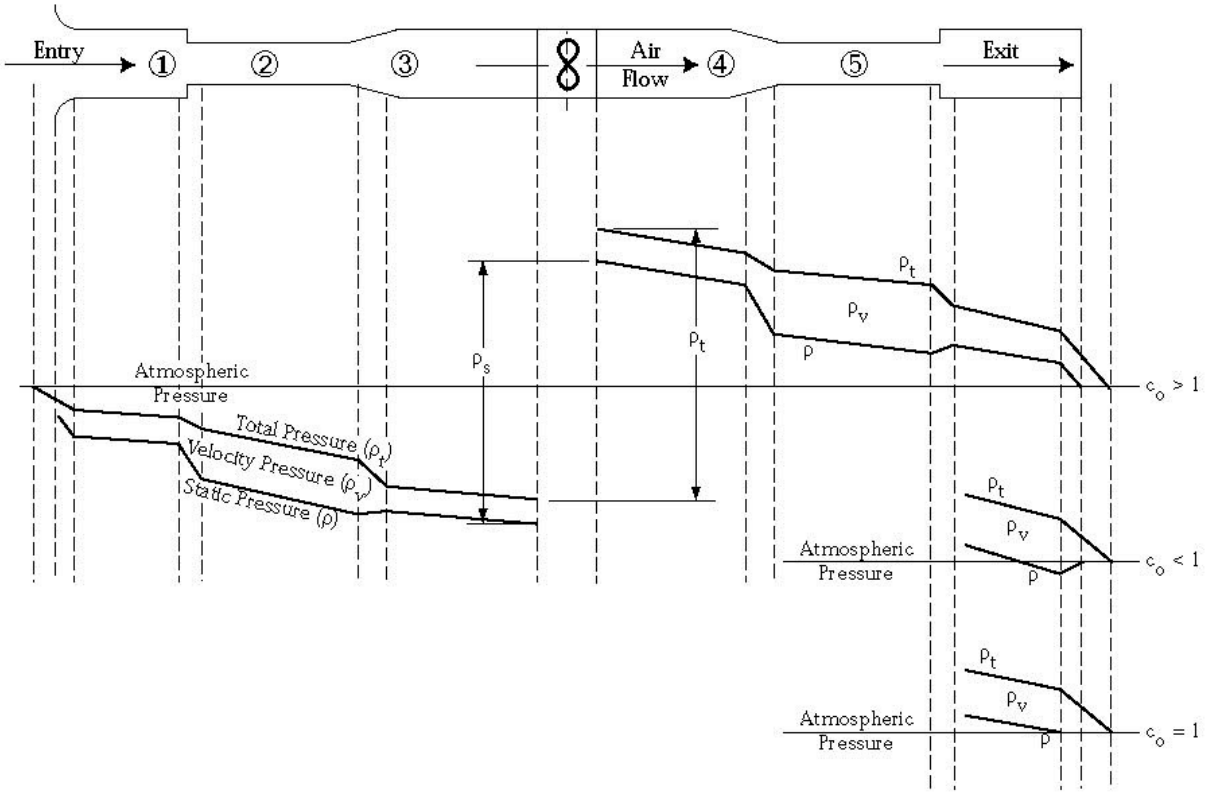


Figure 3.5
Air Conveyance System Air Pressure Field
(from Sauer & Howell, 1990)

People

Pollutant (hot, wet, UV, ozone)

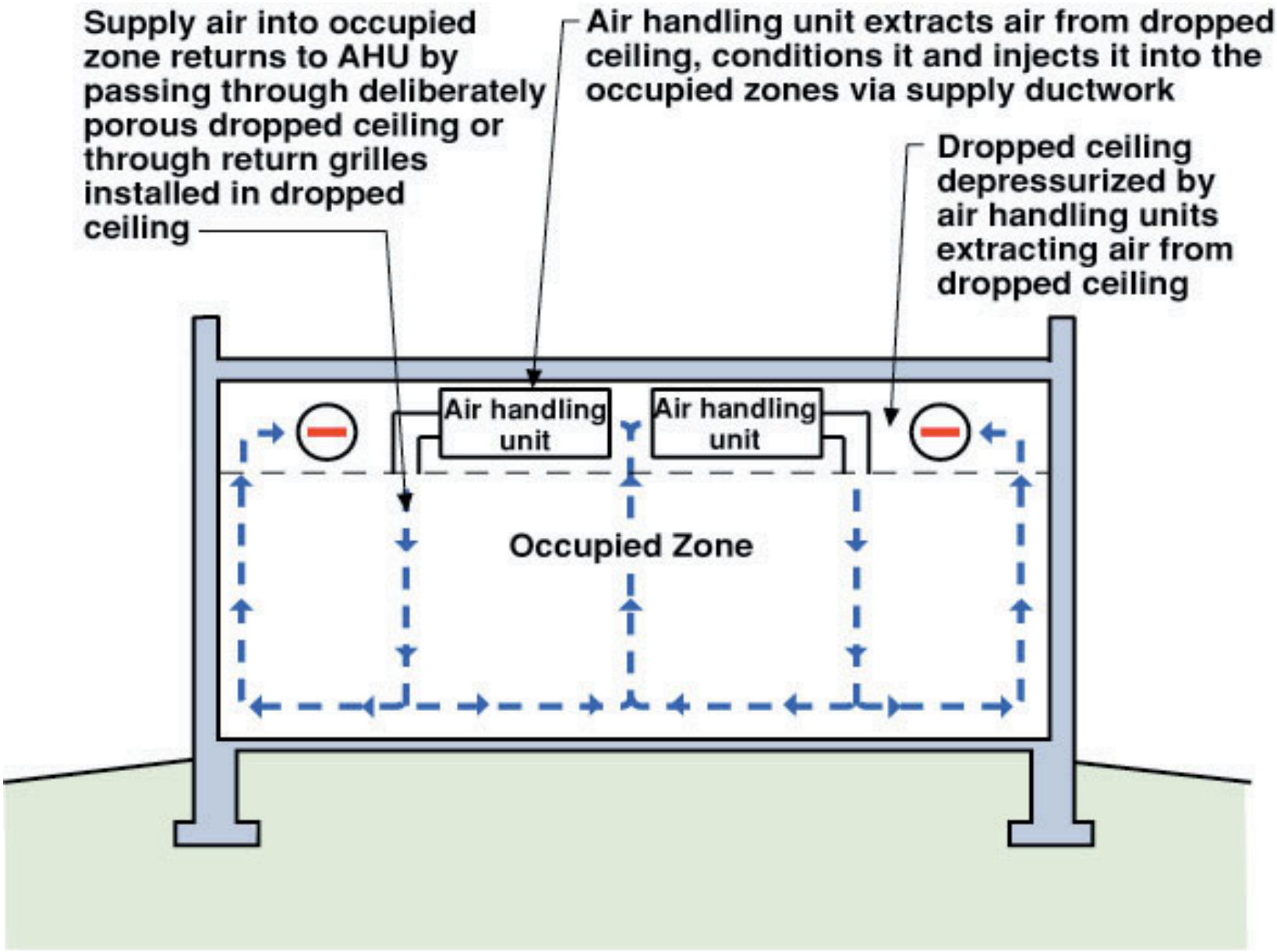
Path

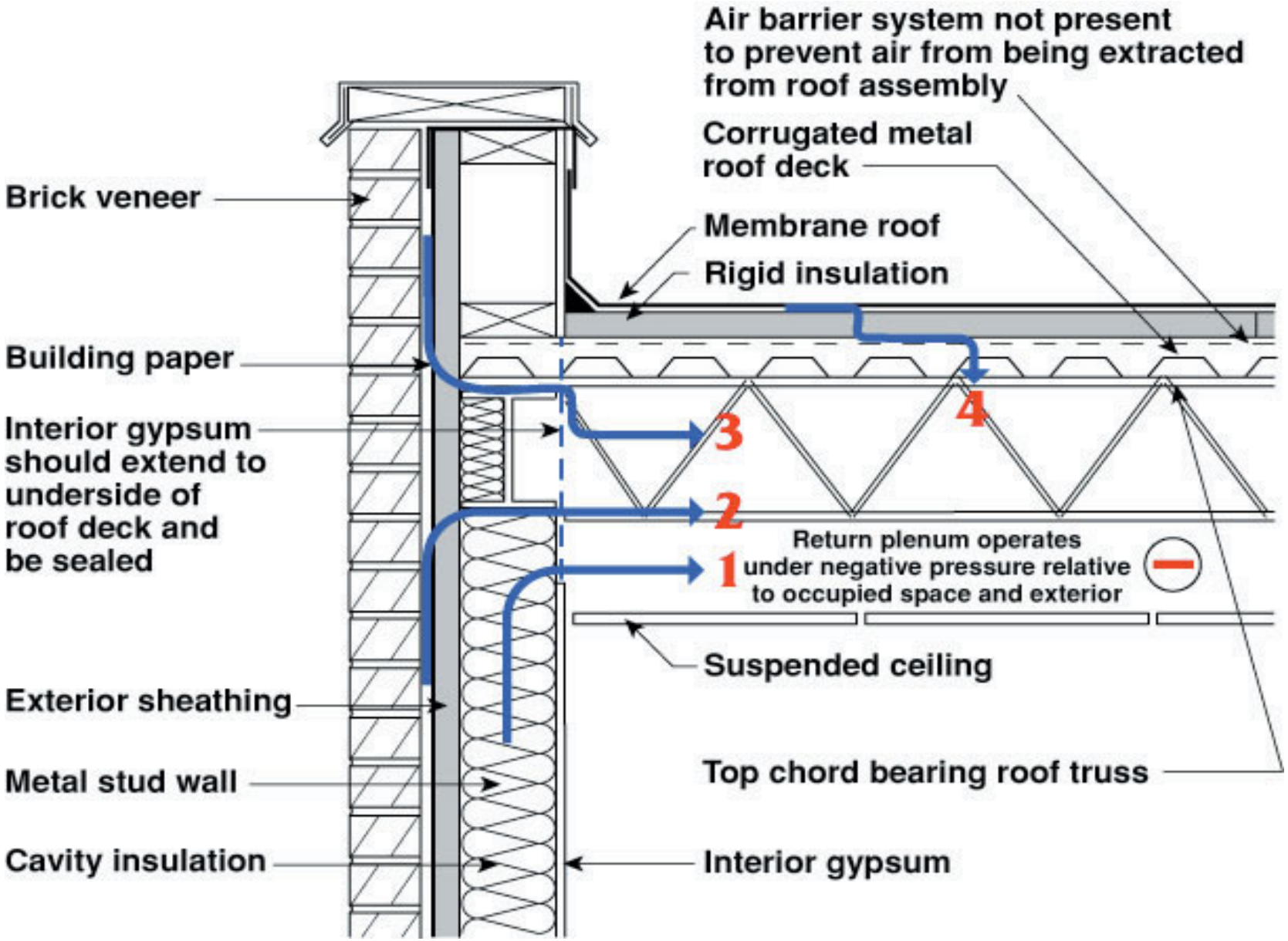
Pressure

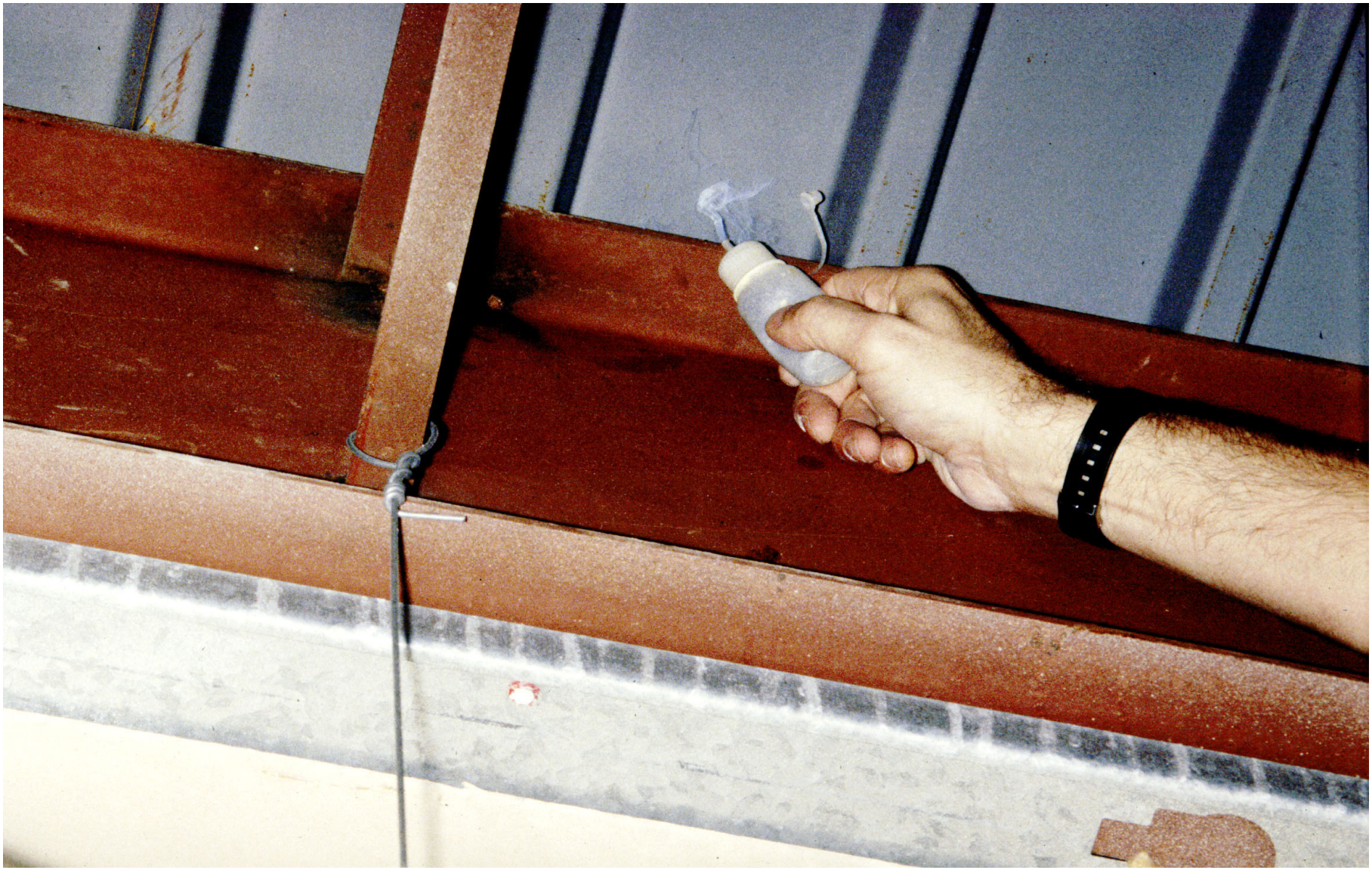

PUBLIC SERVICES
PUBLIC SERVICES

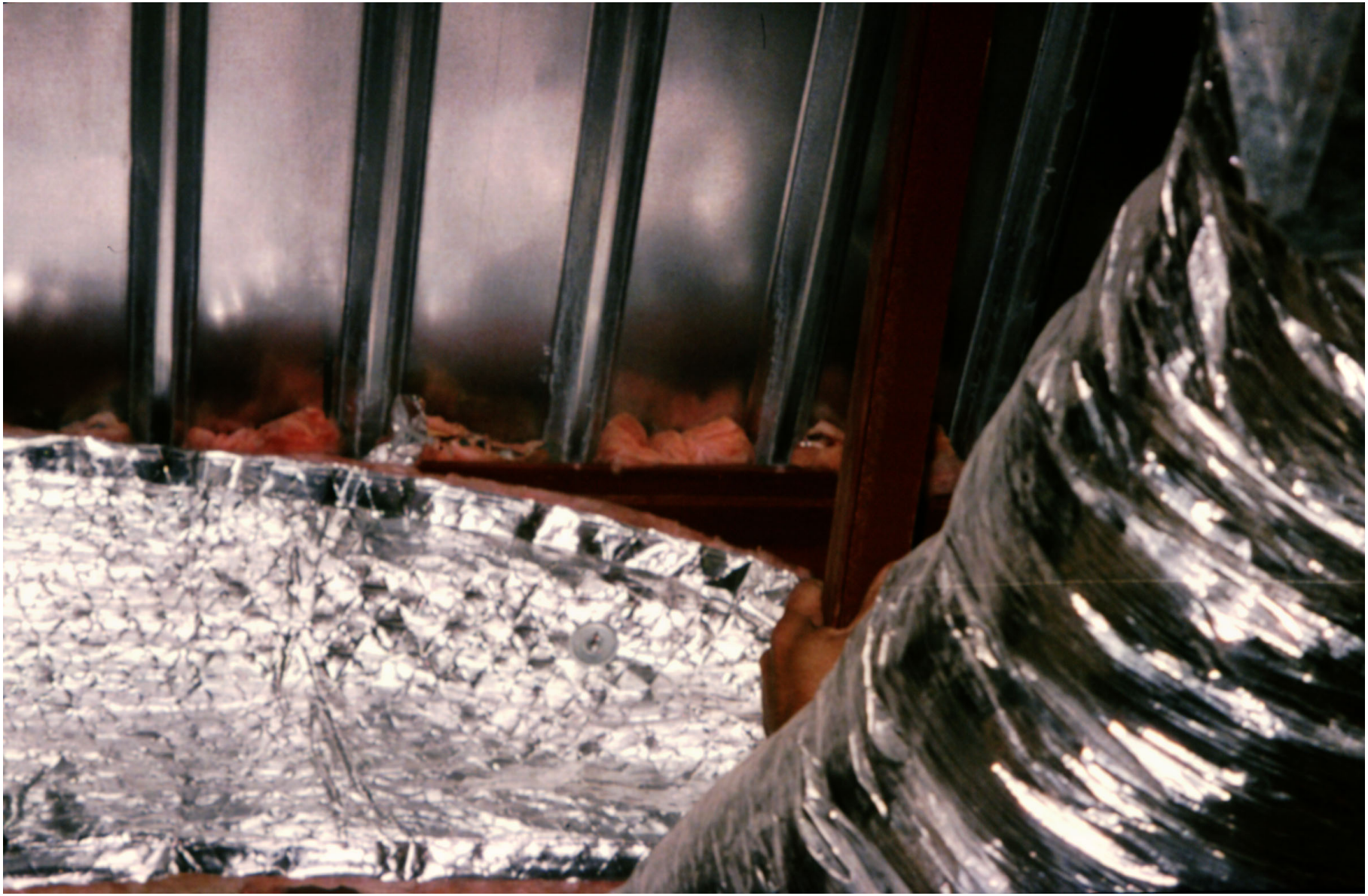

STOP


EXIT


Supply air into occupied zone returns to AHU by passing through deliberately porous dropped ceiling or through return grilles installed in dropped ceiling
Air handling unit extracts air from dropped ceiling, conditions it and injects it into the occupied zones via supply ductwork
Dropped ceiling depressurized by air handling units extracting air from dropped ceiling
Air handling unit
Air handling unit
Occupied Zone

