WJE

Moisture Problems in Building Envelopes

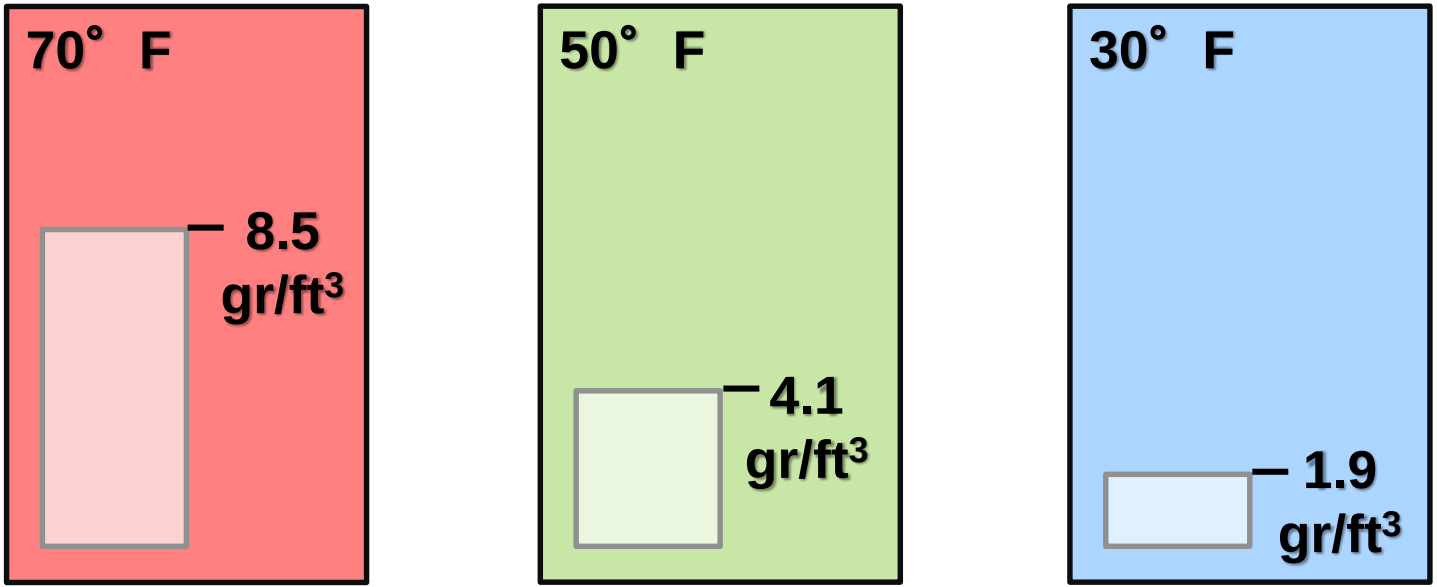
Norbert Krogstad
Principal

Learning Objectives

At the end of this program, participants will be able to:

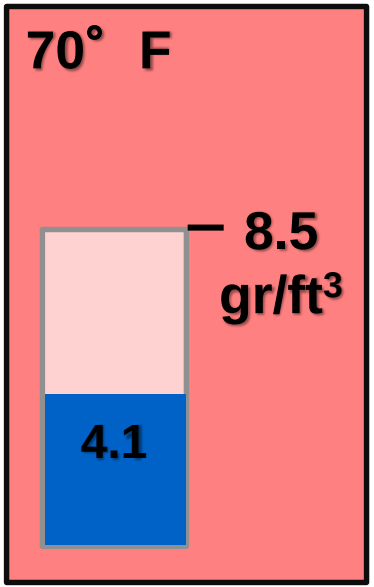
1. Understand the basic physics of condensation as it relates to buildings
2. Understand common causes of condensation problems in buildings.
3. Understand how condensation problems are caused by pressure differentials.
4. Learn to identify condensation problems and discuss some repair approaches through the use of case studies.

Moisture Capacity of Air

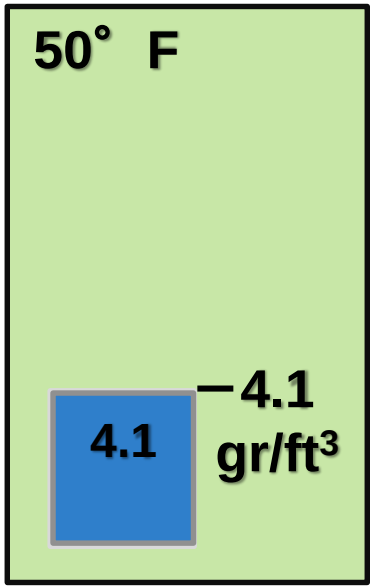


Warm air holds more water than cold air

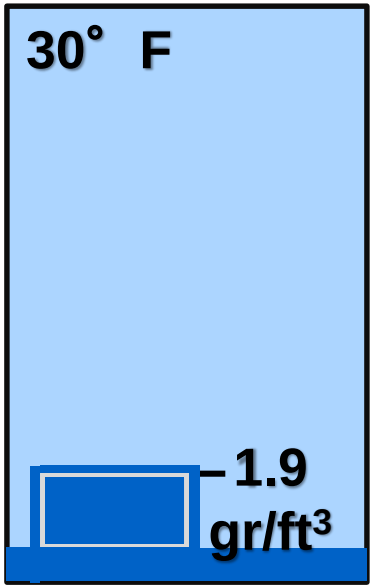
Moisture Capacity of Air



4.1/8.5 = 48% RH
Dew Point = 50° F



4.1/4.1 = 100% RH
Dew Point = 50° F



1.9/1.9 = 100% RH
Dew Point = 30° F

Moisture Deposition

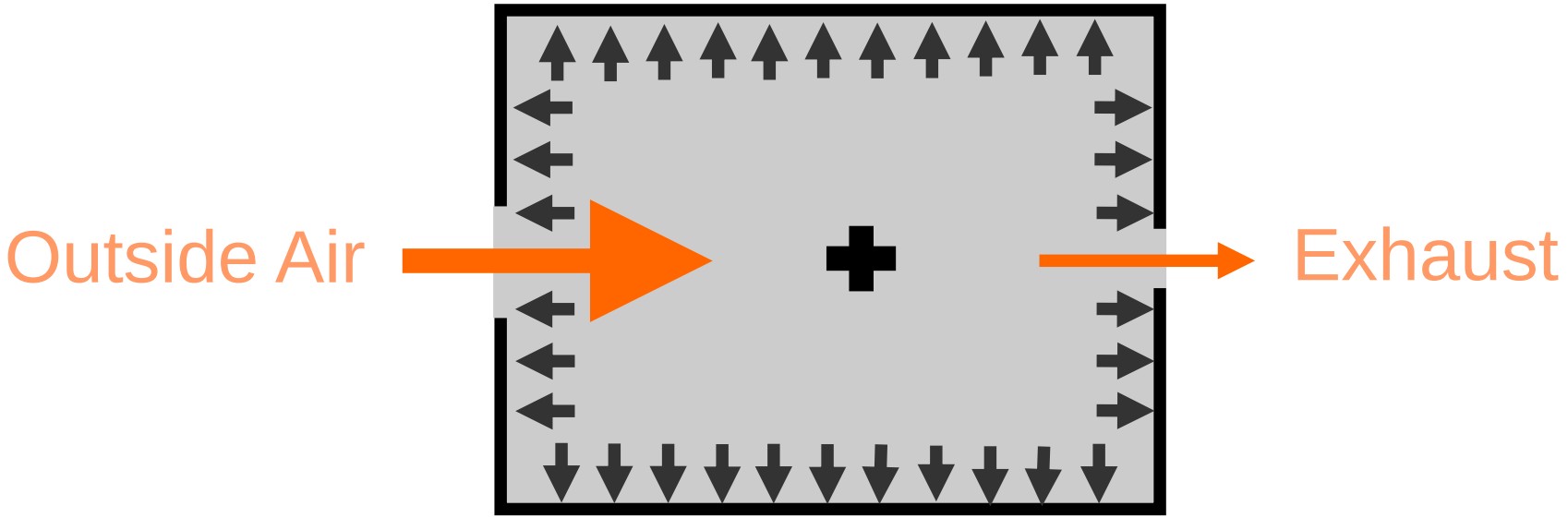
Cold objects will cool adjacent air. If these objects are colder than the dew point temperature of this, water from the air is deposited (condensation).

Dew Point is the Key Indicator

Temperature of Air	Relative Humidity	Dew Point
13 degrees F	100 percent	13 degrees F (0.85 gr/ft3)
70 degrees F	10 percent	13 degrees F (0.85 gr/ft3)
70 degrees F	24 percent	32 degrees F (2.03 gr/ft3)
70 degrees F	30 percent	38 degrees F (2.54 gr/ft3)
70 degrees F	40 percent	45 degrees F (3.39 gr/ft3)
70 degrees F	50 percent	51 degrees F (4.23 gr/ft3)

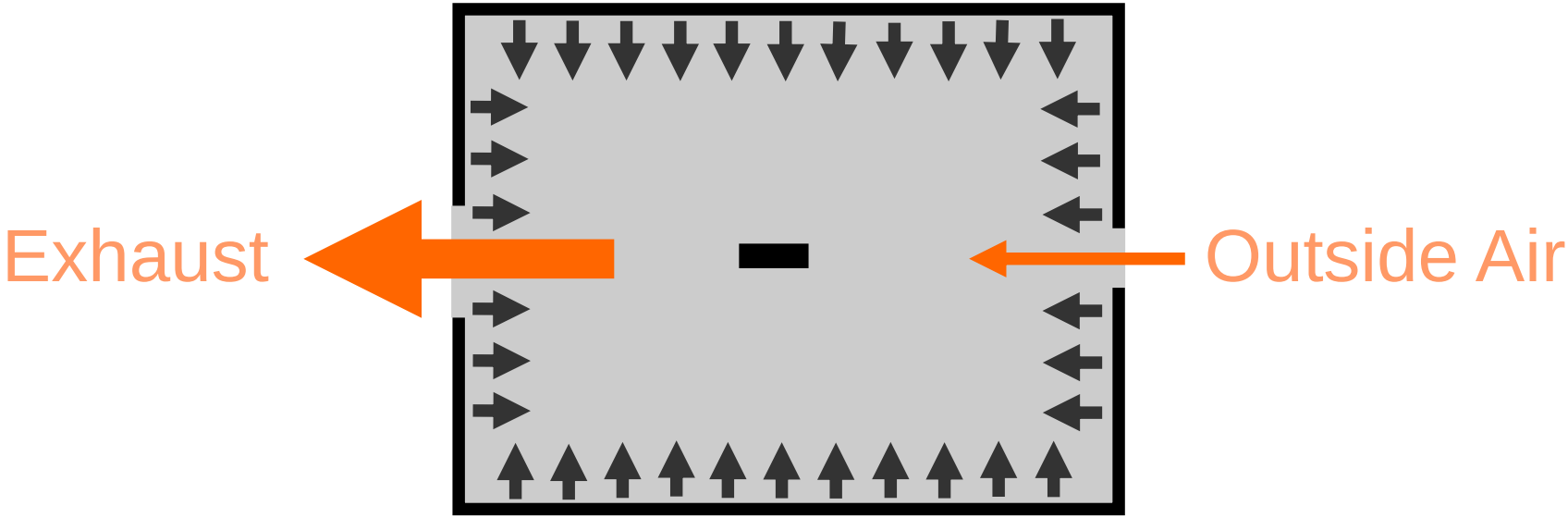
Mechanical System Pressurization

Positive Mechanical System Pressurization

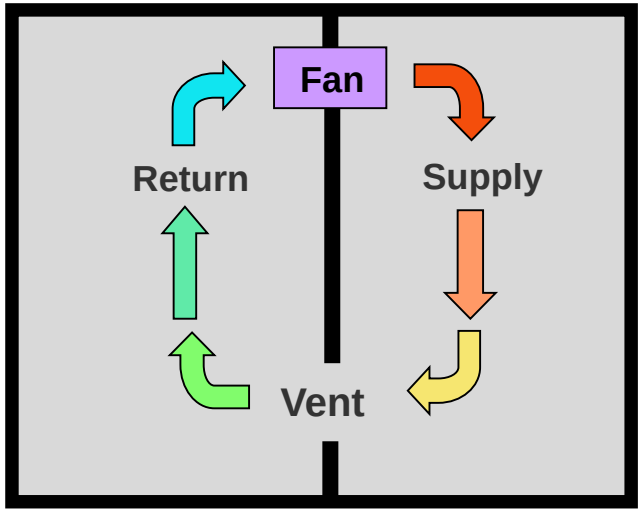


Mechanical System Pressurization

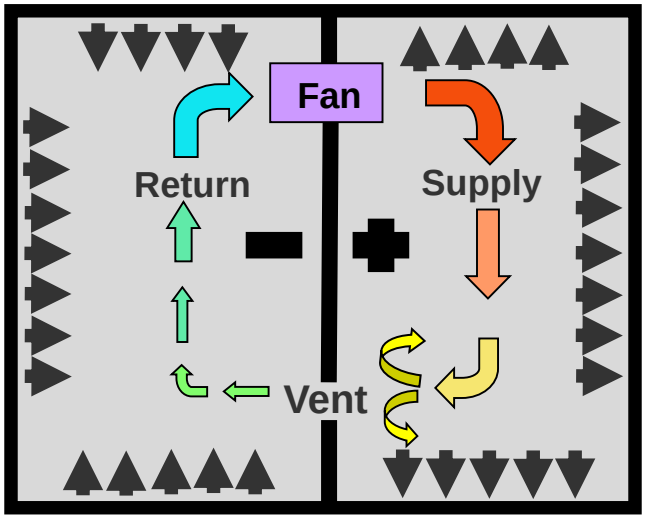
Negative Mechanical System Pressurization



