Mold, Controlling Moisture Entry, Codes, and Design Strategies

Presented by: A. James Partridge, PE

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Mold Science

The presence of fungi on building materials as identified by a visual assessment or by bulk/surface sampling results does not necessitate that people will be exposed or exhibit health effects. In order for humans to be exposed indoors, fungal spores, fragments must be released into the air and inhaled, physically contacted, or ingested. Whether or not symptoms develop in people exposed to fungi depends on the nature of the fungi material (e.g., allergenic, toxic, or infectious), the amount of exposure, and the susceptibility of exposed persons.

Remediation:

In all situations, the underlying cause of water accumulation must be rectified or fungal growth will recur. Any initial water infiltration should be stopped and cleaned immediately. An immediate response (within 24 to 48 hours) and thorough clean up, drying, and/ or removal of water-damaged materials will prevent mold growth.

Mold Amplification Indoors

Molds are very successful. They have adapted to building materials by developing digestive enzymes to break down cellulose. The branching growth tips provide for expansion and penetration into various building materials. Spores can remain dormant for long periods of time and amplify when conditions are suitable.

Growth Requirements:

- Nutrients
  - High cellulose
  - Low nitrogen
  - Porous Building Materials are optimum
- Temperature Requirements are the same as for people 58°-85°F
- Moisture (limiting factor)

Nutrient Sources:

Construction Materials

- Wet insulation
- Damp carpets and/or pads
- Wet wall coverings
- Wood
- Paper layer of gypsum board
- Latex paints

Personal goods

- Cardboard boxes
- Cotton clothes
- Leather goods
- Furniture

Moisture:

Moisture can come from direct impact of water onto a substrate (i.e. flood), or from indirect sources (condensation). Mold will amplify on cellulose materials that remain wet for more than 48 hours.

Mold And The Building Industry

Mold growth in buildings illustrates a disconnect between the technical wisdom of building science, and its practitioners and the economics of the market for hasty building construction and operation.

There are currently no laws or regulations in place that control the testing, evaluation, and remediation of mold issues. Furthermore, there are no regulations to control who can say they are a “mold expert”. The consensus standards usually referenced are ACGIH, IICRC, and NYC Guidelines.

Faced with the explosive growth of mold related damage claims the insurance industry acted to eliminate their loss exposure. By adding exclusions for mold, fungus, and microbial matter claims, the insurance industry has shifted the financial burden for those losses back onto property owners, contractors, design professionals, suppliers, real estate agents, and lenders.

Wood Facts:

•Mold on framing is generally surface mold and can readily be removed by washing and only stain will remain.

•Wood will begin to decay at 28% moisture content and will stop at 20% (consensus)

•The more processing (cooking) the wood product has had the more prone it is to be “mold candy”.

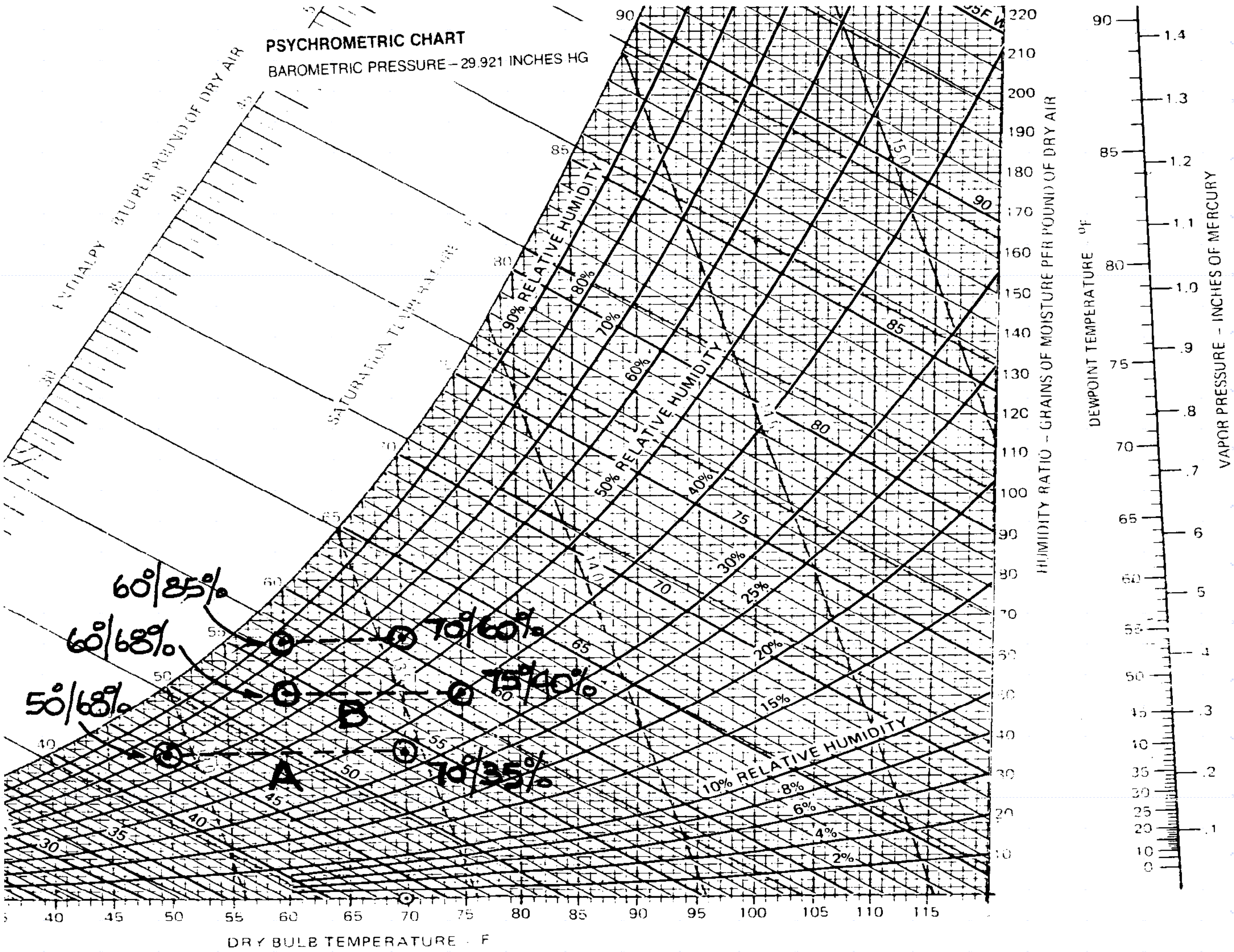
Why Mold Now?