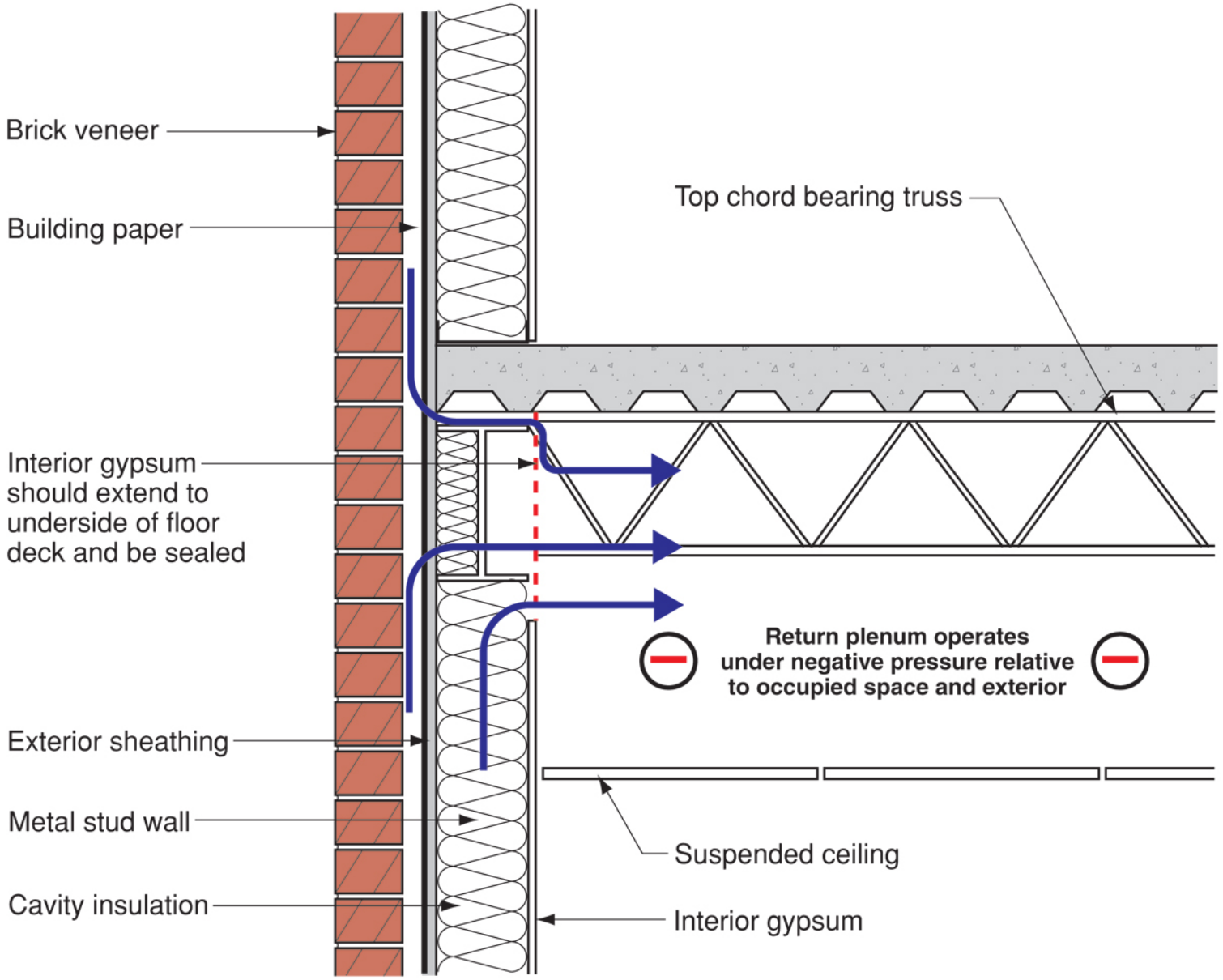

Air barrier system not present to prevent air from being extracted from roof assembly
Corrugated metal roof deck
Membrane roof
Rigid insulation
Brick veneer
Building paper
Interior gypsum should extend to underside of roof deck and be sealed
3
4
2
1
Return plenum operates under negative pressure relative to occupied space and exterior
Suspended ceiling
Exterior sheathing
Metal stud wall
Cavity insulation
Top chord bearing roof truss
Interior gypsum

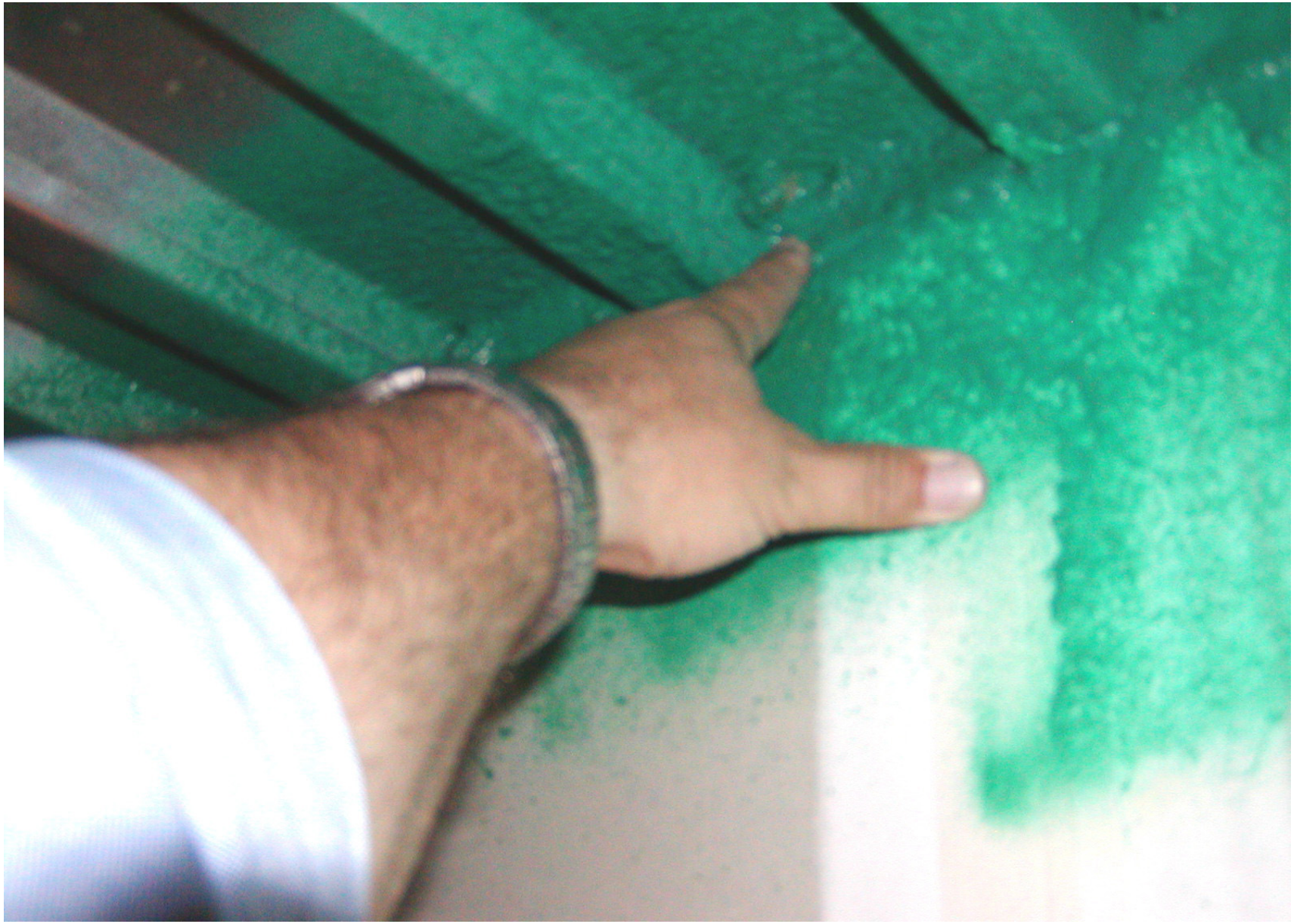


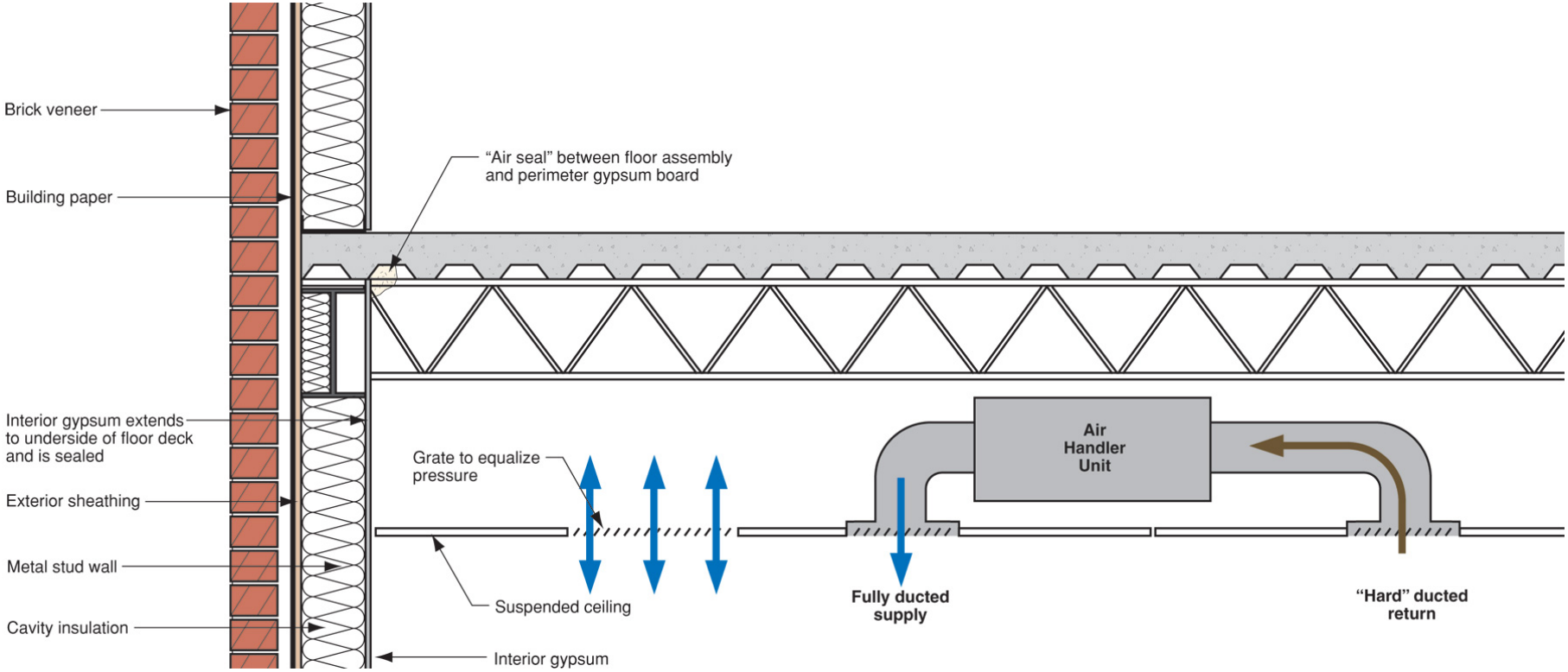



Tyvek


RE COMPANY


Brick veneer
Building paper
Interior gypsum should extend to underside of floor deck and be sealed
Exterior sheathing
Metal stud wall
Cavity insulation
Top chord bearing truss
Return plenum operates under negative pressure relative to occupied space and exterior
Suspended ceiling
Interior gypsum




Brick veneer
Building paper
"Air seal" between floor assembly and perimeter gypsum board
Interior gypsum extends to underside of floor deck and is sealed
Exterior sheathing
Metal stud wall
Cavity insulation
Grate to equalize pressure
Suspended ceiling
Interior gypsum
Air Handler Unit
Fully ducted supply
"Hard" ducted return

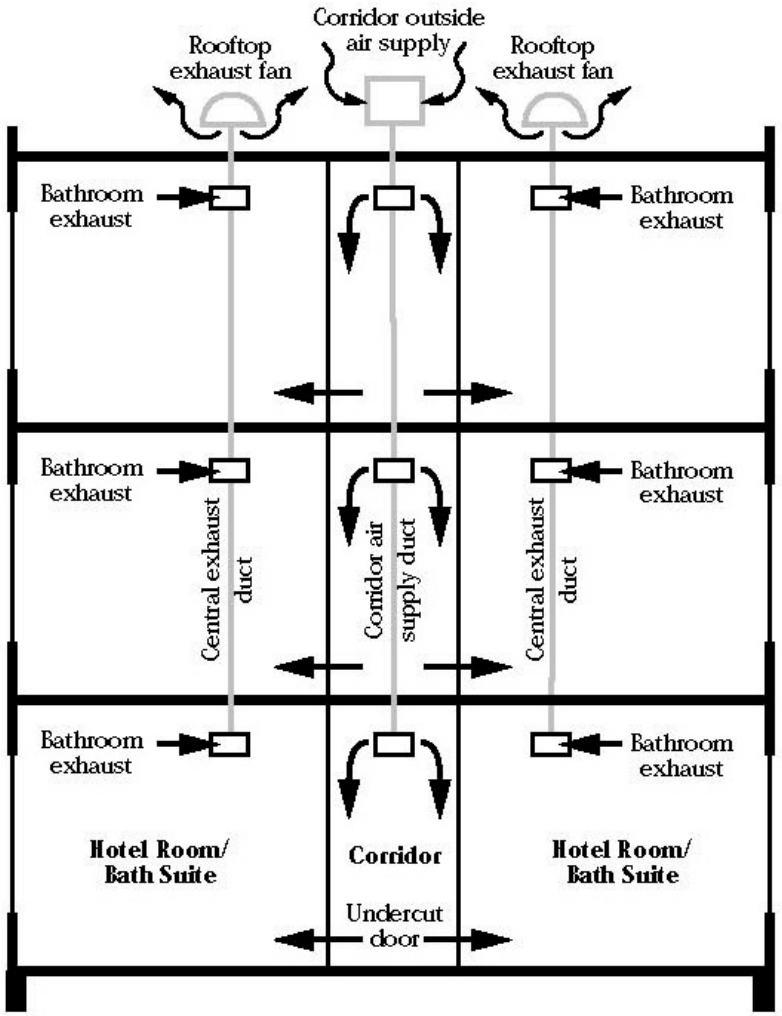
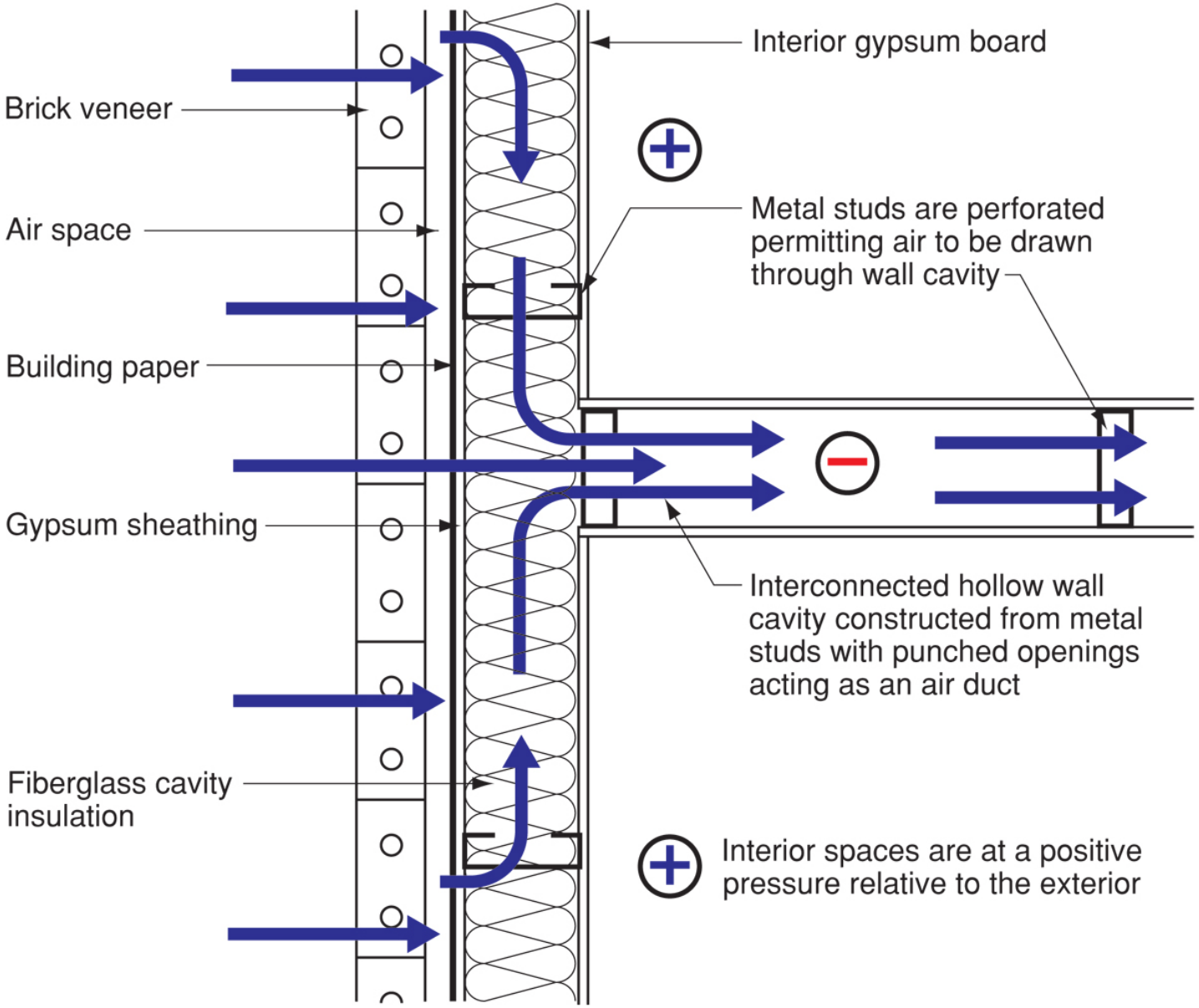