Mechanical System Pressurization

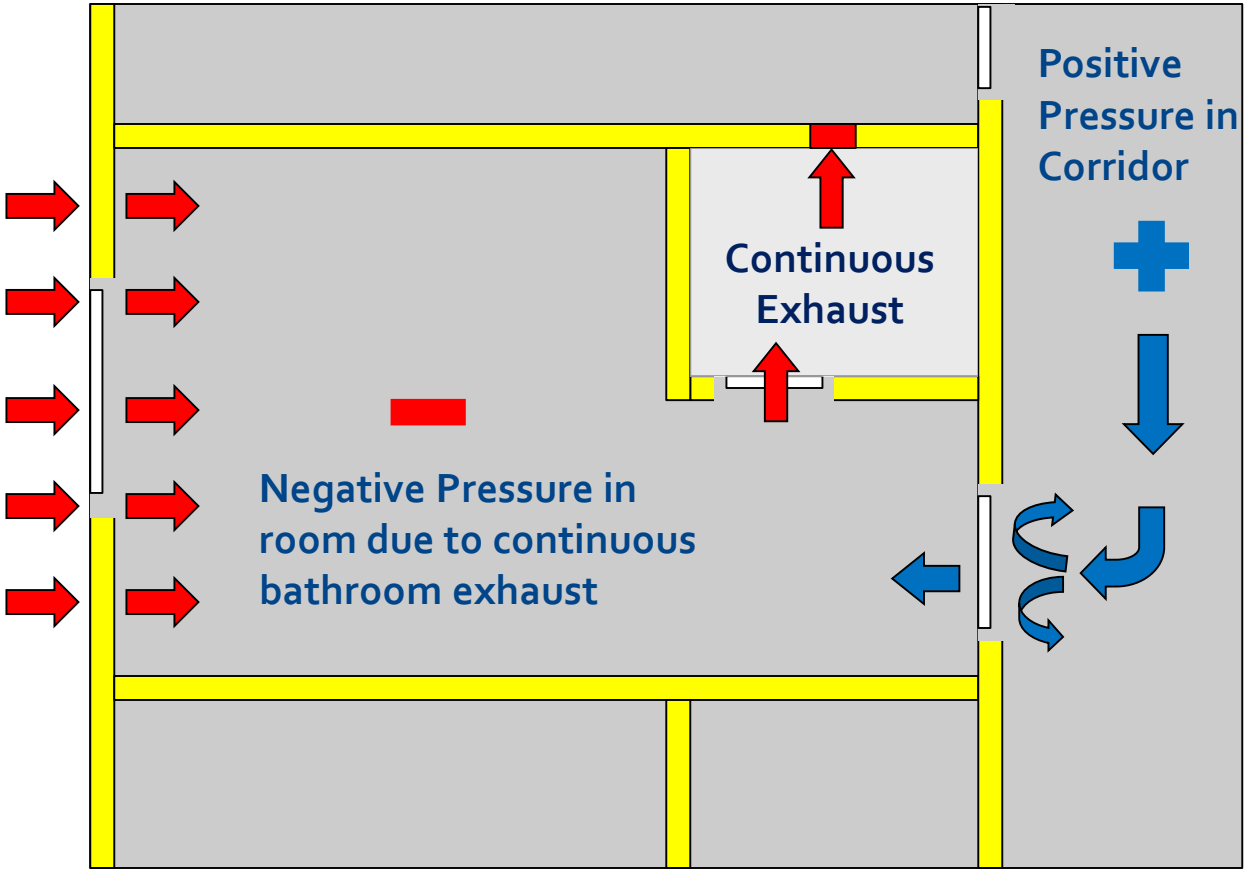


Return Air Unrestricted

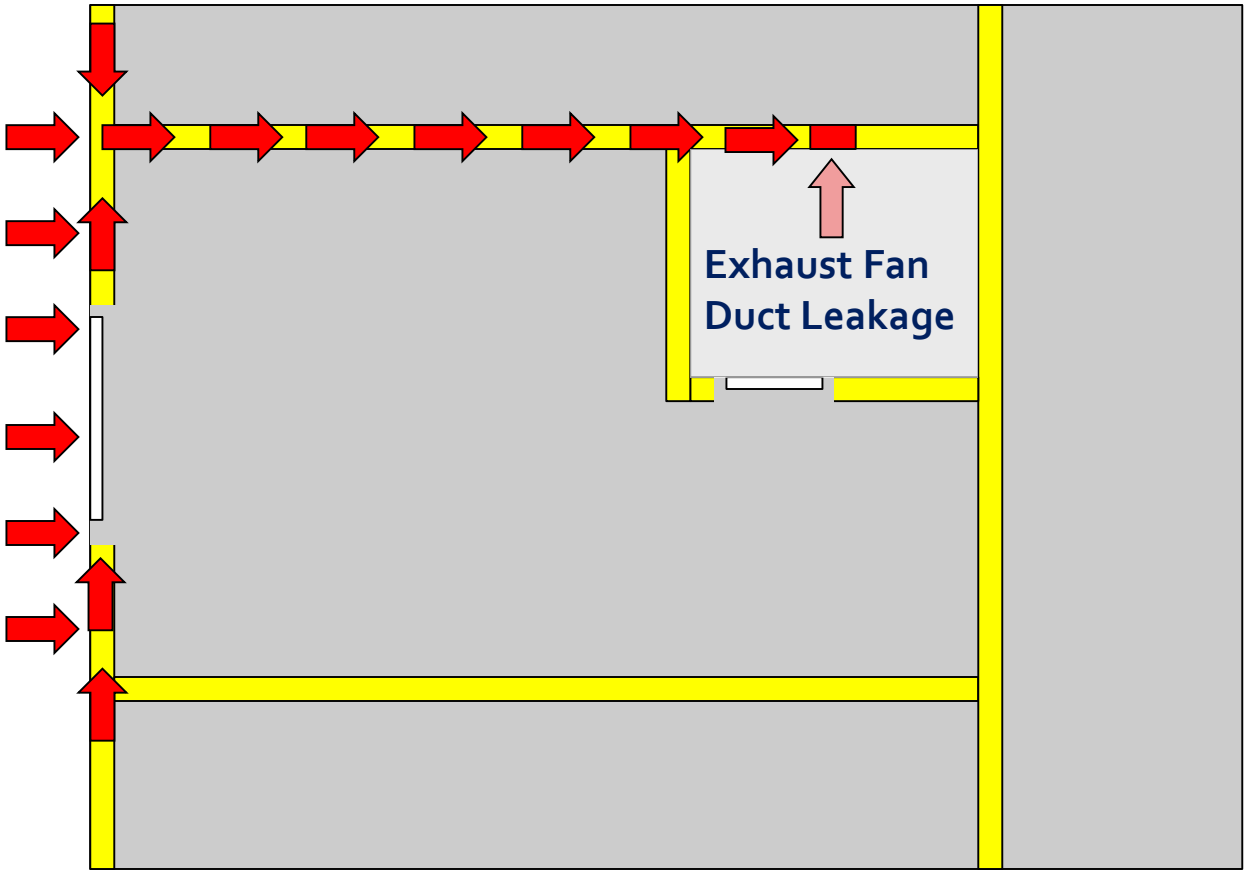


Return Air Restricted

Restricted Makeup Air

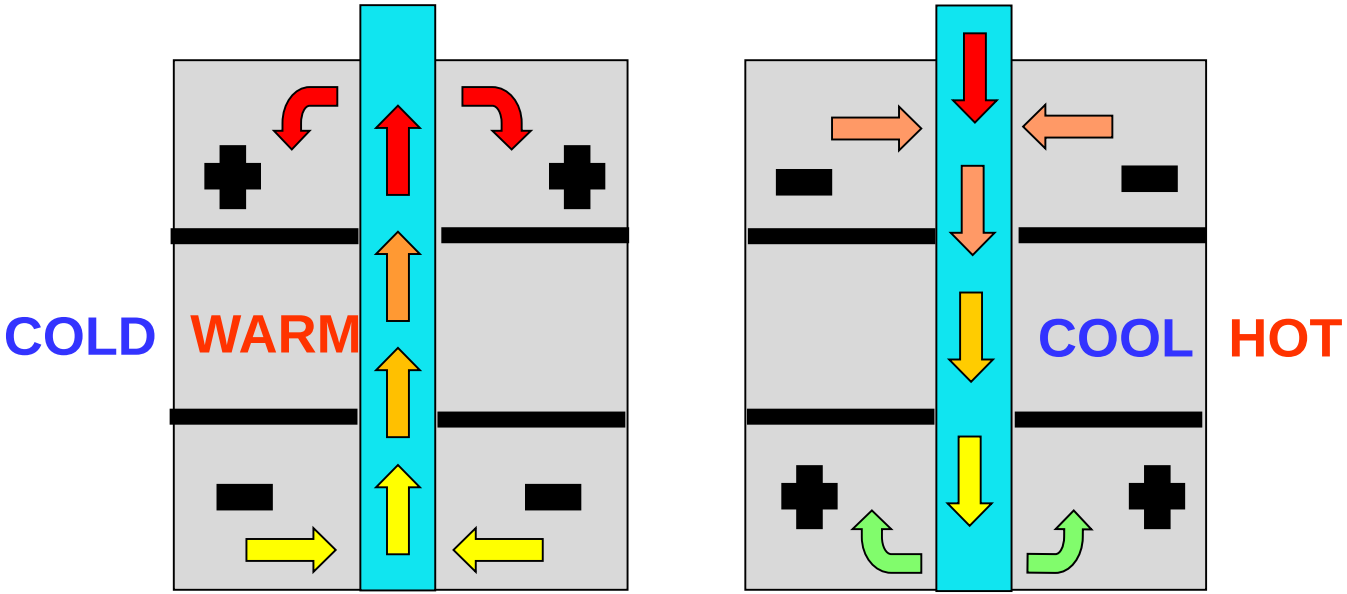


Duct Leakage

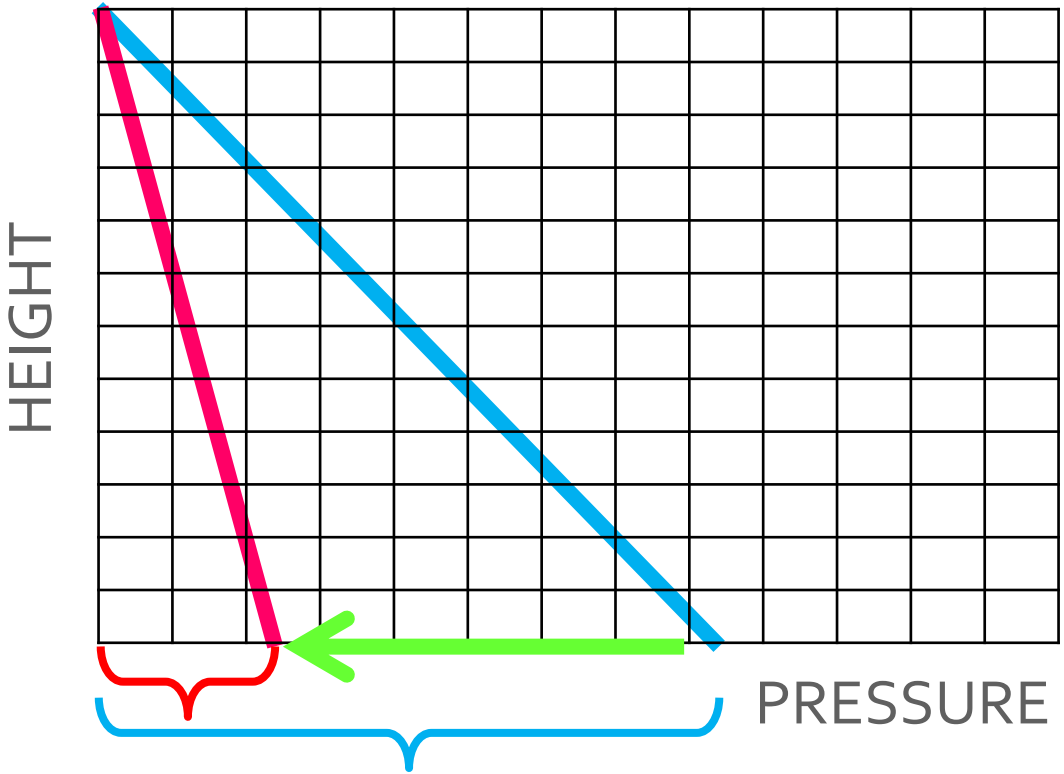