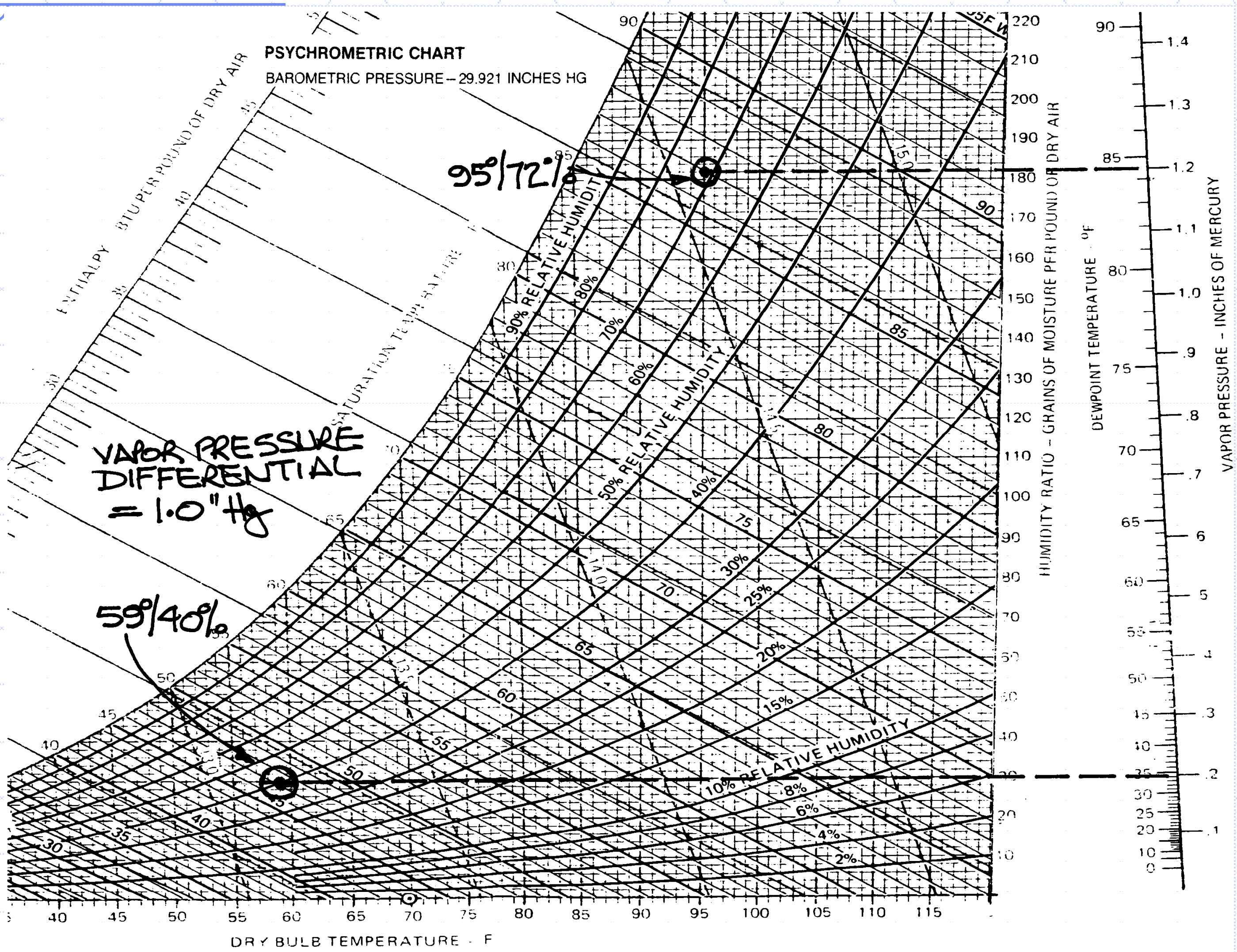
- Reduce water entry but retarding its escape is much longer
- Preventing wetting decreased the potential to dry.
- Energy code is requiring more insulation has helped create the mold issue as it's now more difficult to dry out envelopes
- Overall the water permeability of building envelopes has changed

- Rate of wetting greater than the rate of drying and the structures ability to accumulate water results in mold
- Water will penetrate all claddings
- Building in the heating climate designed for heating comfort and for microbial activity in the summer because of vapor barriers
- Current construction techniques and wet materials will result in about 20% of all wood buildings developing a mold problem

- Use of material with paper (wood component) in exterior walls
- Use of vapor retarders on basement walls
- Power washing of aluminum or vinyl siding especially with detergent which destroys the drainage plane
- Surfactant issues associated with mortar and its effect on the plastic-warp ((more research by presenter required))

Psychometrics





PSYCHROMETRIC CHART
BAROMETRIC PRESSURE – 29.921 INCHES HG
95°/72%
VAPOR PRESSURE DIFFERENTIAL = 1.0" Hg
59°/40%
ENTHALPY – BTU PER POUND OF DRY AIR
SATURATION TEMPERATURE
90% RELATIVE HUMIDITY
50% RELATIVE HUMIDITY
10% RELATIVE HUMIDITY
HUMIDITY RATIO – GRAINS OF MOISTURE PER POUND OF DRY AIR
DEWPOINT TEMPERATURE – °F
VAPOR PRESSURE – INCHES OF MERCURY
DRY BULB TEMPERATURE – F

Codes

Flashings

Michigan Building Code (MBC) 2000 (1403.2) and Michigan Residential Code (MRC) 2000 (R703.1) require a weather-resistive exterior wall envelope with a water-resistive barrier behind the exterior veneer.