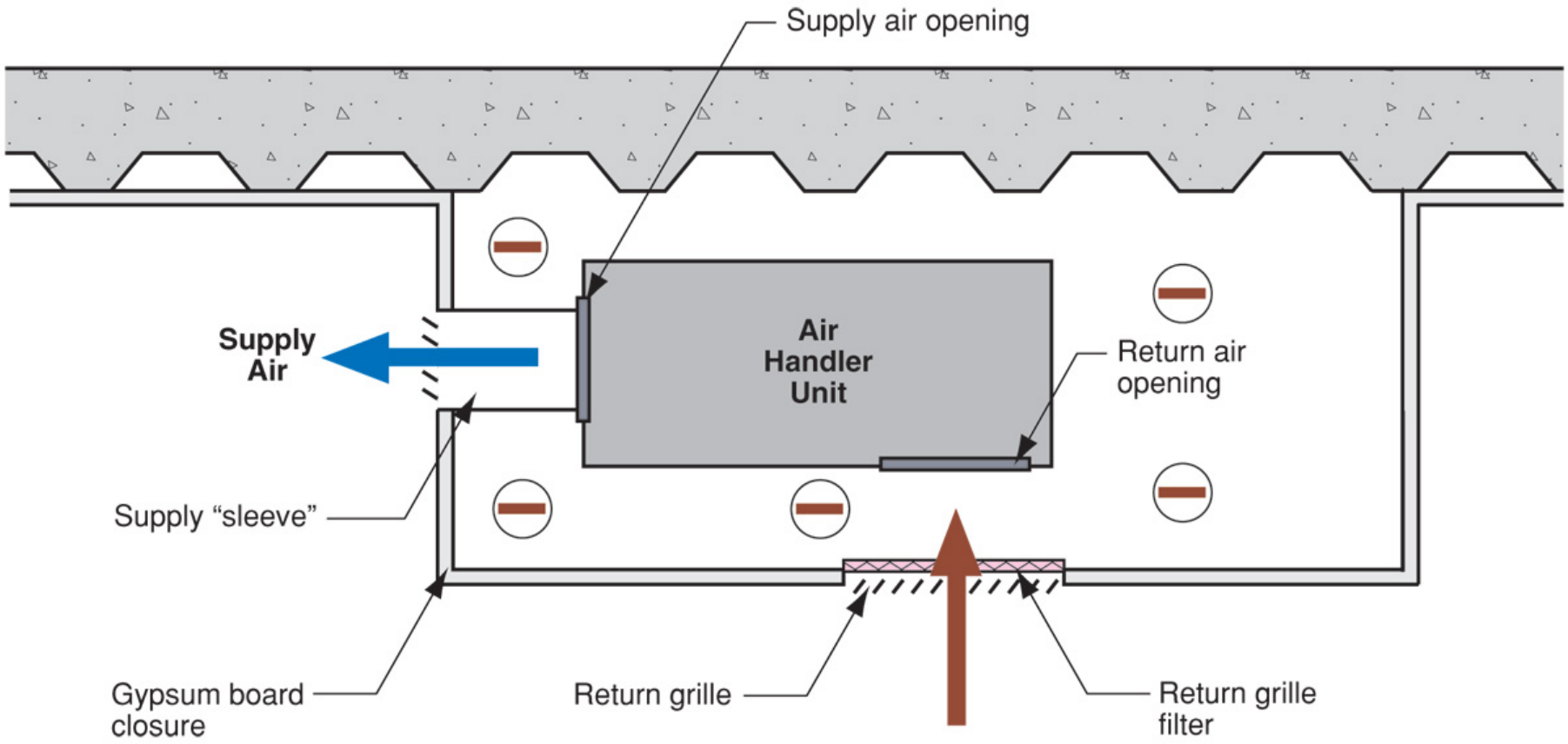
Figure 3.8

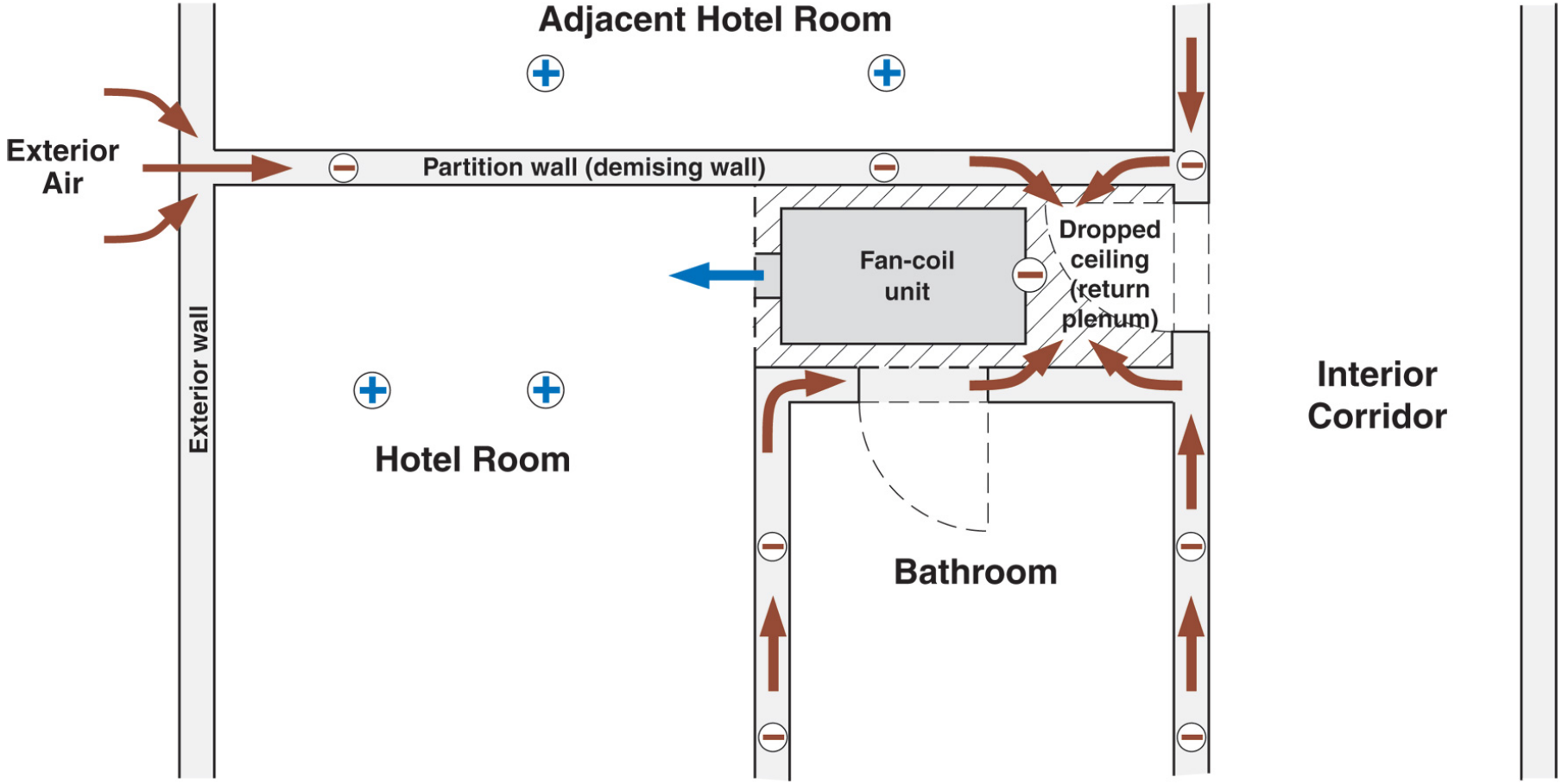
Hotel HVAC System

- Air exhausted from bathrooms via central rooftop exhaust fans
- Air supplied from corridors via undercut doors


Zenith


Brick veneer
Air space
Building paper
Gypsum sheathing
Fiberglass cavity insulation
Interior gypsum board
Metal studs are perforated permitting air to be drawn through wall cavity
Interconnected hollow wall cavity constructed from metal studs with punched openings acting as an air duct
Interior spaces are at a positive pressure relative to the exterior


Supply air opening
Supply
Air
Air
Handler
Unit
Return air
opening
Supply "sleeve"
Gypsum board
closure
Return grille
Return grille
filter


Adjacent Hotel Room
Exterior Air
Partition wall (demising wall)
Exterior wall
Fan-coil unit
Dropped ceiling (return plenum)
Hotel Room
Bathroom
Interior Corridor

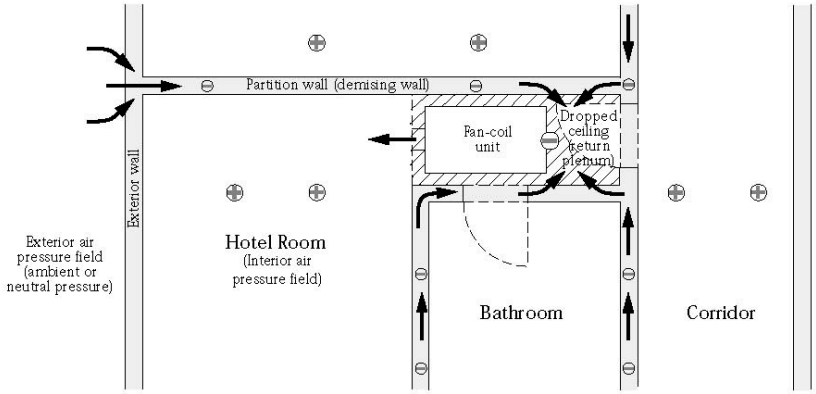


Figure 3.10
Pressure Field Due to Fan-Coil Unit
Plan View

- Room is at positive air pressure relative to exterior-driven air from corridor and air supplied to room from fan-coil unit pulling air from exterior through the demising wall
- Fan-coil unit depressurizes dropped ceiling assembly due to return plenum design
- Demising wall cavity pulled negative due to connection to dropped ceiling return plenum

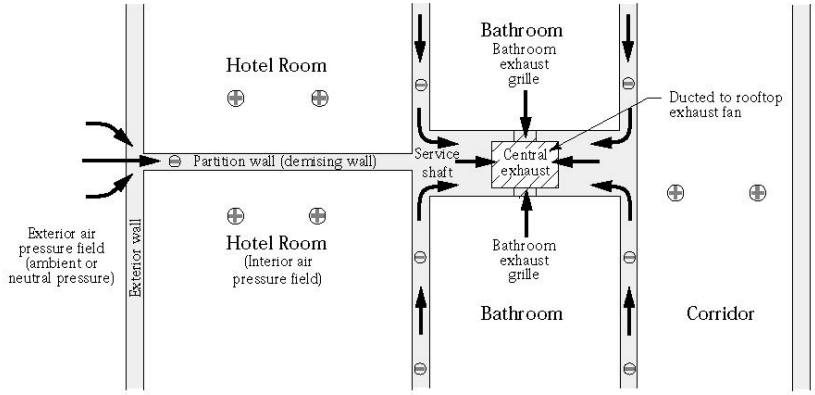
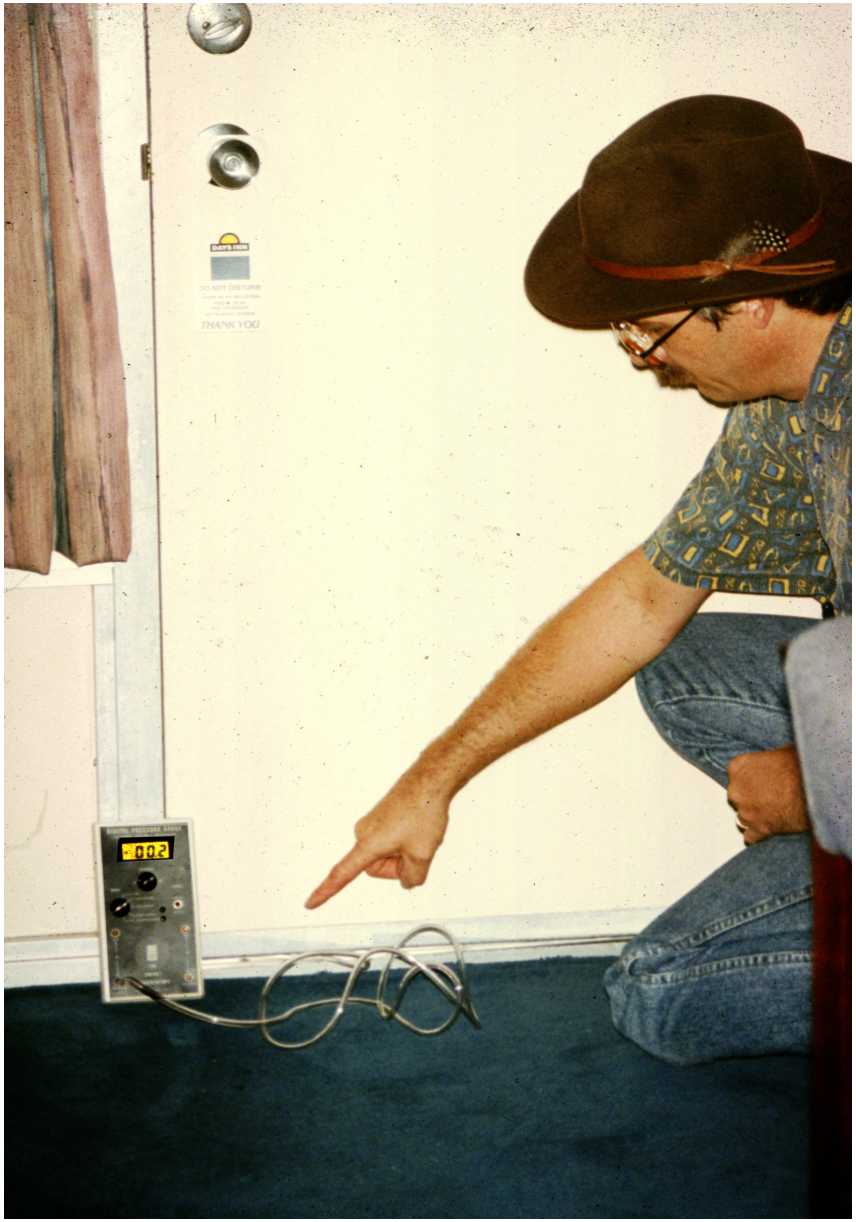
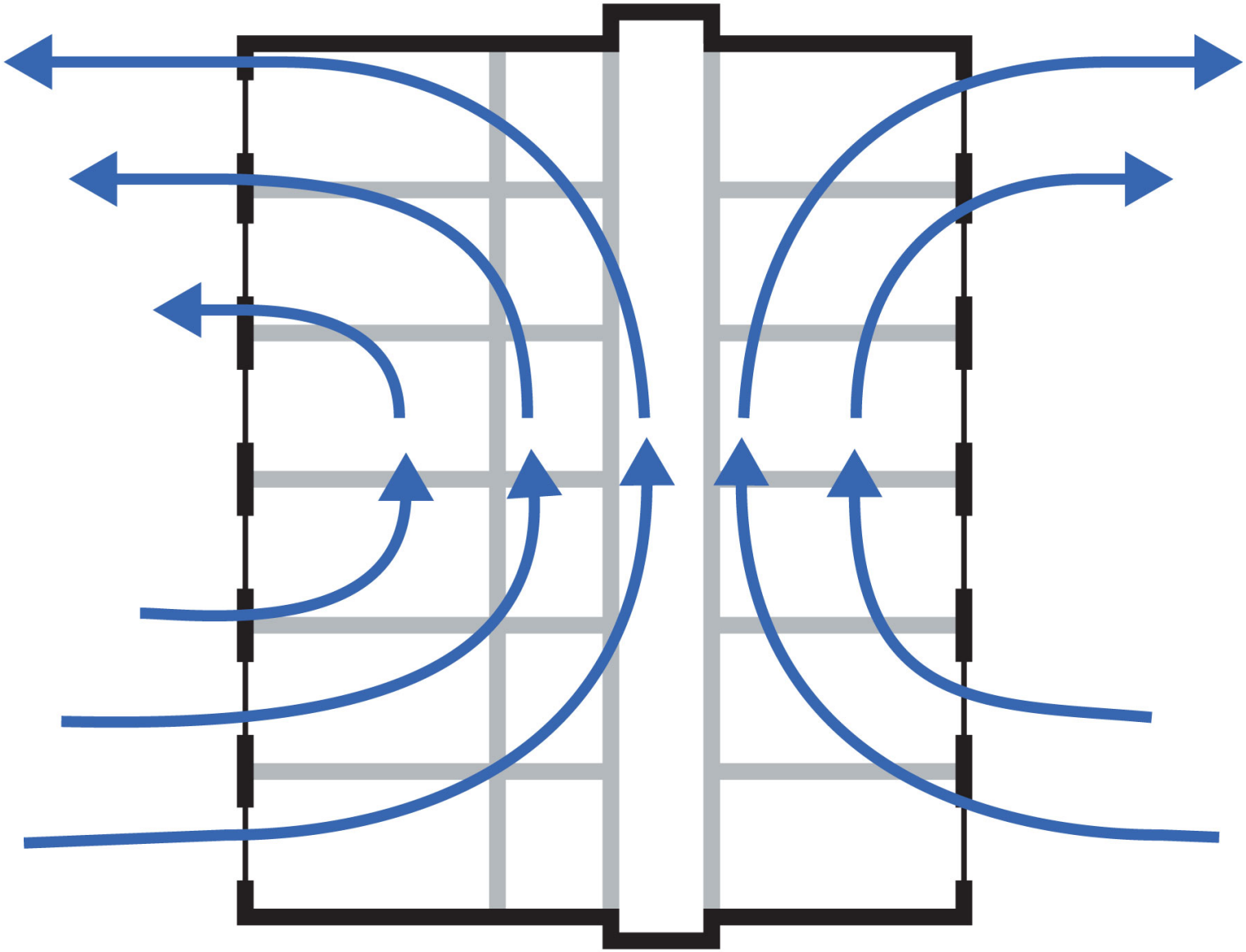


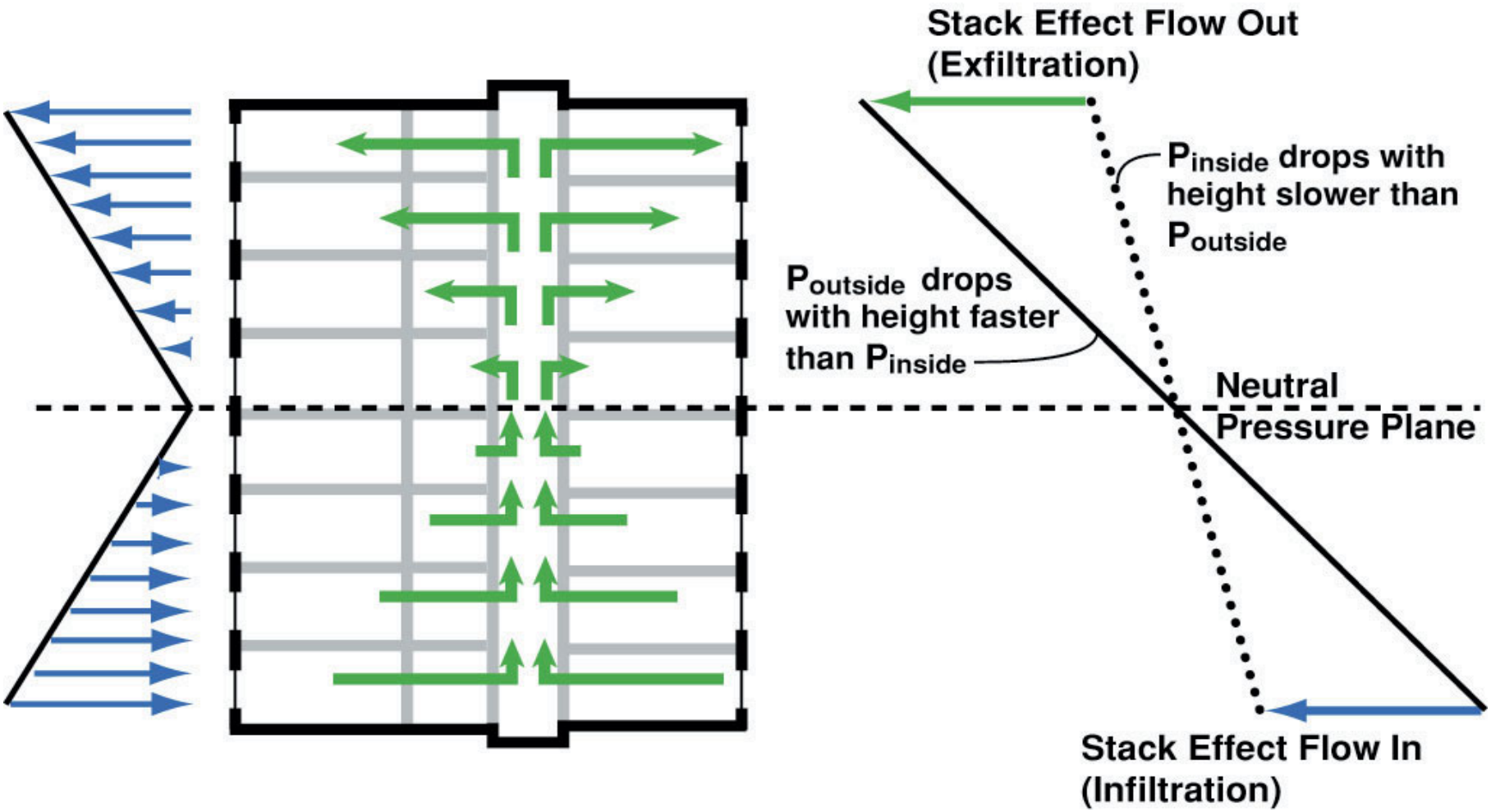
Figure 3.11
Pressure Field Due to Central Exhaust
Plan View

- Leakage of central exhaust duct pulls air out of service shaft depressurizing shaft and demising walls