Duct Leakage

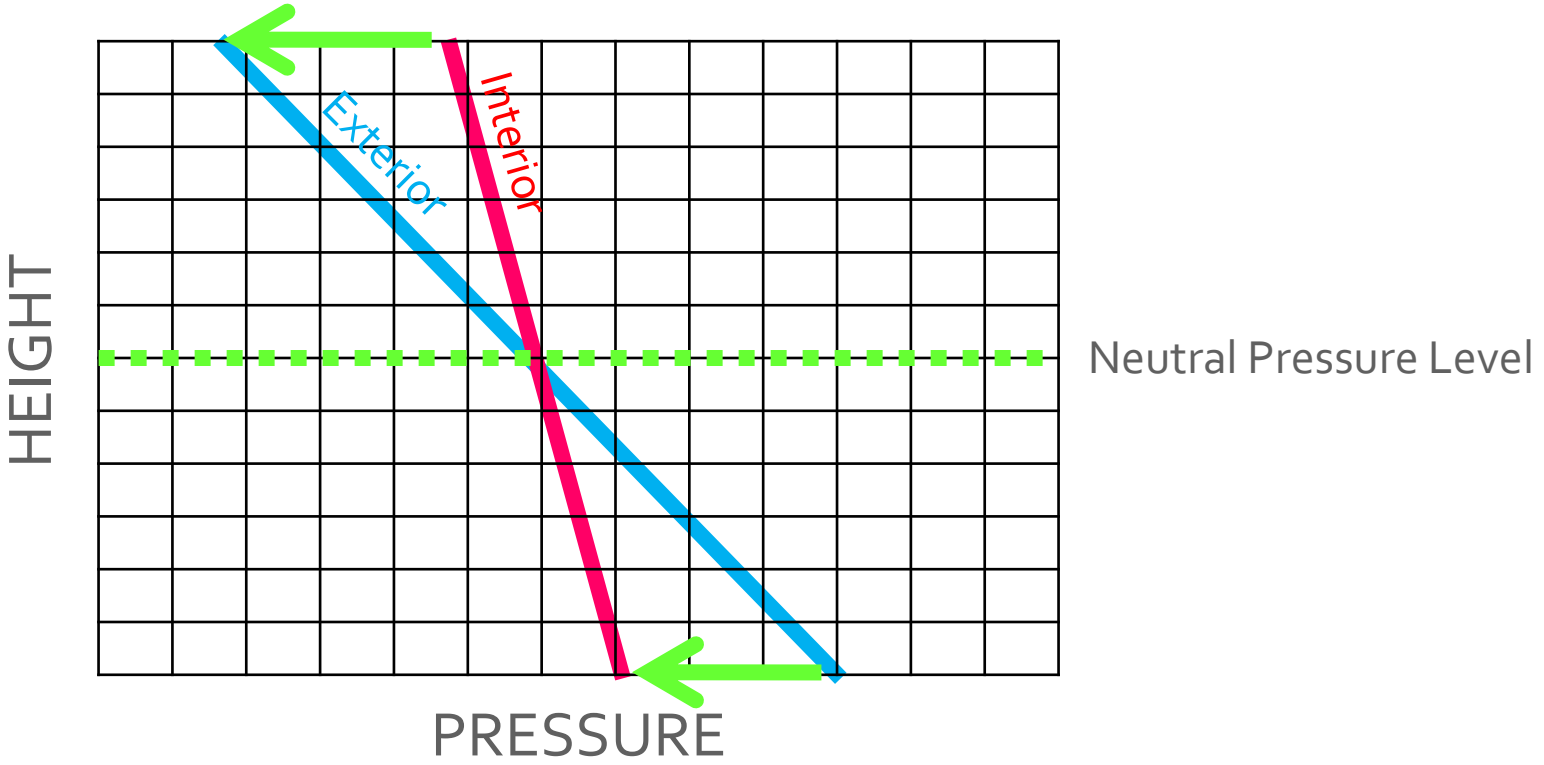
Stack Effect



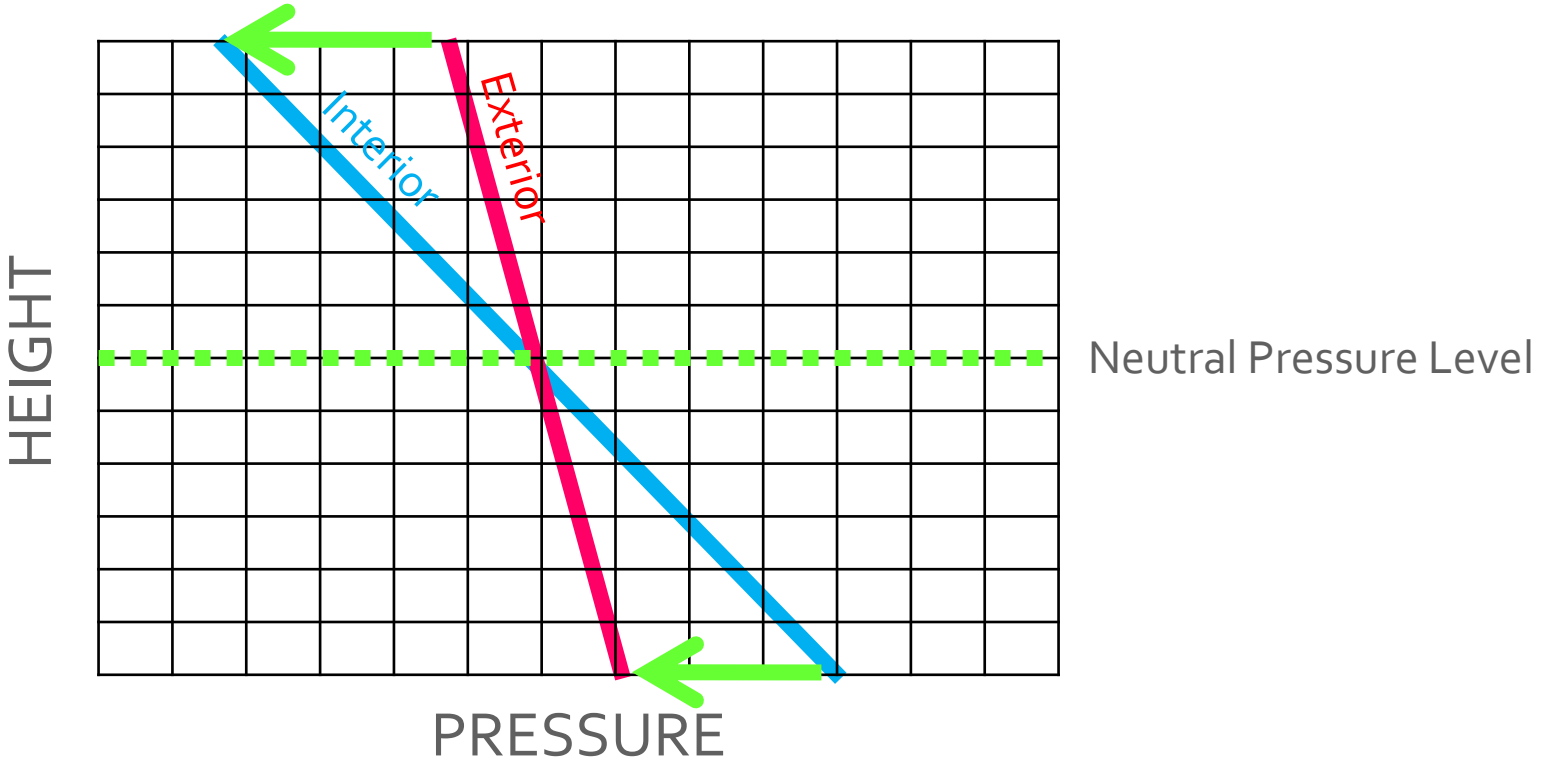
Stack Effect (Cold Weather)



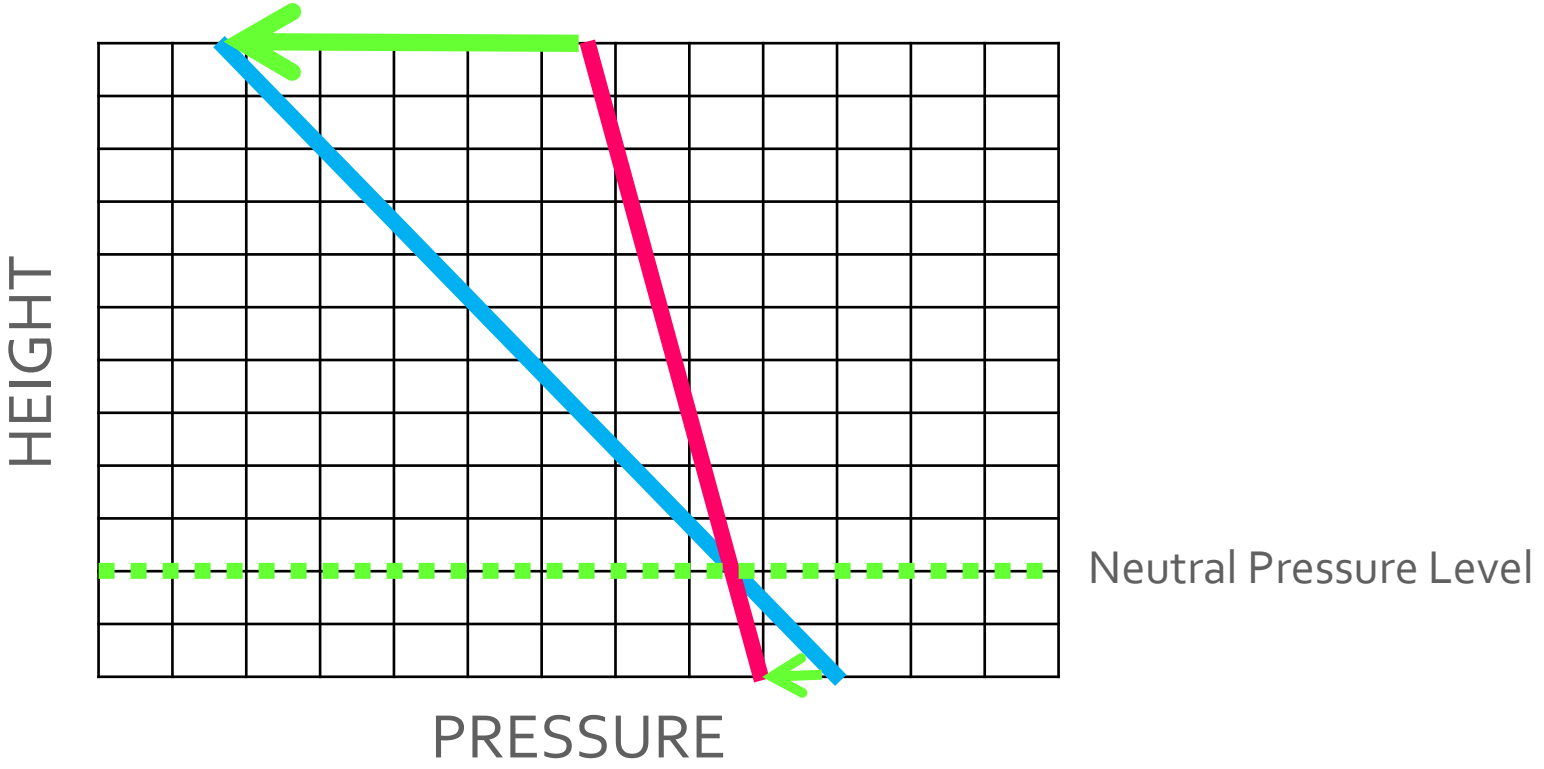
Stack Effect (Cold Weather)



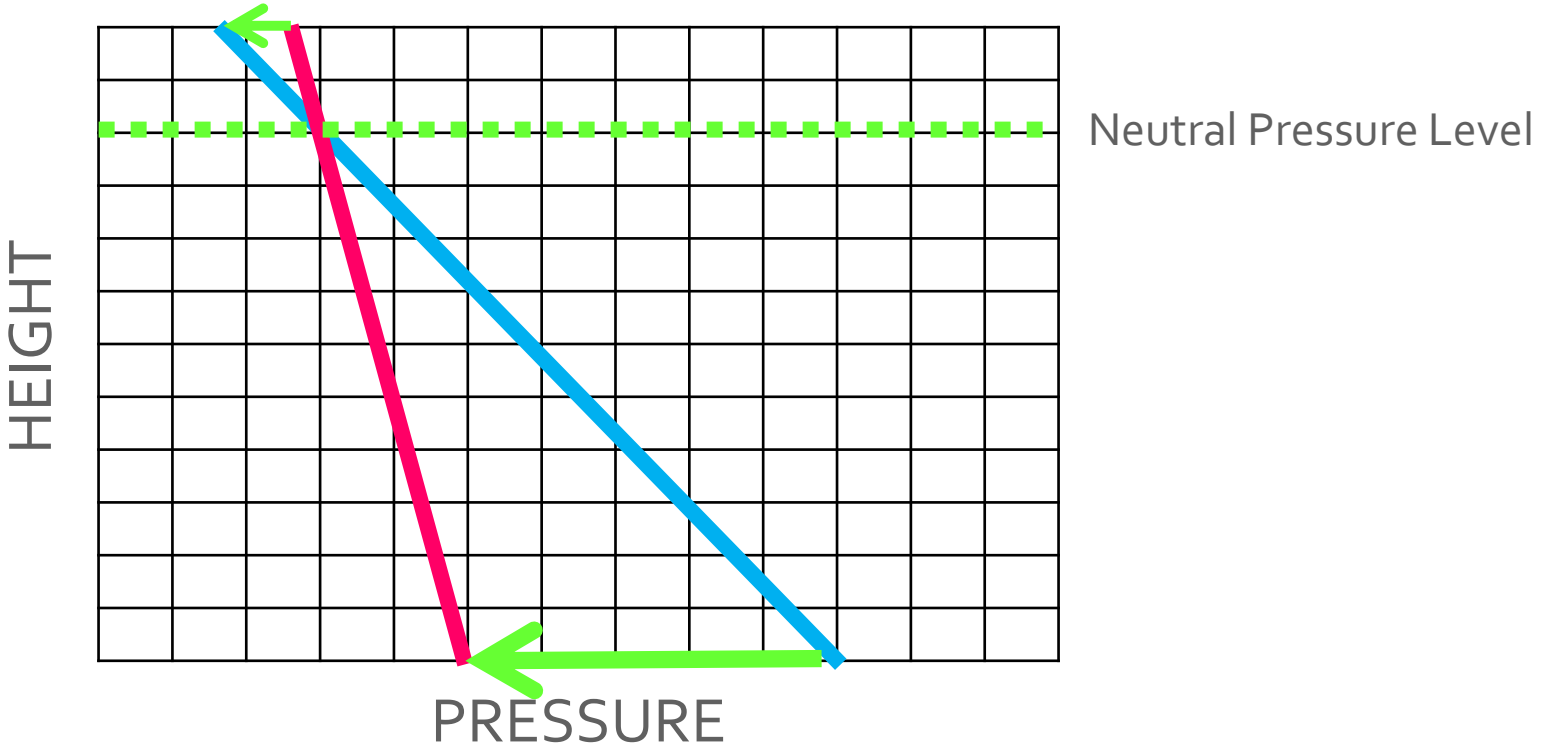
Stack Effect (Hot Weather)