MBC (1404.2) and MRC (R703.2) specify 15 lb. felt or other approved alternate as a water-resistive barrier.

MBC (1405.3) and MRC (R703.8) specify the flashing shall be provided in a manner to prevent entry into the wall cavity and delineates the locations of such flashings.

Michigan Energy Code (MEC), ASHRAE Standard 90.1/1999, (5.2.3.1) specifies envelope sealing to minimize air leakage.

Therefore, Contract Documents must clearly delineate what is to be installed and how the installation must be implemented to preclude water entry.

Controlling Moisture Entry into Buildings

To deal effectively with moisture in buildings, these strategies are imperative:

- Keep water out
- Designing assemblies to dry out
- Provide mechanical ventilation
- Avoid condensation in the building
- Avoid condensation within the building envelope

- Controlling entry of humid outside air
- Controlling indoor sources of humidity
- Avoid (or manage) plumbing leaks
- Provide mechanical dehumidification

Of these strategies many are controlled by the architect. These include:

- Flashing at all door and window penetrations
- Roof penetrations
- Roof-wall intersections
- Drainage planes in the envelope
- Capillary breaks
- Condensation within the envelope
- Condensation in the building

Flashings:

Provide proper flashing at all windows and doors penetrations. All components should be layered so that water is shed down and outward. Flashings can be installed before or after the housewrap or building felt “drainage plane.”

Manufacturers of building wraps (water-resistive barriers (WRB)) provide the details and have the products available to properly flash windows and doors but typically this is not the requirement of the Contract Documents and therefore never installed.

Water-resistive Barriers (WRB's):

The industry as a whole seems perplexed concerning the breathability of wall systems and the effects of WRB's. Don't look to codes for answers. The forthcoming new codes (effective December 31, 2003) requires a WRB over the sheathing regardless of the siding type and doesn't address breathability or alternates to 15 lb. felt.

Vapor pressure differentials can be high in a wall assembly but air infiltration accounts for much more water-vapor entering the cavity than by diffusion. Therefore, the taping of all joints and edges is necessary.

Though 15 lb. felt is usually cited, substitution of “equivalent” materials is allowed-opening the door for plastic building wraps. There is no standard for testing WRB's. Therefore, every manufacturer submits test data to an independent evaluation service and there is no way of comparing their respective properties. I recommend review of this subject from studies conducted by the University of Massachusetts, Building Materials and Wood Technology Department <http://www.umass.edu/bmatwt/>.

Based on my experience of our industries ability to keep water out of building envelopes it is imperative the WRB’s be breathable and let the water vapor escape to the exterior. Thus, a moderate perm rating is recommended.

One problem with plastic building wraps is the loss of water repellency. Contaminants such as surfactants can raise the surface energy of the building paper or lower the surface energy of the water allowing the "wetting" of the building wrap by water. Once this wetting occurs the pores or perforations become filled allowing the water (liquid phase) across the building wrap via capillary action or gravity.

Water soluble components in wood such as tannins and wood sugars are a type of surfactant that contaminate the surface of the plastic building wraps raising their surface energy.

I believe the smaller the holes in the wrap the better their water resistance capabilities in the presence of surfactants.

With surfactants increasing the probability of liquid water penetrating the building wrap it's imperative the wrap have a moderate or above perm value to ensure the wall can dry to the exterior.

In numerous inspections I've seen cedar shingles applied directly to the plastic wrap which insures water intrusion from the surfactants and vapor diffusion if the wetted shingle temperature is raised. A "cedar-breather" or similar air space is essential.

Condensation Control

Vapor Retarder Material:

Material	Thickness, inches	Perm
Aluminum foil	0.00035	0.05
2-mil polyethylene	0.002	0.16
4-mil polyethylene	0.004	0.08
6-mil polyethylene	0.006	0.06
Butyl rubber elastomer	0.015 to 0.04	0.02
Vapor retarder paint	0.0031	0.45
Kraft facing on glass fiber batts	0.0118	0.40

Smart Vapor Retarder:

Kraft paper (on fiber batt insulation) has a perm rating of about 1 at 25% relative humidity and about 8 at 50% RH.

Vapor migration calculation results for a 2 by 6 in. wall without a vapor barrier.

Material description	Thickness, in.	Thermal resistance, *R*, hr-sq ft-F/Btu	Permeance, PERM	Resistance to vapor transmittance, REP (1/PERM)	Surface dry bulb temperature, F	Surface dew point temperature, F	Calculated surface vapor pressure, *Pw*, in. Hg	Saturated air surface vapor pressure, *Px*, in. Hg
Outdoor air					9.00	-5.9089	0.03313	0.06627
Outdoor air film		0.1700	1000.0000	0.00100				
Inner surface					9.4757	-6.3651	0.03318	0.06770
Stone	5.0000	0.1667	0.6400	1.56250				
Inner surface					9.9421	20.2193****	0.10642	0.06912
Air barrier	0.0040	0.0000	77.0000	0.01299				
Inner surface					9.9421	20.3404****	0.10703	0.06912
Exterior plywood	0.5000	0.6200	0.5000	2.00000				
Inner surface					11.6768	34.8143****	0.20077	0.7467
Glass fiber insulation	2.0000	6.9091	60.0000	0.01667				
Inner surface					31.0083	34.9096****	0.20155	0.16929
Glass fiber insulation	3.5000	12.0909	34.2857	0.02917				
Inner surface					64.8383	35.0757	0.20292	0.60344
Gypsum board	0.5000	0.4500	40.0000	0.02500				
Inner surface					66.0974	35.2173	0.20409	0.63044
Paint	0.0024	0.0000	1.5000	0.66667				
Inner surface					66.0974	38.7642	0.23534	0.63044
Indoor air film		0.6800	160.0000	0.00625				
Indoor air					68.0000	39.3304	0.23563	0.67324
Totals	**11.5064**	**21.0867**		**4.3202370**				

Total water vapor transmission: 0.04687193430045 grains/sq ft-hr or 0.00000669599 lb/sq ft-hr.
Sensible heat transfer through the roof (negative value indicates flow from outside to inside): 2.7980 Btu/sq ft-hr.
Indoor air conditions: 68 F/35 percent RH.
Outdoor air conditions: 9 F/50 percent RH.
Elevation: 680 ft.

