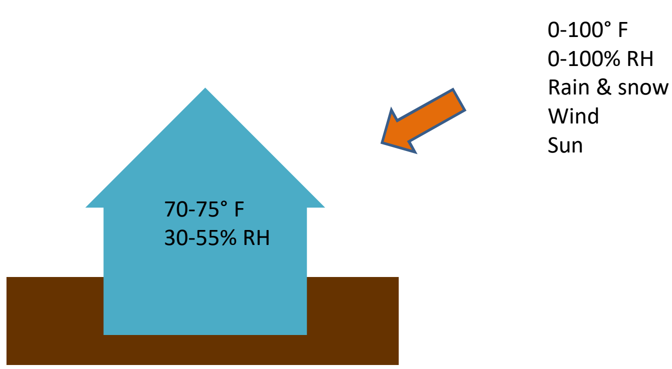
If Walls Could Talk

Designing and Building High-Performance Building Envelopes

Peer-to-Peer Network Meeting

July 2017

The Challenge of Enclosure Design



The Second Law of Thermodynamics

Differences in temperature, pressure, gravitational potential and chemical potential will equilibrate over time

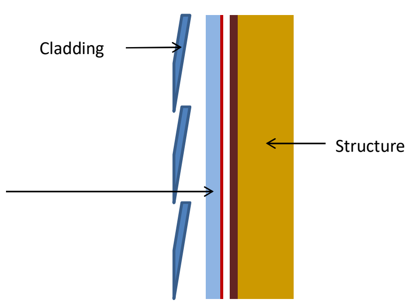
or

Heat flows warm to cold
Moisture flows warm to cold
Moisture flows more to less
Air flows high pressure to low pressure
Gravity acts down

Building Science

A collection of knowledge that focuses on the analysis and control of the physical phenomena affecting buildings

Control Layers
Water Control Layer
Air Control Layer
Thermal Control Layer
Vapor Control Layer

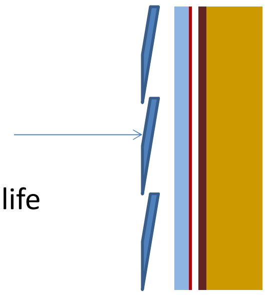


Envelope or Enclosure?

- Water control layer should follow the building envelope but air/thermal/moisture control layers may not
  - Vented attics, unconditioned basements
- Thermal/pressure enclosure is defined by the air/thermal/moisture control layers
- Same principles apply to all parts of the enclosure
  - Slabs and frame floors
  - Walls, windows and doors
  - Ceilings and roofs

Cladding

- Protective outer layer
  - Sun
  - Wind
  - Rain, ice & snow
  - Insects & rodents
- Cladding life often less than building life
  - Proper maintenance essential
  - Venting strongly recommended
    - Improves effectiveness of control layers
    - Extends cladding life

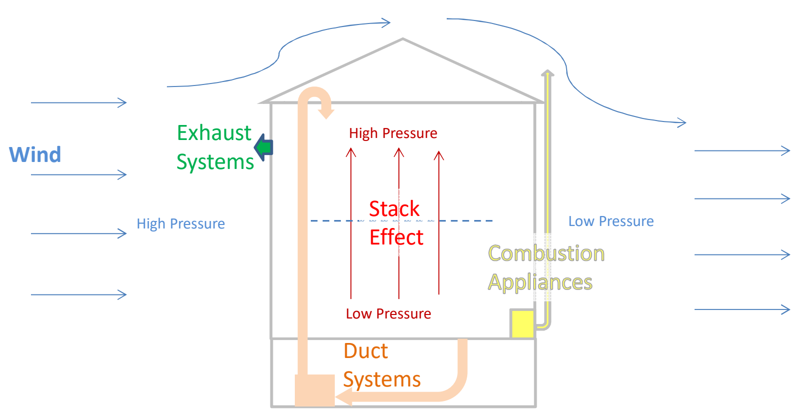


Water Control Layer

- Prevents bulk water intrusion
  - Drainage plane behind cladding
- Everything can leak
  - Detailing important
- May be same as air control later
- May be inside or outside thermal control layer
- Need to protect from below as well as above
  - Capillary breaks

Air Control Layer

Controls air movement due to pressure differences



Measuring Air Tightness

Blower door testing

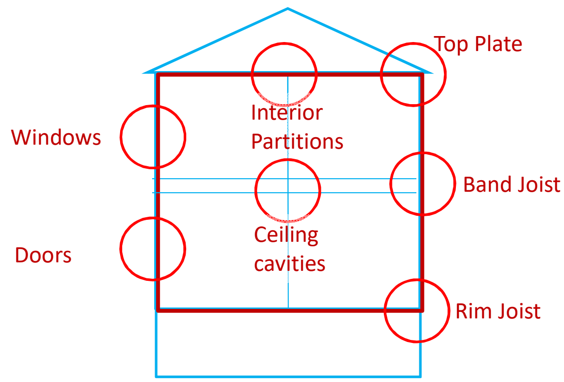
- Measures volume of air exhausted to reduce house pressure by 50 Pascals (0.2” water gauge)
- Finds major flaws in pressure enclosure
- Result expressed as XXX CFM50, usually converted to ACH50 (Air Changes per Hour at 50 Pascals)

$$ACH50 = \frac{CFM50 \times 60}{\text{Volume of Enclosure}}$$

Code & Program Standards

	2016 CT Code	2017 RNC Rebate Program
Detached homes	≤ 3.0 ACH50	≤ 3.0 ACH50
Attached homes	Homes > 850 sf: ≤ 5.0 ACH50 Homes < 850 sf: ≤ 6.5 ACH50	≤ 0.25 CFM50/sf enclosure area

Critical Air Sealing Points



Thermal Control Layer

Most insulation products rely on trapped air to reduce conduction heat flows

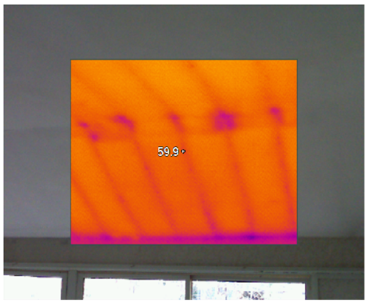
- Smaller cavities = Lower conductivity

Air movement greatly reduces R value of fibrous insulation

- Air barriers essential to achieve rated performance
- 6-side rule

Thermal Bridging Effects

Thermal bridging reduces the performance of cavity insulation systems



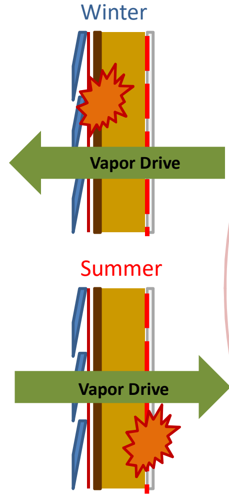
- 2x6/16 wall, R21 cavity insulation
  - Studs are 23% of wall area
  - Studs are 47% of heat loss!
- Add R5 additional insulation
  - Cavity only: Cut total loss 14%
  - Continuous: Cut total loss 30%

Home Energy Technologies

Vapor Control Layer

Winter

20° F
Dry
- 10-15% RH at 70° F



70° F
25-35% RH

Summer

Comfort Zone

85° F Dry bulb
67% RH
- 95% RH at 75° F

75° F
50-55% RH

Home Energy Technologies

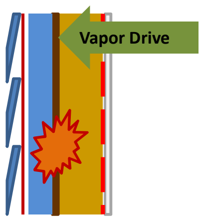
Minimizing Condensation Risks

Exterior insulation inhibits drying to outside if condensation occurs

Dew point of interior air at 70° F 35% RH is 40°F

- Design wall so interior side of sheathing is ≥ 40° F at average daily temperature of the three coldest months
- Temperature of interior side of sheathing may be calculated as follows:

$$T_{interface} = T_{indoor} - \{(T_{indoor} - T_{outdoor}) \times (R_{cavity}/R_{total})\}$$



Average Daily Temperature Dec/Jan/Feb ($T_{outdoor}$)	Minimum Recommended Exterior RFB R-Value	
	R21 Cavity	R15 Cavity
34	4.0	3.0
32	5.5	4.0
30	7.0	5.0
28	8.5	6.0
26	10.0	7.0

Bridgeport 32.5° F

Hartford 28.4° F

Worcester, MA 26.1° F

CT 2016 Code on Vapor Retarders

- Class I or II vapor retarders required on winter-warm side of above-grade frame walls
  - Class I: Poly sheeting (not recommended in CZ5)
  - Class II: Kraft-faced batts or MemBrain or Vapor Retarder paints
- Class III vapor retarders (e.g. latex paint on drywall) also approved for:
  - Vented cladding over OSB, plywood, fiberboard or gypsum
  - Insulated sheathing with R-value of
    - ≥ R5 over 2x4 wall
    - ≥ R7.5 over 2x6 wall

Robust Walls

At the right thickness and with the right details, rigid foam on walls provides a strong defense against moisture

by Ted Cushman

Because of its versatility and convenience, rigid foam sheathing has become more and more common throughout the U.S. Contributing anywhere from R-3 to R-7.5 per inch, sheet foam is a handy way to boost the wall's total R-value without adding too much thickness. But foam sheathing does more than simply improve the thermal performance of a building: Located just inboard of the wall cladding, sheet foam can also function well as an augmented drainage plane to help keep wind-blown water out of walls, and it can act as both an air barrier and as a vapor barrier to defend against the intrusion of air and water vapor. These properties make it a good choice in most coastal climates — but only if you get the details right. A foam-sheathed wall system has to be designed and detailed with all functions in mind, taking into account the site's climate and weather exposure.

INSULATING VALUE

The various foam products on the market have different R-values:

Expanded polystyrene (EPS), an open-cell "thermoplastic" foam that melts at high temperatures, is made by expanding polystyrene beads with steam inside a mold. Its R-value varies from about R-3.2 to R-4.4 per inch, depending on the density of the plastic and the size of the cracks between the expanded beads (a typical value would be R-3.9).

Extruded polystyrene (XPS) is made with the

Exterior foam serves many functions, providing thermal insulation, enhanced drainage, and protection from air infiltration and water vapor. It's not structural, however, and should be applied over OSB- or plywood-sheathed framing.

PHOTOS: CRAIG CAULKINS

same thermoplastic material, but the molten foam is squeezed through an extruder to harden into sheets. With closed cells and with no gaps or cracks, an inch of XPS reaches an R-value of R-4.6 to R-5 (1-inch-thick R-5 sheets are a common product).

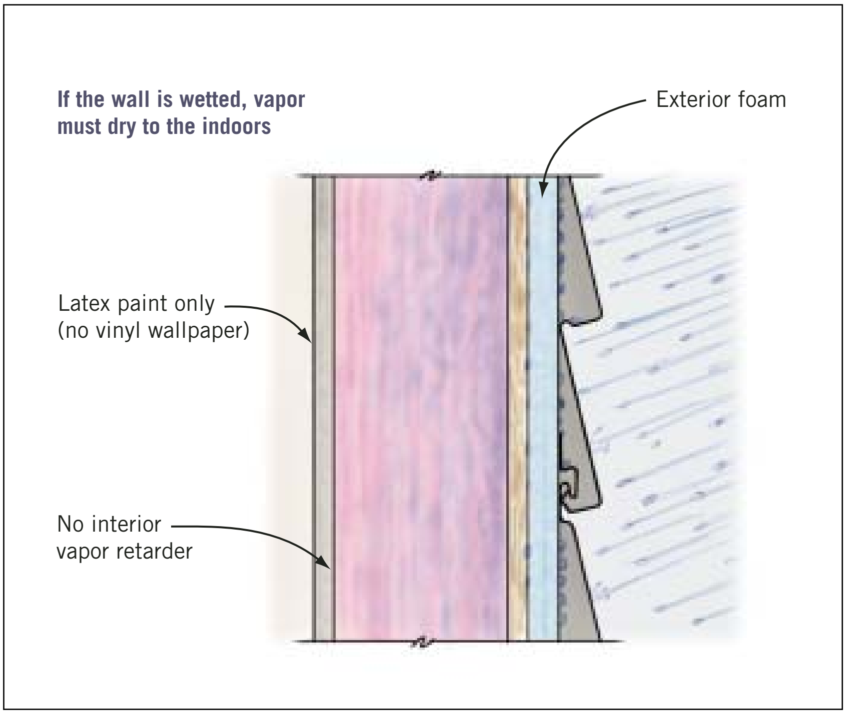
Polyisocyanurate (PIR) is a "thermoset" plastic that cures by chemical reaction and won't melt (although at very high temperatures it will char and burn). Typical polyiso sheets with foil facings stabilize at R-6.5 per inch.

When you're designing a wall for thermal performance, foam sheathing gives you lots of flexibility. Homes in the Houston, Texas, market, for instance, are often built with 3⁄8-inch XPS sheathing over an R-11 or R-13 fiberglass-insulated stud wall, for an R-13 to R-15 assembly. But a superinsulated solar house in coastal Maine might use 2x6 framing with R-19 or R-21 cavity insulation and 2-inch R-13 sheets of foil-faced PIR, for a wall system rated at R-32 or R-34. Between these extremes lie a whole range of choices, with more than one way to meet or exceed energy-code R-value minimums.

VAPOR PERMEABILITY

In addition to being a good insulator, foam sheathing resists vapor diffusion. Permeability varies — EPS is the most vapor-permeable and foil-faced PIR the least — but any foam you apply over the wall studs or wall sheathing amounts to an exterior vapor retarder.

Vapor retarders can be problematic. They work well when kept on the warm side of the wall, so that any vapor they stop will stay warm and won't condense into liquid water. But predicting which side of the wall is the warm side can be tricky when the climate changes. Water vapor wants to move from warm, high-humidity areas to cool, low-humidity areas, so the direction of the vapor drive can reverse when the temperature and humidity change.



CHUCK LOCKHART

FIGURE 1. It's inevitable that walls will get wet at some point — either during construction, from wind-driven rain, from a leak or a flood, or from elevated humidity levels. For this reason, all walls must be able to dry. With foam on the exterior, the only place to dry is to the inside, so it's critical that no poly vapor retarder or vinyl wallpaper be installed on the interior and that the wall be painted with a breathable latex paint.

Foam, which acts as a vapor retarder, can work on the exterior in any climate, says building scientist Joe Lstiburek, as long as the foam's R-value is matched to outdoor conditions — and as long as the wall's interior face is vapor-permeable, so it can dry to the inside.