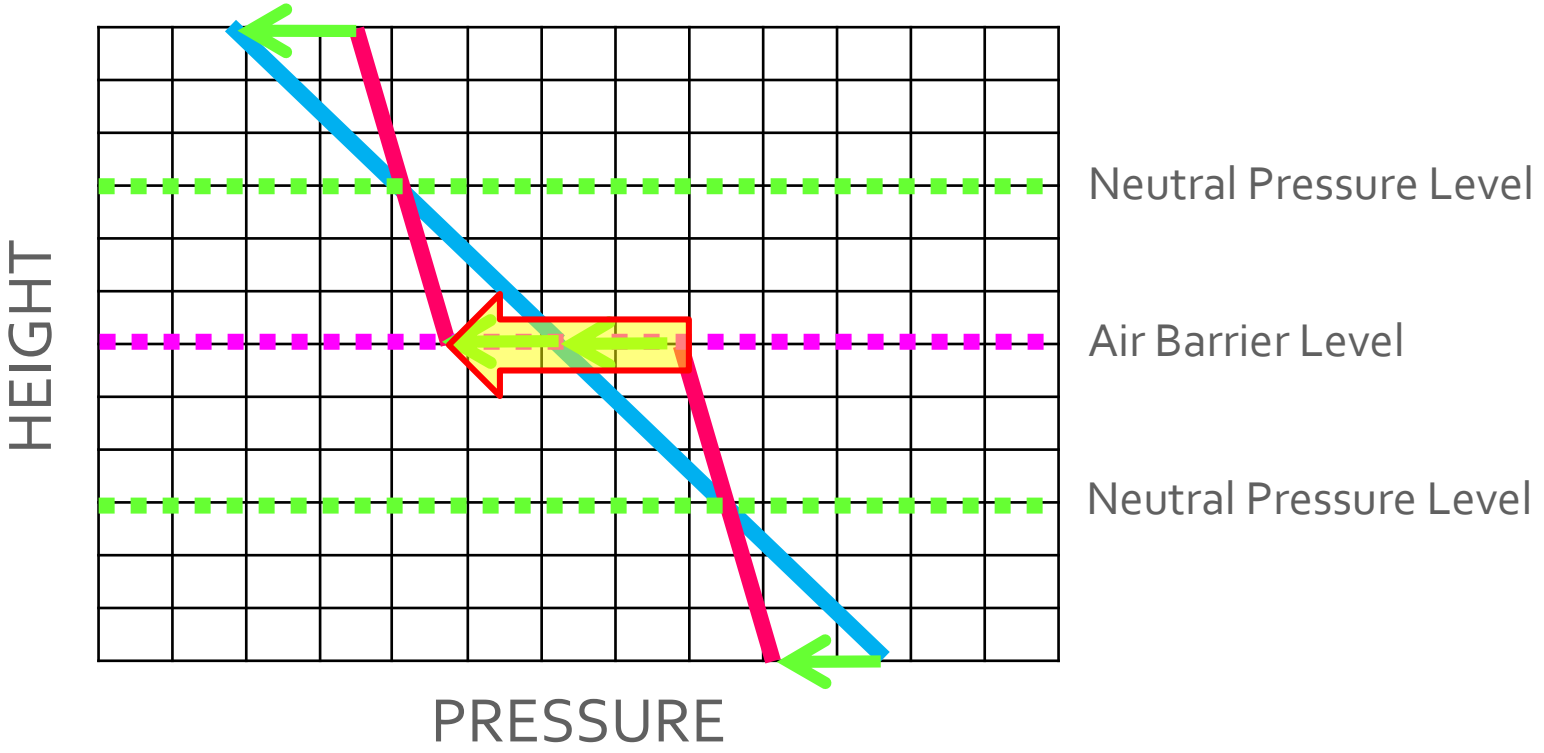
Stack Effect (Neutral Pressure at Lower Floors)



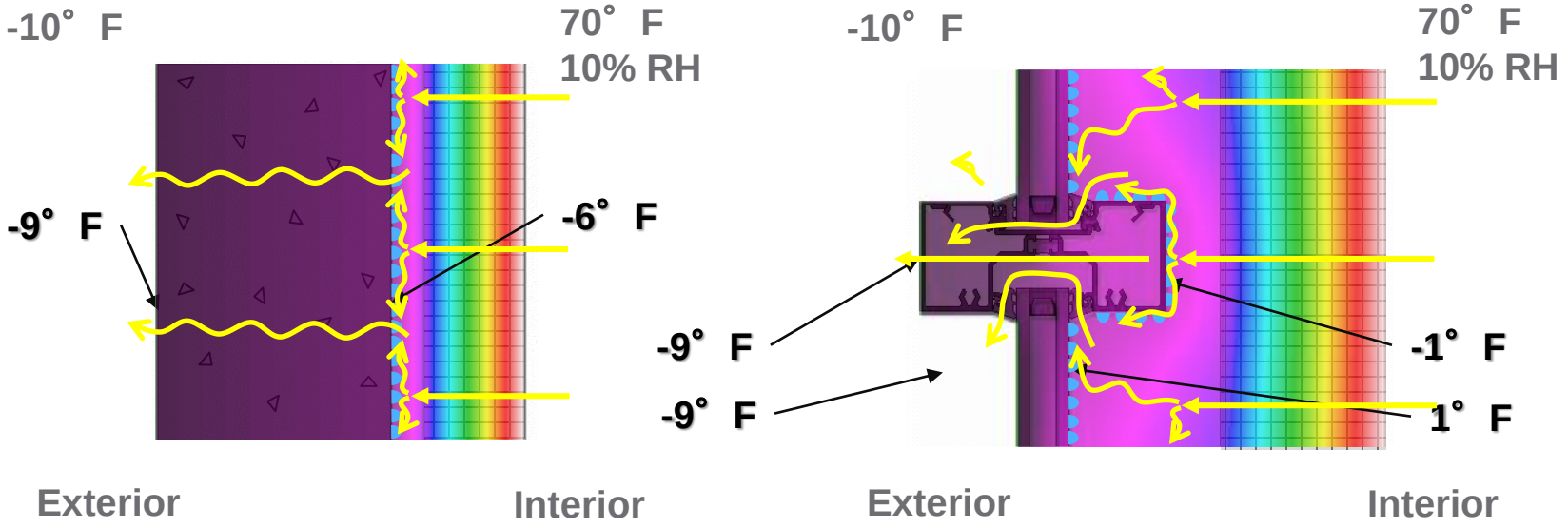
Stack Effect (Neutral Pressure at Upper Floors)



Stack Effect (Air Barrier Cold Weather)

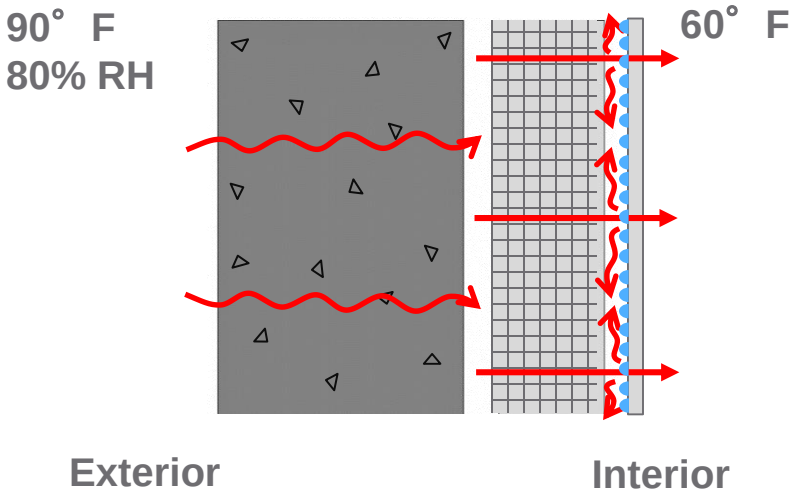


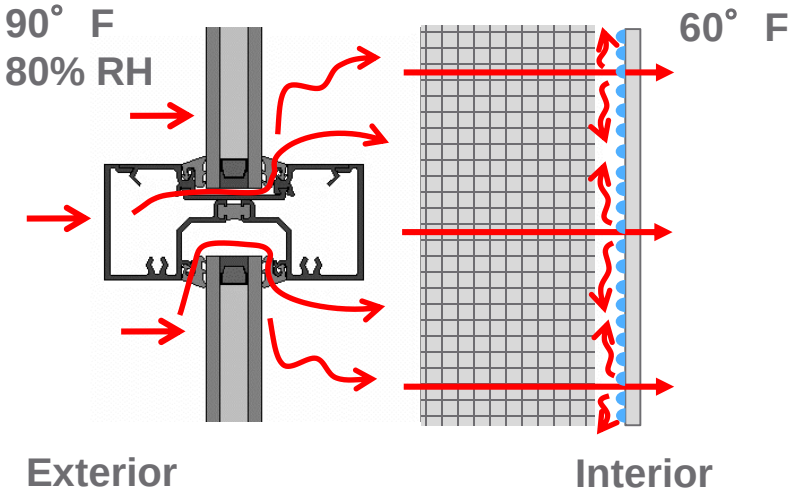
Positive Pressure Issues during Cold Weather



If moist interior air flows into the space between the insulation and the wall element, the air is cooled. If the wall element is colder than the dew point temperature of the air, condensation will form on the wall element.

Negative Pressure Issues during Warm Weather





When the exterior air pressure is greater than the interior air pressure, warm moist exterior air can flow into and through the wall via open joints and voids allowing moisture to condense on surfaces cooled by the interior air conditioning.

Reservoir Cladding

CASE STUDIES

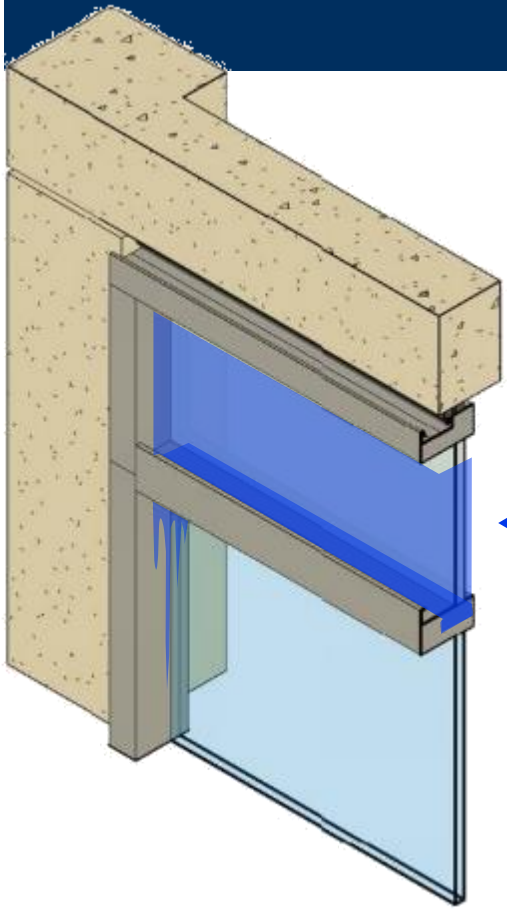
Hospital

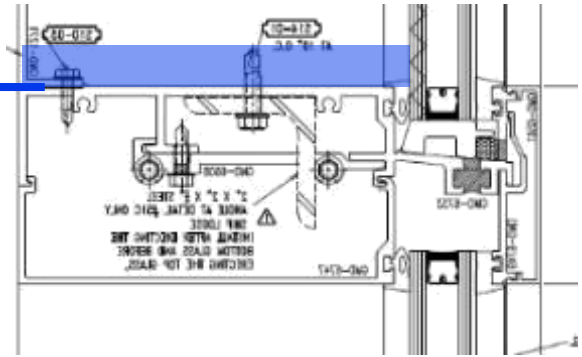
Moisture in Walls Due to Flow of Interior Air