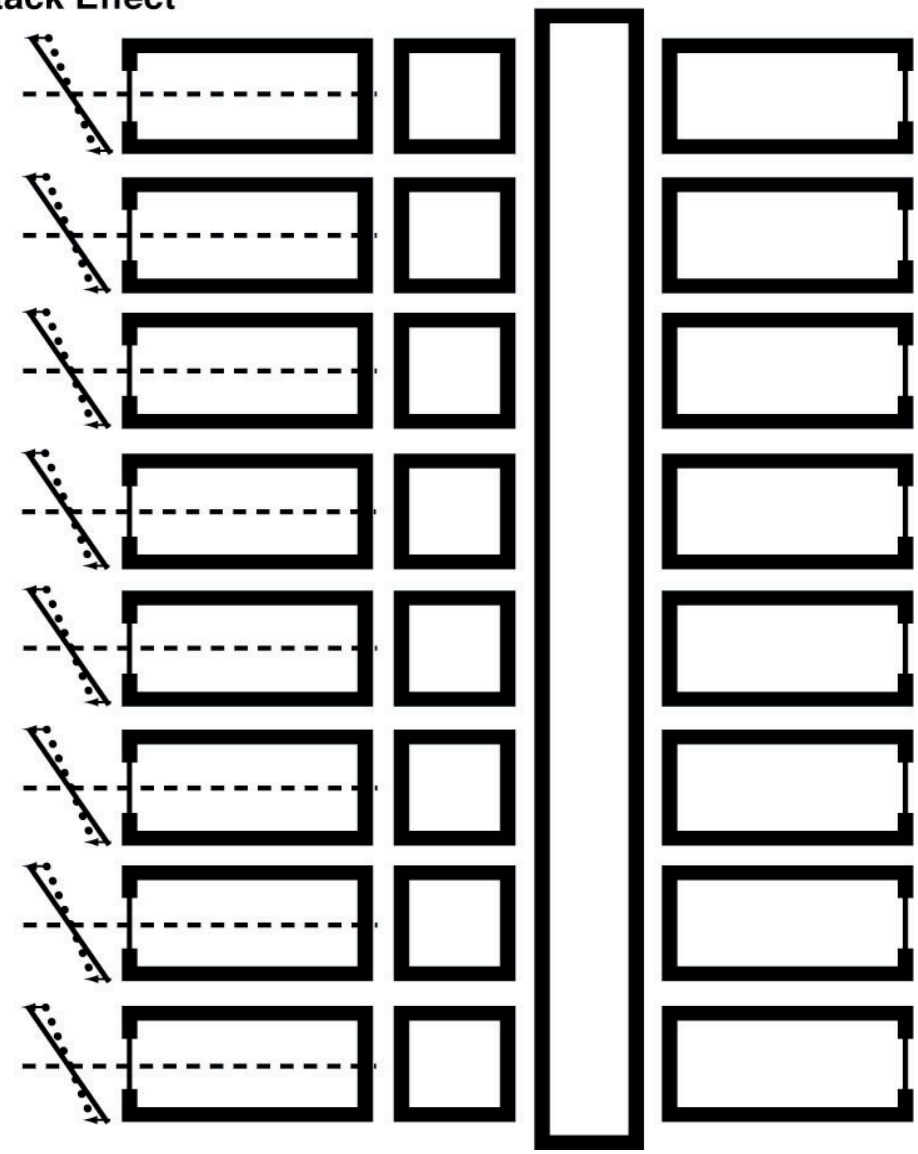

DAYS INN

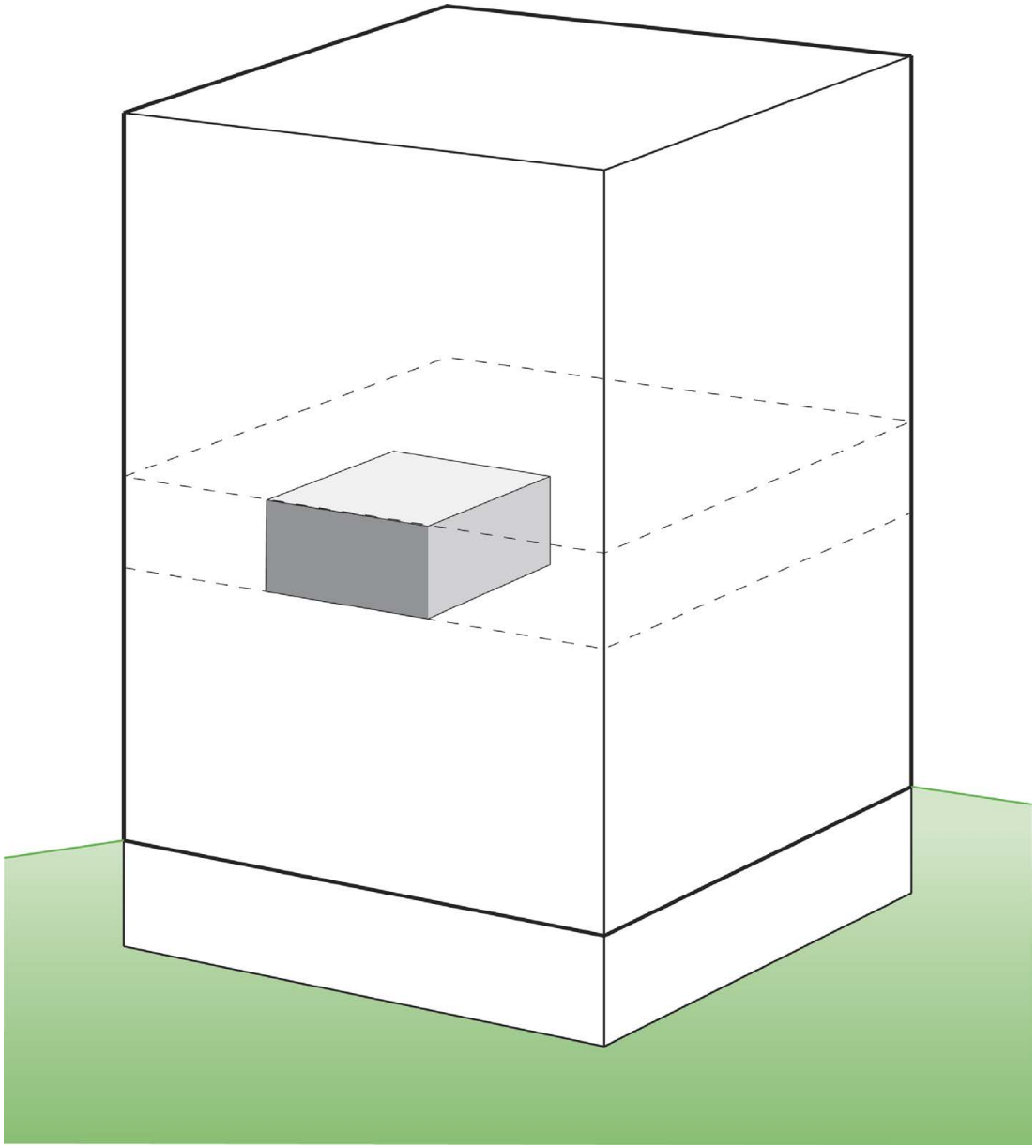

DO NOT DISTURB
THANK YOU
-.002

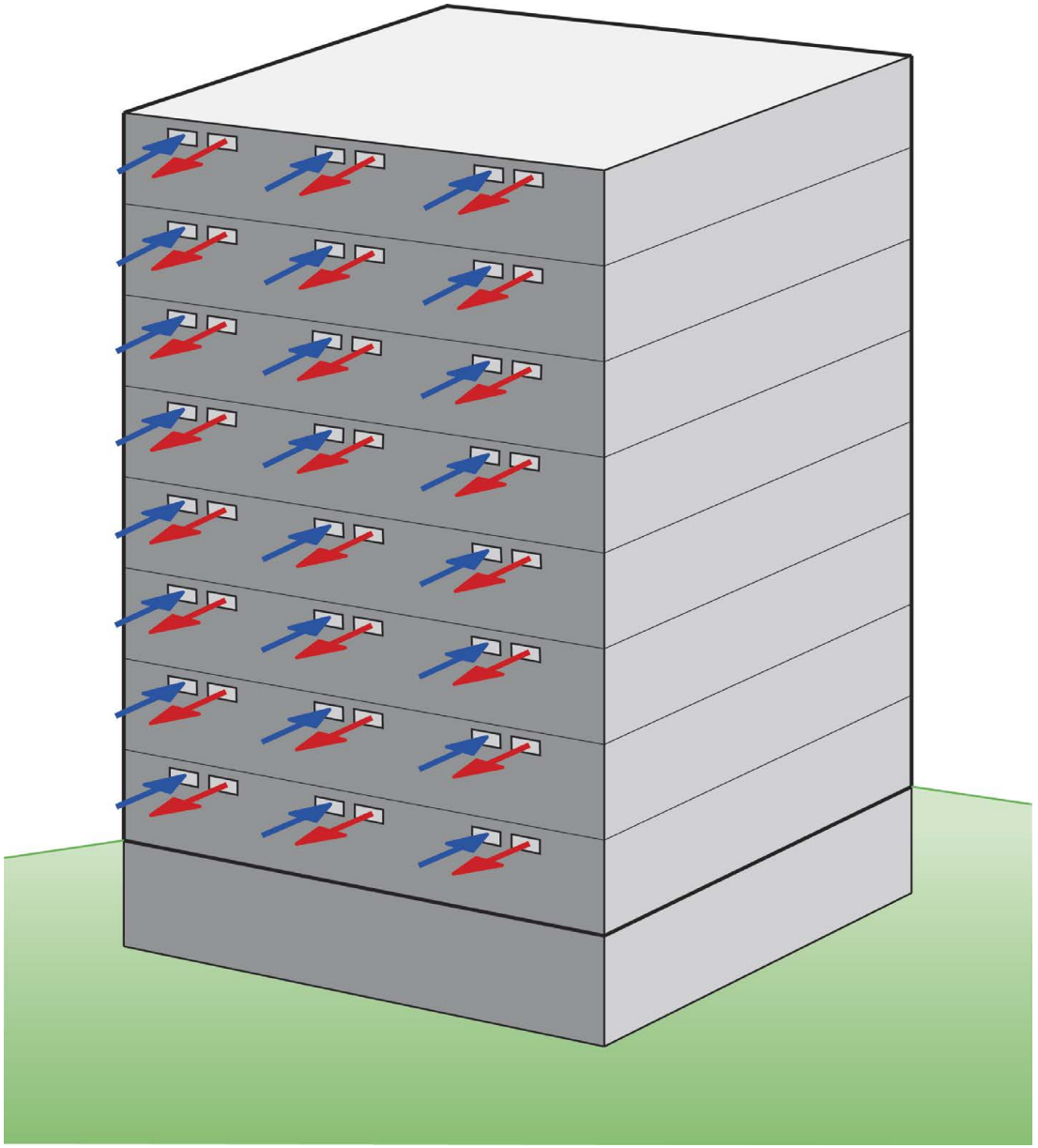


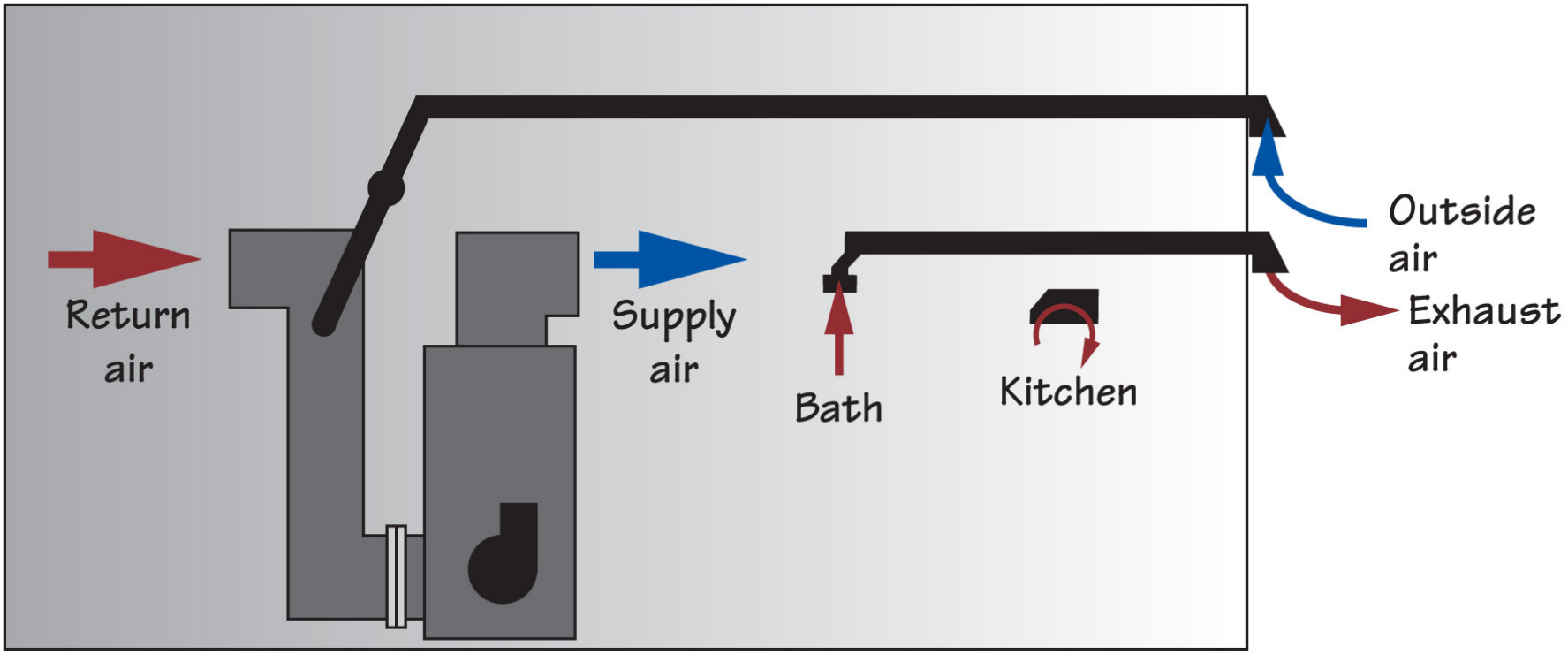

Stack Effect Flow Out
(Exfiltration)
Pinside drops with
height slower than
Poutside
Poutside drops
with height faster
than Pinside
Neutral
Pressure Plane
Stack Effect Flow In
(Infiltration)