Match R-value to climate. In the Deep South, explains Lstiburek, an exterior vapor barrier works even if it's not also an insulator. When you're air conditioning (so the inside is cold and dry and the outside is hot and humid), the vapor barrier on the outside makes a lot of sense. As you move north, conditions change: Homes interiors are heated, and the outdoor design temperatures grow progressively colder. "At some point, the back side of the exterior foam [facing the interior] is going to accumulate or condense water in the wintertime," observes Lstiburek. "So we want to increase the thermal resistance of that layer, in order to prevent condensation." The foam must be thick enough to insulate the back side, keeping it above the dew point. "The farther north you go, the colder the outdoor temperature, the greater the R-value required, and the thicker the foam has to be. It's simple," says Lstiburek.

Dryable to the inside. Just as important, a wall should not have two vapor barriers, because that could trap moisture inside the wall (**Figure 1**). So if insulating sheathing is used, no poly vapor barrier should be attached to interior wall faces. But in very cold climates, says Lstiburek, Kraft-paper-faced batts are recommended. These facings are semipermeable, so they will slow vapor intrusion into the wall while still allowing moisture to escape into the heated space.

FOAM THICKNESS

How thick should the foam be? That depends on the climate. In the most general terms, an inch or less of XPS will probably work anyplace south of Long Island. From Rhode Island through Maine, you might need to use an inch of PIR (R-6.5) or 1$^1\!/_2$ inches of XPS (R-7.5) on a 2x6 wall. Of course, the thicker the foam, the more energy efficient the wall and the safer it is against condensation.

Lstiburek's organization, Building Science Corp., has spent years running detailed computer simulations to predict moisture conditions within walls and experimenting with different wall assemblies to verify the calculations. Eventually, the group settled on a simple way to specify exterior foam thickness: "You take the average temperature of the three coldest months of the year in your location," says Lstiburek. "Take the average temperature for December, the average temperature for January, and the average temperature for February — and you average those, and use that average as your design temperature for outside. You set your interior design condition as 70°F and 35% relative humidity. Then you do a simple calculation to make sure that the condensing surface doesn't drop below the dew point. As long as you don't see 100% relative humidity at the interface between the foam and the cavity insulation, you won't have condensation on the back side of the sheathing." (See "Calculating Foam Thickness," next page.)

Lstiburek admits that his simple assumptions are not perfectly realistic. "When someone says, 'Yeah, but that's not really what's going on,' well, that's true. But it's a very good approximation — it gets us 98% accuracy with one easy calculation." And he's backed it up with lots of experimental work and lots of very detailed measurements and calculations. Anyone who's not comfortable with it, he says, can always run a more detailed simulation for the particular structure — or simply increase the foam thickness for good measure.

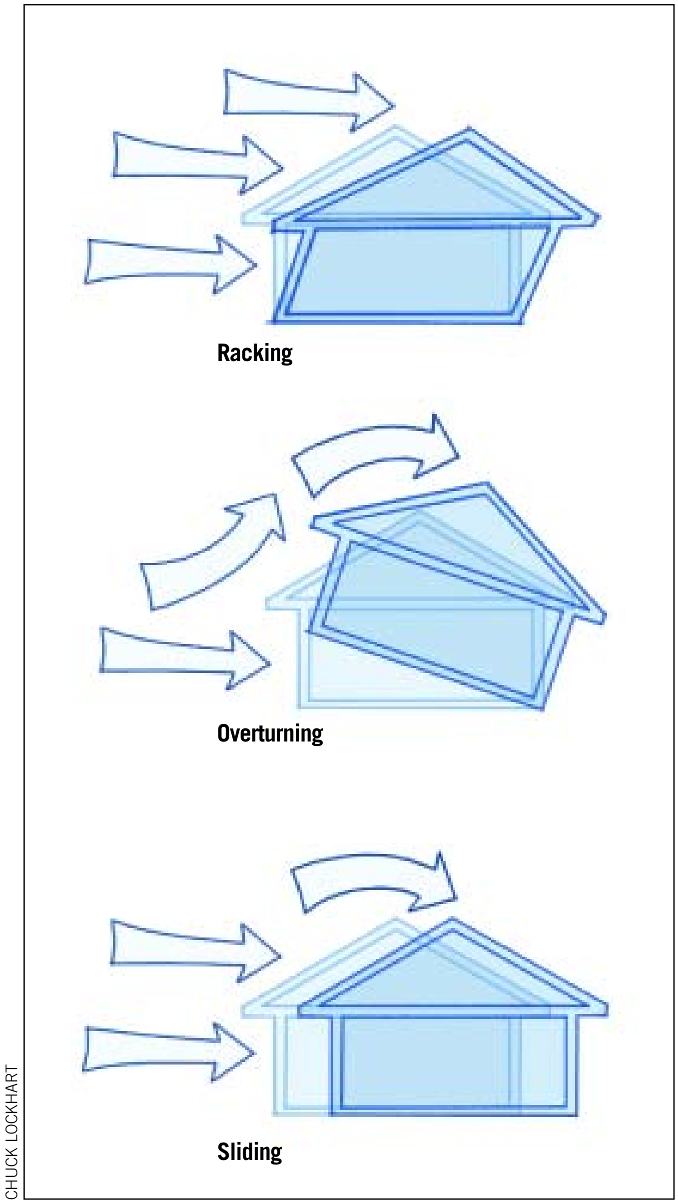


FIGURE 2. To resist the wind, as well as the possibility of a tidal surge, coastal homes must be stiff enough to resist racking, and they must also be anchored against sliding and overturning. The stiffness comes from plywood or OSB sheathing; foam isn't enough.

Fastening foam. The thickness of the foam, of course, affects the fastening of the siding and trim. Foam by itself won't anchor a fastener, so nails and screws have to be long enough to go through the foam into solid wood. According to Lstiburek, the practical limit for normal fastening through foam is between 1 and 1½ inches. "For foam thicker than an inch and a half, I go to 1x4 strapping screwed through the foam into the framing or sheathing behind it," he says. "We've done 8-inch to 10-inch layers of foam that way. The barn at my house [near Boston, Mass.] has 8 inches of foam on the outside, battened on using 12-inch screws."

STRUCTURAL PERFORMANCE

In some parts of the country, you can get away with rigid foam as the main sheathing, with OSB or plywood used only for bracing at wall corners, plus an occasional sheet at mid-wall. But that method won't wash in high-speed wind zones by the ocean (**Figure 2**). In general, houses near the shore will need full structural panel sheathing under the insulating foam.

Racking resistance. "The main function of the wood structural panel sheathing," explains Joe Lstiburek, "is to provide racking resistance. It also helps support the housewrap. So I don't think you're going to be able to build in [coastal] conditions without sheathing your entire building with plywood or OSB."

CALCULATING FOAM THICKNESS

The illustrations below show the predicted temperatures within walls with insulated vapor-barrier sheathing in Boston, Mass. These predictions are based on a simple calculation described by Joseph Lstiburek of Building Science Corporation:

Interface temp. =
Indoor temp. – [(Indoor temp. – Outdoor temp.) X (Cavity R / Total R)]

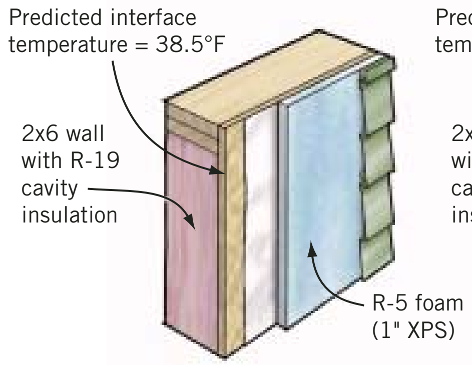
The goal here is to find an interface temperature (the temperature at the inside face of the foam) that is *above* the dew point for the indoor conditions. If it falls below the dew point, there is a higher risk that water vapor will condense inside the wall and lead to moisture problems. In that case, increasing the thickness of the foam will better insulate the framed wall and maintain the interface temperature at a higher level.

For this calculation, the indoor conditions are assumed to be 70°F and 35% relative humidity — reasonable values if the rest of the house system is functioning well.

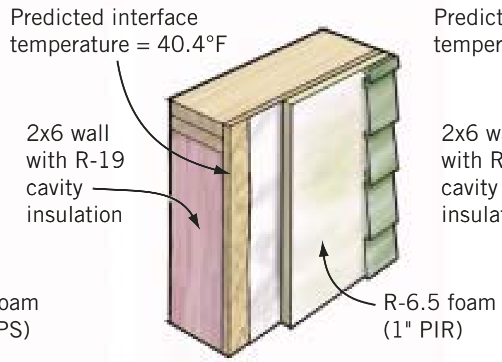
At this temperature and humidity, the dew point is 40°F, so the idea is to choose a foam sheathing R-value that will result in a calculated interface temperature above 40°F.

The outdoor design temperature is found by averaging the temperatures for the three coldest months for the year. For this example, in Boston: 33°F (Dec.), 28°F (Jan.), and 30°F (Feb.), for an average of 30.3°F. (Note: These represent monthly *average* temperatures, not monthly lows or average lows.)

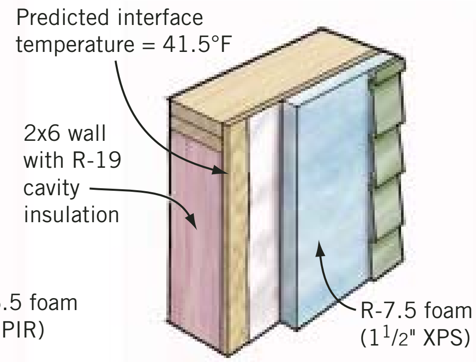
After running the numbers, Case A is found to surpass the energy code, but risks condensation because the vapor-barrier temperature is below the dew point for the design indoor conditions. Case D does not risk condensation, but falls below the R-19 energy-code minimum for wall insulation. All other cases satisfy moisture concerns as well as energy codes.



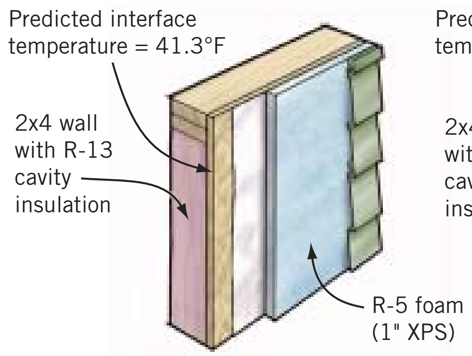
Case A. Total insulation = R-24



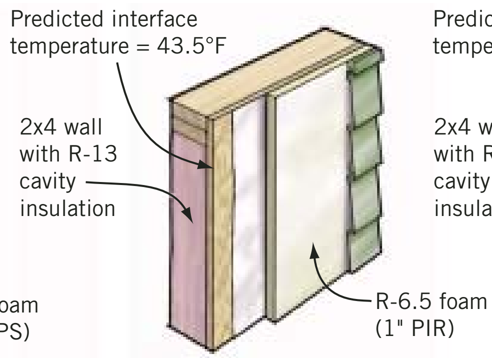
Case B. Total insulation = R-25.5



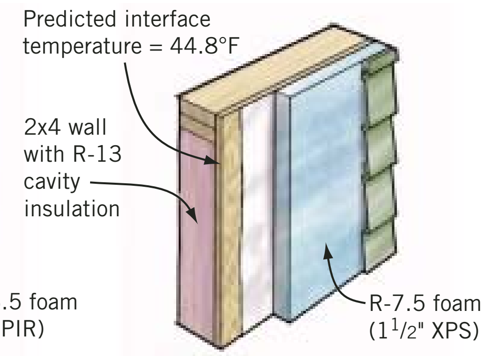
Case C. Total insulation = R-26.5



Case D. Total insulation = R-18



Case E. Total insulation = R-19.5



Case F. Total insulation = R-20.5

CHUCK LOCKHART

FIGURE 3. Contractor Craig Caulkins of Caulkins Building & Design in Niantic, Conn., routinely applies 1⁄2-inch or 1-inch Dow Styrofoam to home exteriors under vinyl siding (above right). While foam is water resistant and provides a good barrier against the bulk of the weather, wind-driven rain can find its way around panels and through joints, so Caulkins relies on a housewrap and careful window flashing installed over a fully sheathed structure before installing the foam (above left).

In coastal states, homes in sheltered locations far from the water may be able to substitute foam sheathing for wood-panel sheathing. However, they'll still need wall bracing — either a code-recognized method, or an engineered design (see "Wall Bracing and the IRC," July/August 2006; www.coastalcontractor.net). The easiest way to do this is with fully sheathed walls. In many cases, this may require the addition of engineered shear walls as well.

Stabilizing the shell. Foam can also have a positive effect on the structural performance of the wall. By placing an insulating, air-blocking, and vapor-blocking skin between the house's framing and sheathing and the exterior weather, foam sheathing lets the builder bring the home's wood structure into a relatively protected zone that is closer to the conditioned indoor environment. Notes Lstiburek: "Wall frames move because of moisture-change differentials between the inside faces of the studs and the outside face of the studs. That moisture-content difference increases if the temperature difference is greater. When you put insulating sheathing outside, the wall frame sees more constant and uniform conditions, and you actually reduce drywall cracking and building-frame movement."

DRAINAGE PLANES

Just as important in any wet climate, foam serves as a building's drainage plane for rainwater management. A "Guide to Insulating Sheathing" posted among the technical resources on the buildingscience.com Web site offers several ways to detail the foam skin under siding. But for the severe weather of coastal conditions, Lstiburek calls for a more robust system.

Fully sheathe the building, he says, and then apply a layer of drainable housewrap (**Figure 3**). "Attach the windows and doors directly to the

FIGURE 4. In combination with Andersen flanged vinyl windows, says Caulkins, no special furring or attaching method is required: window flanges extend far enough from the wall to cover all foam edges. Crews flash the window openings with self-adhering membrane, fasten the window directly to OSB-sheathed wall, and then apply a two-piece window surround from CertainTeed. The base piece of the window surround is nailed through the foam into the window rough frame (above left), and the matching top piece snaps into place over it (above right).

sheathing, and flash everything just as if you weren't applying the foam." After that, the foam gets installed over the housewrap and flashings (**Figure 4**). Most rainwater will be deflected by the cladding or by the foam sheathing beneath it, says Lstiburek, but any water that penetrates further will be shed by the flashings and housewrap; and any minor, incidental leaks should be able to dry into the conditioned space.

Robust performance. The field experience of others supports Lstiburek's recommendations. Dennis McCoy of Ram Builders, Inc. (www.rambuilders.com), a specialist in the repair of failed stucco-clad walls, says he's observed that foam sheathing can improve the weather performance of wall systems and protect against moisture damage. McCoy's company has torn apart and repaired or rebuilt thousands of moisture-damaged stucco walls in the hot, humid, coastal climate of Houston, Texas. "Walls with foam sheathing, in our experience, show less moisture damage, especially when the interior plastic vapor barrier is omitted from the walls," notes McCoy. Even if there is only one layer of building paper on the wall (good stucco practice requires two layers), walls with foam sheathing generally do better than walls without, he reports.