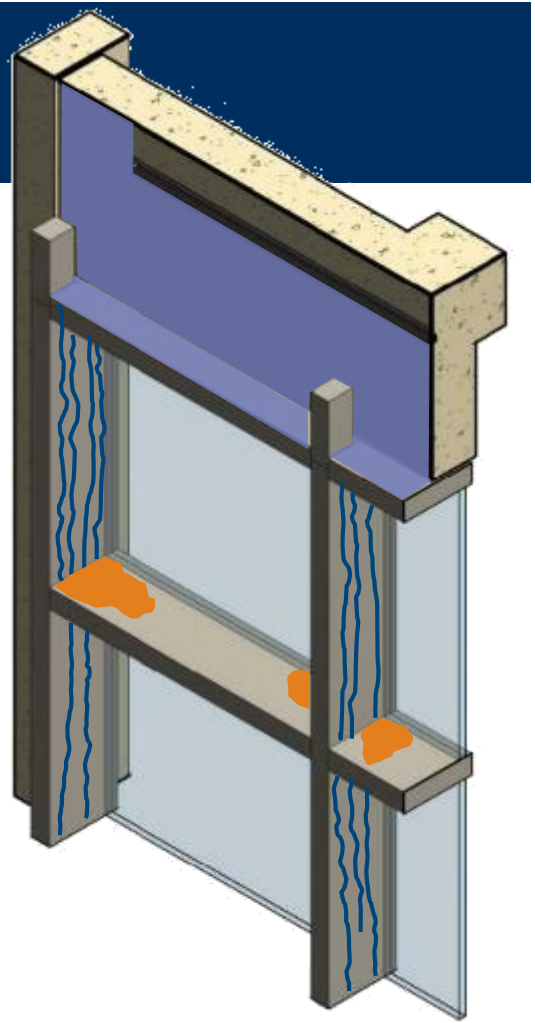
Problem

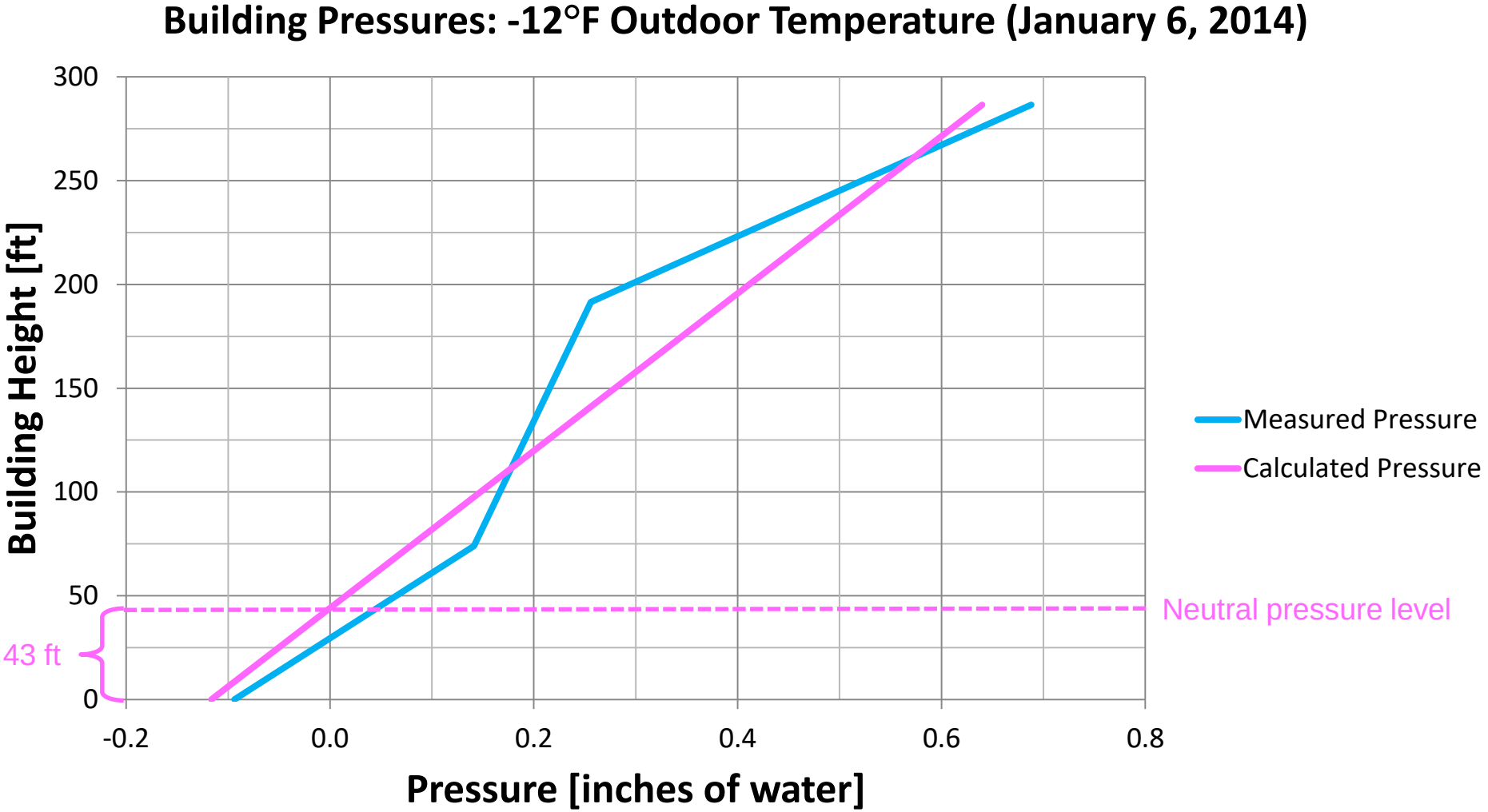
Cause (Cold Surfaces at Precast)

Cause (Cold Surfaces at Precast)



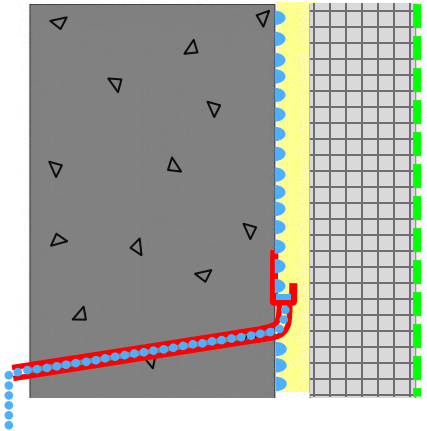




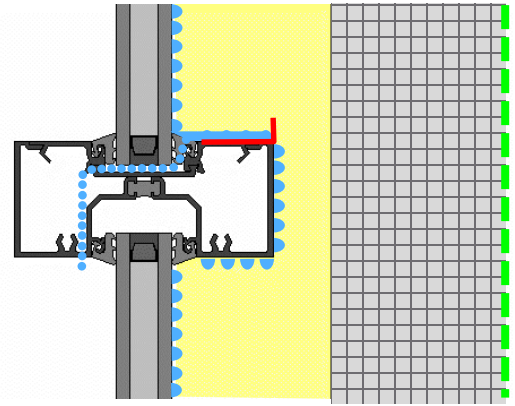

Building Pressures: -12°F Outdoor Temperature (January 6, 2014)
Building Height [ft]
300
250
200
150
100
50
0
43 ft
-0.2
0.0
0.2
0.4
0.6
0.8
Pressure [inches of water]
Measured Pressure
Calculated Pressure
Neutral pressure level

Cause (Airflow Paths)

1. FSK Air Barrier
2. Air Space
3. Gutters

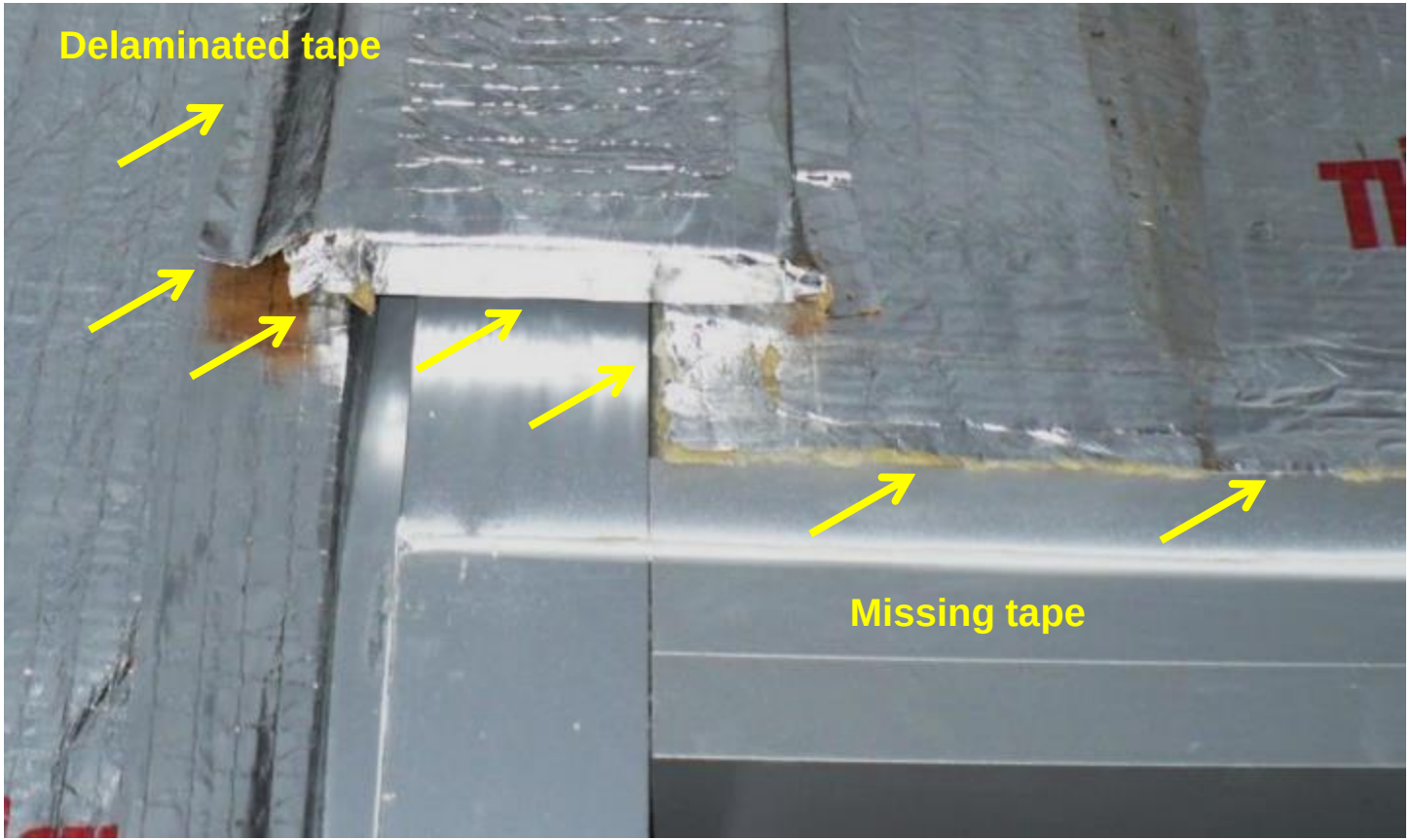


Exterior Interior

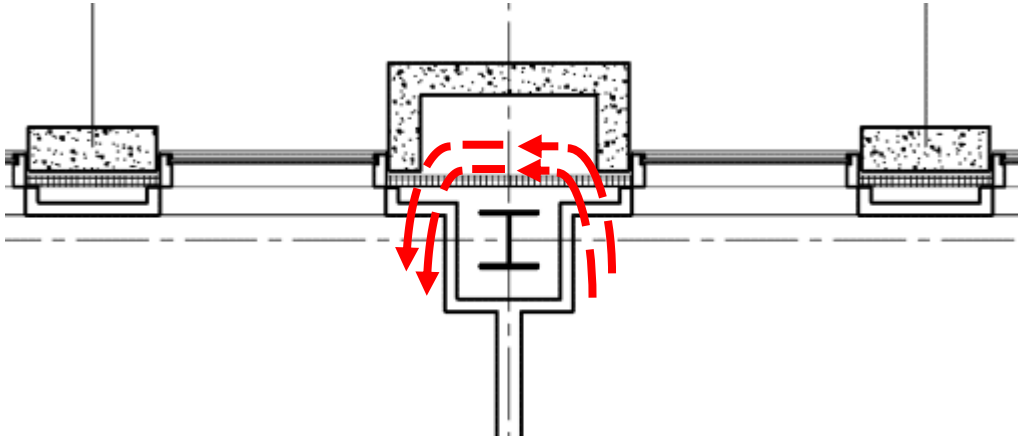


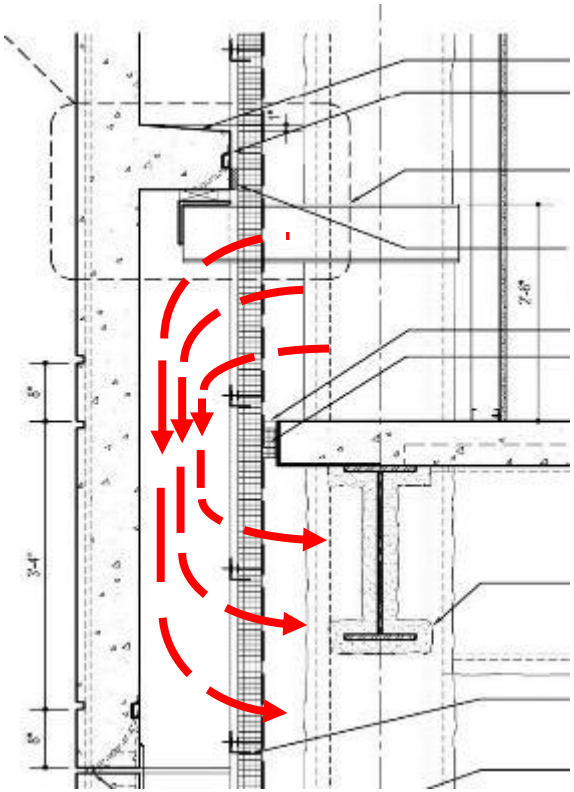
Exterior Interior

Cause (Airflow Path – FSK)

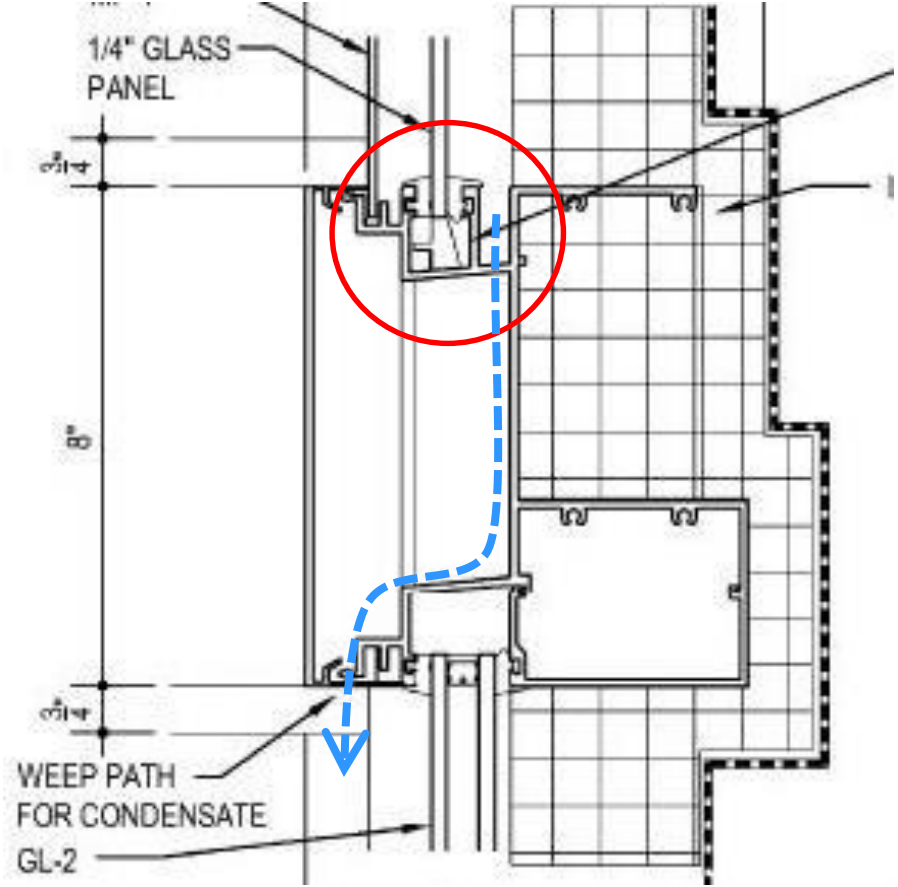


Cause (Airflow Paths between Rooms and Floors)