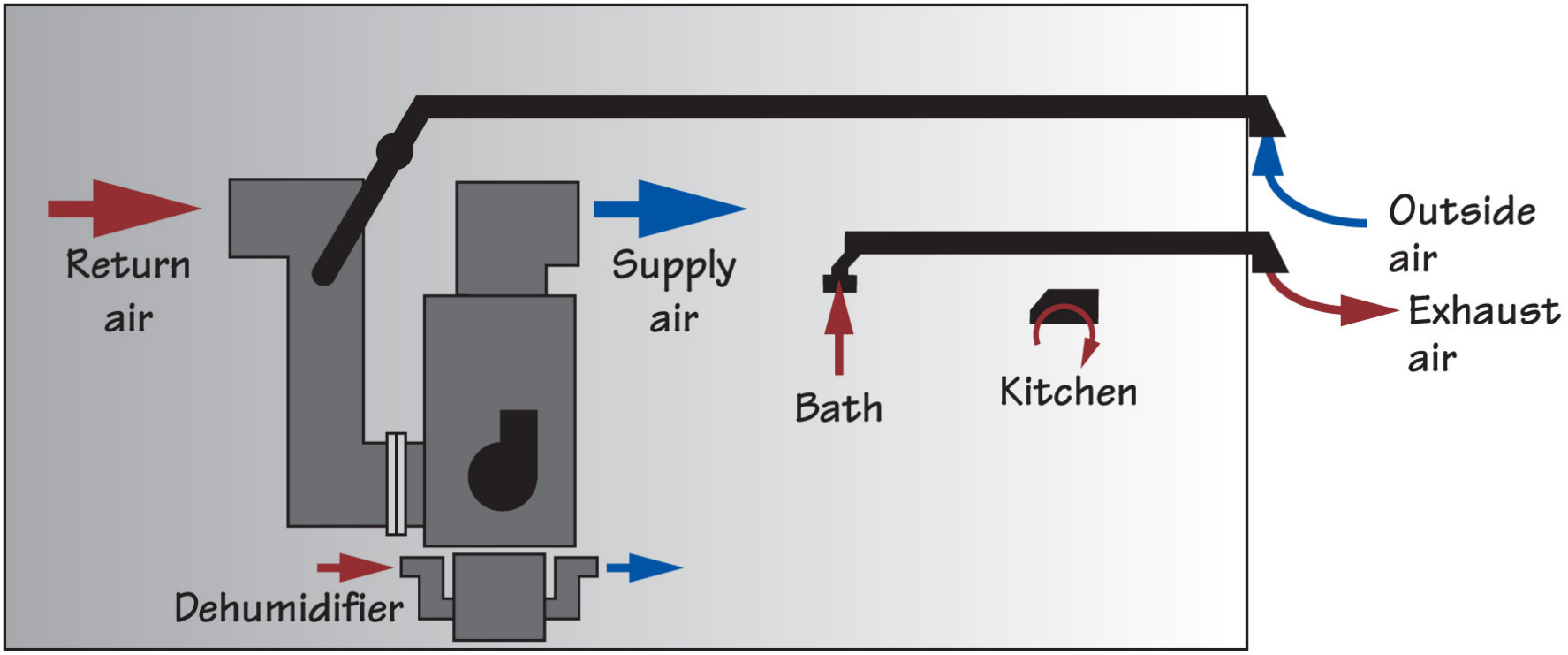
Reduced Individual Unit Stack Effect

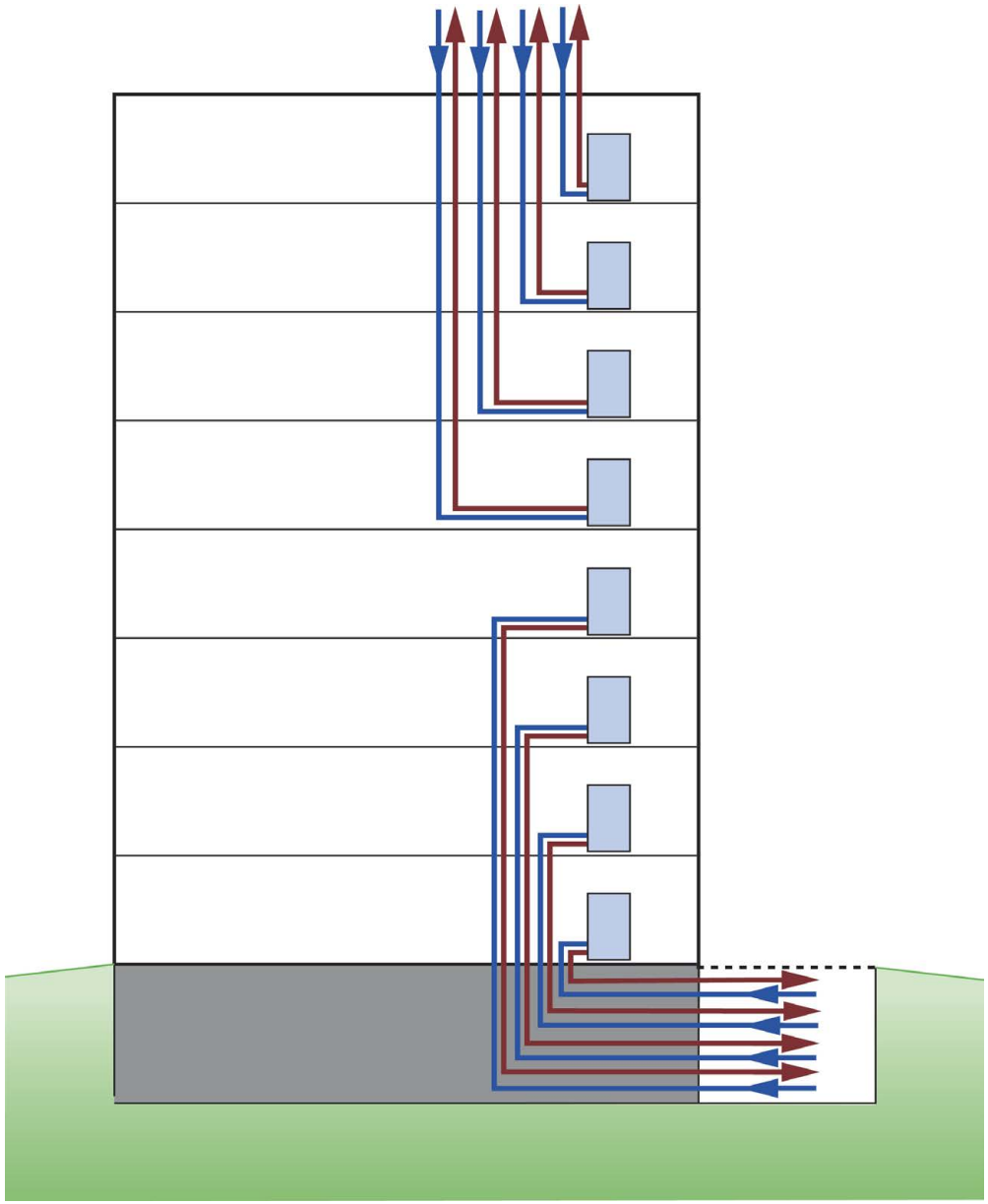


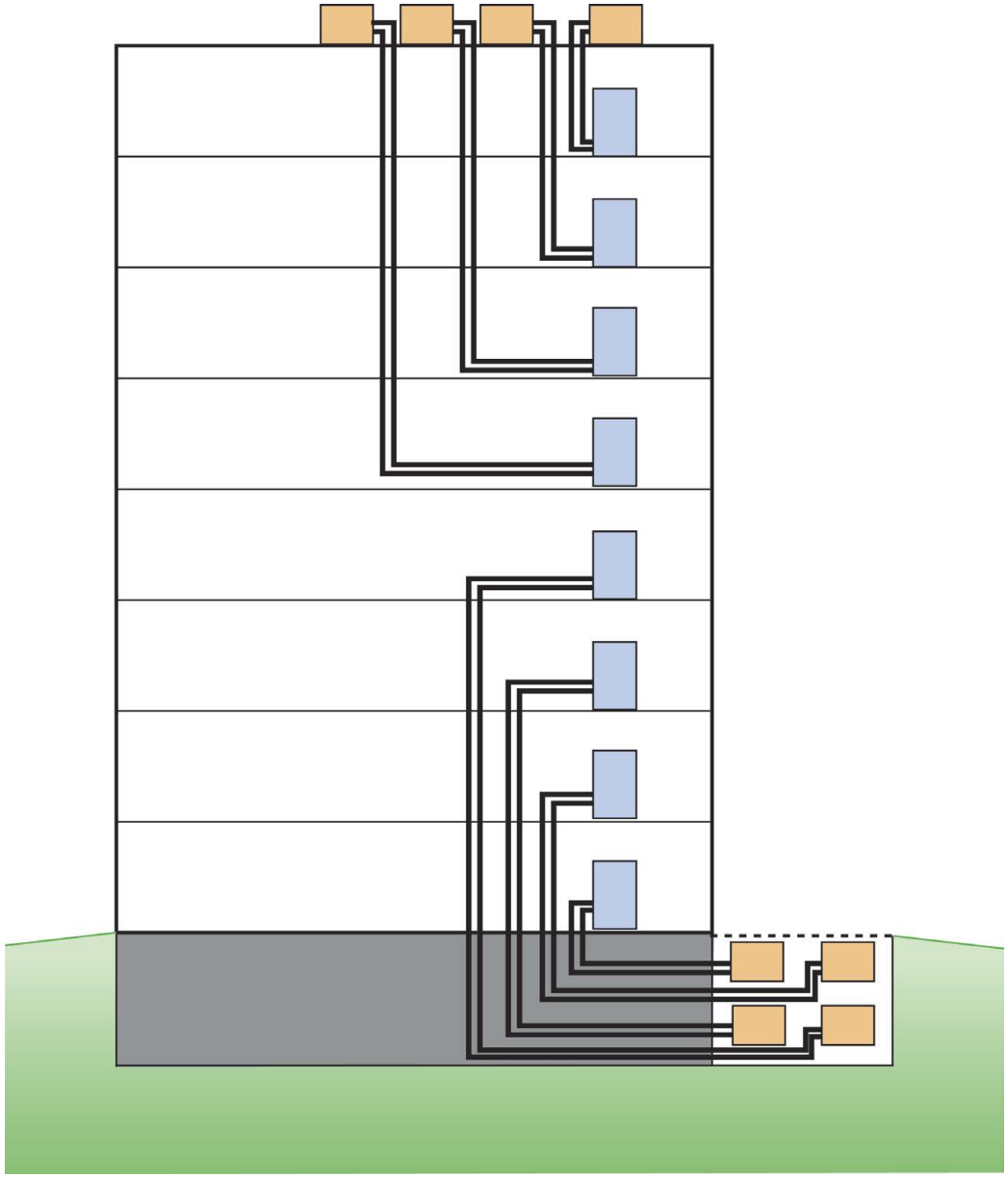


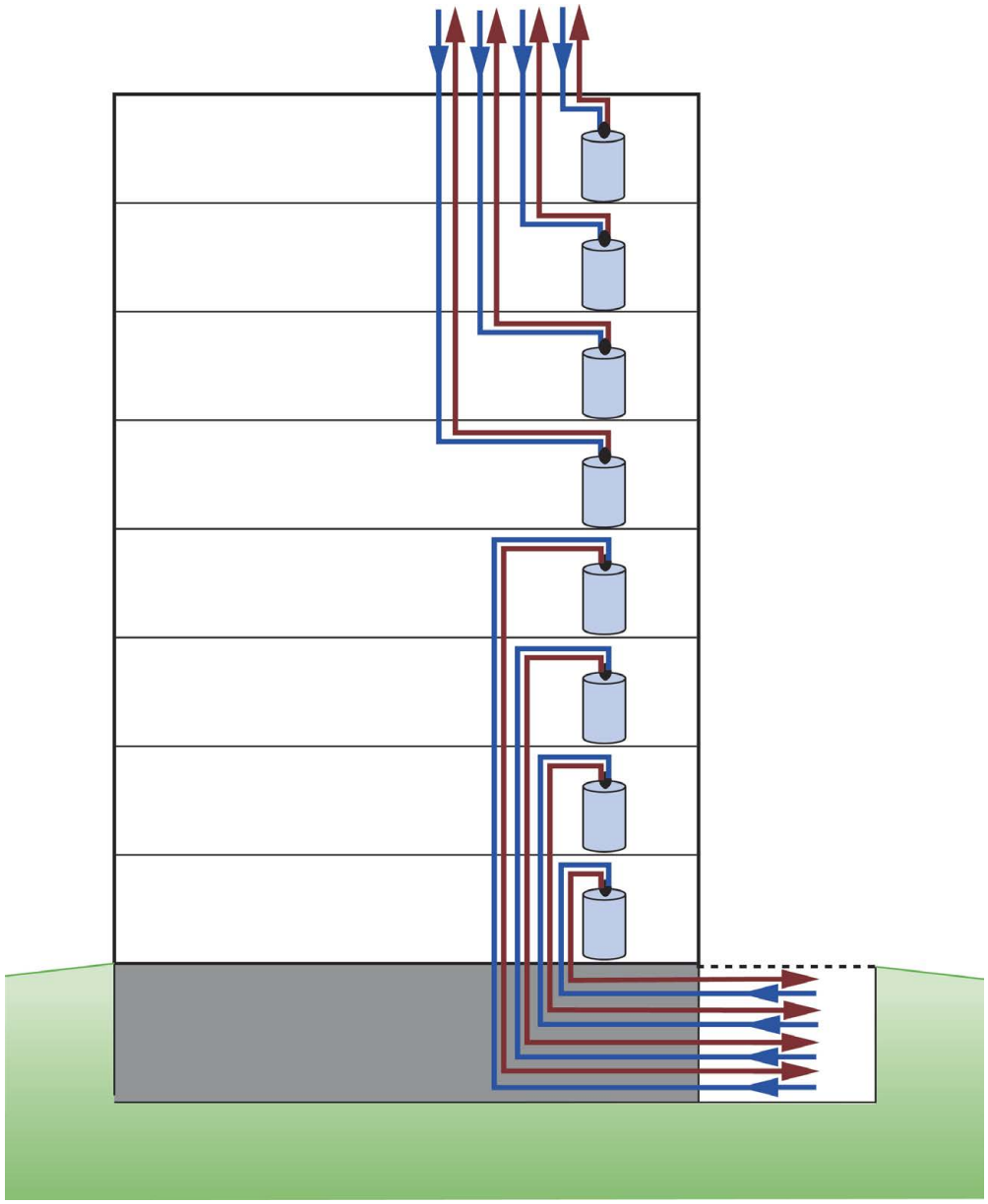



Return
air
Supply
air
Bath
Kitchen
Outside
air
Exhaust
air


Return air
Supply air
Outside air
Exhaust air
Bath
Kitchen
Dehumidifier





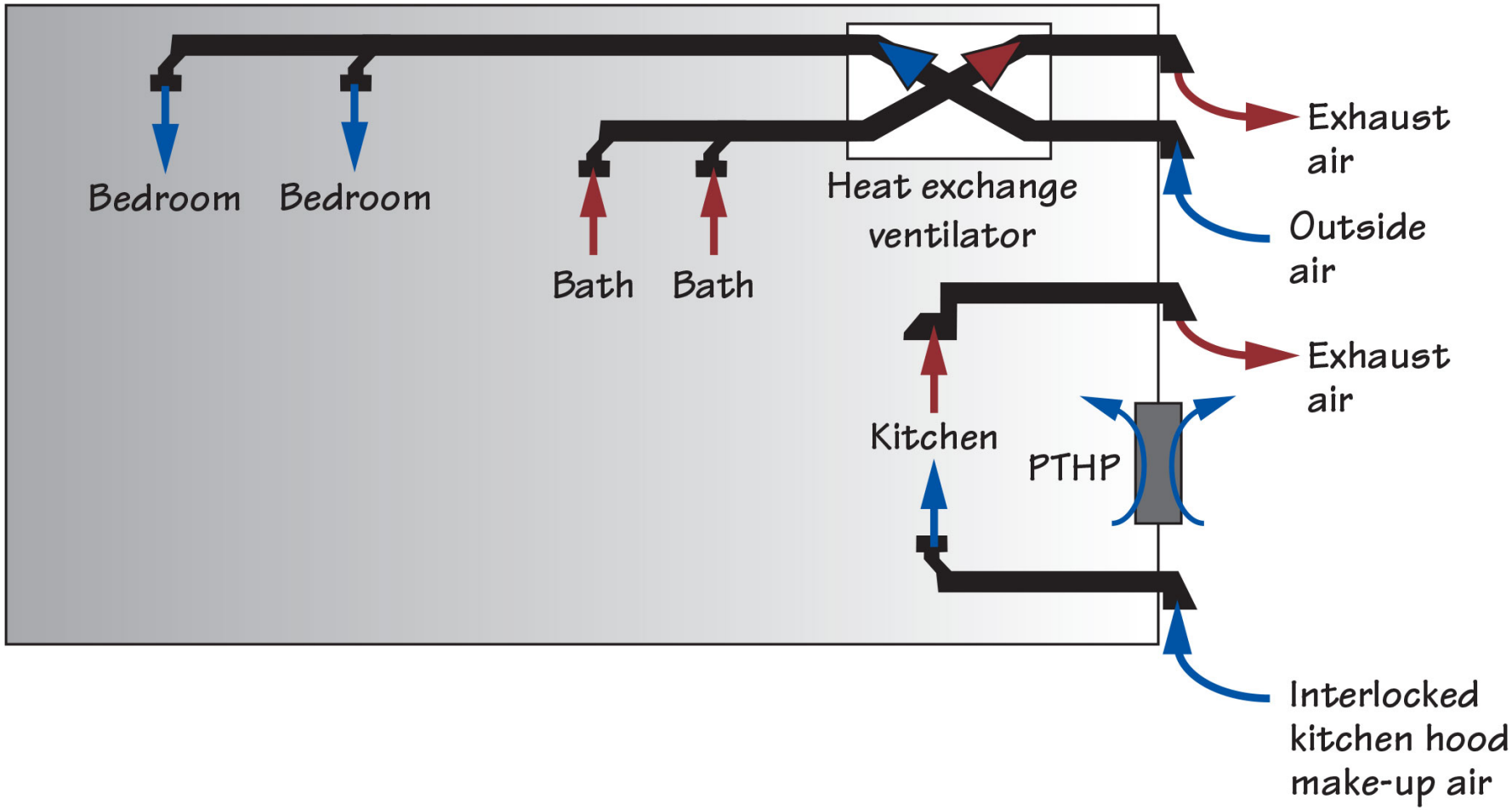


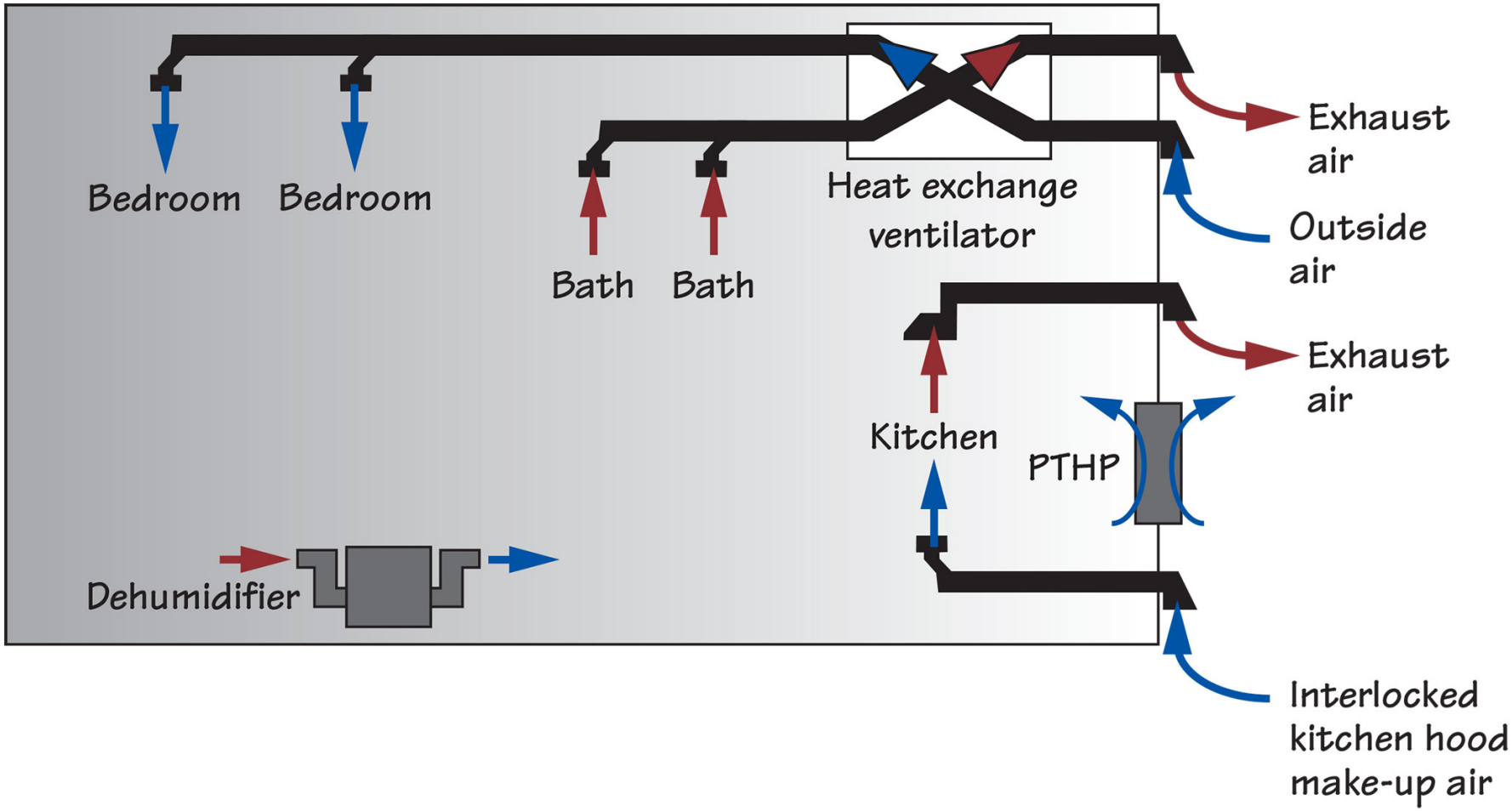

HOT WATER


YORK
YORK


Goodman
Goodman
Goodman

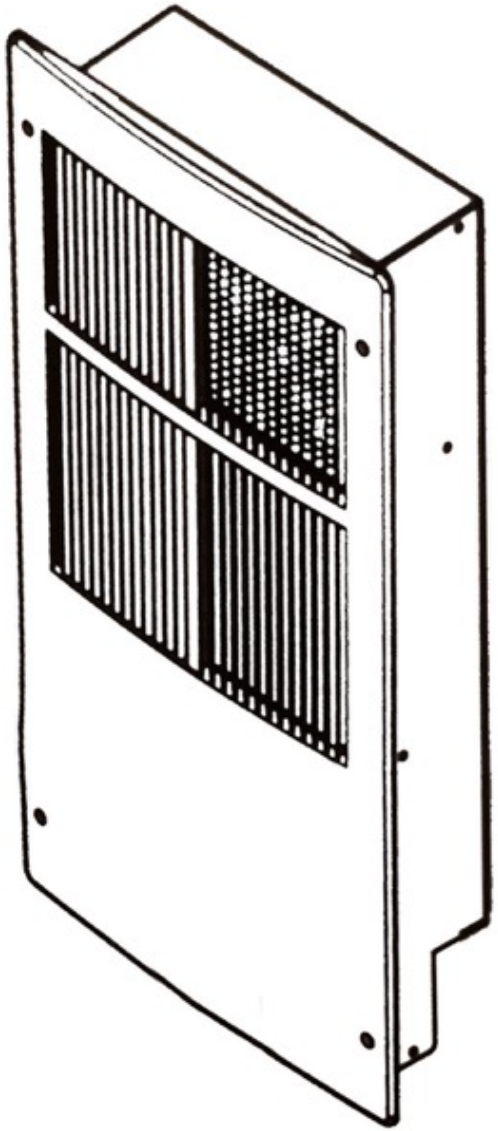

EASTERN
Carrier


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

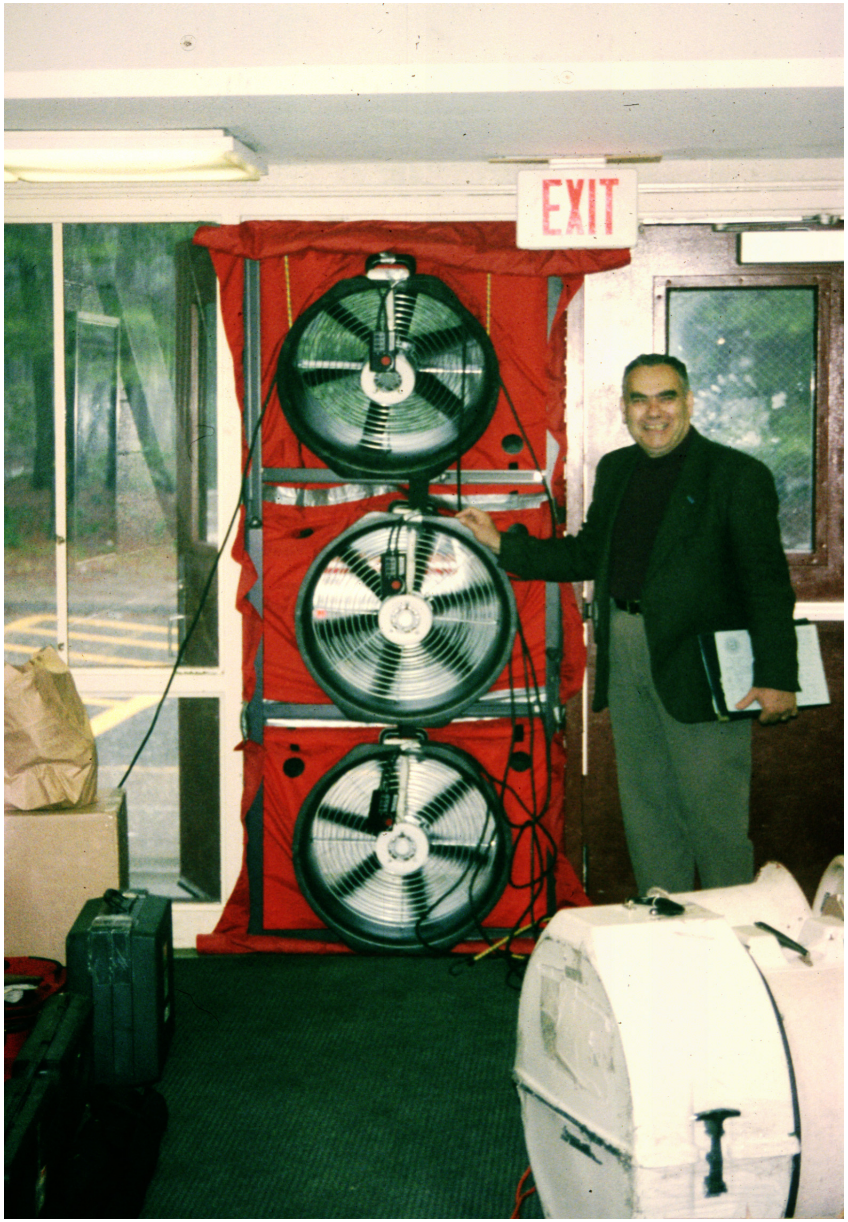

Bedroom
Bedroom
Bath
Bath
Heat exchange ventilator
Exhaust air
Outside air
Exhaust air
Kitchen
PTHP
Dehumidifier
Interlocked kitchen hood make-up air