****If *Pw* is greater than or equal to *Px*, condensation will occur in that region.
****If the dew point temperature is greater than or equal to the dry bulb temperature, condensation will occur.

Vapor migration calculation results for a 2 by 6 in. wall with a vapor barrier.

Material description	Thickness, in.	Thermal resistance, *R*, hr-sq ft-F/Btu	Permeance, PERM	Resistance to vapor transmittance, REP (1/PERM)	Surface dry bulb temperature, F	Surface dew point temperature, F	Calculated surface vapor pressure, *Pw*, in. Hg	Saturated air surface vapor pressure, *Px*, in. Hg
Outdoor air					9.00	-5.9089	0.03313	0.06627
Outdoor air film		0.1700	1000.0000	0.00100				
Inner surface					9.4757	-6.3873	0.03315	0.06770
Stone	5.0000	0.1667	0.6400	1.56250				
Inner surface					9.9421	3.1351	0.05196	0.06912
Air barrier	0.0040	0.0000	77.0000	0.01299				
Inner surface					9.9421	3.2000	0.05211	0.06912
Exterior plywood	0.5000	0.6200	0.5000	2.00000				
Inner surface					11.6768	11.6040	0.07619	0.7467
Glass fiber insulation	2.0000	6.9091	60.0000	0.01667				
Inner surface					31.0083	11.6631	0.07639	0.16929
Glass fiber insulation	3.5000	12.0909	34.2857	0.02917				
Inner surface					64.8383	11.7669	0.07674	0.60344
Poly vapor barrier	0.0040	0.0000	0.0800	12.50000				
Inner surface					64.8383	37.8835	0.22723	0.60344
Gypsum board	0.5000	0.4500	40.0000	0.02500				
Inner surface					66.0974	37.9167	0.22753	0.63044
Paint	0.0024	0.0000	1.5000	0.66667				
Inner surface					66.0974	38.7875	0.23556	0.63044
Indoor air film		0.6800	160.0000	0.00625				
Indoor air					68.0000	39.3304	0.23563	0.67324
Totals	11.5104	21.0867		16.8202370				

Total water vapor transmission: 0.01203894247757 grains/sq ft-hr or 0.00000171985 lb/sq ft-hr.
Sensible heat transfer through the roof (negative value indicates flow from outside to inside): 2.7980 Btu/sq ft-hr.
Indoor air conditions: 68 F/35 percent RH.
Outdoor air conditions: 9 F/50 percent RH.
Elevation: 680 ft.

Ice Protection (R905.2.7.1)

Two methods of providing ice protection are code approved:

- Two layers of underlayment cemented together.
- Self-adhering polymer modified bitumen sheet.

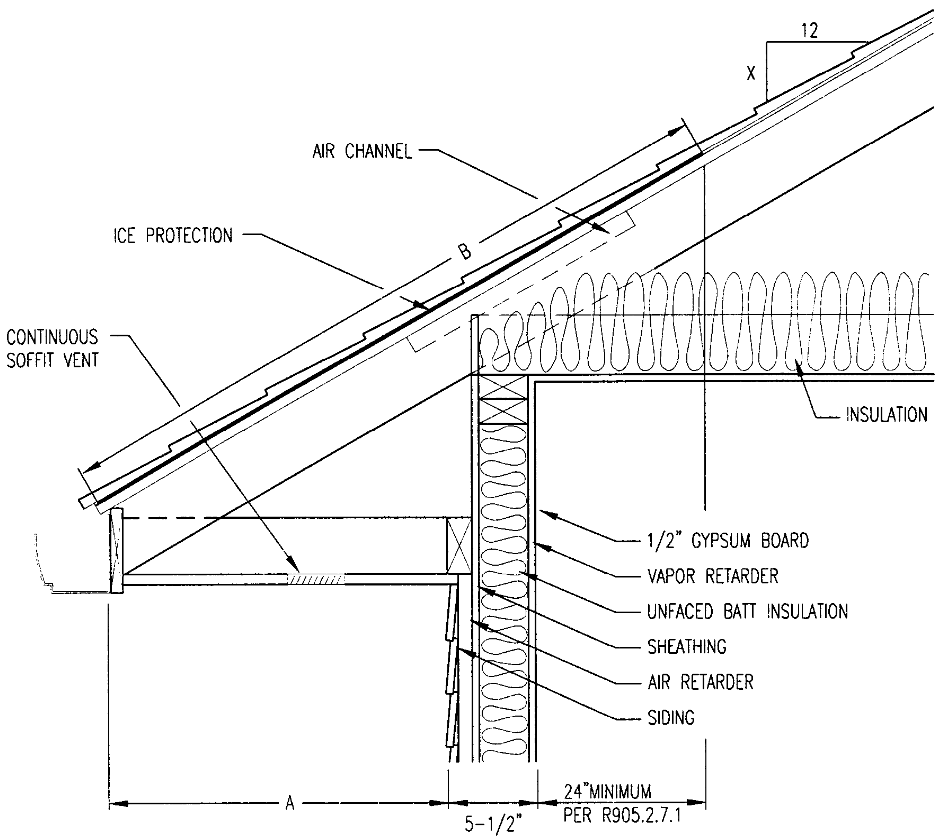
In many instances, a single felt is used and in some cases, we have seen roofs without felts. We would prefer the self-adhering bitumen sheet be specified exclusively and the extent of the installation stipulated on the Contract Documents.

The ice protection must extend at least 24” beyond the inside face of the exterior wall.

For various roof slopes and soffit widths, the length of the ice shield varies.

In many instances, a single 36” width of ice protection is installed in lieu of code mandates.