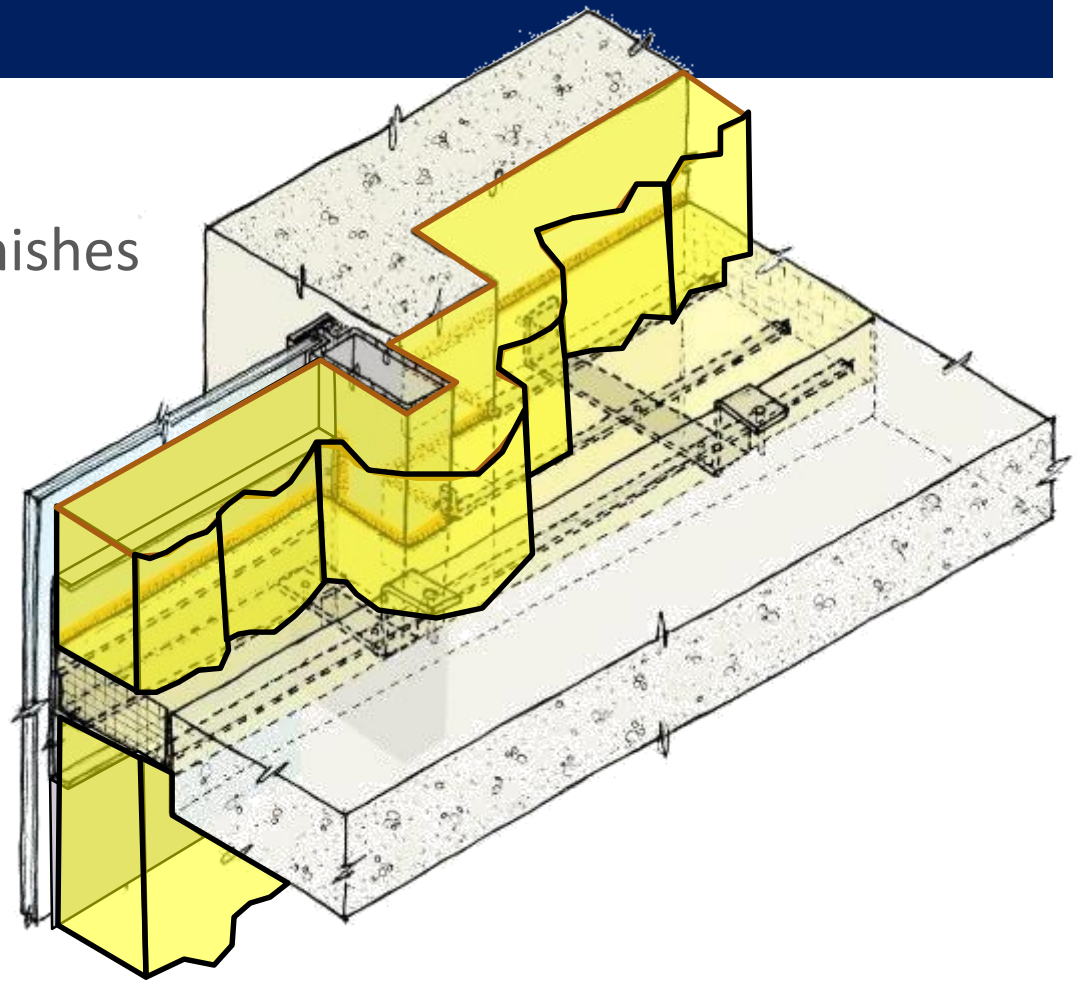


Cause (Airflow Path – Gutters)



Solution

1. Create air barrier by:
    a. Removing interior finishes
    b. Installing back pans
    c. Installing firestop
    d. Installing spray foam
    e. Reinstalling interior



Housing for the Elderly

Ventilation issues and ductwork leakage

Staining and Growth at Windows

Dripping Water over Windows

Building Systems

Exterior Wall Construction

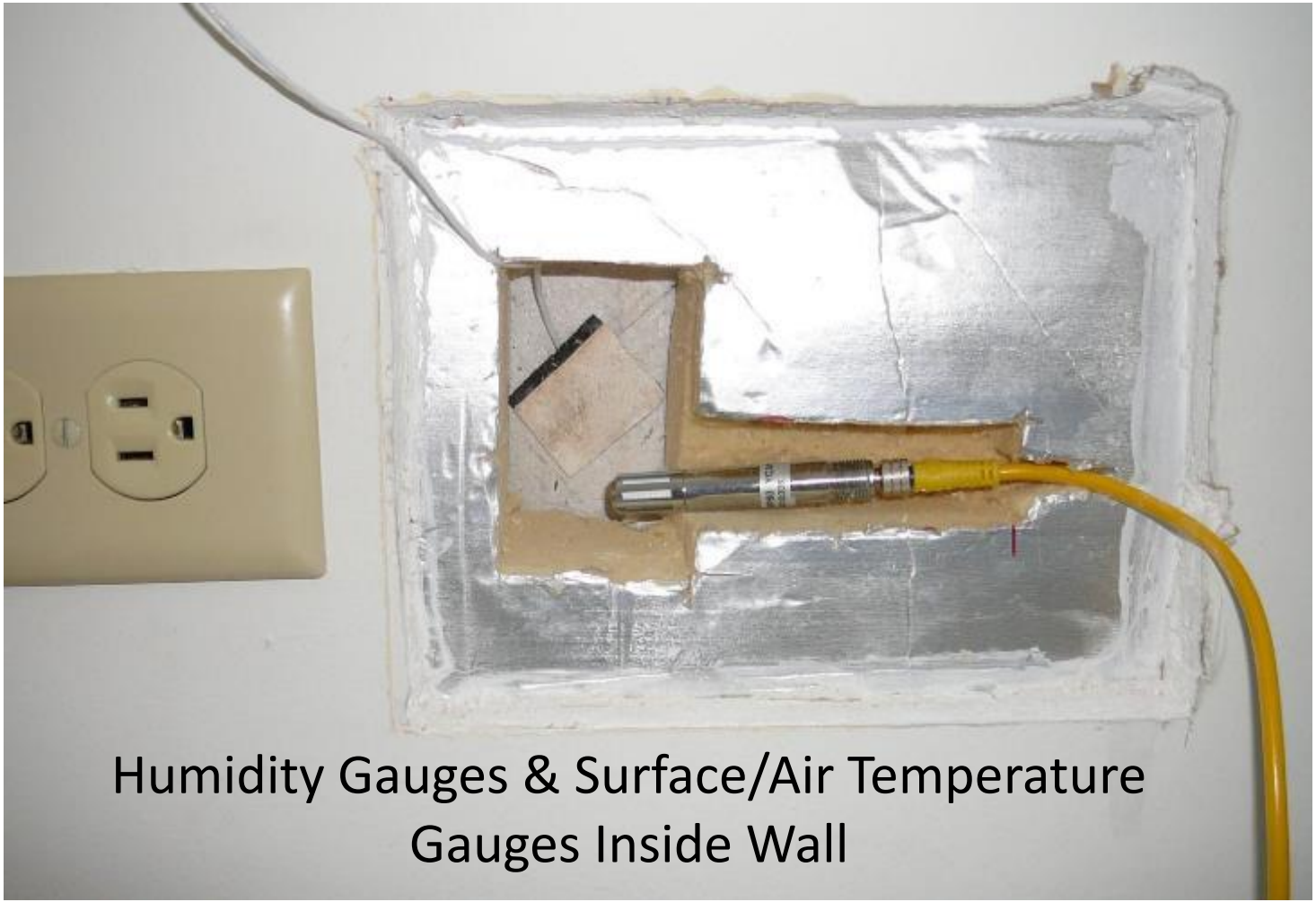
1. Simulated brick precast concrete panels with foil-faced foam insulation boards applied to interior face
2. Gypsum wallboard attached to metal Z-furring between insulation boards
3. Vinyl Doors and Windows

Mechanical System

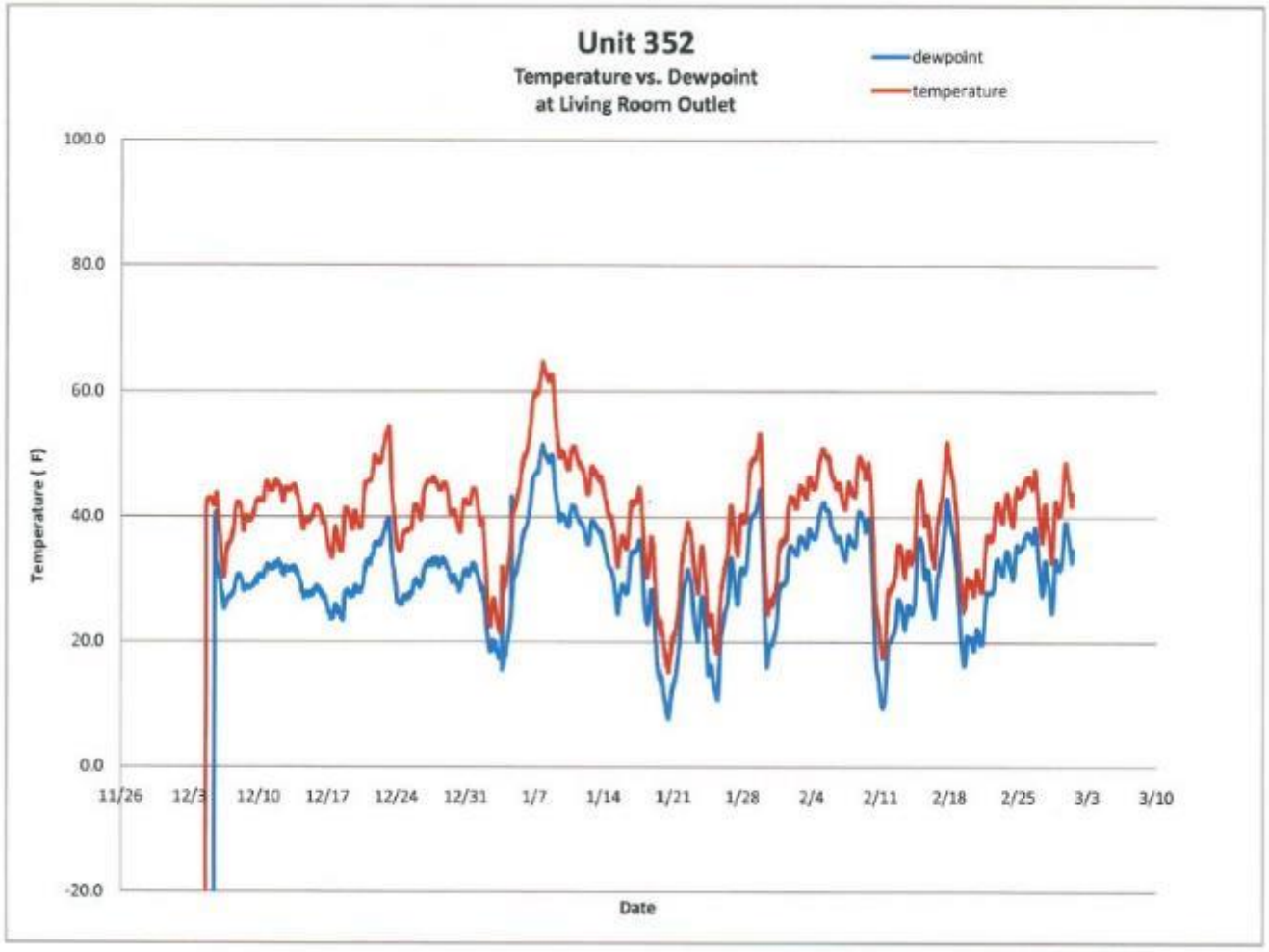
1. Rooftop mechanical units supply hallways and public spaces.
2. Switch operated bathroom exhaust.
3. Mechanical units in rooms recirculate and conditioned air.
4. Ventilation only by light and ventilation schedule.

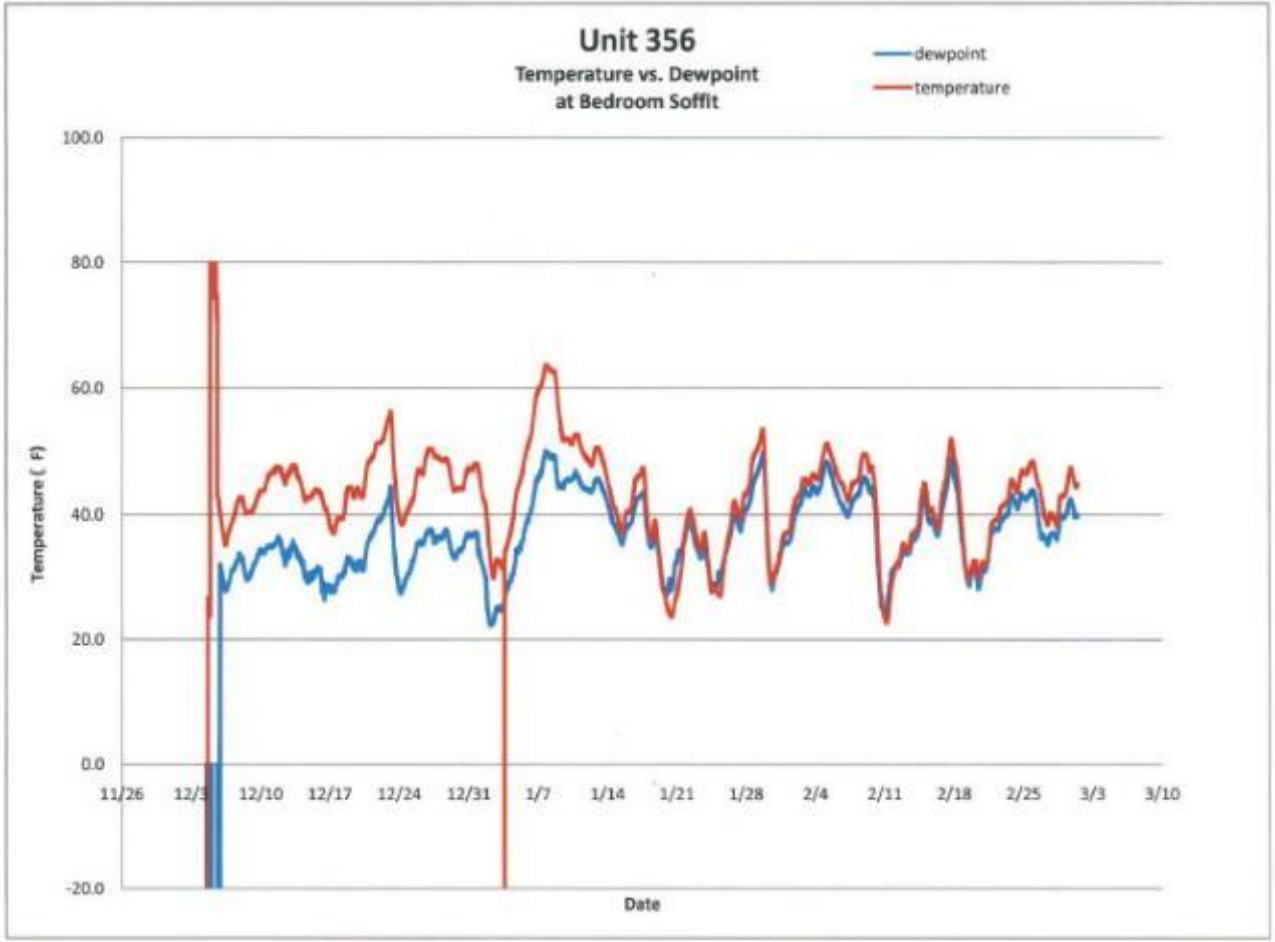
Cause (#1)

1. Lack of ventilation
    a. The building provided makeup air only to the corridors.
    b. Ventilation in rooms only by opening windows.
    c. Occupants were not opening windows during frigid exterior temperatures
    d. Moisture and carbon dioxide build up in rooms.
2. Repair
    a. Continuous bath exhaust
    b. Eliminate bottom gasket at door.