Ideally, McCoy would like to see stucco-clad wall frames protected by two layers of building paper and flashing, then a layer of foam, before the lath and stucco are applied. "We call the building paper a secondary weather barrier," he says. "The stucco cladding is the primary weather barrier. But if you include the foam, now you actually have a third weather barrier to help handle rainwater."

In cases he has investigated, McCoy reports, the foam indeed seems to protect against both exterior rain and interior moisture. "The walls don't get condensation on the back side of the OSB sheathing," he says. "And where there are leaks, they seem to be able to dry to the inside as long as there's no plastic vapor barrier in the way. I can't explain the science, but it works. It's a hard sell to customers, especially after all the trouble that has happened with EIFS [exterior insulated finish systems]. But if someone's willing to pay for it, I'd like to put exterior foam insulation on every wall we fix." ~

Ted Cushman reports on the building industry from his home base in Great Barrington, Mass.

AIR SEALING GUIDE

MULTIFAMILY MASONRY CONSTRUCTION

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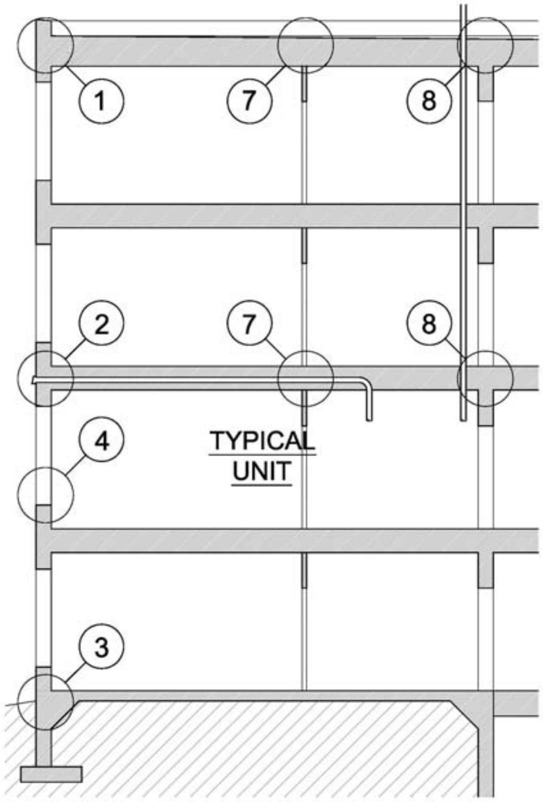
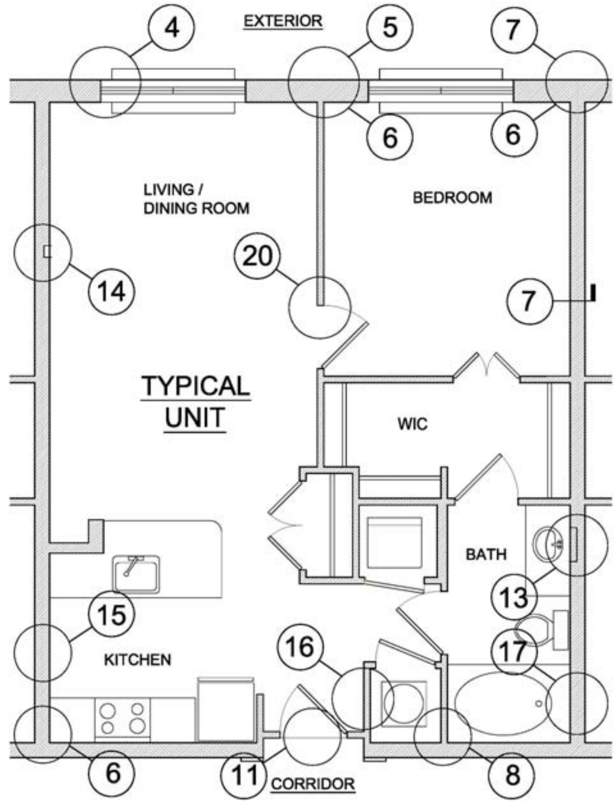


SECTION KEY
TYPICAL MULTIFAMILY BUILDING



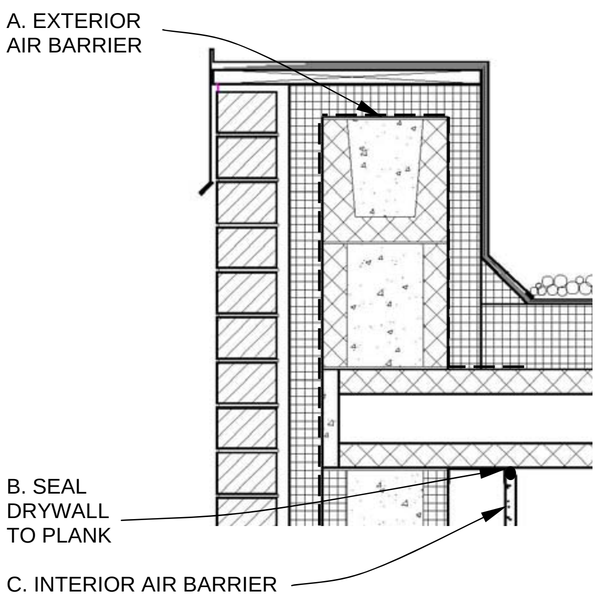
PLAN KEY
TYPICAL UNIT PLAN

RULES OF THUMB

1. Use shrink/crack-proof caulk to seal gaps smaller than 1/4”
2. Use expanding foam to seal gaps larger than 1/4”
3. Spray-on air sealing products are very effective (e.g. EcoSeal)
4. Use low-expanding foam at window/door openings
5. Use temperature-appropriate sealant (e.g. high-temp caulk at flues, heating pipes, etc.)
6. Clean out cracks before applying sealant (e.g. compressed air, vacuum, damp cloth, etc.)
7. Assign responsibility to one trade/person for confirming completion of air sealing tasks (this guide includes suggestions for which trades should be initially responsible for each task)

1 EXTERIOR WALL - PARAPET (GRAVEL STOP SIMILAR)

(SECTION VIEW)



Notes:

A. Typically fluid-applied or adhesive membrane on CMUs (e.g. Grace / Henry products)

B. Intent: reduce leakage between wall cavity and apartment

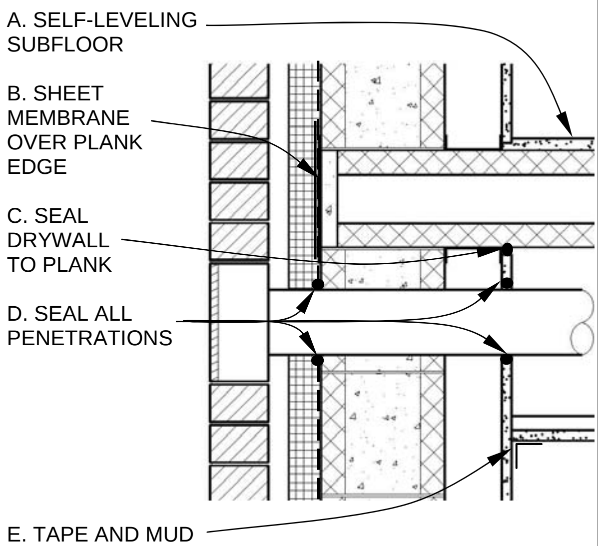
C. Typically drywall

Responsibilities:

Envelope: A
Drywall: B, C

2 EXTERIOR WALL - MIDDLE (DEMISING/CORRIDOR WALLS SIM.)

(SECTION VIEW)



Notes:

A, C. Intent: reduce leakage between floor and wall cavities

A. Option: seal drywall to slab (in lieu of plank)

B. Incorporate with exterior air barrier

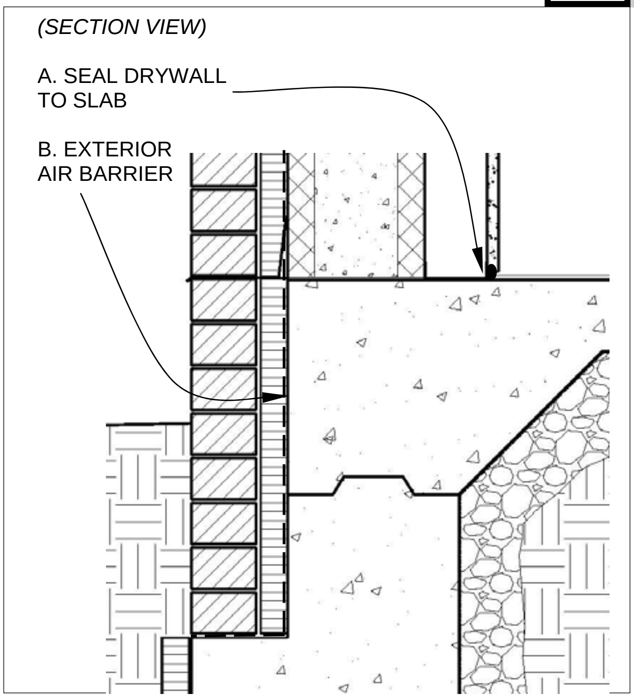
D. Includes ducts, pipes, wires, etc. (high priority)

E. Typical

Responsibilities:

Envelope: B
Drywall: C, E
Mech/elec/plumb: D

3 EXTERIOR WALL - BOTTOM



Notes:

A. Intent: reduce leakage between wall cavity and apartment

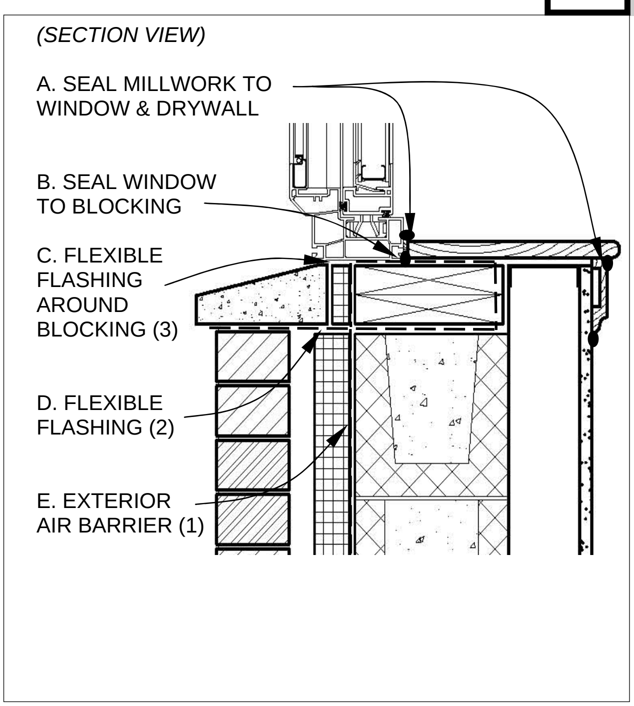
A. Option: self-leveling subfloor (i.e. gypcrete)

- Seal any remaining gaps between self-leveling subfloor and drywall with caulk

Responsibilities:

Drywall: A
Envelope: B

4 WINDOW SILL (HEAD AND JAMB SIMILAR



Notes:

A. Intent: reduce leakage between wall cavity and apartment

B. Intent: reduce leakage between wall cavity and outdoors

B. Seal any gaps at shims

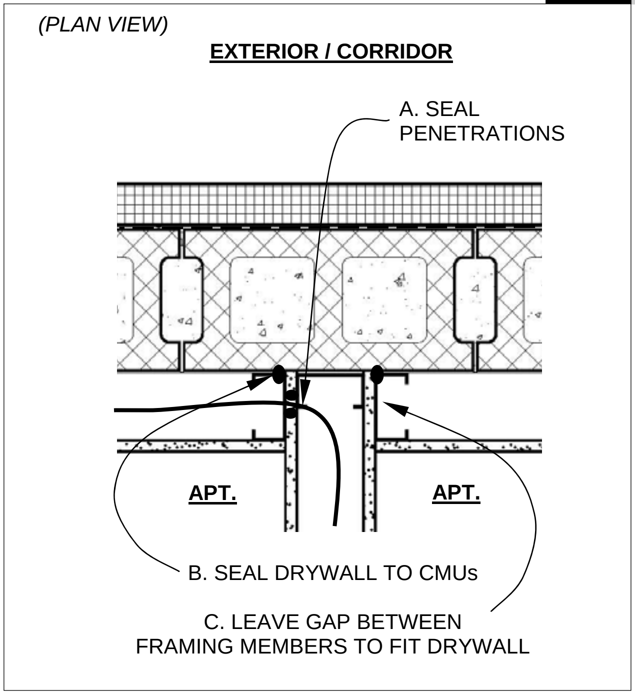
C, D, E: Sequence of installation shown (1, 2, 3)

D. Wrap entire window opening with flexible flashing

Responsibilities:

Envelope: B, C, D, E
Paint: A

5 DEMISING WALL/INTERIOR PARTITION AT EXTERIOR/CORRIDOR WALL



Notes:

A, B. Intent: reduce leakage between exterior/corridor wall and demising wall / interior partition

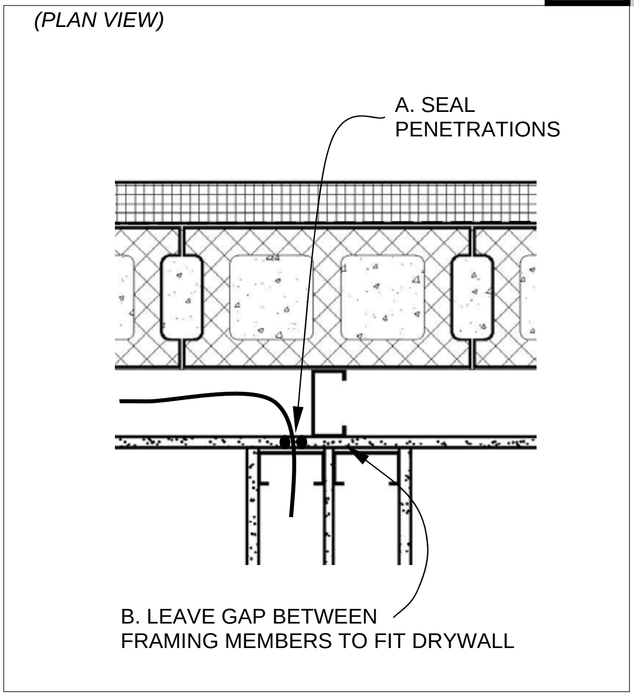
A. Includes ducts, pipes, wires, etc.