ICE PROTECTION REQUIREMENTS FOR 5-1/2" WALL WIDTH

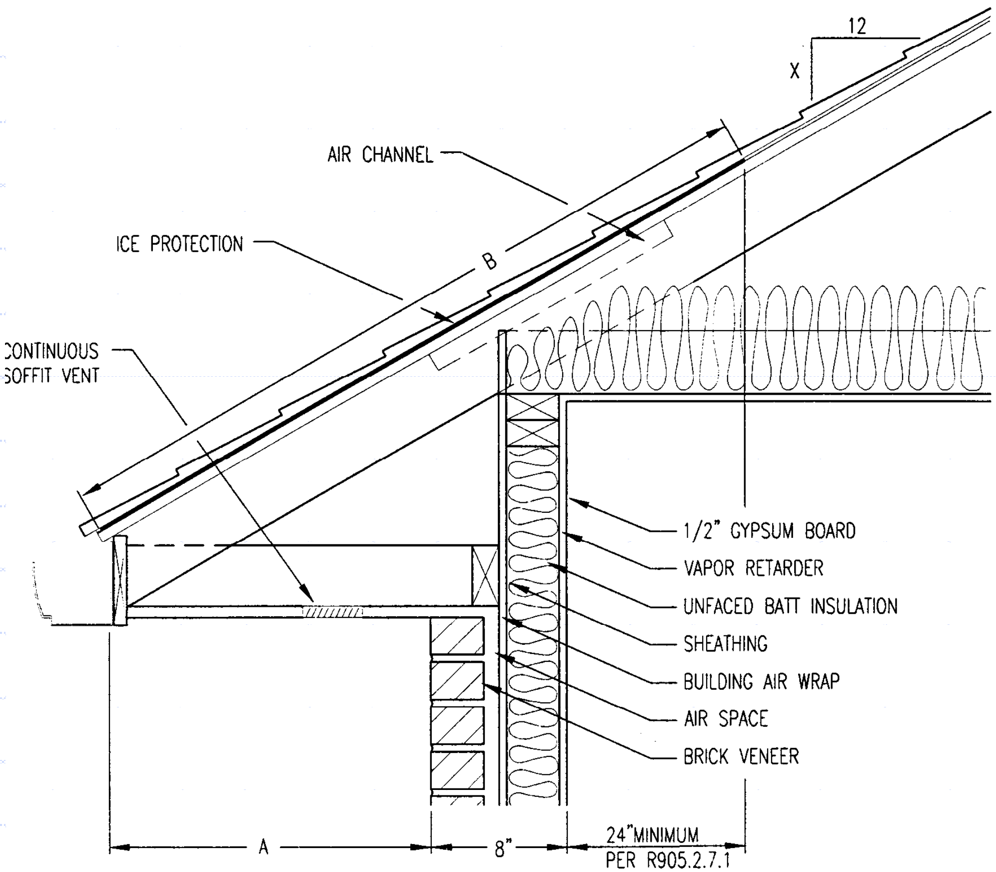


ICE PROTECTION DETAIL

NO SCALE

A	B							
	SLOPE "X"							
	2.5	3	4	5	6	8	10	12
4	34.2	34.5	35.3	36.3	37.5	40.3	43.6	47.4
8	38.3	38.7	39.5	40.6	41.9	45.1	48.8	53.0
10	40.3	40.7	41.6	42.8	44.2	47.5	51.4	55.9
12	42.4	42.8	43.7	45.0	46.4	49.9	54.0	58.7
14	44.4	44.8	45.9	47.1	48.6	52.3	56.6	61.5
16	46.5	46.9	48.0	49.3	50.9	54.7	59.2	64.3
18	48.5	49.0	50.1	51.5	53.1	57.1	61.8	67.2
20	50.6	51.0	52.2	53.6	55.3	59.5	64.4	70.0
22	52.6	53.1	54.3	55.8	57.6	61.9	67.0	72.8
24	54.6	55.1	56.4	58.0	59.8	64.3	69.6	75.7

ICE PROTECTION REQUIREMENTS FOR 8"± WALL WIDTH



ICE PROTECTION DETAIL

NO SCALE

A	B							
	SLOPE "X"							
	2.5	3	4	5	6	8	10	12
4	36.8	37.1	37.9	39.0	40.2	43.3	46.9	50.9
8	40.9	41.2	42.2	43.3	44.7	48.1	52.1	56.6
10	42.9	43.3	44.3	45.5	47.0	50.5	54.7	59.4
12	44.9	45.4	46.4	47.7	49.2	52.9	57.3	62.2
14	47.0	47.4	48.5	49.8	51.4	55.3	59.9	65.1
16	49.0	49.5	50.6	52.0	53.7	57.7	62.5	67.9
18	51.1	51.5	52.7	54.2	55.9	60.1	65.1	70.7
20	53.1	53.6	54.8	56.3	58.1	62.5	67.7	73.5
22	55.2	55.7	56.9	58.5	60.4	64.9	70.3	76.4
24	57.2	57.7	59.0	60.7	62.6	67.3	72.9	79.2

Mechanical Engineer/ HVAC Systems (Commercial)

- Control infiltration by pressurizing the building to at least 0.02"wg (250 pascals).
- Ventilate and control humidity.
- Use caution in implementing ASHRAE Standard 62.
- Make sure the building enclosure can contain the conditioned air.
- Commission the building envelope to determine if the specified (?) envelope–performance characteristics are met.
- Design HVAC that maintains positive building pressure.
- Utilize dedicated outdoor air ventilation systems.

- Provide increased ventilation in high moisture generating areas utilizing excess air from code mandated occupancy levels.
- Avoid “value engineering” out the HVAC systems that will prevent IAQ problems.
- Kitchens are high moisture producing areas and are typically tempered which results in a much higher moisture level than desirable – (owner economics).
- Building interstitial spaces (envelope) and the mechanical systems distribution/ air flow zone create a negative pressure in all buildings resulting in air flow to the inside.

HVAC engineers should design for positive pressure to retard unwanted air infiltration not to “dry out the exterior wall” as some practioners believe but to control the sizing of the mechanical system. Generally, in most commercial buildings the outside air volume required by code exceeds the building mechanical exhaust and the excess air should be used to retard infiltration. This format doesn’t increase energy utilization.