Humidity Gauges & Surface/Air Temperature Gauges Inside Wall


Unit 352
Temperature vs. Dewpoint
at Living Room Outlet
dewpoint
temperature
100.0
80.0
60.0
40.0
20.0
0.0
-20.0
Temperature (F)
11/26
12/3
12/10
12/17
12/24
12/31
1/7
1/14
1/21
1/28
2/4
2/11
2/18
2/25
3/3
3/10
Date


Unit 356
Temperature vs. Dewpoint
at Bedroom Soffit
dewpoint
temperature
100.0
80.0
60.0
40.0
20.0
0.0
-20.0
Temperature (F)
11/26
12/3
12/10
12/17
12/24
12/31
1/7
1/14
1/21
1/28
2/4
2/11
2/18
2/25
3/3
3/10
Date

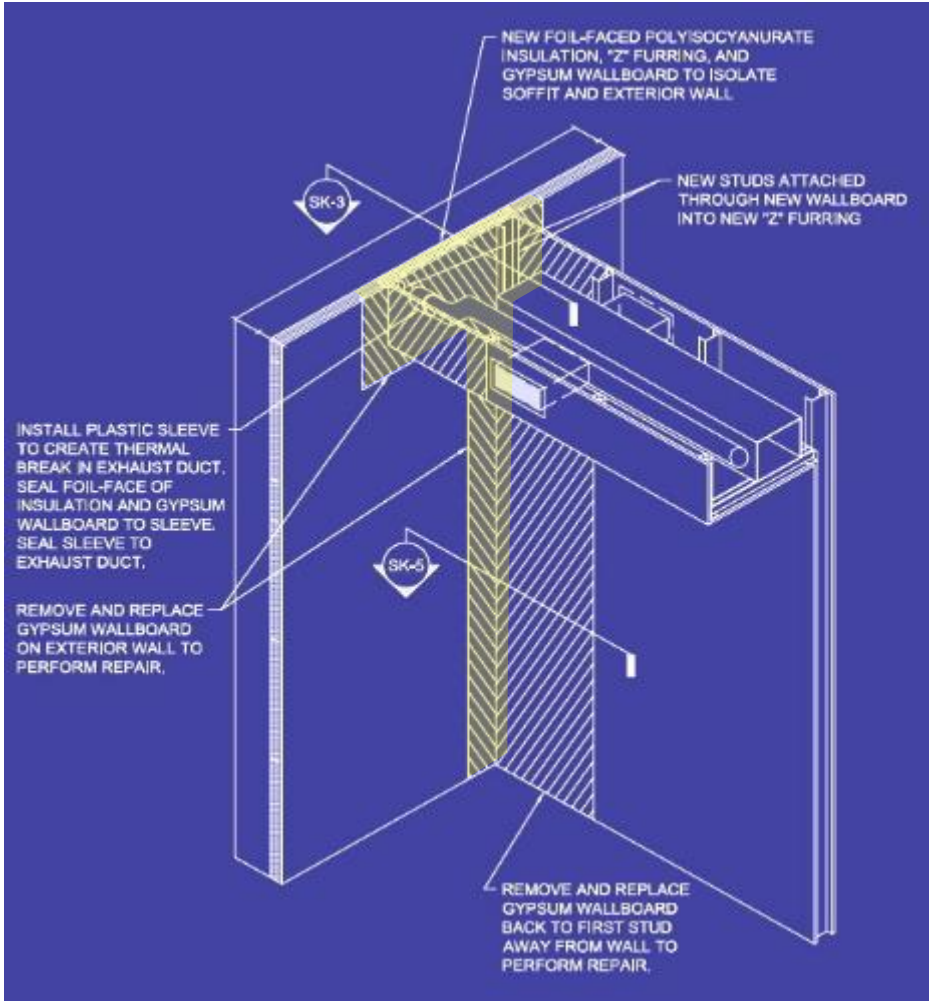
Air moves from pressurized soffit to wall


TUFF-R


Nominal Board Thickness
Stabilized R-VALUE
TUFF-R

Cause (#2)

1. Duct leakage
    a. Soffit containing duct with pressurized supply air was connected to the exterior walls (no barrier).
    b. Joints in ductwork are not airtight.
    c. Humidified air leaking from ductwork flowed against the interior surface of the precast concrete.
2. Repair
    a. Isolate soffit containing duct from wall.


NEW FOIL-FACED POLYISOCYANURATE INSULATION, "Z" FURRING, AND GYPSUM WALLBOARD TO ISOLATE SOFFIT AND EXTERIOR WALL
SK-3
NEW STUDS ATTACHED THROUGH NEW WALLBOARD INTO NEW "Z" FURRING
INSTALL PLASTIC SLEEVE TO CREATE THERMAL BREAK IN EXHAUST DUCT. SEAL FOIL-FACE OF INSULATION AND GYPSUM WALLBOARD TO SLEEVE. SEAL SLEEVE TO EXHAUST DUCT.
SK-5
REMOVE AND REPLACE GYPSUM WALLBOARD ON EXTERIOR WALL TO PERFORM REPAIR.
REMOVE AND REPLACE GYPSUM WALLBOARD BACK TO FIRST STUD AWAY FROM WALL TO PERFORM REPAIR.

Hospital

Negative Pressure with Reservoir Cladding

Wall Construction

1. 4” brick veneer
2. 2”cavity with polystyrene insulation
3. 4” concrete masonry
4. 2” studs with foil-faced batt insulation
5. Gypsum wallboard
6. Vinyl wall covering

Cause of Damage

1. Water penetrates and saturates masonry during rains.
2. Air infiltration (due to negative pressure) carries moist cavity air into walls cooled by air conditioning
    a. Damage is worse at areas with large negative pressure (infection control)
    b. No damage at the positively pressurized ICU
3. The wall covering does not allow water to evaporate to the interior.
4. Mold grows on the paper face of the gypsum wallboard and paste for the wall covering.

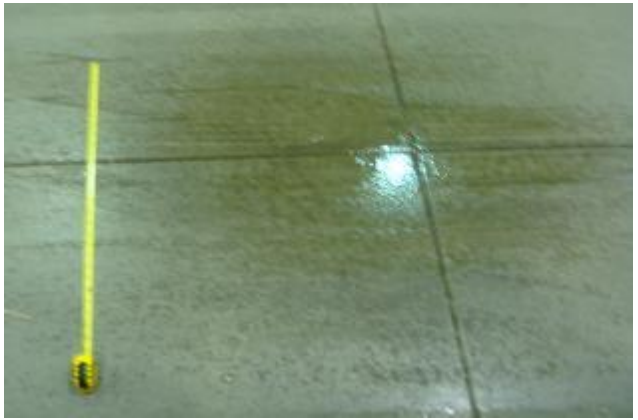
Solution

1. Increase pressurization at areas that were negatively pressurized.
2. Remove the interior gypsum wallboard and vinyl wall covering and install new painted gypsum wallboard.

Warehouse

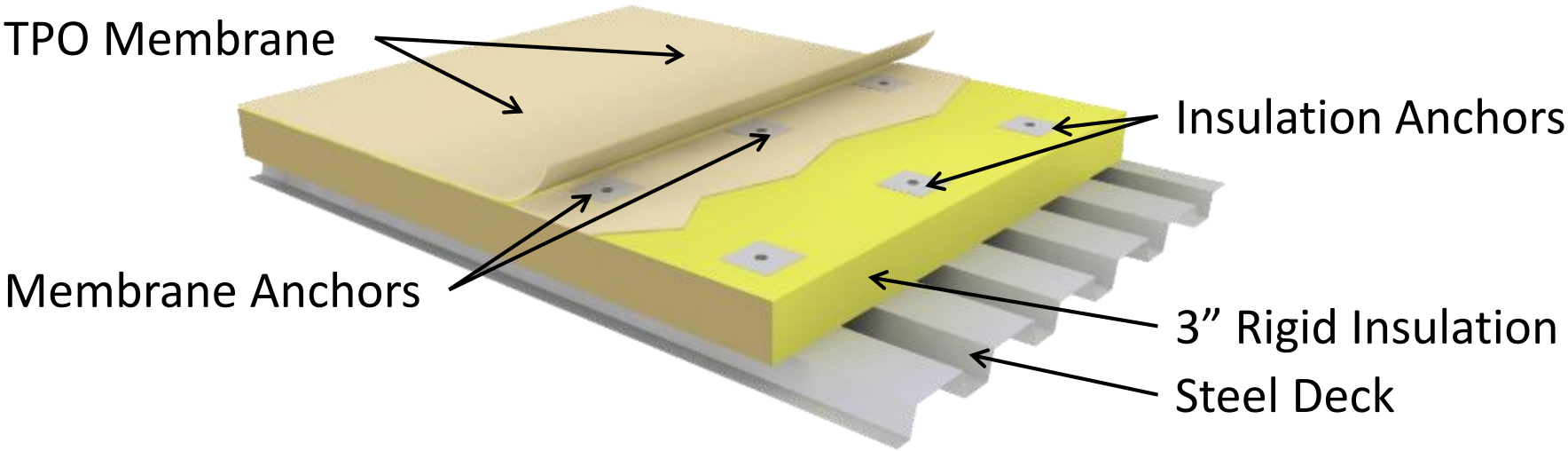
Condensation in Mechanically Fastened Roof

Water Dripping from Roof



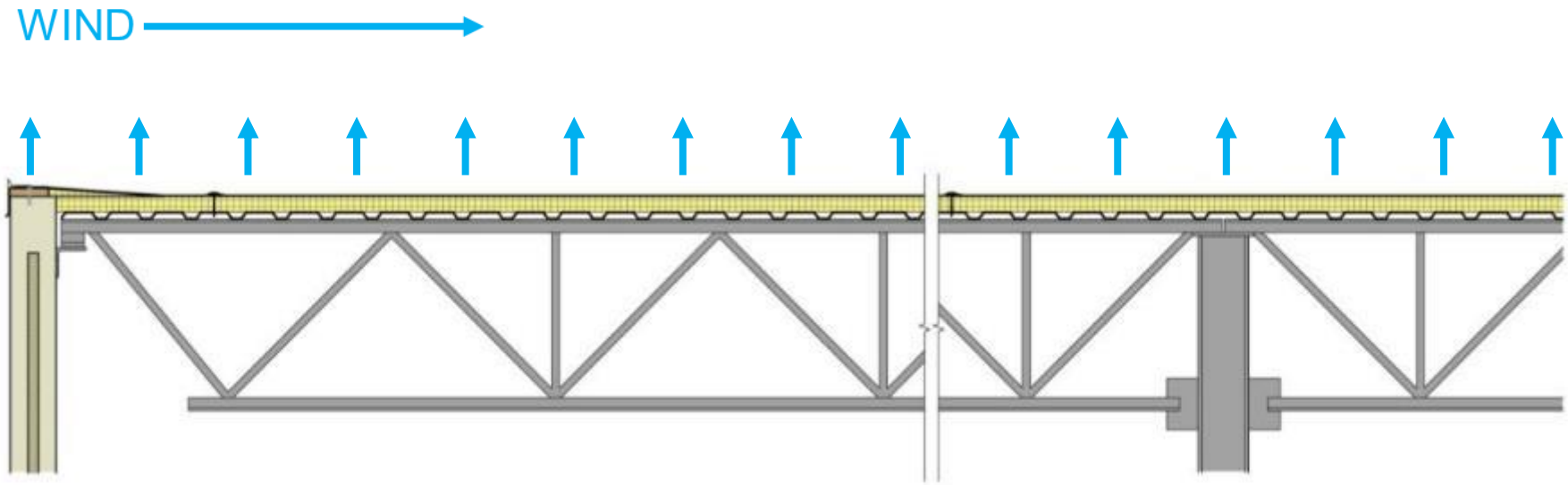
Design/Construction

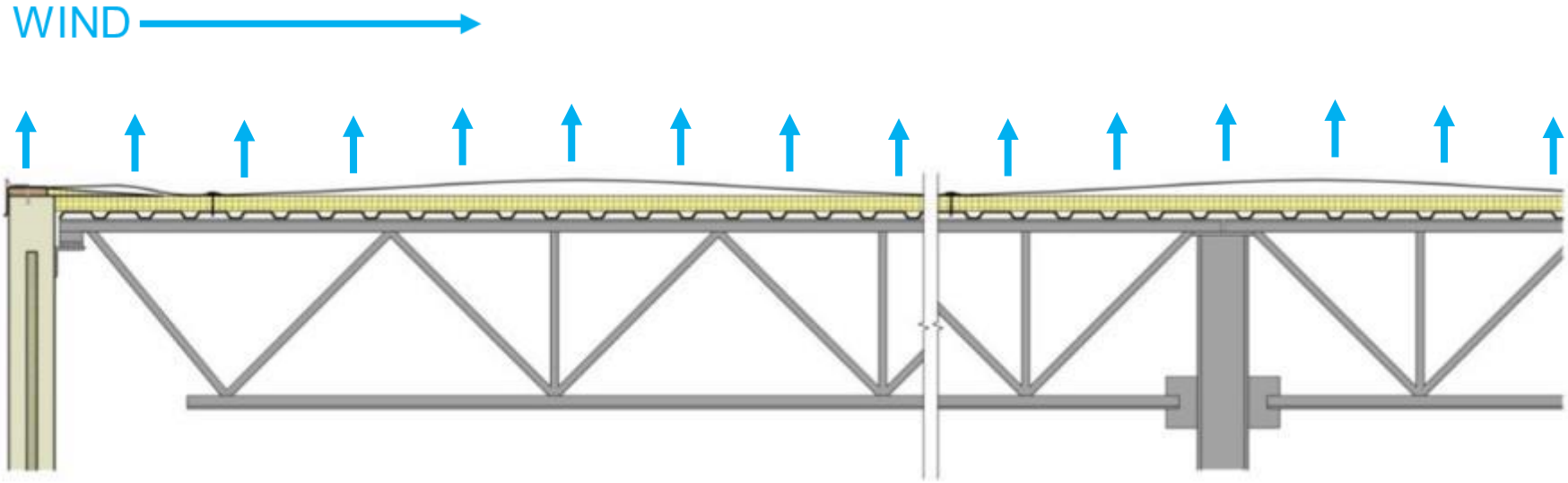
1. Low-sloped roof system (1/4 inch in 12 inches)
2. Steel deck supported by steel framing
3. 3 inch thick mechanically fastened polyisocyanurate insulation
4. Mechanically fastened white thermoplastic membrane (12 foot wide sheets)
5. Relatively high interior relative humidity under positive pressure