ASKO
ASKO
ENERGUIDE
209


MAXIMUM

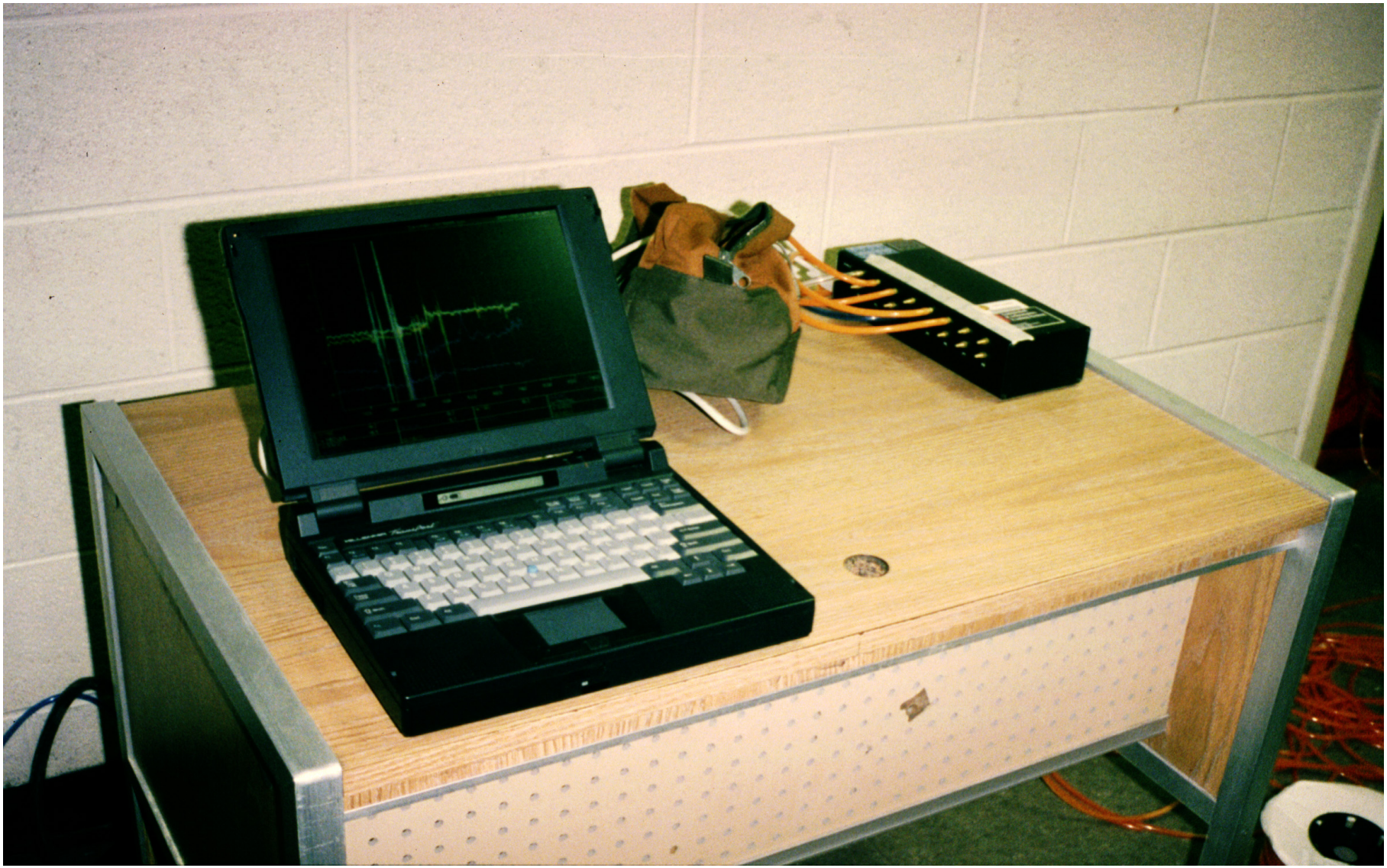


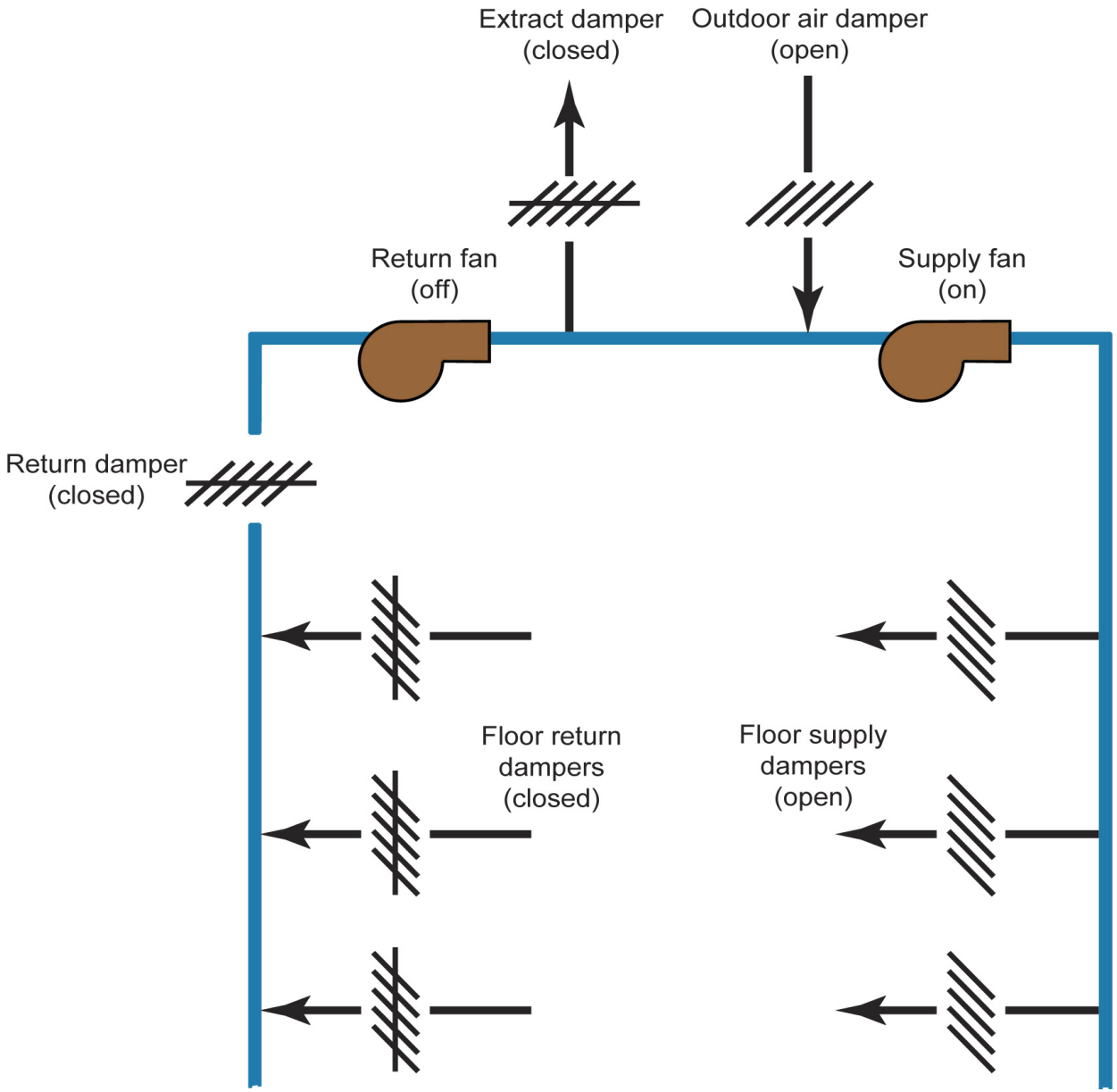

WESTFORD
ACADEMY

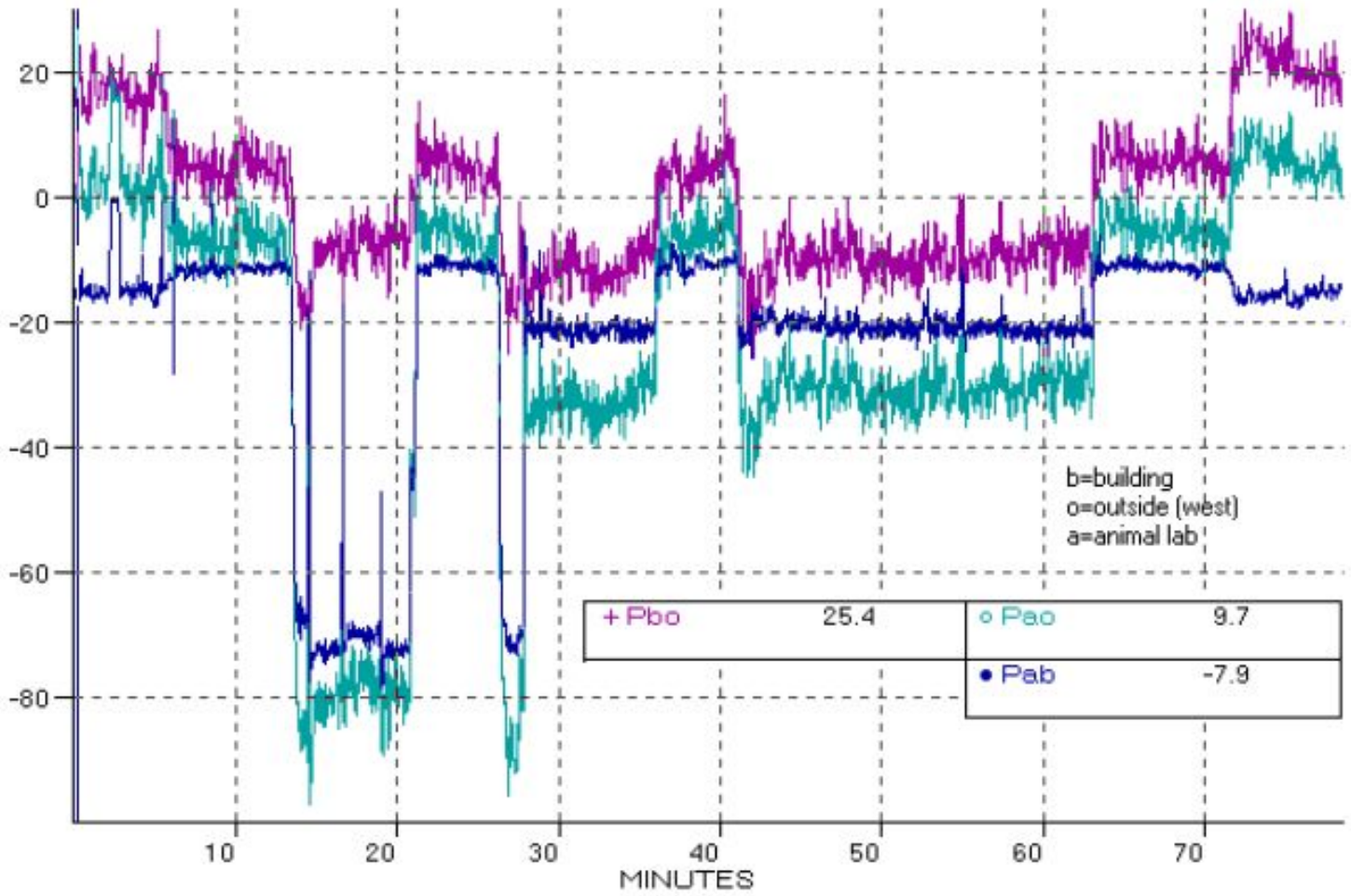

EXIT

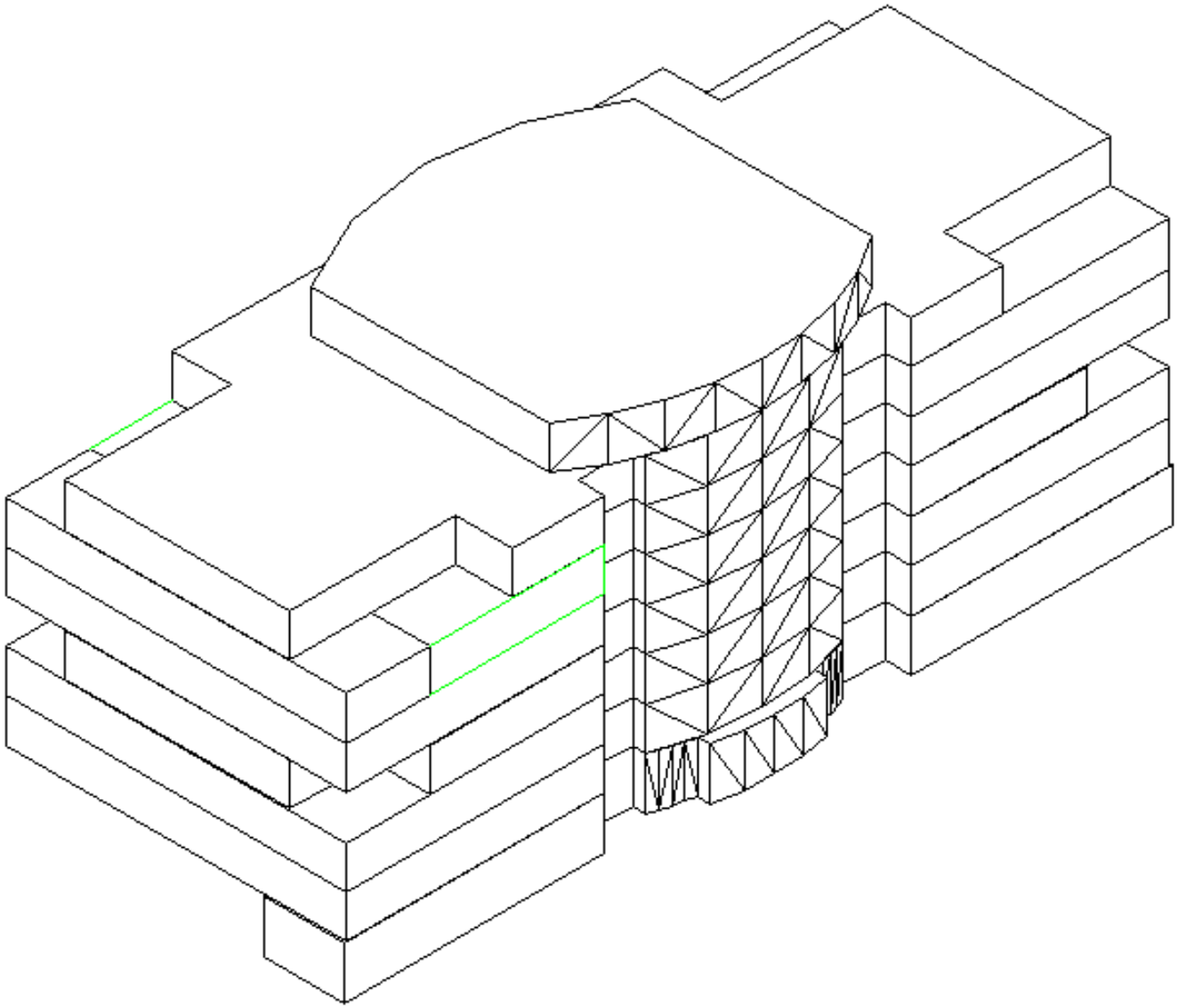

EXIT
Science

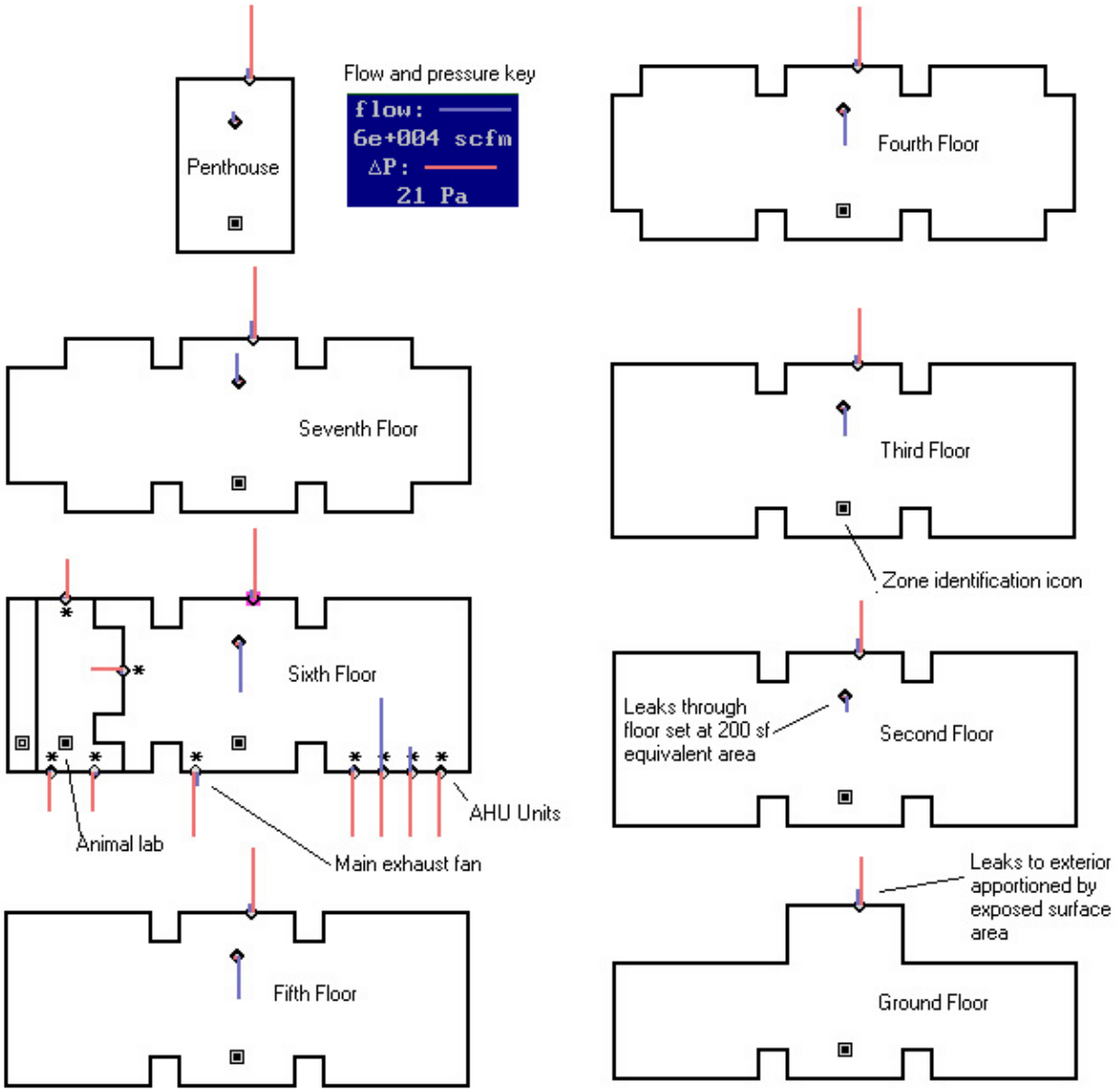

Shriners Hospitals for Crippled Children
Galveston Burns Institute
STOP
MAIN ENTRANCE




Extract damper
(closed)
Outdoor air damper
(open)
Return fan
(off)
Supply fan
(on)
Return damper
(closed)
Floor return
dampers
(closed)
Floor supply
dampers
(open)


20
0
-20
-40
-60
-80
10
20
30
40
50
60
70
MINUTES
b=building
o=outside (west)
a=animal lab
+ Pbo 25.4
○ Pao 9.7
● Pab -7.9




Penthouse
Flow and pressure key
flow:
6e+004 scfm
ΔP:
21 Pa
Fourth Floor
Seventh Floor
Third Floor
Zone identification icon
Sixth Floor
Leaks through
floor set at 200 sf
equivalent area
Second Floor
AHU Units
Animal lab
Main exhaust fan
Leaks to exterior
apportioned by
exposed surface
area
Fifth Floor
Ground Floor