Slope the bottoms of OAI ducts to louver and caulk the entire perimeter of the louver.

Outside air intake ducts are prone to condensation formation especially at butt joints and branch connections and the resulting condensation can leak onto ceiling tiles and mold will result – possible in a return air plenum.

Mechanical Engineer/ HVAC Systems (Residential)

- Control infiltration by pressurizing.
- Evaluate total building exhaust
  - Exhaust fans
  - Kitchen cooking hoods
  - Clothes dryers
  - Fireplaces
- Thermostat with limiting cooling humidity level.

- Run supply air fan continuously (except at night).
- Heat recovery ventilator.
- Automatic timer on bathroom exhaust fan.
- Ductwork outside the habitable spaces.
- Properly sized cooling components with variable speed fans and constant speed condensing units.
- Locate ultra-violet light at cooling coil.

Plumbing Engineer

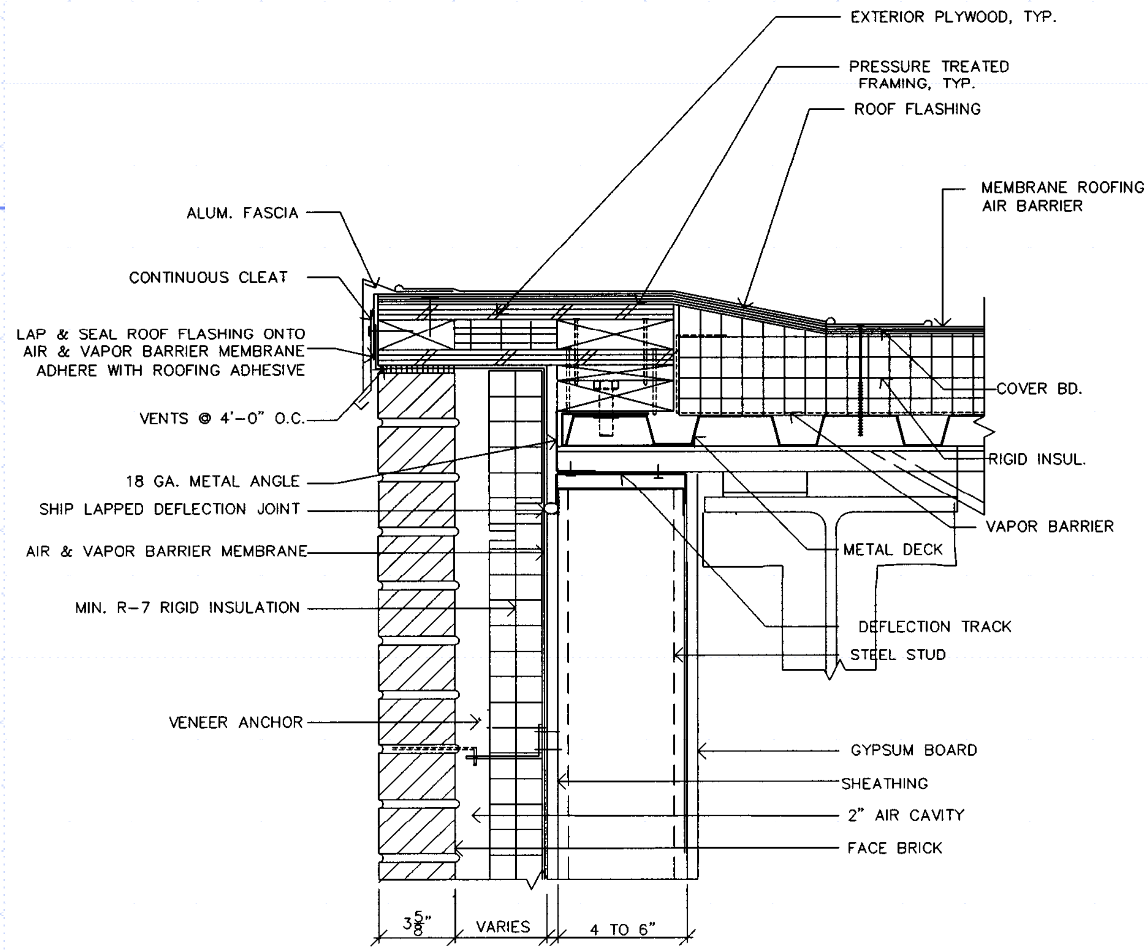
- Avoid the use of scuppers as secondary drains, utilize dammed roof sumps. Calculate the maximum height of the rim to prevent overloading the roof.
- Require potable water and drainage, and waste systems to be tested.