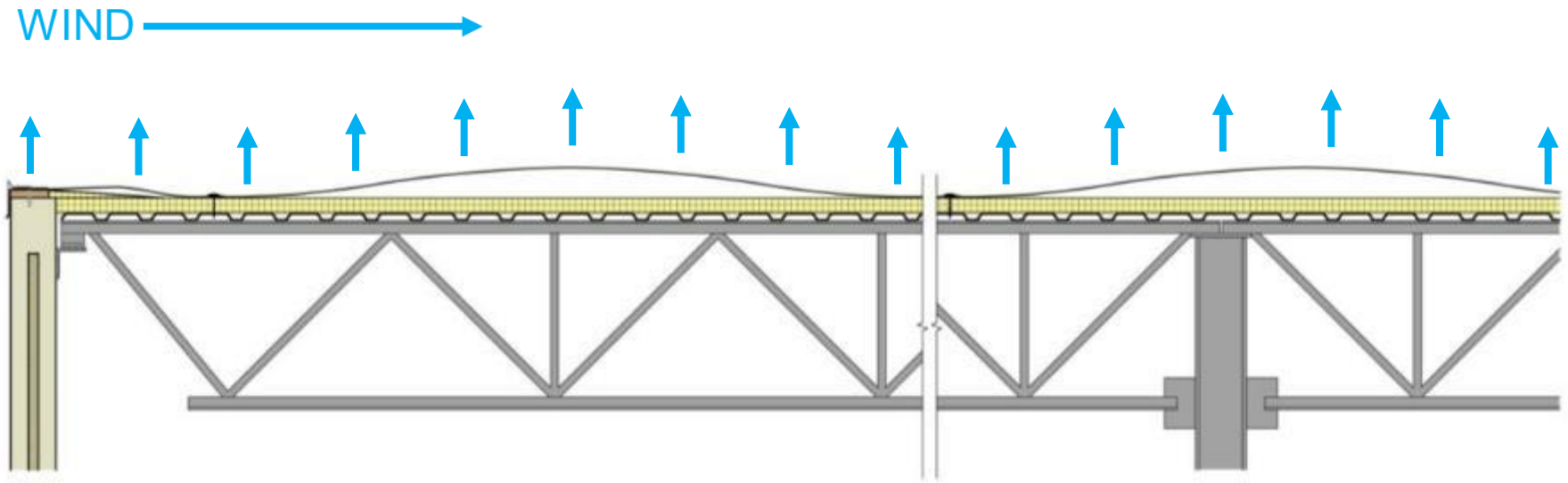

TPO Membrane
Insulation Anchors
Membrane Anchors
3” Rigid Insulation
Steel Deck

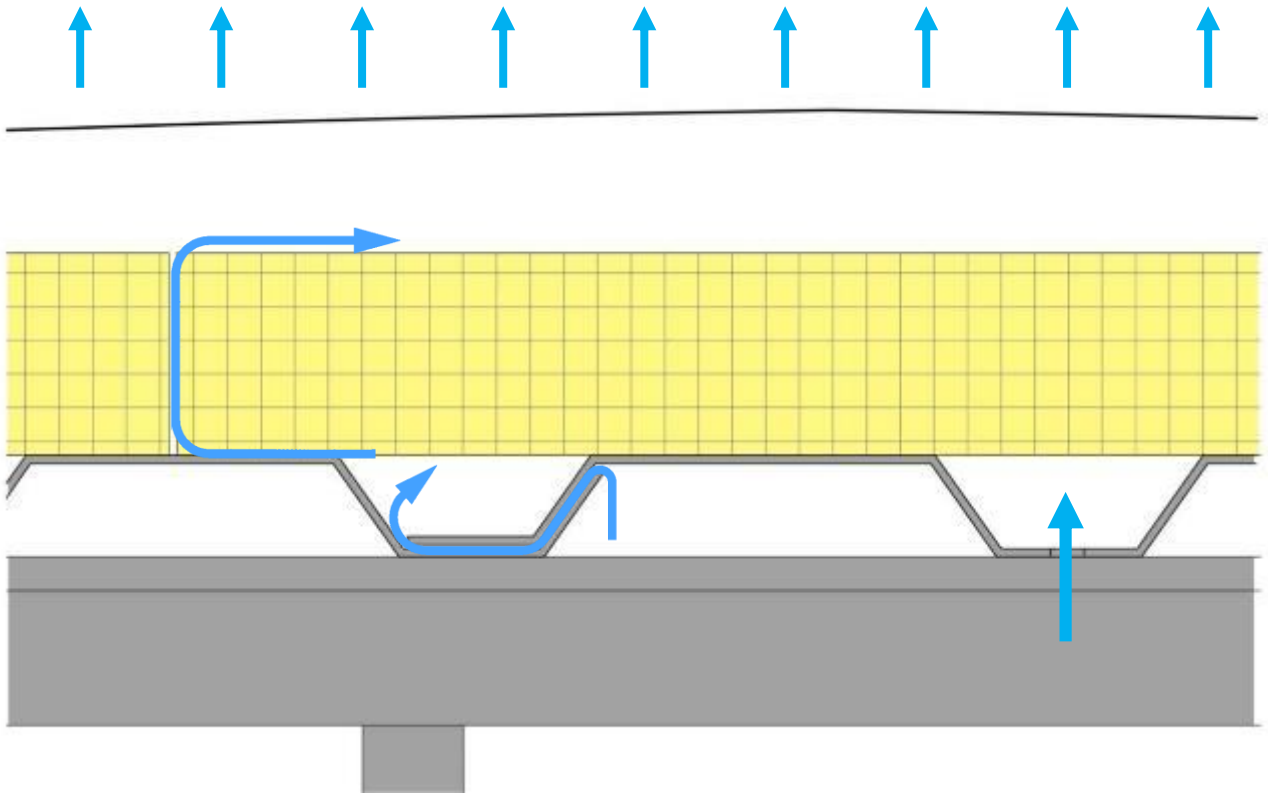
Cause

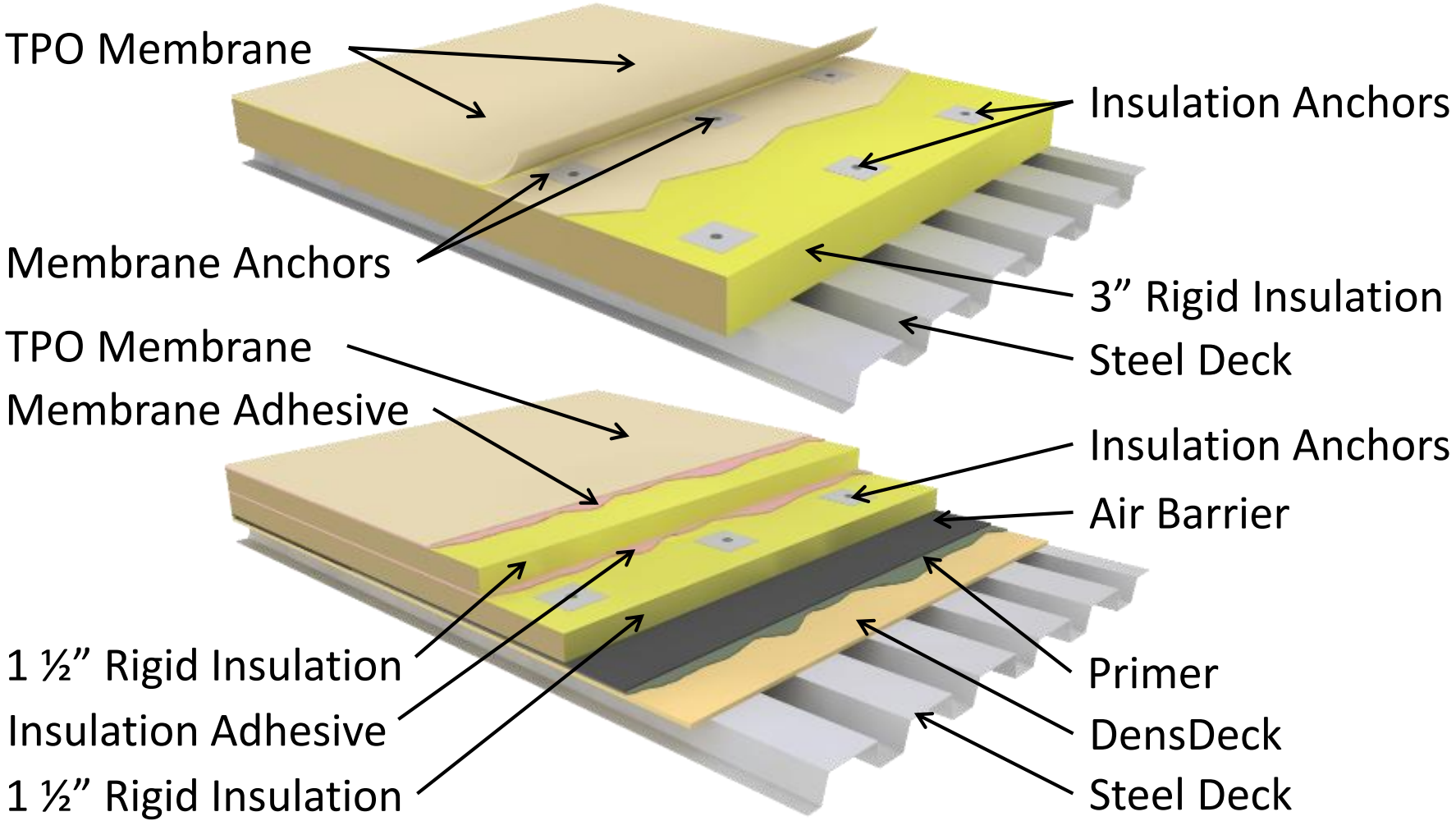
1. Moisture added to interior air by heaters and materials stored
2. Positive air pressure differential between interior and exterior
3. Airflow paths from interior to roof assembly (steel deck is a vapor retarder but not an air barrier)
4. Sustained cold temperatures followed by melting


WIND


WIND

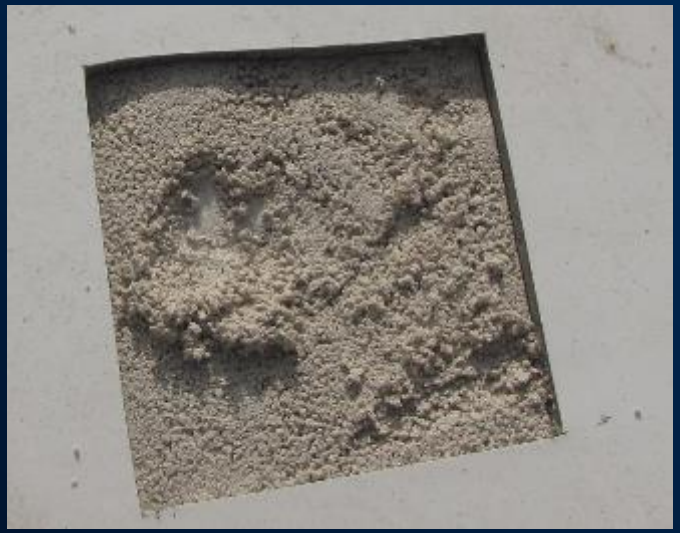

WIND




TPO Membrane
Insulation Anchors
Membrane Anchors
3” Rigid Insulation
Steel Deck
TPO Membrane
Membrane Adhesive
Insulation Anchors
Air Barrier
1 ½” Rigid Insulation
Insulation Adhesive
1 ½” Rigid Insulation
Primer
DensDeck
Steel Deck

Hospital

Roof Damage from Air Pressure and No Air Barrier



Moisture Damage in Roof

Cause (Airflow Path)

Solution

1. Install ballast to resist wind uplift and seal all roof deck penetrations with fire and smoke barrier as initial solution.
2. When roof is replaced in the future, install new air barrier on top surface of concrete that is fully sealed at all penetrations.

Key Points

1. Most cladding system condensation problems are caused by airflow and not vapor diffusion.
2. Air flows from HIGH pressure to LOW pressure. Since warm air can hold significantly more moisture than cold air, condensation typically occurs when WARM air flows to COOLER areas.
3. Air barriers are critical to prevent moisture problems; especially in pressurized, humidified buildings in cold climates.
4. Building with tight air barriers and no makeup air will have buildup of moisture and carbon dioxide within interior air.