B. Size of gap depends on thickness of drywall to be installed

Responsibilities:

Framing: C
Drywall: B
Mech/elec/plumb: A

6 ALTERNATE METHOD FOR WALL CAVITY SEPARATION



Notes:

A. Intent: reduce leakage between exterior/corridor wall and demising wall / interior partition

A. Includes ducts, pipes, wires, etc.

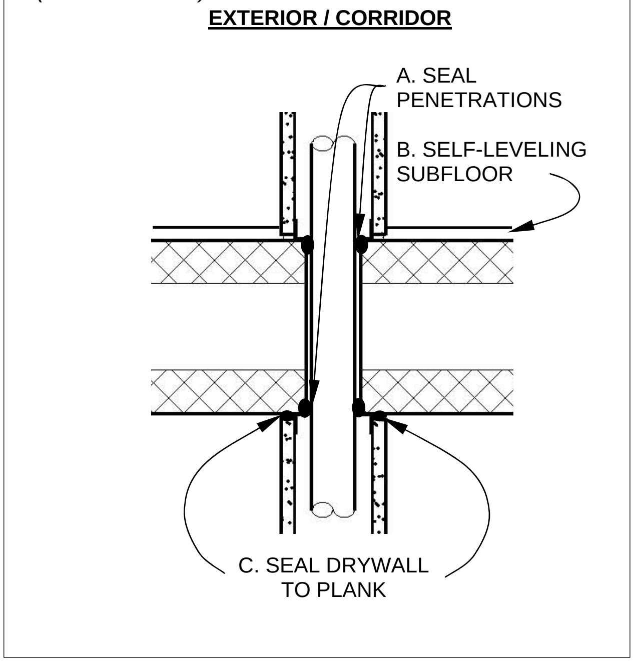
B. Size of gap depends on thickness of drywall to be installed

Responsibilities:

Framing: B
Mech/elec/plumb: A

7 INTERIOR WALLS - TOP/BOTTOM

(SECTION VIEW)



Notes:

A, B, C. Intent: reduce leakage between wall cavities and apartments

A. Includes ducts, pipes, wires, etc.

B. Size of gap depends on thickness of drywall to be installed

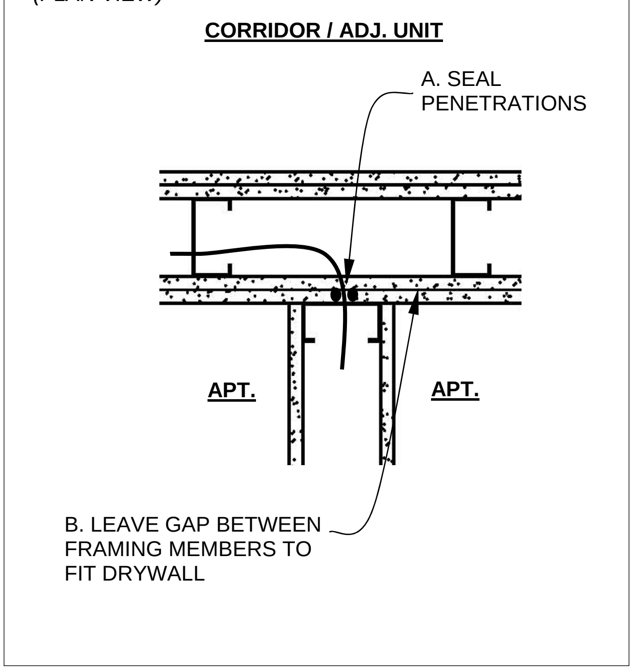
C. Option: seal drywall to slab (in lieu of plank)

Responsibilities:

Drywall: C
Mech/elec/plumb: A

8 INTERIOR PARTITION AT DEMISING/ CORRIDOR WALL

(PLAN VIEW)



Notes:

A. Intent: reduce leakage between corridor/demising wall and interior partition

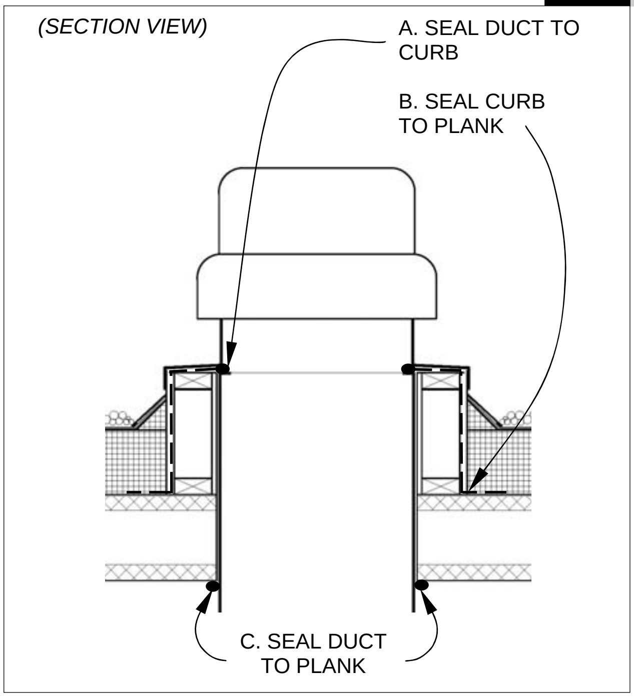
A. Includes ducts, pipes, wires, etc.

B. Size of gap depends on thickness of drywall to be installed

Responsibilities:

Framing: B
Mech/elec/plumb: A

9 ROOF FAN



Notes:

A, B. Intent:
- Reduce leakage between conditioned & unconditioned space
- Reduce duct leakage

C. Intent: Reduce leakage between conditioned & unconditioned space

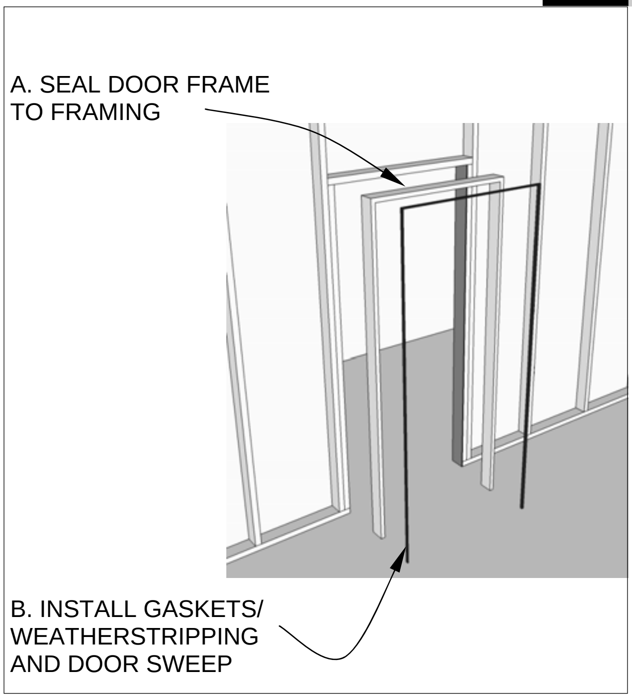
Note: connect fan to curb tightly (but do not seal permanently to allow removal for maintenance)

Responsibilities:

Roofing: B
Mech/elec/plumb: A, C

10 (NOT USED)

11 CORRIDOR/EXTERIOR DOOR



Notes:

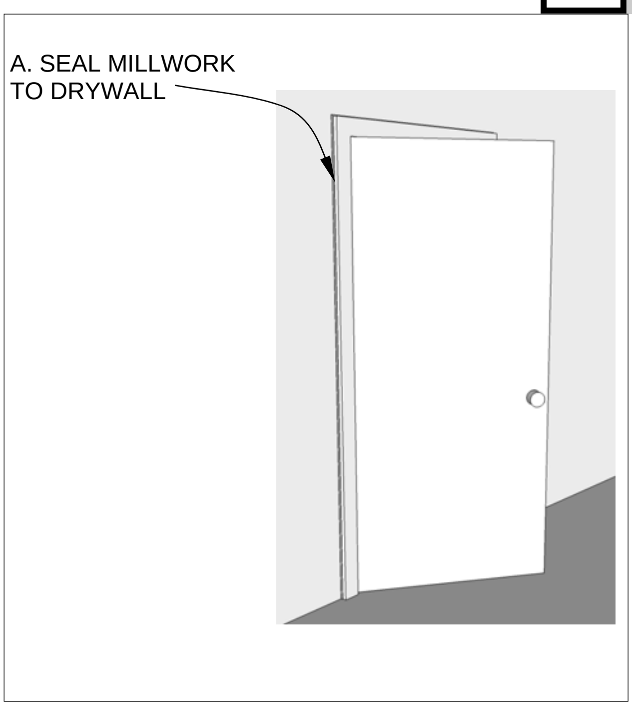
A, B. Intent: reduce leakage between apartment and corridor/outdoors

A, B. Also applicable at rooms that are vented to outdoors (i.e. boiler room, trash room, etc.)

Responsibility:

Framing: A
Window/door: B

12 MILLWORK (TRIM)



Notes:

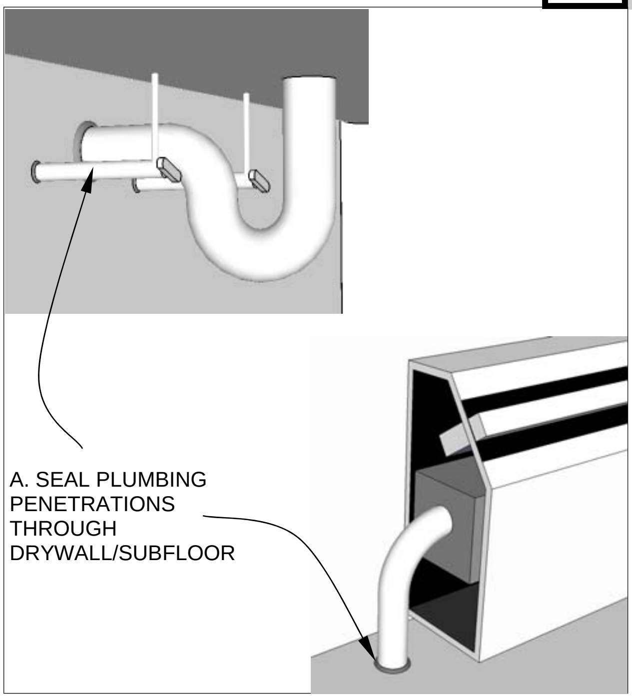
A. Seal ALL edges of millwork

A. Intent: reduce leakage between wall cavities and apartment

Responsibility:

Drywall: A

13 PLUMBING PENETRATIONS



Notes:

A. Seal all penetrations BEFORE installing cabinetry

A. Intent: reduce leakage between wall cavities and apartment

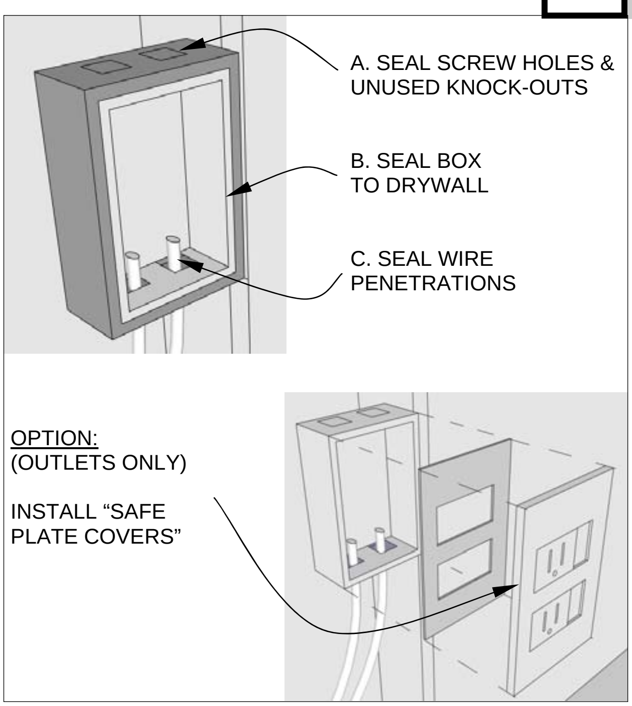
A. Seal penetrations before installing escutcheons

A. Typical plumbing penetrations include:
- Sink faucet supplies & drain
- Toilet supply
- Showerhead stub-out
- Heating supply/return
- Gas supply
- Sprinklers

Responsibility:

Drywall: A

14 ELECTRICAL BOXES



Notes:

A, B, C. Intent: reduce leakage between structural cavities and apartment

A, B, C. Includes boxes in floors and ceilings

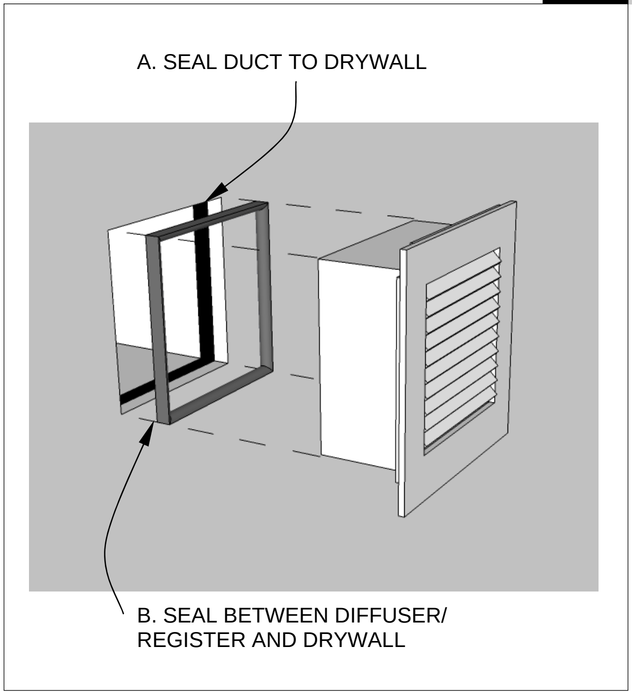
A, C. Options:
- Caulk
- Foam
- Mastic (over entire box)
- Putty pack

Option (at outlets only): In lieu of A/B/C, install air-tight covers and gaskets

Responsibility:

Drywall: B
Electrical: A, C

15 DUCTWORK



Notes:

A. Seal penetration BEFORE installing diffuser/ register

A. Intent:
- Reduce leakage between wall cavities and apartment
- Reduce duct leakage into wall cavities

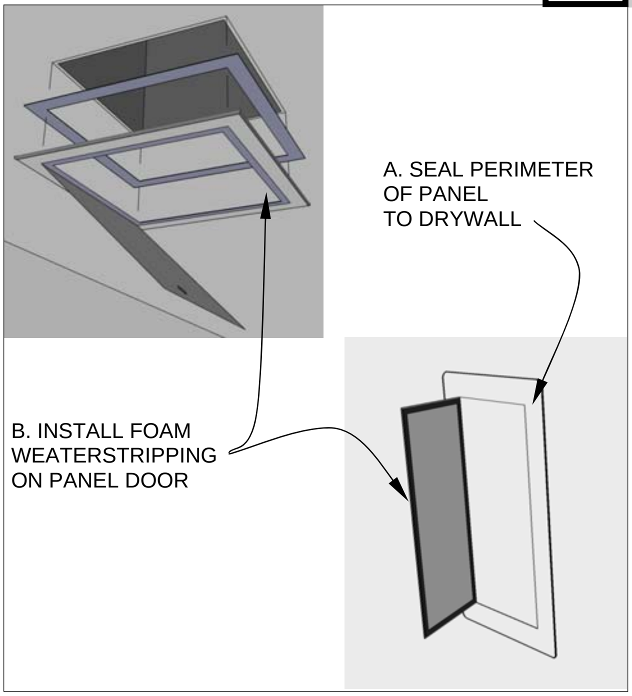
A. Typical penetrations include:
- Heating/cooling ductwork
- Exhaust ductwork
- Exhaust fans
- Dryer vent

B. Suggested (options: caulk, foam, gasket)

Responsibility:

Drywall: A
Mechanical: B

16 UTILITY/ACCESS PANELS



Notes:

A, B. Intent: reduce leakage between structural cavities and apartment

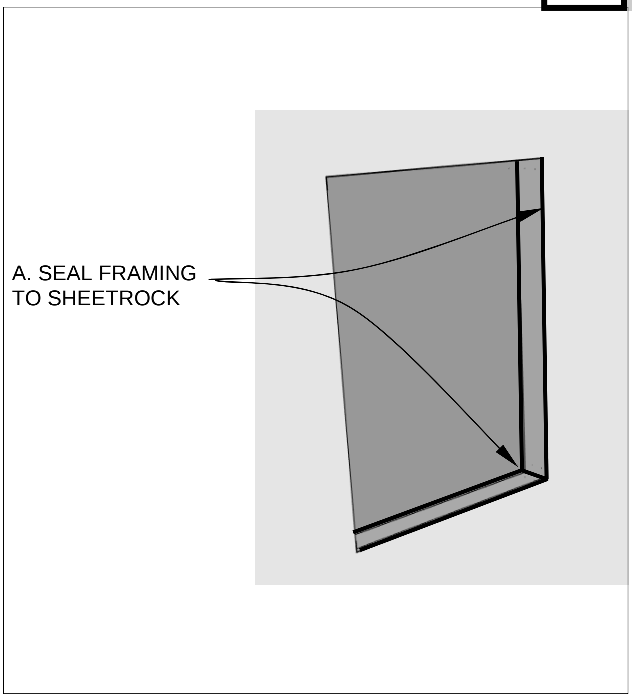
A. Options:
- Caulk
- Foam
- Gasket

B. Inexpensive, adhesive-backed weatherstripping usually works best

Responsibility:

Drywall: A
Mech/elec/plumb: B

17 RECESSED COMPONENTS



Notes:

A. Seal all cracks/seams BEFORE recessed component is installed

A. Intent: reduce leakage between wall cavities and apartment

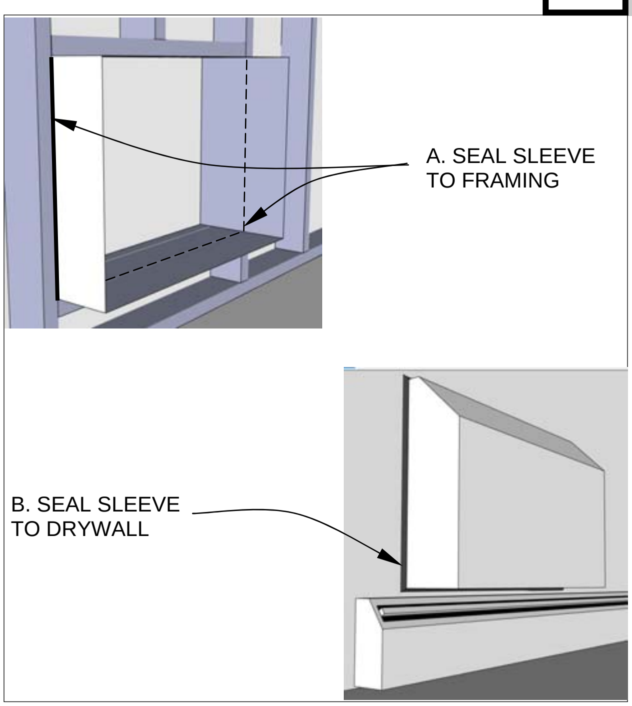
A. Seal holes in metal framing (if applicable)

A. Typical recessed components include:
- Medicine cabinet
- Fire extinguisher cabinets
- Mailboxes

Responsibility:

Drywall: A

18 PACKAGED HEATING/COOLING EQUIPMENT (PTACs)



Notes:

A. Intent: reduce leakage between apartment and outdoors

B. Intent: reduce leakage between wall cavity and apartment

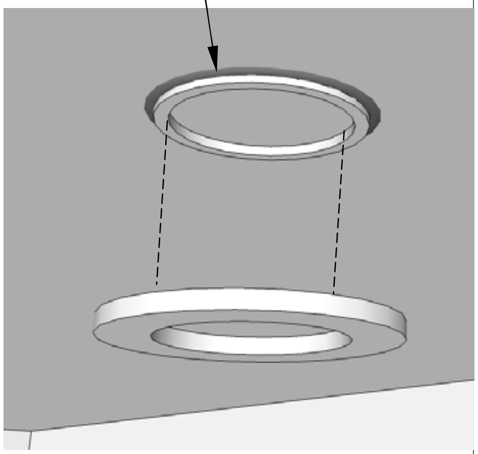
Additional measures:

- Seal PTAC equipment to sleeve
- Provide insulated interior cover with compressible gasket

Responsibility:

Mechanical: A
Drywall: B

19 RECESSED LIGHTING



Notes:

A. Intent: reduce leakage between attic/floor cavities and apartment

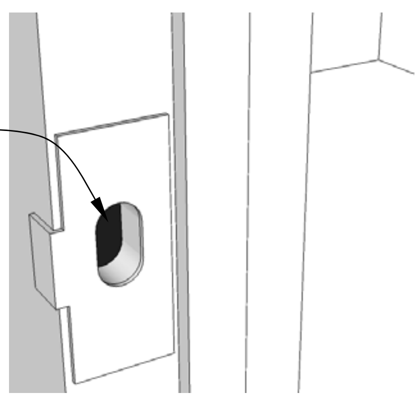
A. Options:
- Caulk
- Foam
- Gasket

A. Use insulation contact air-tight cans (ICAT)

Responsibility:

Drywall: A

20 DOOR LATCH HOLE



Notes:

A. Intent: reduce leakage between wall cavities and apartment

A. Expanding foam works best (be careful not to overspray)

Responsibility:

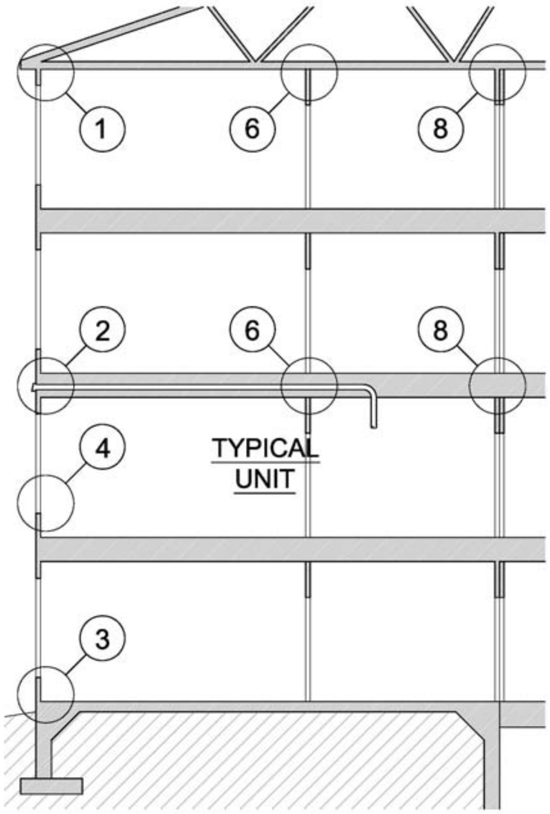
Drywall: A

AIR SEALING GUIDE

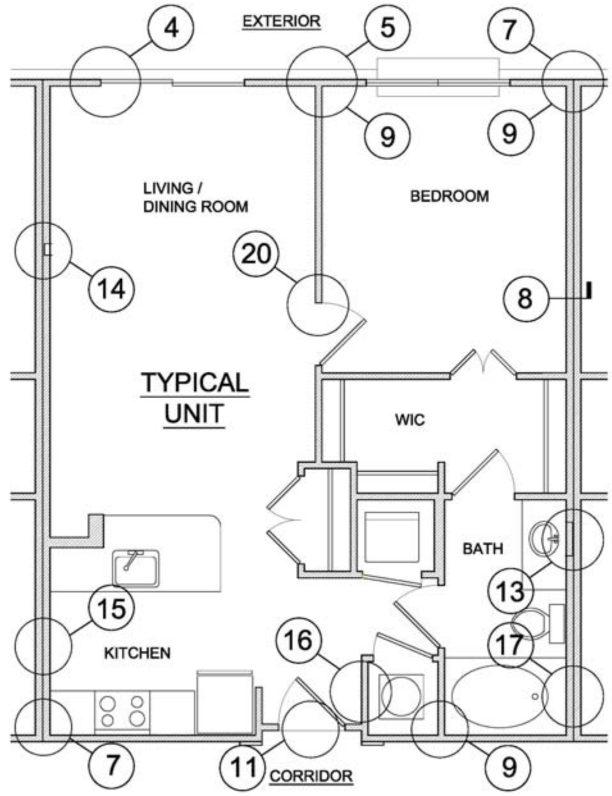
MULTIFAMILY WOOD CONSTRUCTION

Steven Winter Associates, Inc. www.swinter.com

61 Washington Street, Norwalk, Connecticut 06854 tel 203-857-0200 fax 203-852-0741
307 7th Avenue, Suite 1701, New York, NY 10001 tel 212-564-5800 fax 212-741-8673
1112 16th Street NW, Suite 240, Washington, D.C. 20036 tel 202-628-6100 fax 202-393-5043

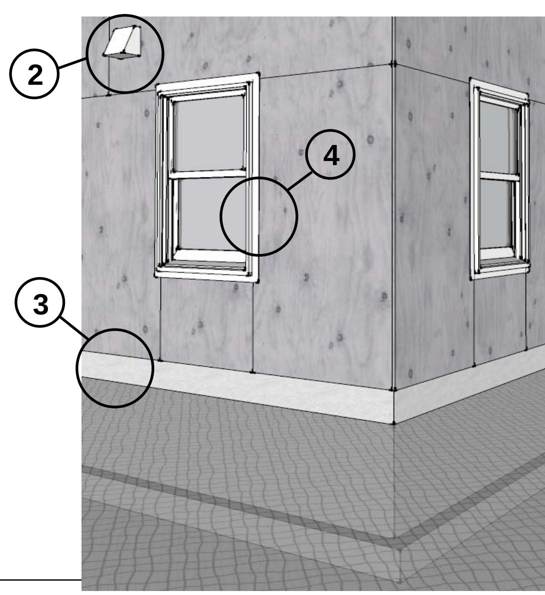


SECTION KEY
TYPICAL MULTIFAMILY BUILDING



PLAN KEY
TYPICAL UNIT PLAN

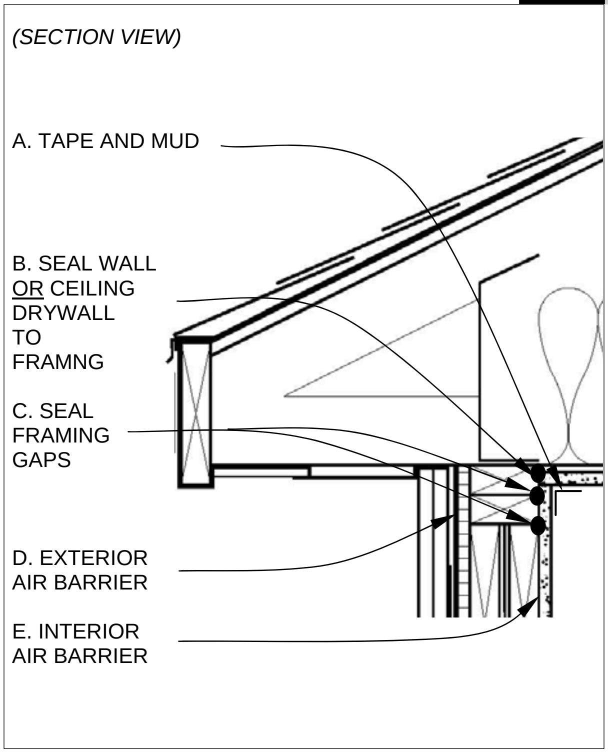
ELEVATION KEY
TYPICAL WOOD-FRAMED BUILDING



RULES OF THUMB

1. Use shrink/crack-proof caulk to seal gaps smaller than 1/4”
2. Use expanding foam to seal gaps larger than 1/4”
3. Spray-on air sealing products are very effective (i.e. EcoSeal)
4. Use low-expanding foam at window/door openings
5. Use temperature-appropriate sealant (i.e. high-temp caulk at flues, heating pipes, etc.)
6. Clean out cracks before applying sealant (i.e. compressed air, vacuum, damp cloth, etc.)
7. Assign responsibility to one trade/person for confirming completion of air sealing tasks (this guide includes suggestions for which trades should be initially responsible for each task)

1 EXTERIOR WALL - TOP



Notes:

A. Typical

B. Intent: reduce leakage between unconditioned attic and wall cavities (stops air movement through crack between drywall and top plate)