Building Envelope Designs

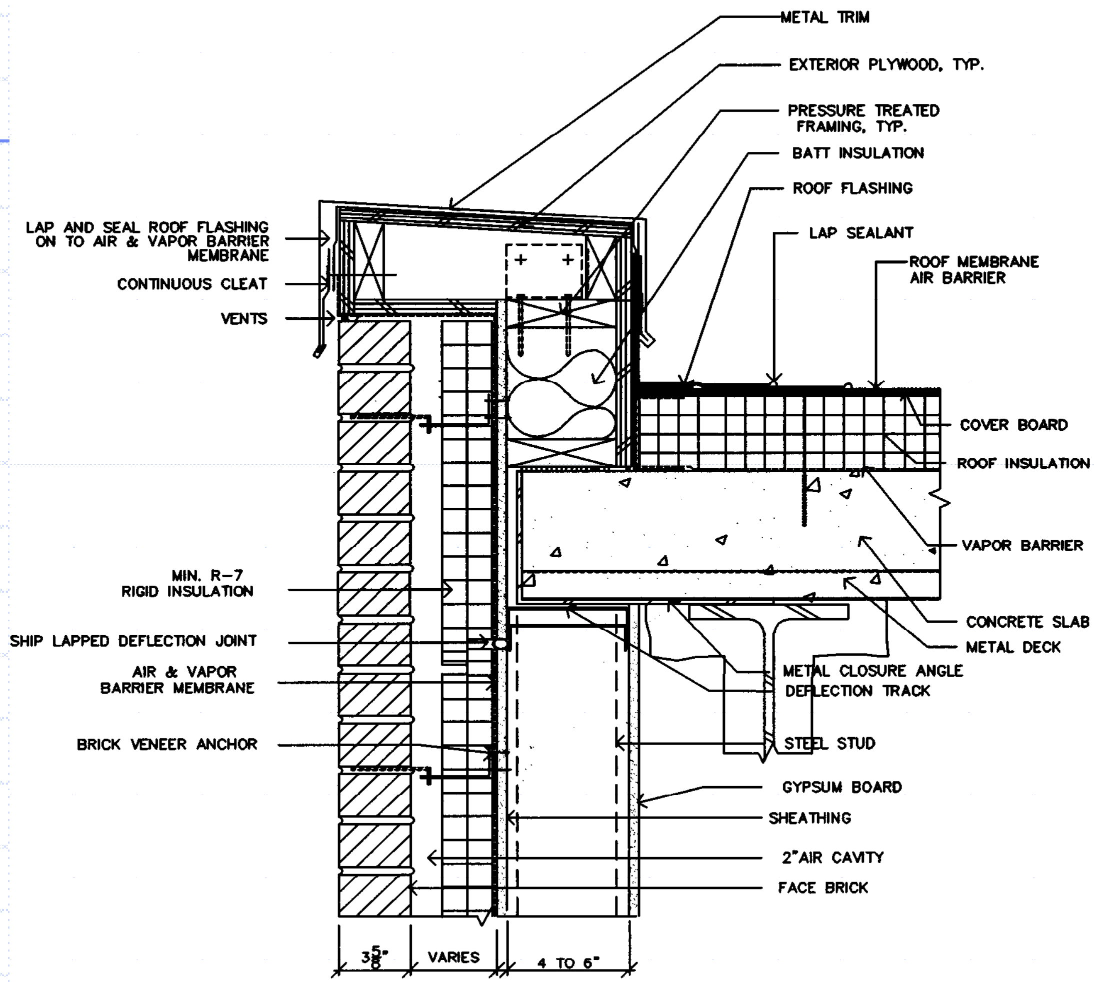
The Boston Society of Architects (BSA) was approached by the Board of Regulators and Standards to develop building envelope details demonstrating compliance with the new energy code. The following details were developed by the task force.

For additional information:

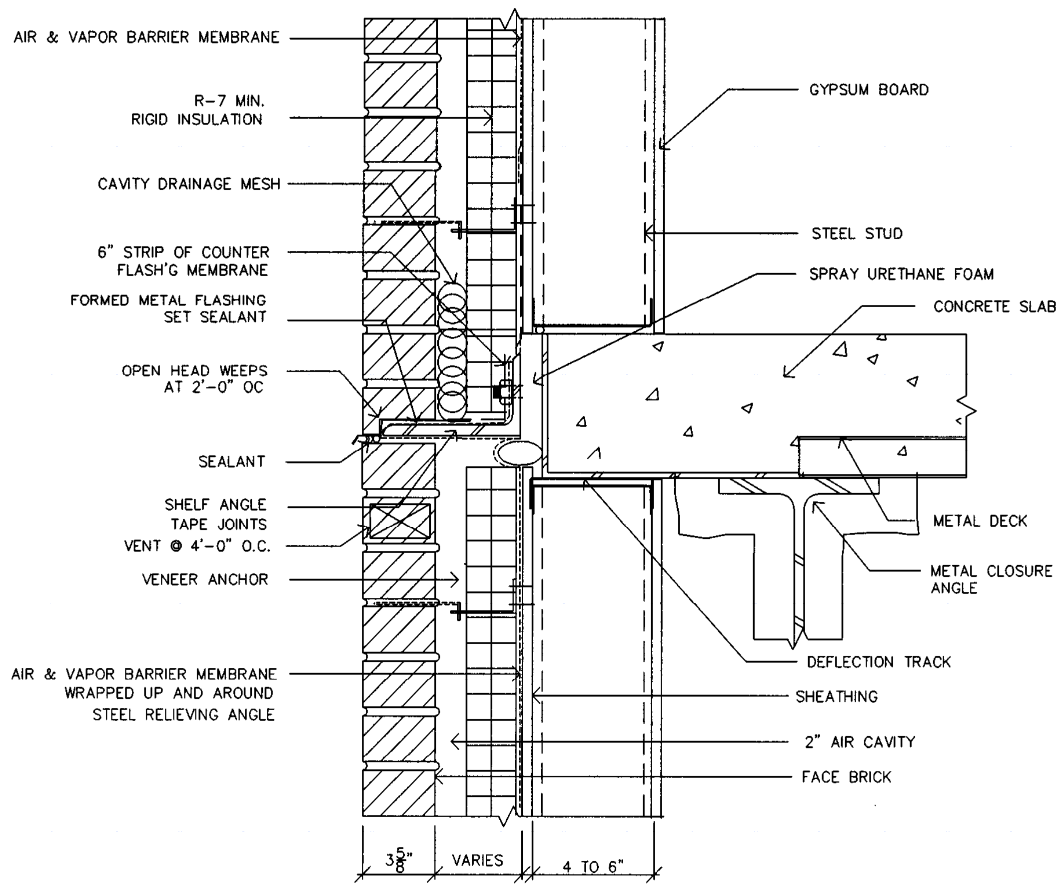
<www.state.ma.us/bbrs/sample_details.htm>