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

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

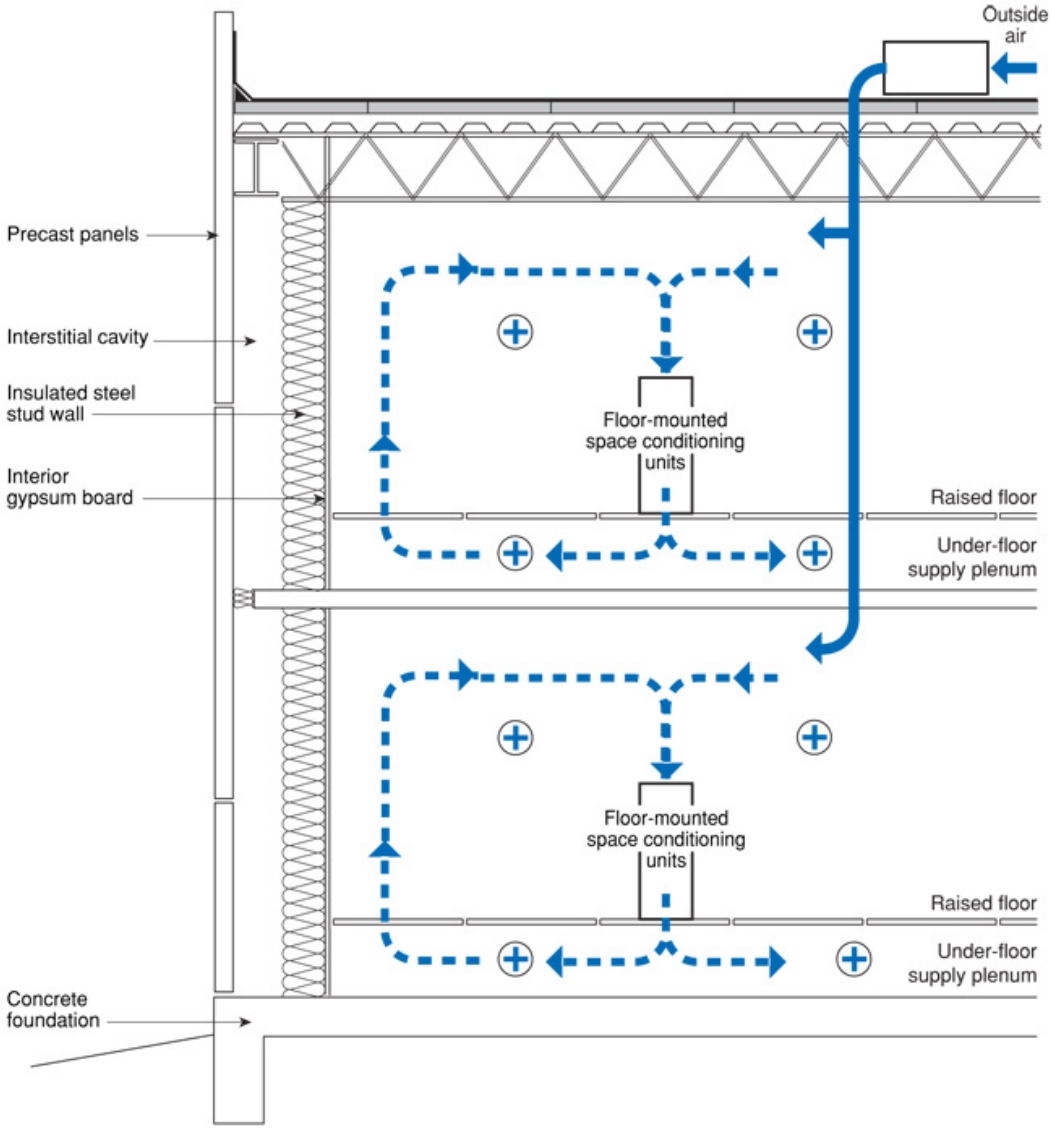


Figure 5.10
HVAC System as Designed

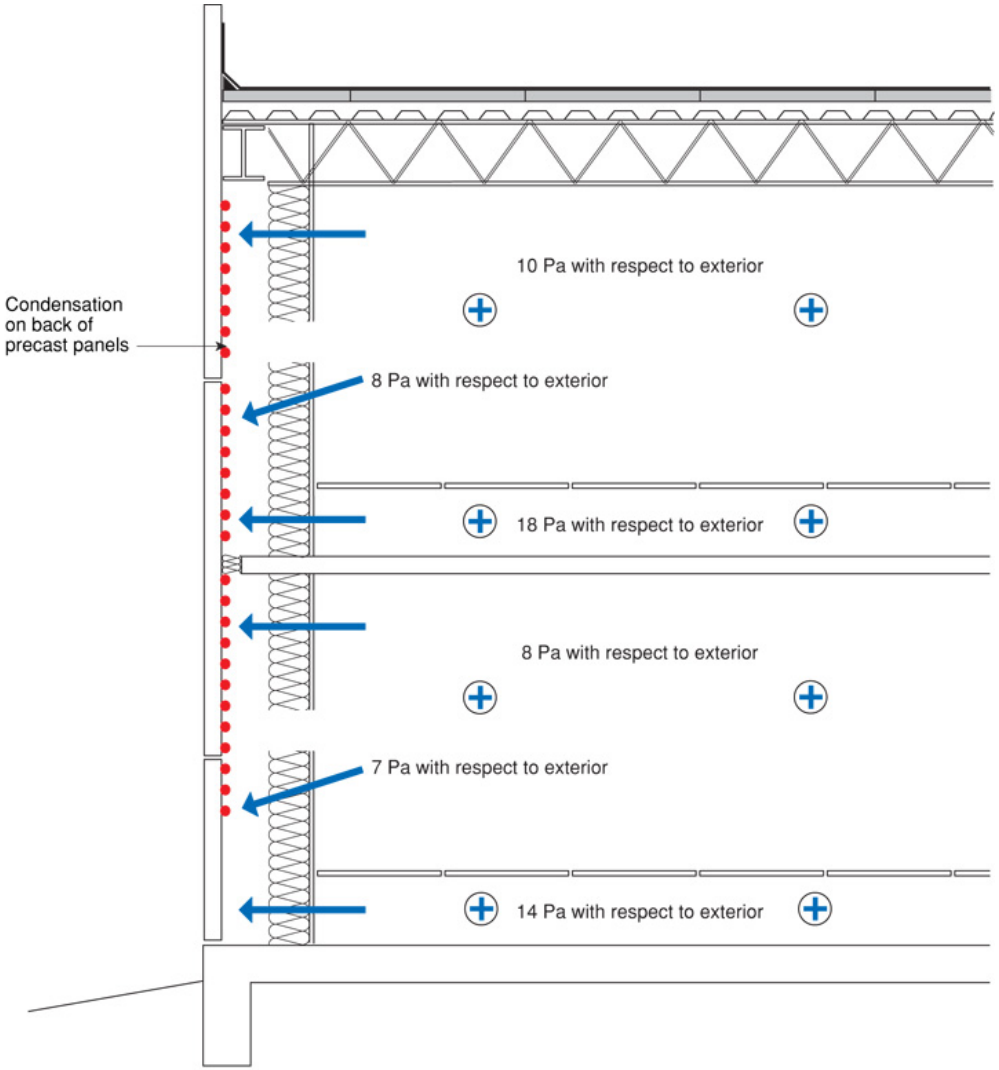


Figure 5.11
Unintended Pressurization of Interstitial Cavity

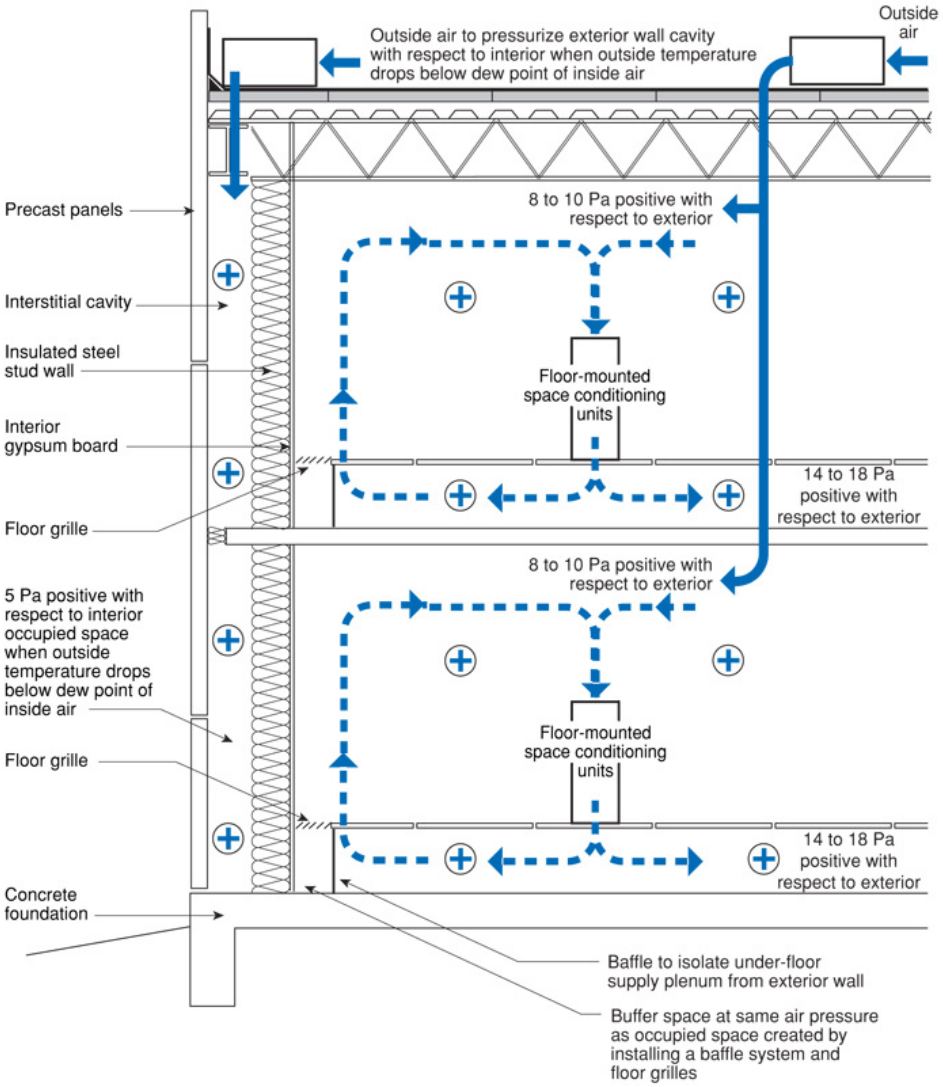
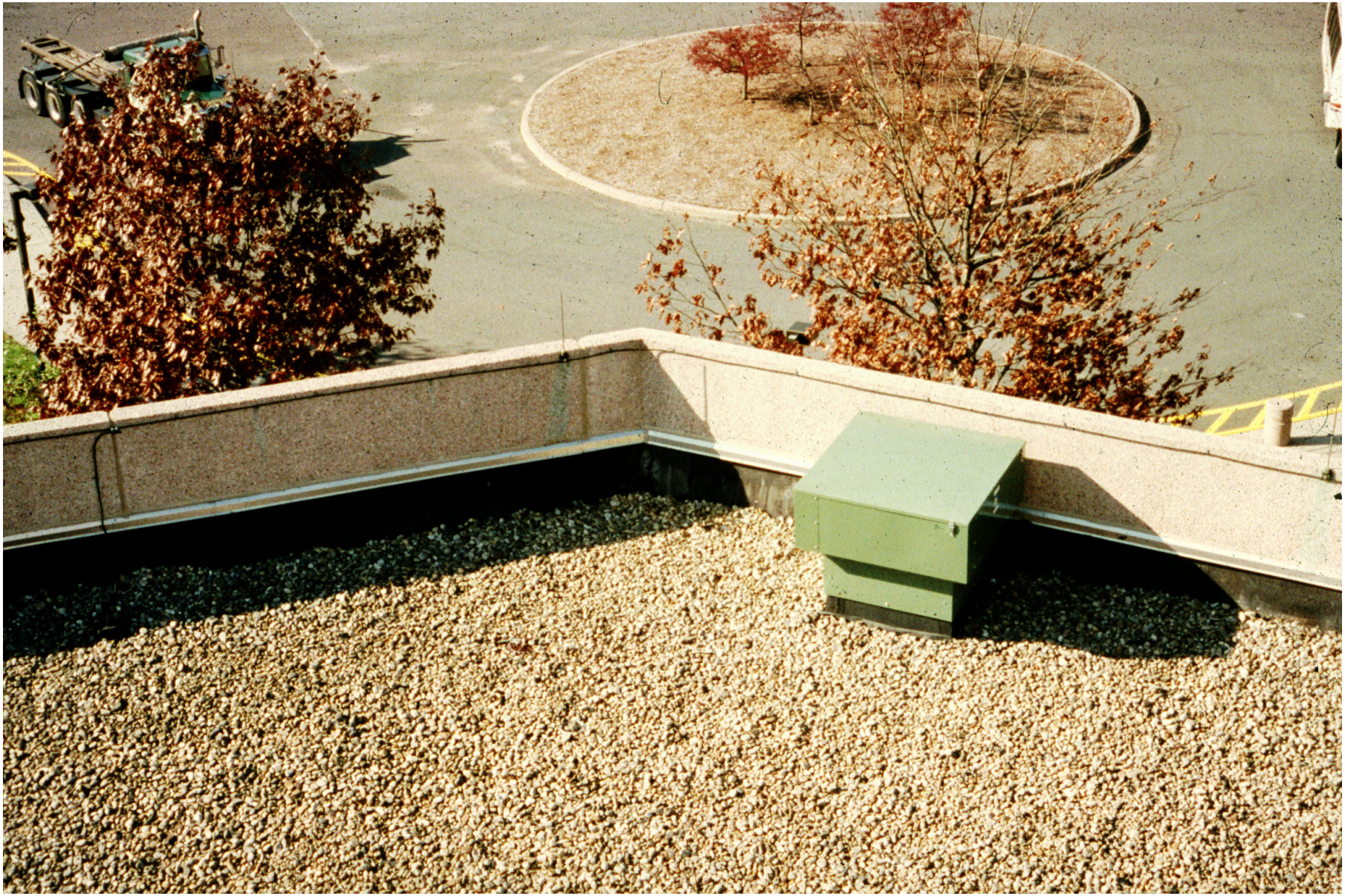
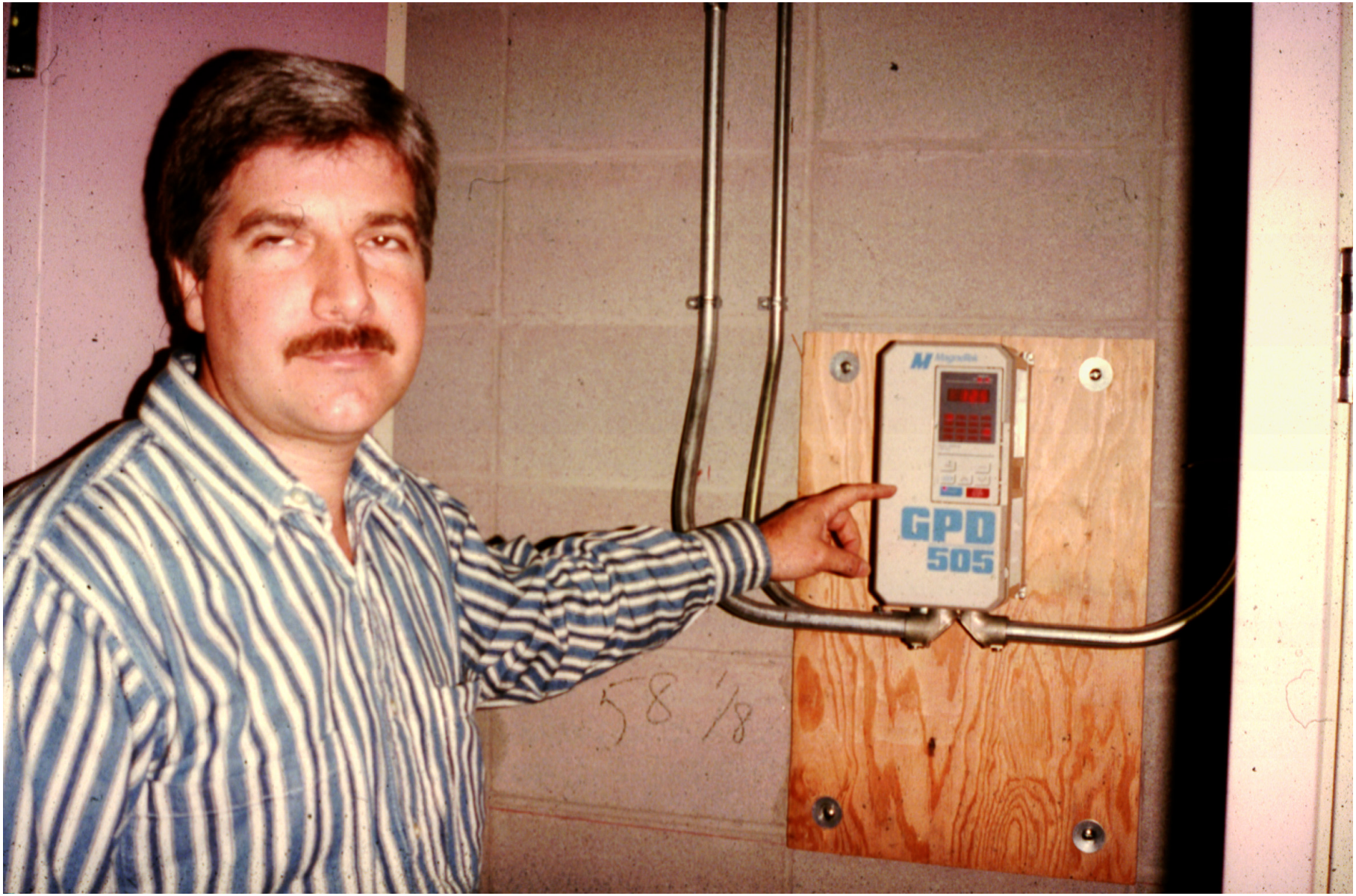