B. Option: apply drywall adhesive to framing BEFORE installing drywall ("screw & glue")

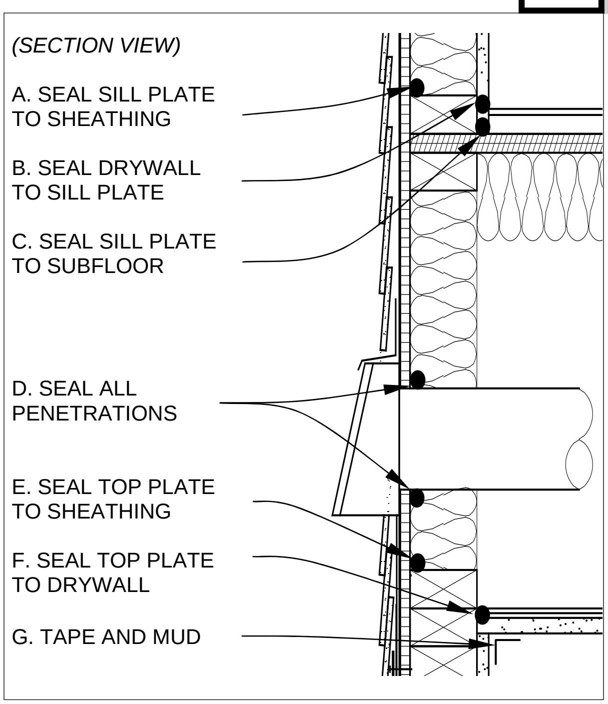
C. Intent: same as item B (but instead addresses the crack between the sheathing and the top plate)

D. Options:
- sheathing with seams sealed (i.e. ply wood or rigid foam board)
- rolled membrane/wrapping (i.e. Tyvek) with seams taped
- fluid-applied/adhesive membrane on sheathing (i.e. Grace / Henry products)

E. Typically drywall

Responsibilities:
Framing: C, D
Drywall: A, B, E

2 EXTERIOR WALL - MIDDLE



Notes:

A, C. Intent: reduce leakage between floor and wall cavities

B. Intent: reduce leakage between wall cavity and apartment

B, C. Option: self-leveling subfloor (i.e. gypcrete)

D. Includes ducts, pipes, wires, etc. (high priority)

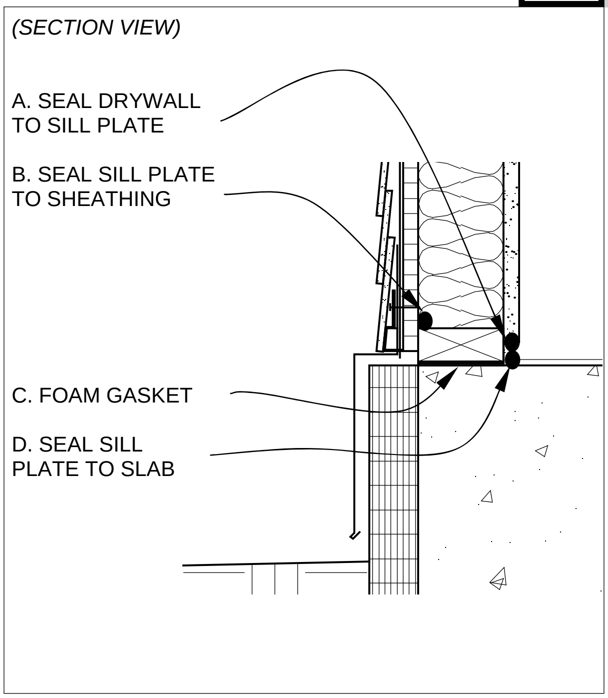
E, F. Intent: reduce leakage between floor and wall cavities

F. Option: apply drywall adhesive to framing BEFORE installing drywall

G. Typical

Responsibilities:
Framing: A, C, E
Drywall: B, F, G
Mech/elec/plumb: D

3 EXTERIOR WALL - BOTTOM (INTERIOR WALL SIMILAR)



Notes:

A. Intent: reduce leakage between wall cavity and apartment

B. Intent: reduce leakage between wall cavity and outdoors

A. Option: apply drywall adhesive to framing BEFORE installing drywall

A, B. Option: self-leveling subfloor (i.e. gypcrete)

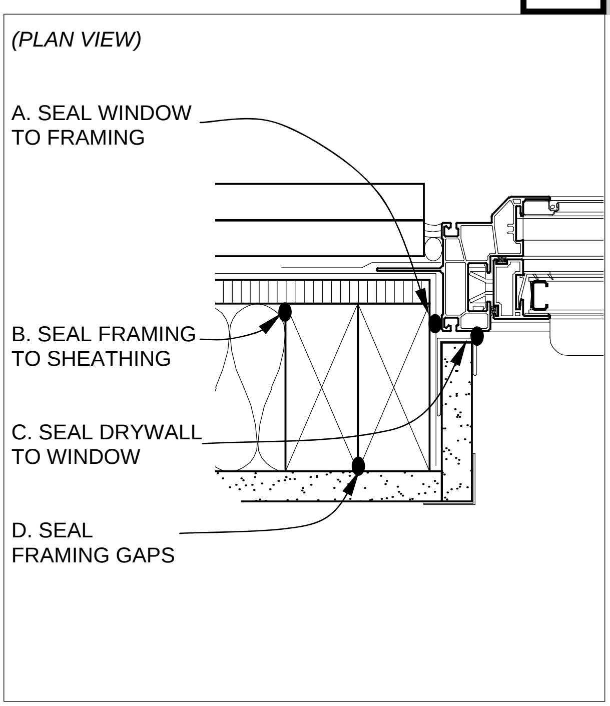
C. To be installed in addition to sealant between the plate and slab

D. Same intent as item B

Responsibilities:

Framing: B, C, D
Drywall: A

4 WINDOW JAMB (HEAD AND SILL SIMILAR)



Notes:

A. If using foam, use low-expanding foam

B. Intent: reduce leakage between wall cavity and outdoors (stops air movement through crack between sheathing and framing)

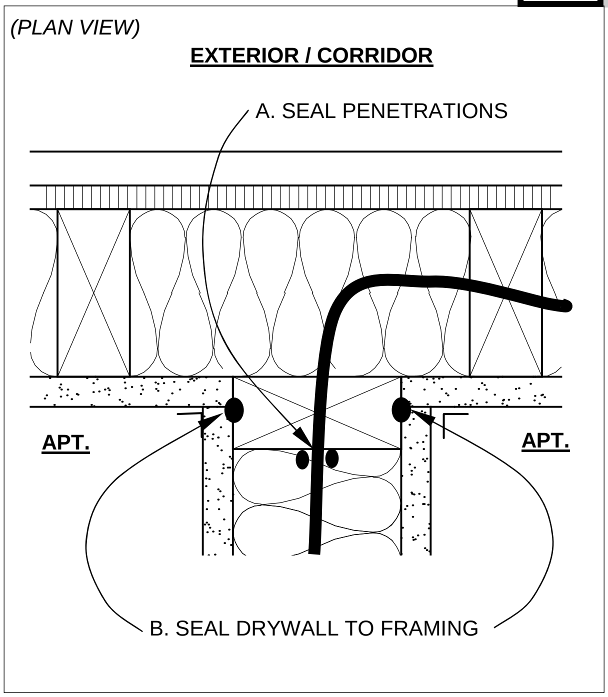
C. Similar detail at wood casing/trim

D. Same intent as item B

Responsibilities:

Framing: A, B, D
Drywall: C

5 DEMISING WALL/INTERIOR PARTITION AT EXTERIOR/CORRIDOR WALL



Notes:

A. Intent: reduce leakage between exterior/corridor wall and demising wall / interior partition

A. Includes ducts, pipes, wires, etc.

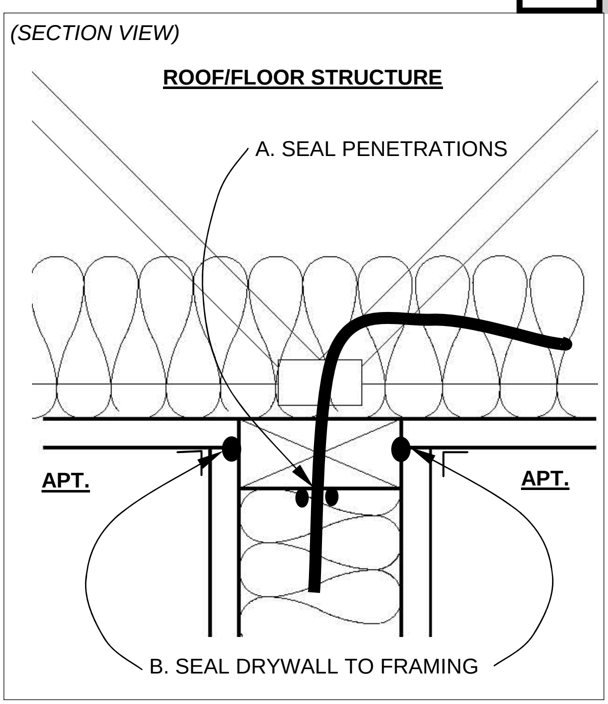
B. Intent: same as item A

B. Option: apply drywall adhesive to framing BEFORE installing drywall

Responsibilities:

Drywall: B
Mech/elec/plumb: A

6 CORRIDOR/DEMISING WALL/INTERIOR PARTITION - TOP (BOTTOM SIMILAR)



Notes:

A. Intent: reduce leakage between unconditioned attic / floor structure and demising wall / interior partition

A. Includes pipes, wires, etc.

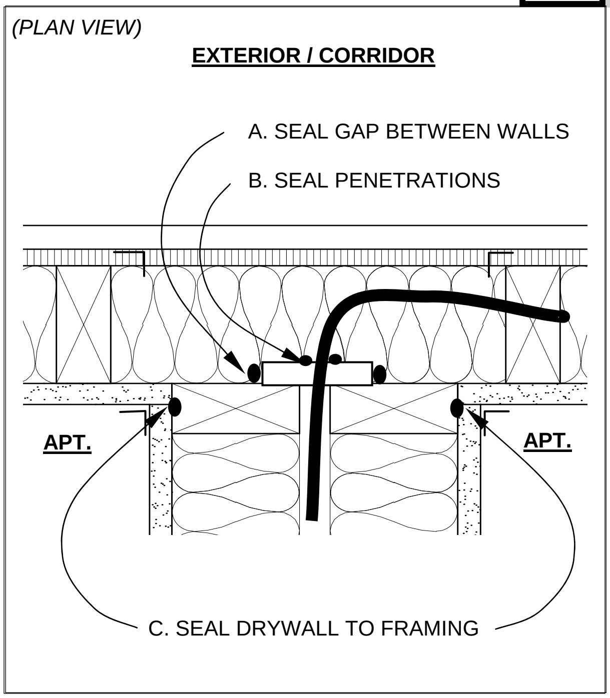
B. Intent: same as item A

B. Option: apply drywall adhesive to framing BEFORE installing drywall

Responsibilities:

Drywall: B
Mech/elec/plumb: A

7 DOUBLE WALL AT EXTERIOR/ CORRIDOR WALL



Notes:

A. Intent: reduce leakage between exterior/corridor wall and demising wall / interior partition

A. Options:

- Expanding foam
- Plywood/drywall/rigid foam board will edges caulked

A. Mineral wool / fiberglass batts are NOT acceptable

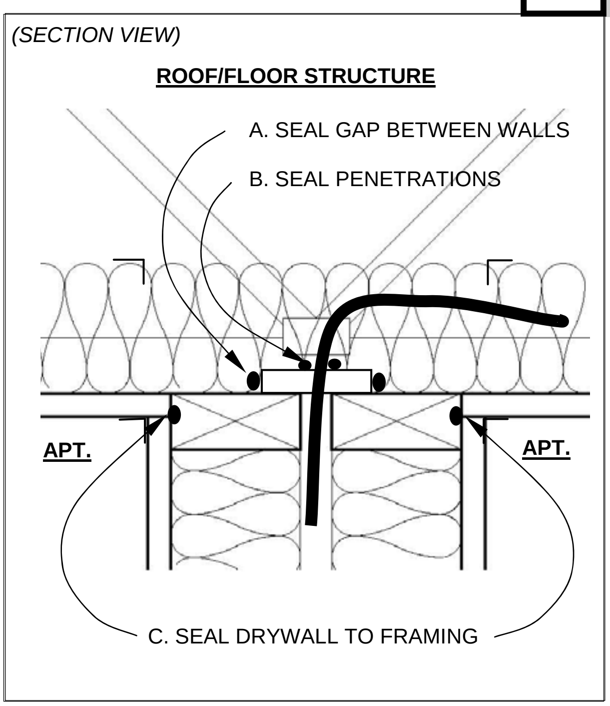
B, C. Intent: same as item A

C. Option: apply drywall adhesive to framing BEFORE installing drywall

Responsibilities:

Drywall: C
Mech/elec/plumb: A, B

8 DOUBLE-WALL - TOP (SHAFTS SIMILAR)



Notes:

A. Intent: reduce leakage between unconditioned attic / floor structure and demising wall / interior partition / shaft

A. Options:

- Expanding foam
- Plywood/drywall/rigid foam board will edges caulked

A. Mineral wool / fiberglass batts are NOT acceptable

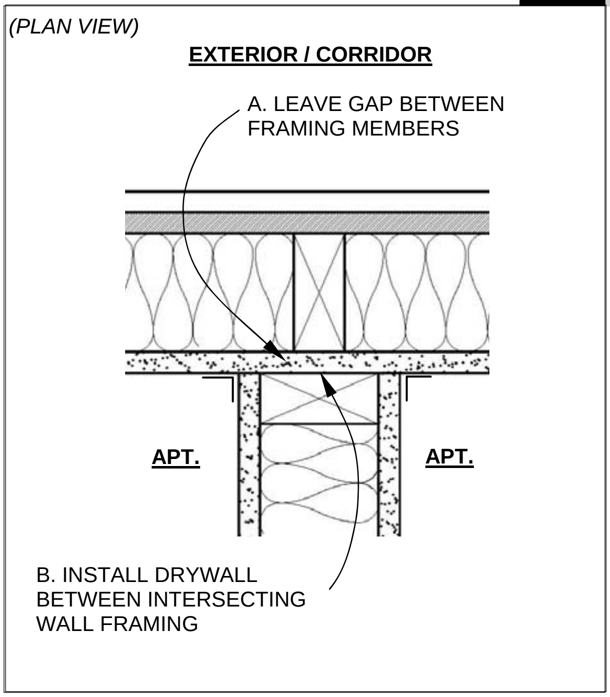
B, C. Intent: same as item A

C. Option: apply drywall adhesive to framing BEFORE installing drywall

Responsibilities:

Drywall: C
Mech/elec/plumb: A, B

9 DEMISING WALL/INTERIOR PARTITION AT EXTERIOR/CORRIDOR WALL



Notes:

A, B. Intent: reduce leakage between exterior/corridor wall and demising wall / interior partition

A. Size of gap depends on thickness of drywall to be installed

B. Option: sheathing (at shear walls)

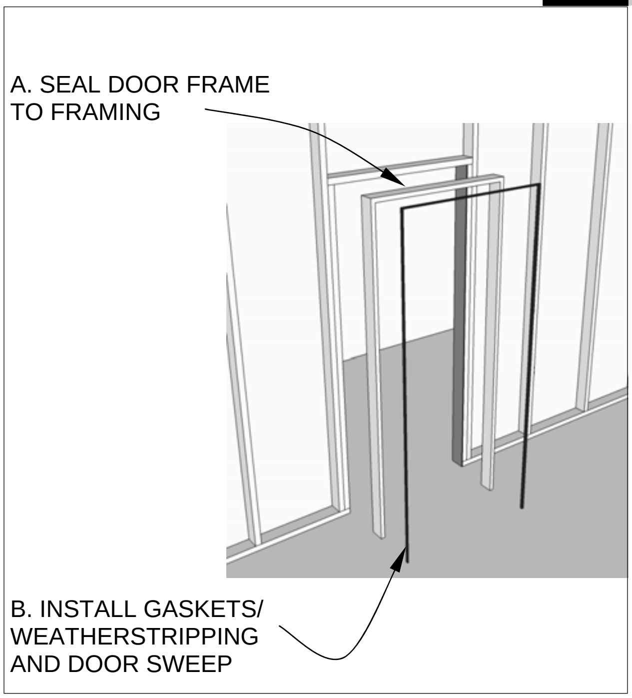
A, B. Similar at double walls

Responsibilities:

Framing: A
Drywall: B

10 (NOT USED)

11 CORRIDOR/EXTERIOR DOOR



Notes:

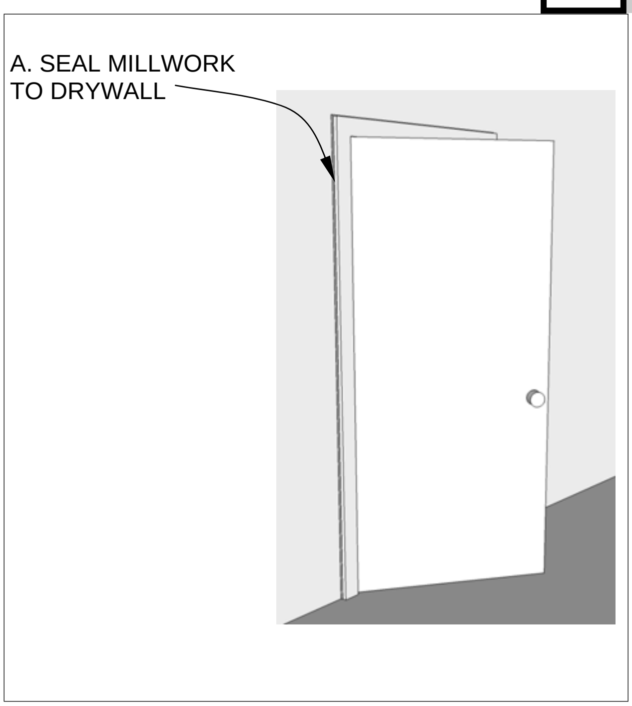
A, B. Intent: reduce leakage between apartment and corridor/outdoors

A, B. Also applicable at rooms that are vented to out-doors (i.e. boiler room, trash room, etc.)

Responsibility:

Framing: A
Window/door: B

12 MILLWORK (TRIM)



Notes:

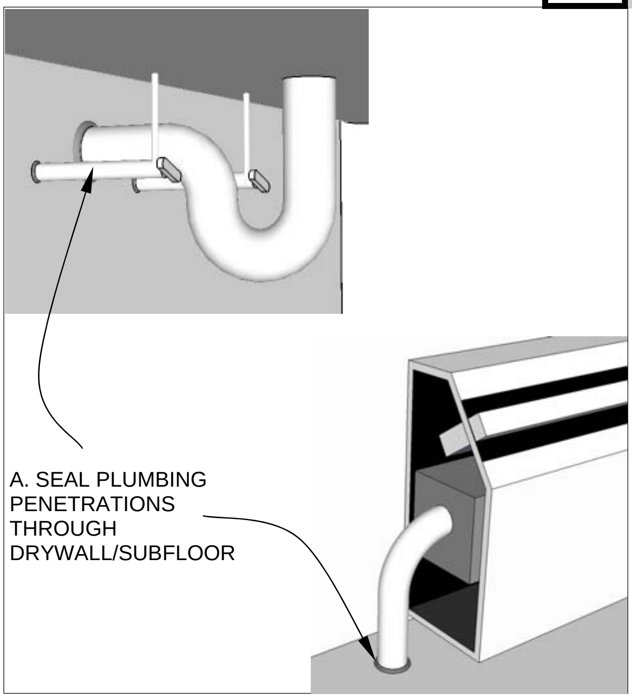
A. Seal ALL edges of millwork

A. Intent: reduce leakage between wall cavities and apartment

Responsibility:

Drywall: A

13 PLUMBING PENETRATIONS



Notes:

A. Seal all penetrations BEFORE installing cabinetry

A. Intent: reduce leakage between wall cavities and apartment

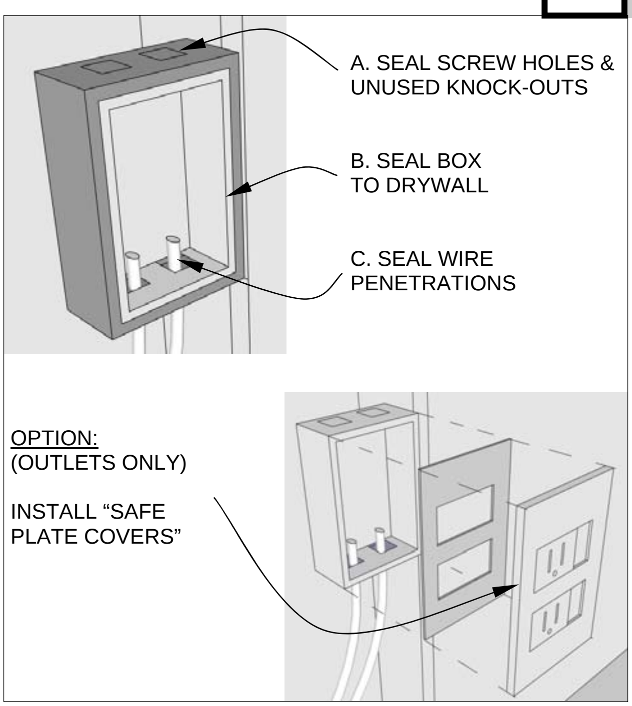
A. Seal penetrations before installing escutcheons

A. Typical plumbing penetrations include:
- Sink faucet supplies & drain
- Toilet supply
- Showerhead stub-out
- Heating supply/return
- Gas supply
- Sprinklers

Responsibility:

Drywall: A

14 ELECTRICAL BOXES



Notes:

A, B, C. Intent: reduce leakage between structural cavities and apartment

A, B, C. Includes boxes in floors and ceilings

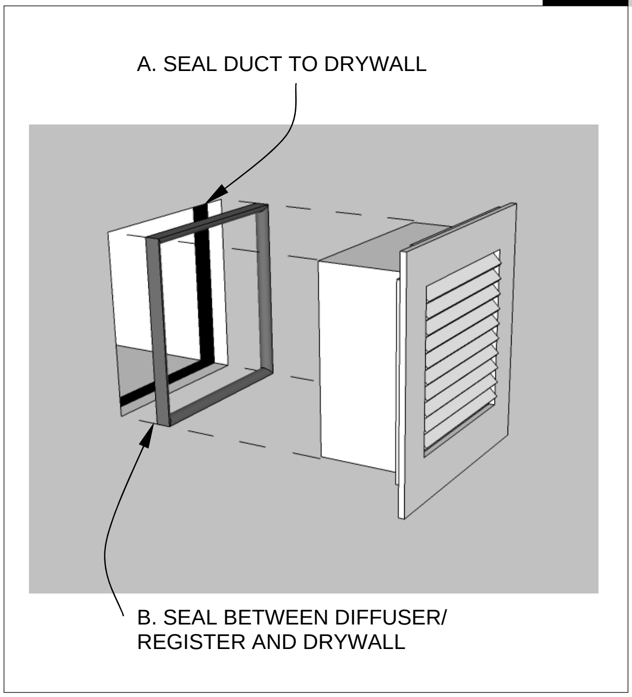
A, C. Options:
- Caulk
- Foam
- Mastic (over entire box)
- Putty pack

Option (at outlets only): In lieu of A/B/C, install air-tight covers and gaskets

Responsibility:

Drywall: B
Electrical: A, C

15 DUCTWORK



Notes:

A. Seal penetration BEFORE installing diffuser/ register

A. Intent:
- Reduce leakage between wall cavities and apartment
- Reduce duct leakage into wall cavities

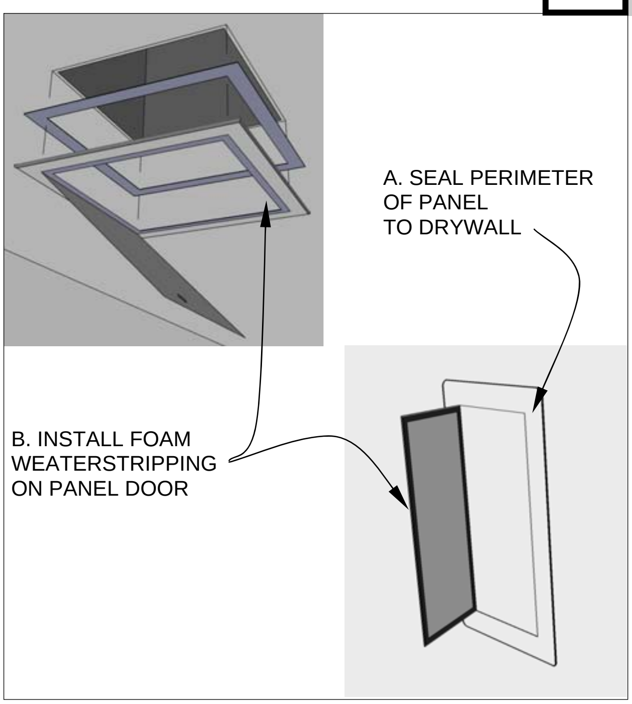
A. Typical penetrations include:
- Heating/cooling ductwork
- Exhaust ductwork
- Exhaust fans
- Dryer vent

B. Suggested (options: caulk, foam, gasket)

Responsibility:

Drywall: A
Mechanical: B

16 UTILITY/ACCESS PANELS



Notes:

A, B. Intent: reduce leakage between structural cavities and apartment

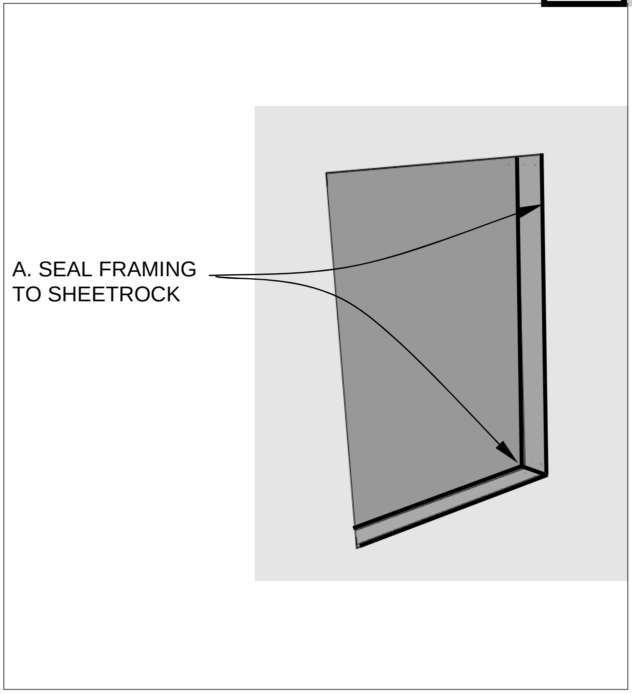
A. Options:
- Caulk
- Foam
- Gasket

B. Inexpensive, adhesive-backed weatherstripping usually works best

Responsibility:

Drywall: A
Mech/elec/plumb: B

17 RECESSED COMPONENTS



Notes:

A. Seal all cracks/seams BEFORE recessed component is installed

A. Intent: reduce leakage between wall cavities and apartment

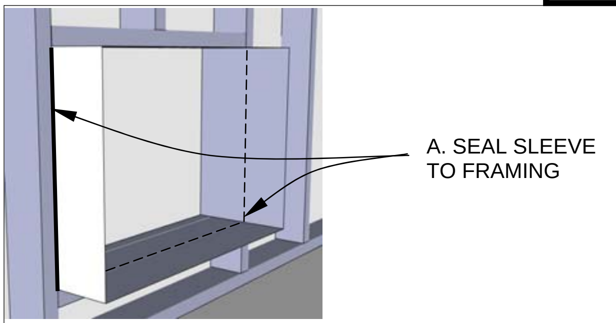
A. Seal holes in metal framing (if applicable)

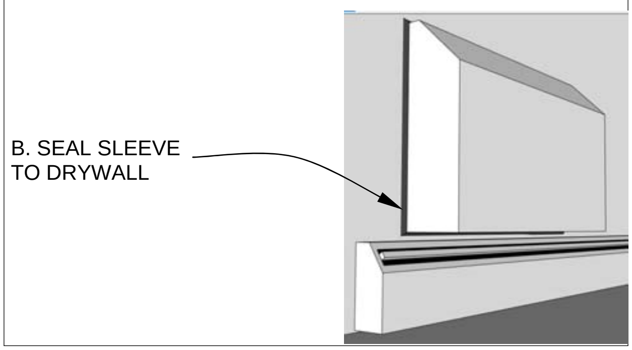
A. Typical recessed components include:
- Medicine cabinet
- Fire extinguisher cabinets
- Mailboxes

Responsibility:

Drywall: A

18 PACKAGED HEATING/COOLING EQUIPMENT (PTACs)





Notes:

A. Intent: reduce leakage between apartment and outdoors

B. Intent: reduce leakage between wall cavity and apartment

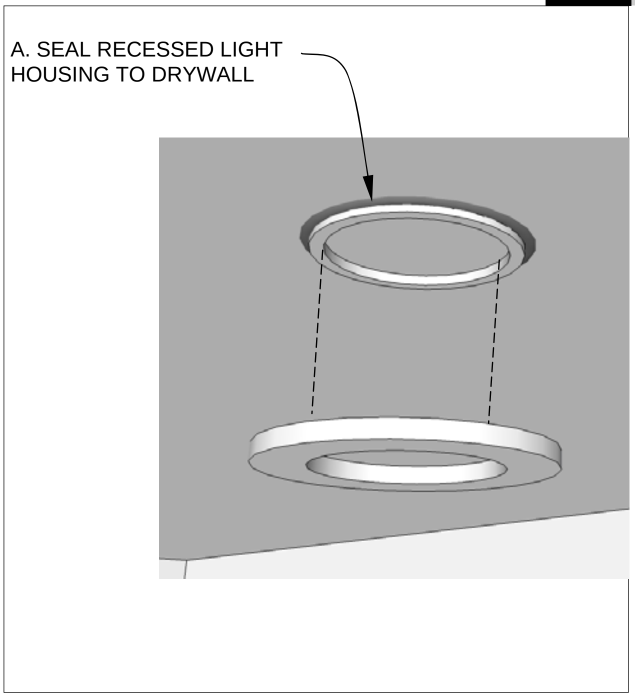
Additional measures:

- Seal PTAC equipment to sleeve
- Provide insulated interior cover with compressible gasket

Responsibility:

Mechanical: A
Drywall: B

19 RECESSED LIGHTING



Notes:

A. Intent: reduce leakage between attic/floor cavities and apartment

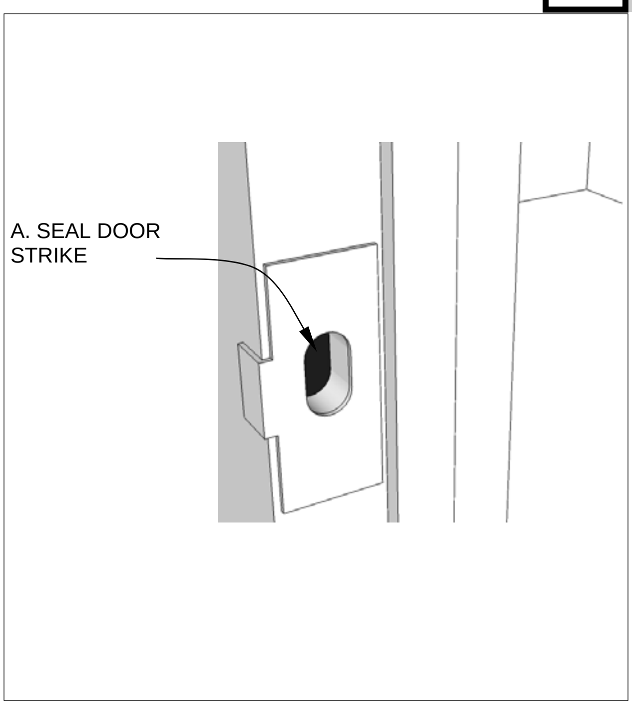
A. Options:
- Caulk
- Foam
- Gasket

A. Use insulation contact air-tight cans (ICAT)

Responsibility:

Drywall: A

20 DOOR LATCH HOLE



Notes:

A. Intent: reduce leakage between wall cavities and apartment

A. Expanding foam works best (be careful not to overspray)

Responsibility:

Drywall: A

HIGH PERFORMANCE WALLS

CLADDING ATTACHMENT SYSTEMS AND THEIR IMPACT ON CONTINUOUS EXTERIOR INSULATION EFFICIENCY

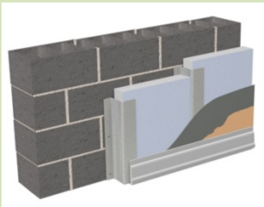
Document Summary: This document is meant to serve as a guide for designers and builders to compare the thermal performance of different cladding attachment systems. The first section is a catalogue of products, split into brick veneer and cladding finish systems. The second section presents thermal modeling results of these systems from a study conducted by Steven Winter Associates (SWA).

Thermal Efficiency: percentage of continuous insulation R-value that is effective.

- **100%** thermal efficiency = continuous insulation without thermal bridging
- **20%** thermal efficiency = continuous insulation derated to 20% of installed R-value

For Cladding Finish Systems: Girts

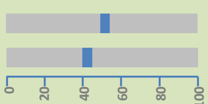
Galvanized Girts



Description

Typical z-girts are usually galvanized steel. Most projects use these to support their cladding systems.

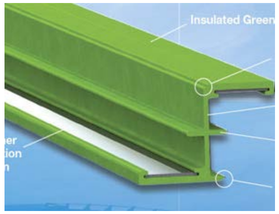
Thermal efficiency per SWA: **43%-53%**



53% for Steel backup
43% for CMU backup

Standard Product

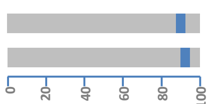
Fiberglass Girts



Description

Fiberglass girts are installed and used the same way as typical metal z-girt. The fiberglass material reduces thermal bridging.

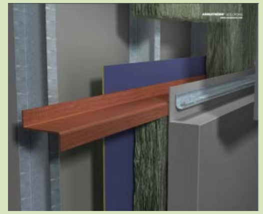
Thermal efficiency per SWA: **91%-95%**



91% for Steel backup
95% for CMU backup

Example Products:
Green Girt- Simple Z

Thermoset Resin Girts



Description

These girts have a low thermal conductivity. Made of fire resistant resin material. Can be spaced 16” or 24” o.c. and is very strong.

Thermal efficiency per SWA: **96%**

96% for Steel backup
96% for CMU backup

Example Products:
Armatherm Z Girt

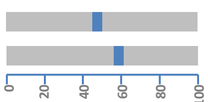
For Cladding Finish Systems: Clips

Galvanized Metal Clips

Description

These clips are usually galvanized steel and are used to support rainscreen and panel cladding systems.

Thermal efficiency per SWA: **46-59%**



46% for Steel backup
59% for CMU backup

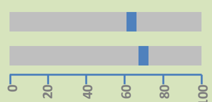
Standard Product

Stainless Steel Clips

Description

Replacing galvanized steel clips with stainless steel ones can greatly reduce the thermal conductivity.

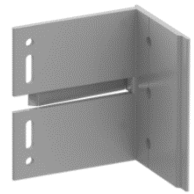
Thermal efficiency per SWA: **63-74%**



63% for Steel backup
74% for CMU backup

Example Products:
A-Clip. MFSSCHAN

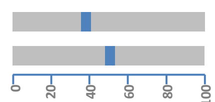
Aluminum Clips



Description

Aluminum clips are light weight and strong. They are a more elastic and non corrosive alternative to traditional metal clips.

Thermal efficiency per SWA: **38-52%**



38% for Steel backup
52% for CMU backup

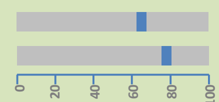
Example Products:
Alpha Brackets

Fiberglass Clips

Description

Fiberglass clips have a much lower thermal transmittance coefficient than any metal equivalent.

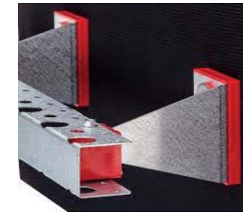
Thermal efficiency per SWA: **64-79%**



64% for Steel backup
79% for CMU backup

Example Products:
Cascada Clip

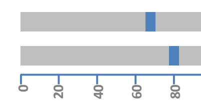
Thermal Stop Clips



Description

This clip has a plastic thermal stop at the base and head to help mitigate thermal bridging.

Thermal efficiency per SWA: **67-80%**



67% for Steel backup
80% for CMU backup

Example Products:
Pos-I-Tie Thermal Clip, Nvelope NV1 Thermal Clip

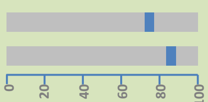
For Brick Veneer Systems: Ties

Galvanized Steel Brick Ties

Description

Typical brick ties are galvanized steel. Most brick veneer projects use this type of product.

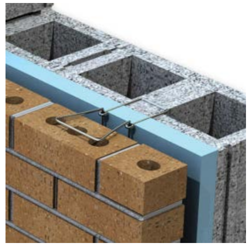
Thermal efficiency per SWA: **75-84%**



75% for Steel backup
84% for CMU backup

Standard Product

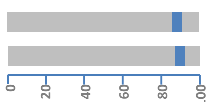
Stainless Steel Brick Ties



Description

Stainless steel ties are less conductive than galvanized steel ties.

Thermal efficiency per SWA: **87-93%**



87% for Steel backup
93% for CMU backup

Example Products:
2 Seal Tie Thermal, Original Pos-I-Tie

Thermal Break Brick Ties

Description

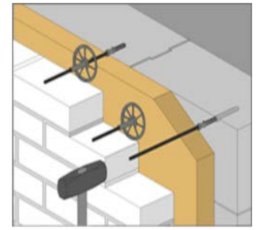
This stainless steel brick tie has a plastic coating, which reduces thermal bridging.

Thermal efficiency per SWA: **88-94%**

88% for Steel backup
94% for CMU backup

Example Products:
2 Seal Tie Thermal Wing Nut Anchor

Basalt Fiber Wall Ties



Description

Basalt fiber is a material made from fine fibers of basalt. They tend to be stronger and lighter than stainless steel wall ties and much less thermally conductive.

Example Products:
Teplo Ties, Galen Wall Ties

Connectors

Description

These are used in place of brick ties. The combination of horizontal and vertical elements increases strength despite its small size.

These can be applied prior to liquid applied air barrier installation, so air tightness is improved.

Example Products:
Block Shear Connector

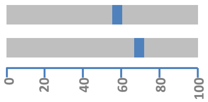
For Brick Veneer Systems: Angles

Typical Shelf Angle

Description

Typically, shelf-angles are made of galvanized steel.

Thermal efficiency per SWA: **58-69%**



58% for Steel backup
69% for CMU backup

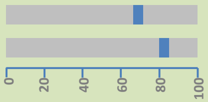
Standard Product

Stand-off Shelf Angle

Description

This stand off shelf angle allows insulation to be installed behind it. The bracket can be used with readily available shelf angles.

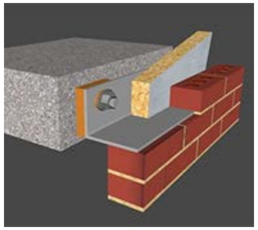
Thermal efficiency per SWA: **73-81%**



73% for Steel backup
81% for CMU backup

Example Products:
FAST (Fero Angle Support Technology),

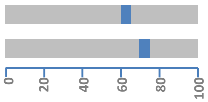
Shelf Angle with Thermal Break



Description

The thermal break plate is installed between the shelf angle and bracket to reduce the thermal bridge at those points.

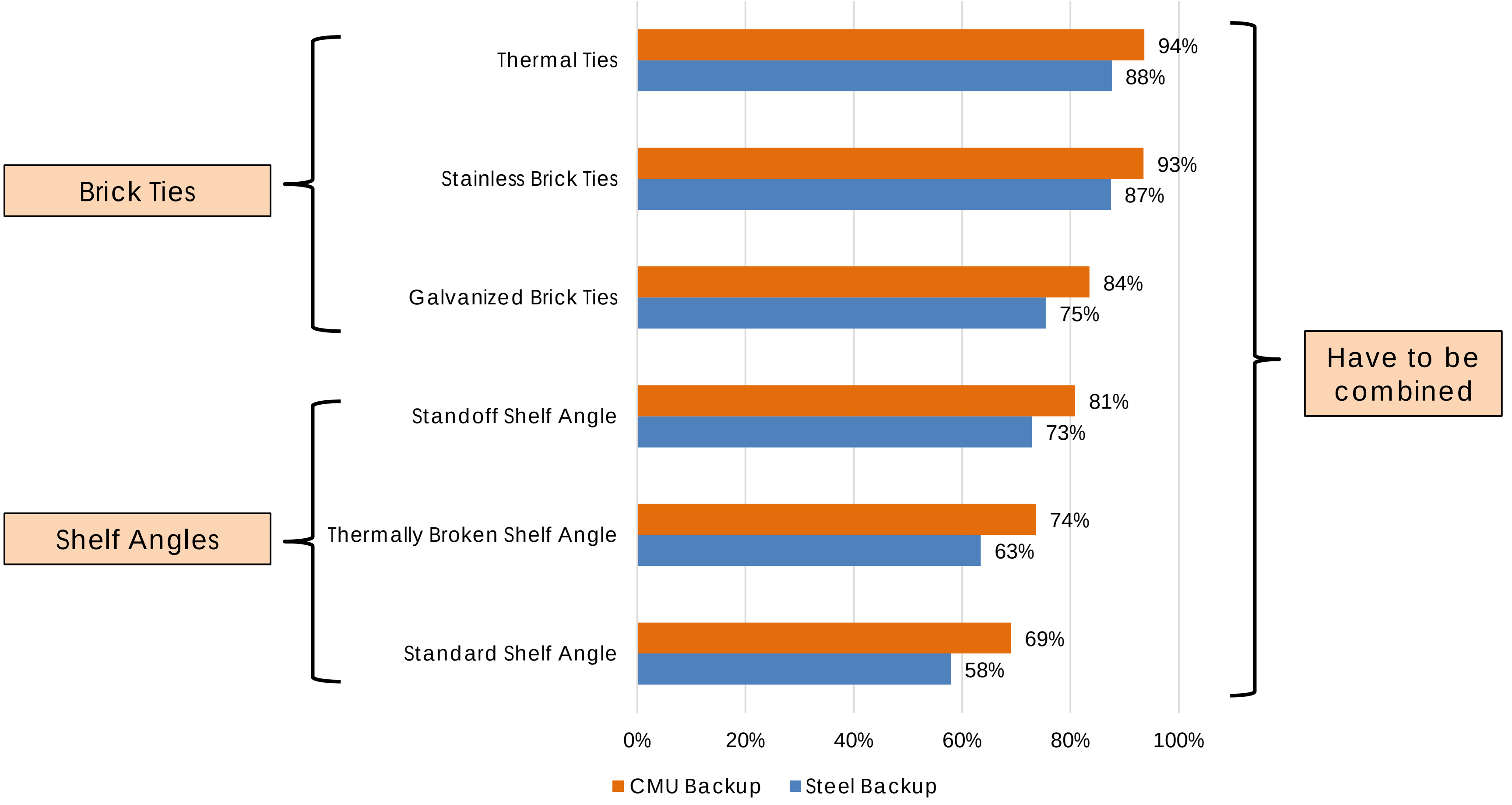
Thermal efficiency per SWA: **63-74%**



63% for Steel backup
74% for CMU backup

Example Products:
Armatherm Shelf Angle

Results: Brick Veneer



Results: Panel Cladding