Figure 5.12
Modified Pressure Relationship



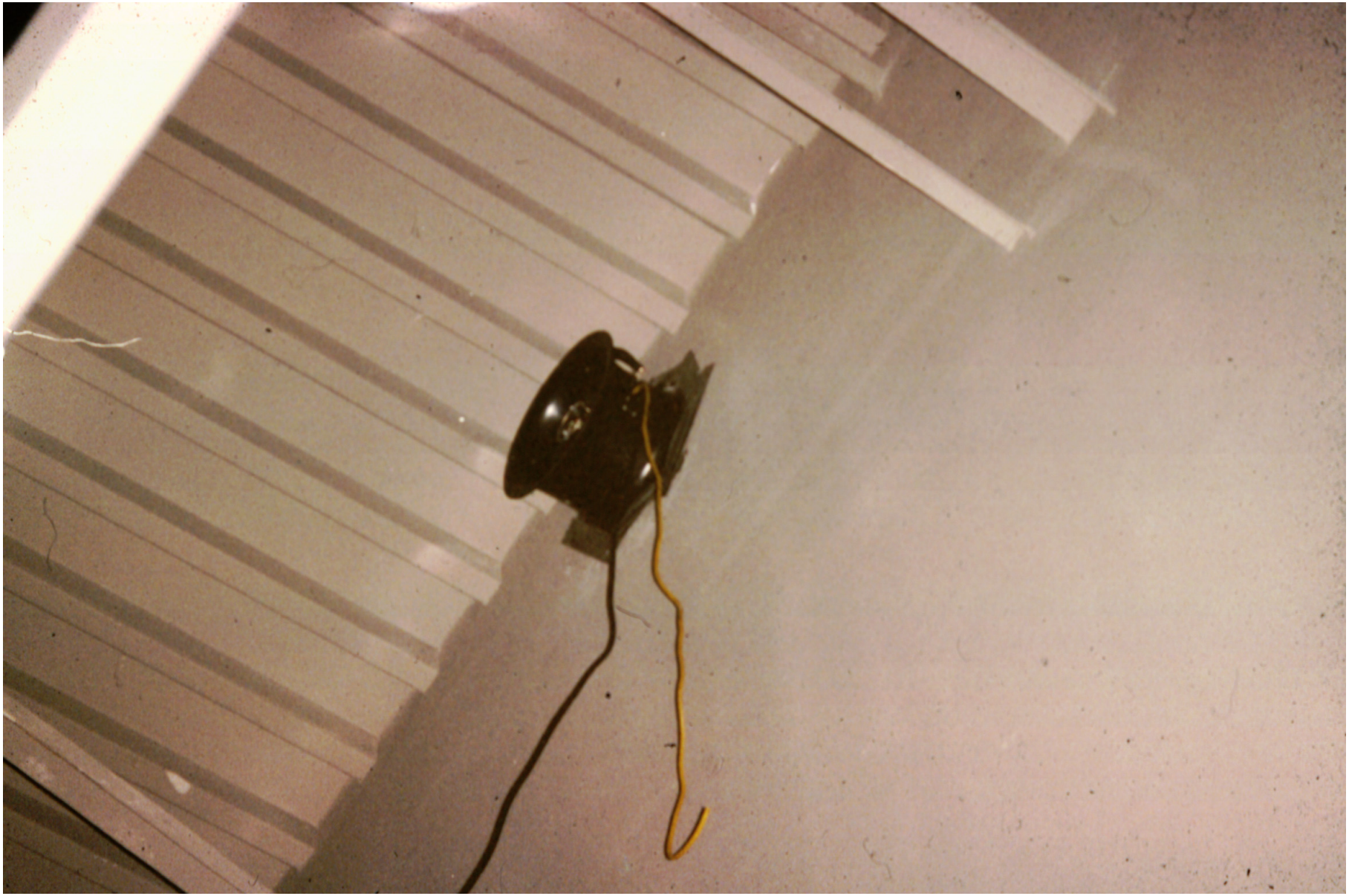

GPD
505


CABINET 32
CDP PRESSURIZATION FANS
EPSON

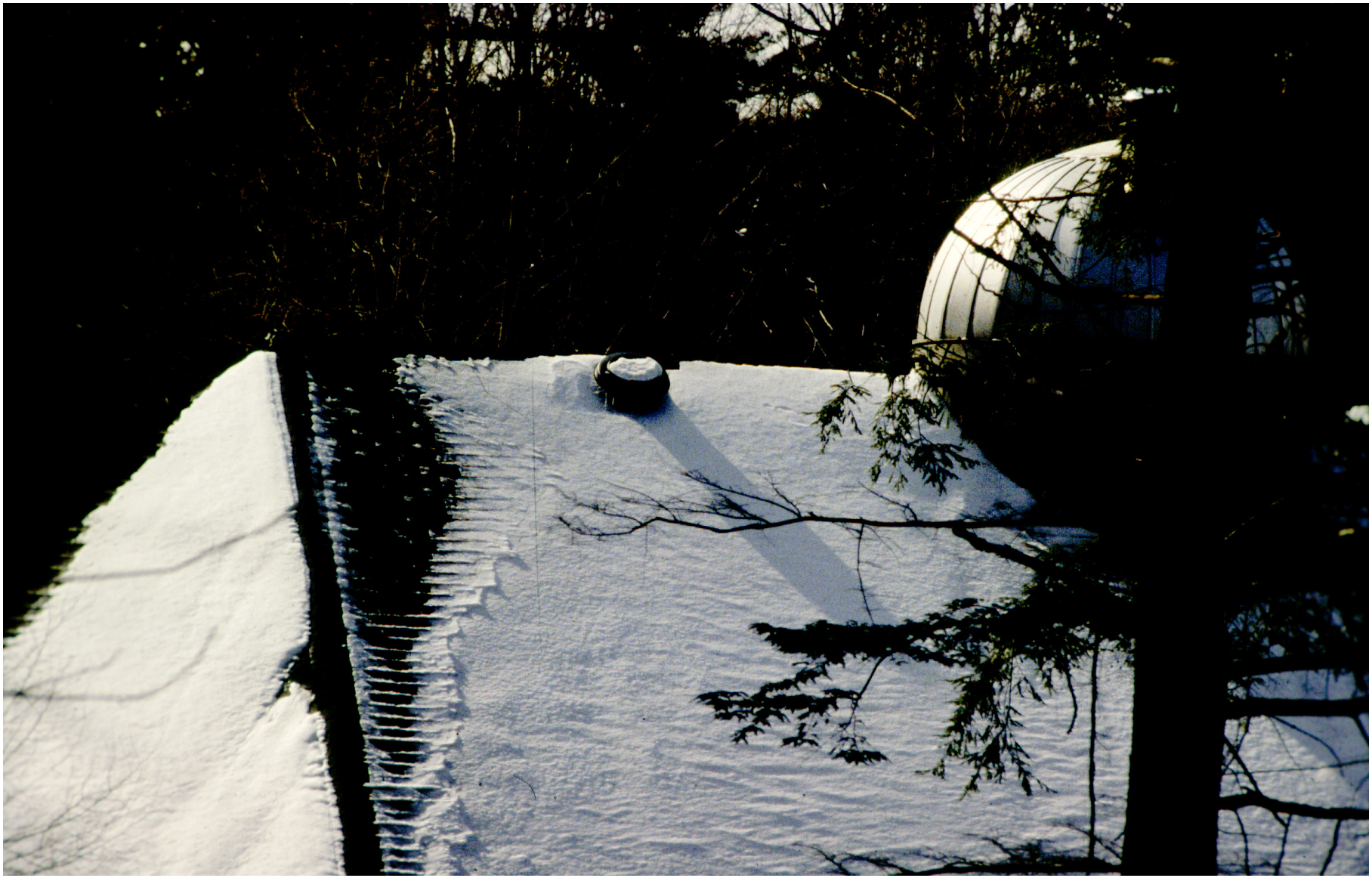

GIA MUSEUM of

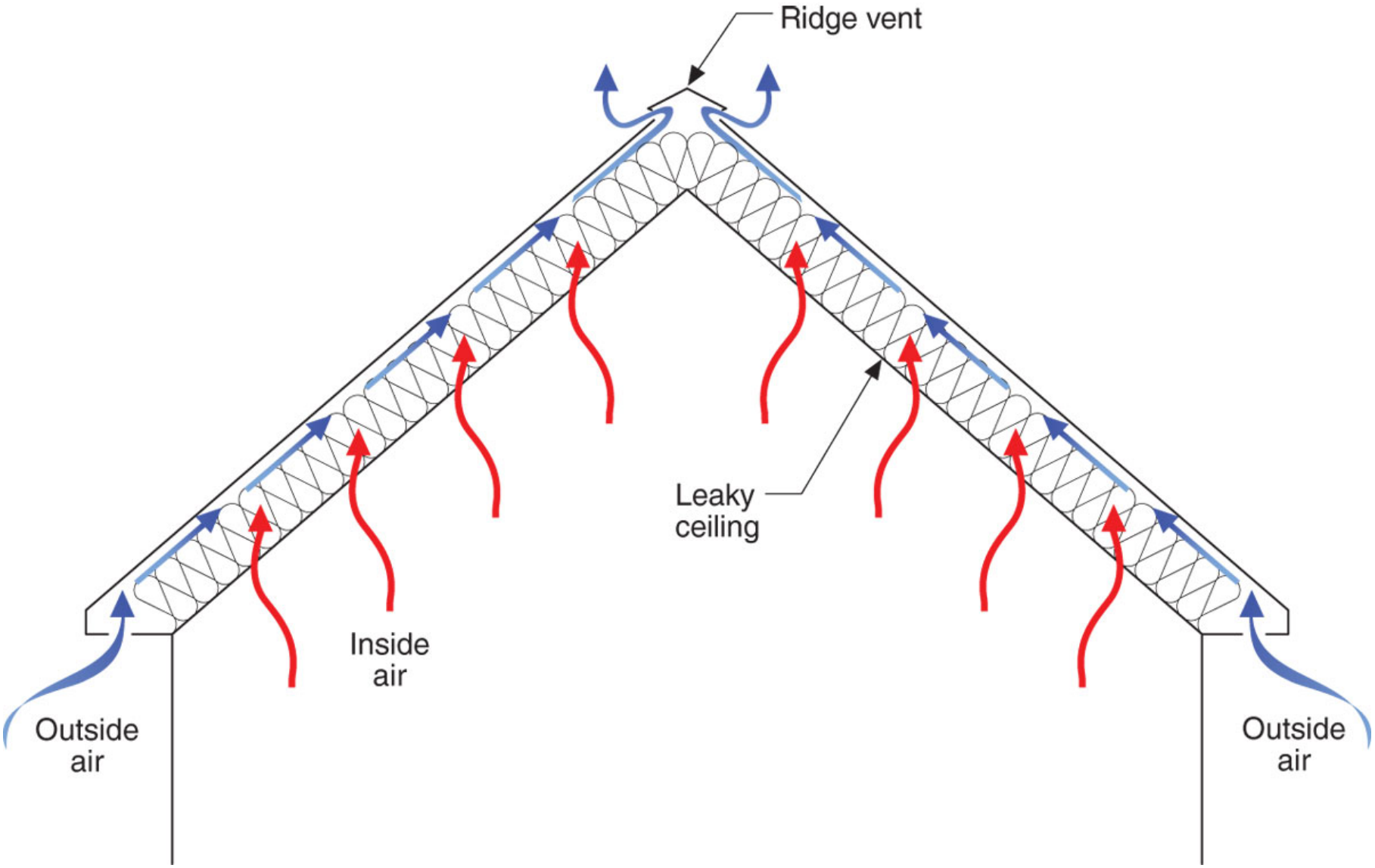

GEORGIA MUS

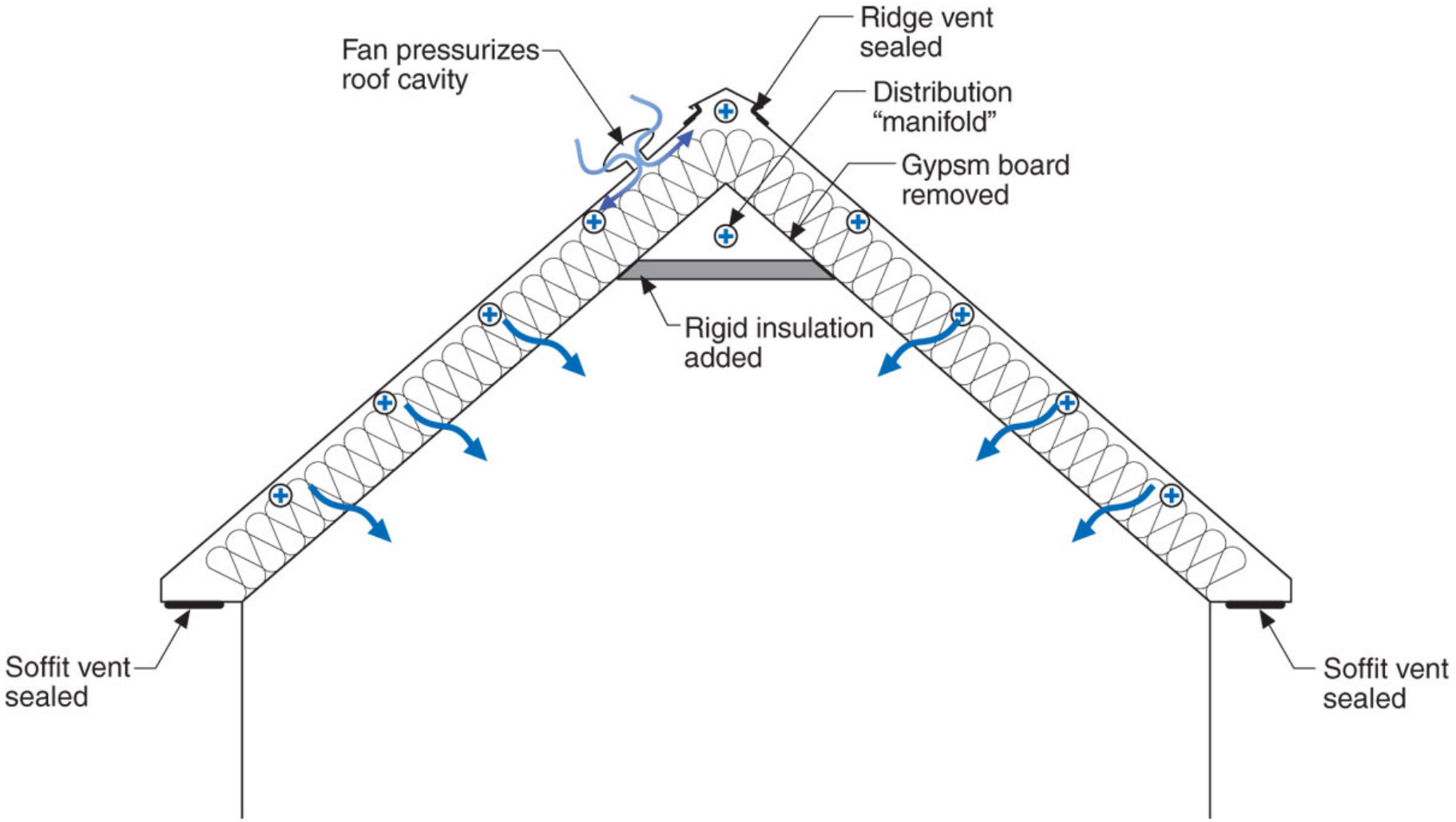

LABELWAGON 2000 XL

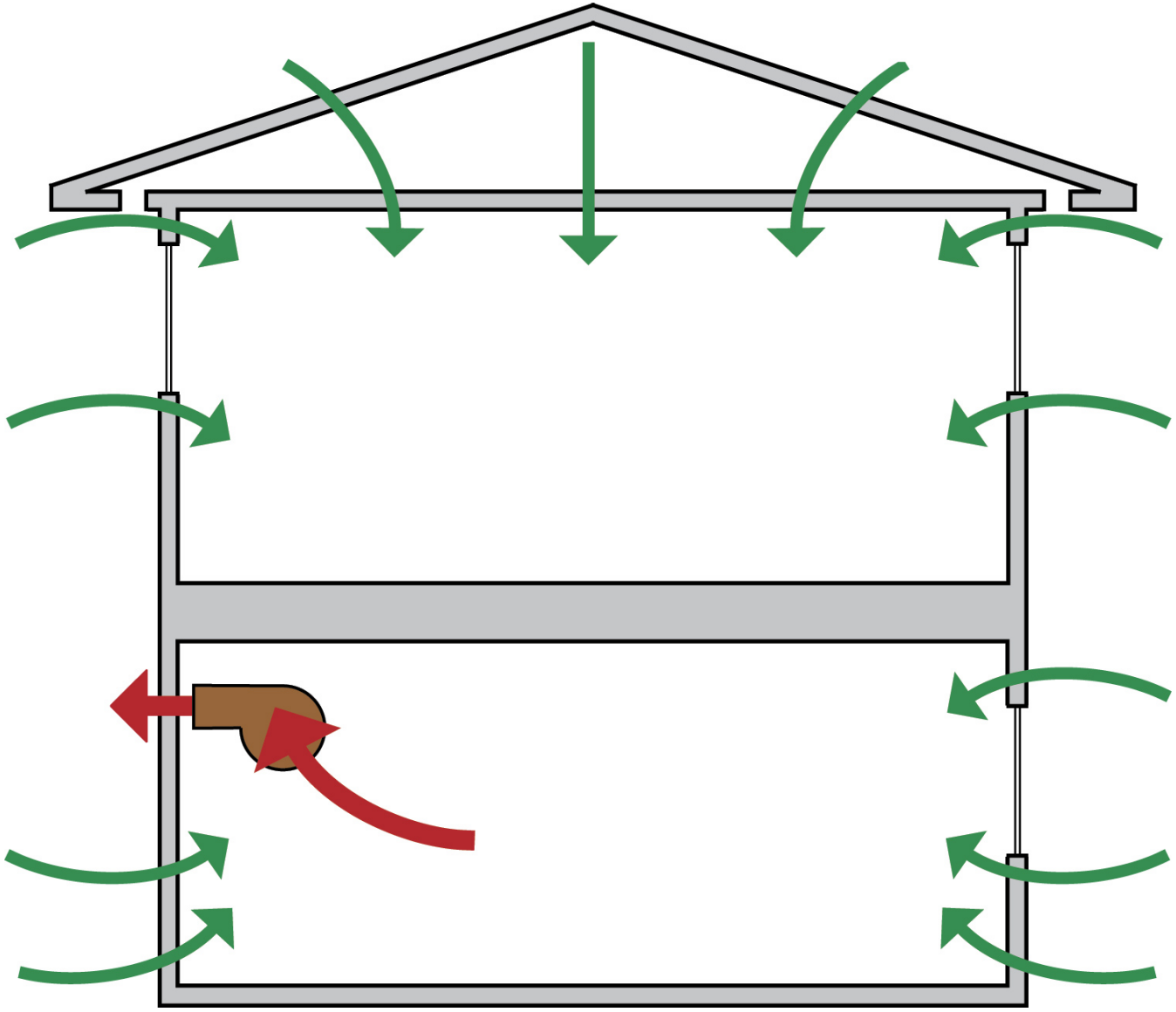



FLEXWRAP

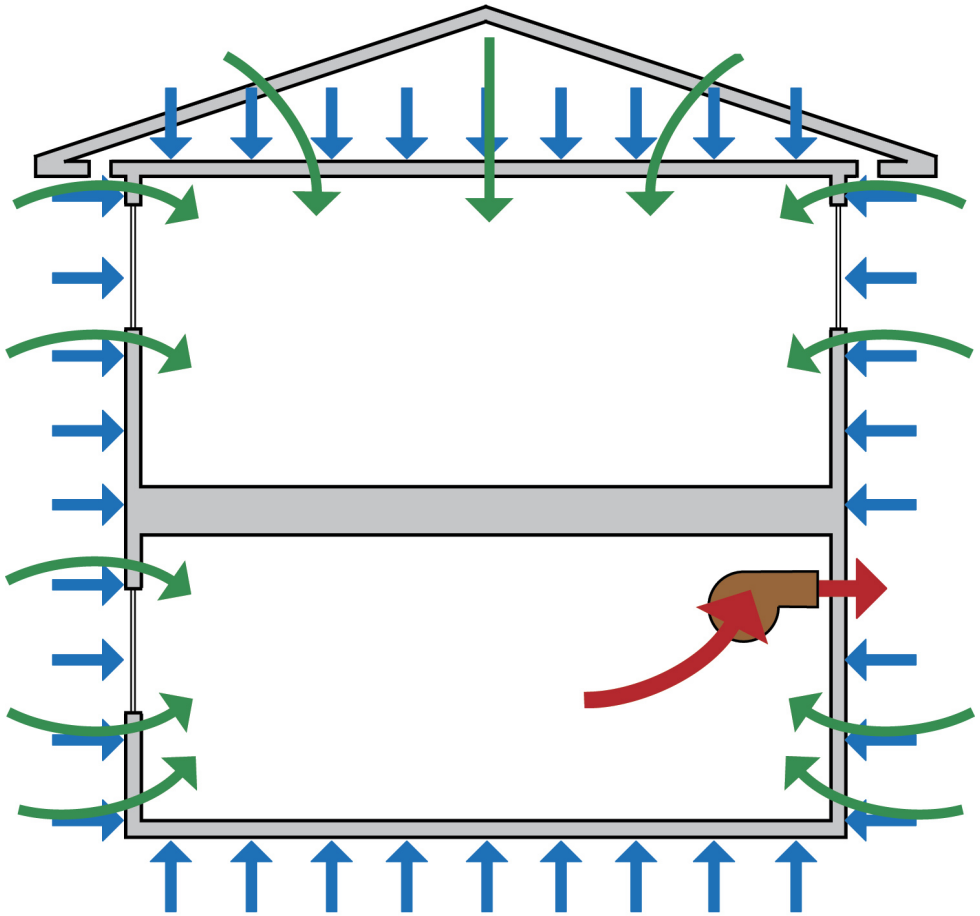



Ridge vent
Leaky ceiling
Inside air
Outside air
Outside air


Fan pressurizes roof cavity
Ridge vent sealed
Distribution "manifold"
Gypsm board removed
Rigid insulation added
Soffit vent sealed
Soffit vent sealed



$$ELA \approx C \times \frac{\text{Rate of flow}}{\sqrt{\text{Pressure difference}}}$$



$$(\text{Meters})^2 \approx \frac{1}{780} \times \frac{\text{Litres per second}}{\sqrt{\text{Pascals}}}$$