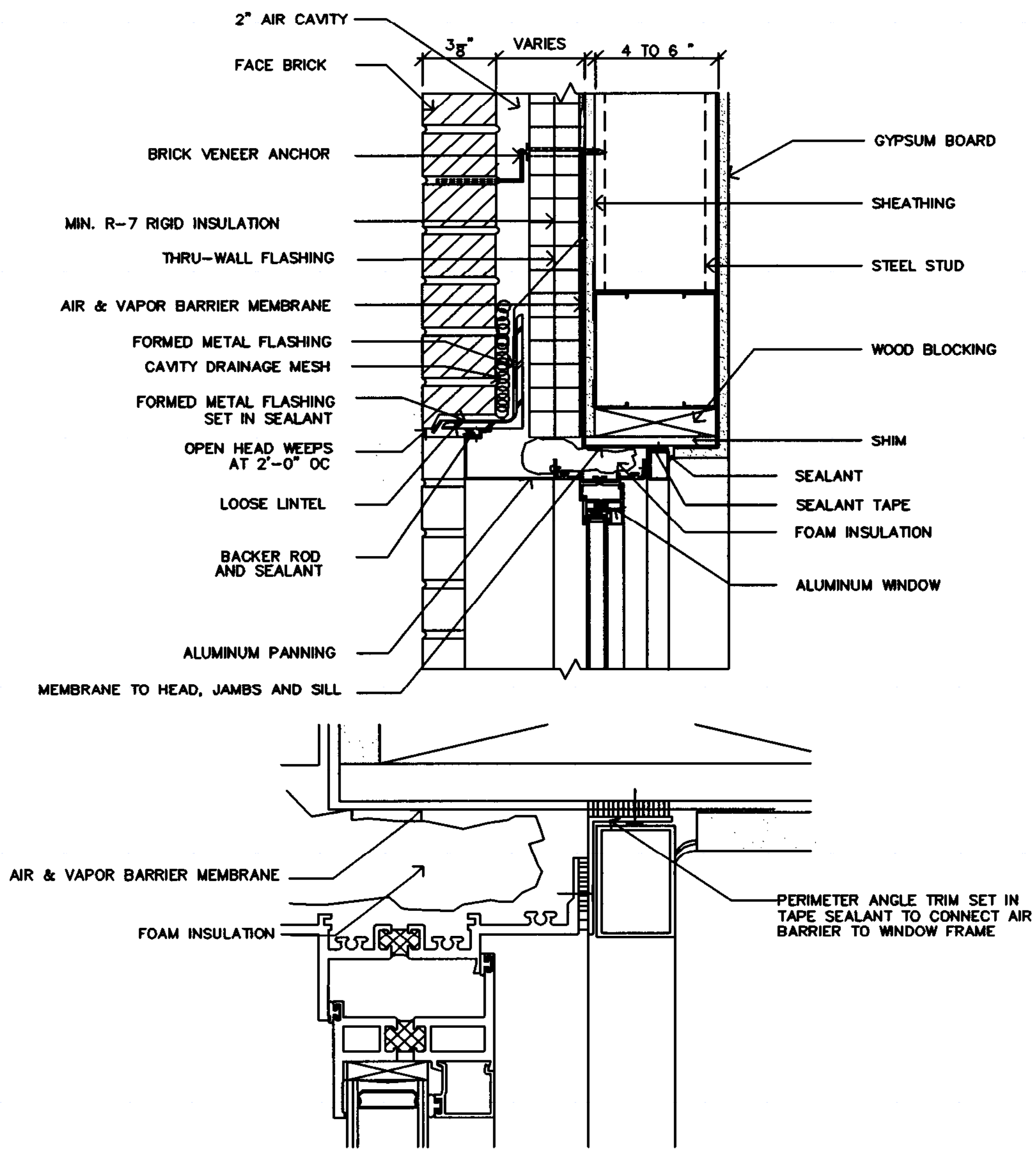
DETAIL AT ROOF EDGE



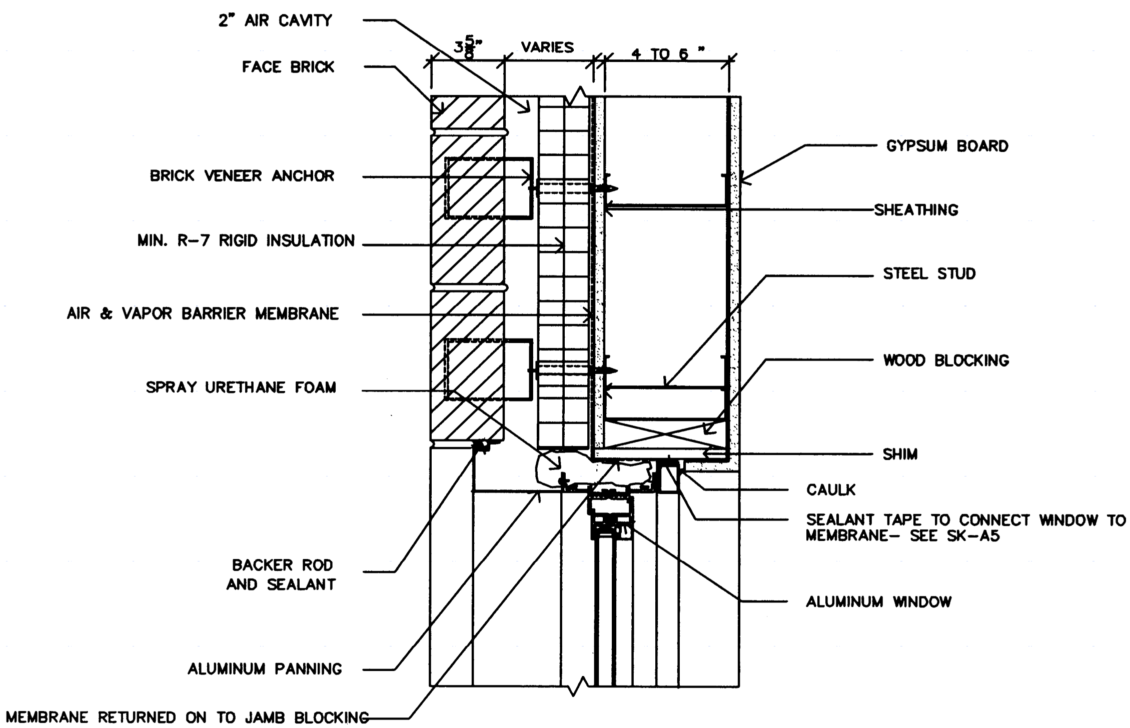
DETAIL AT ROOF PARAPET



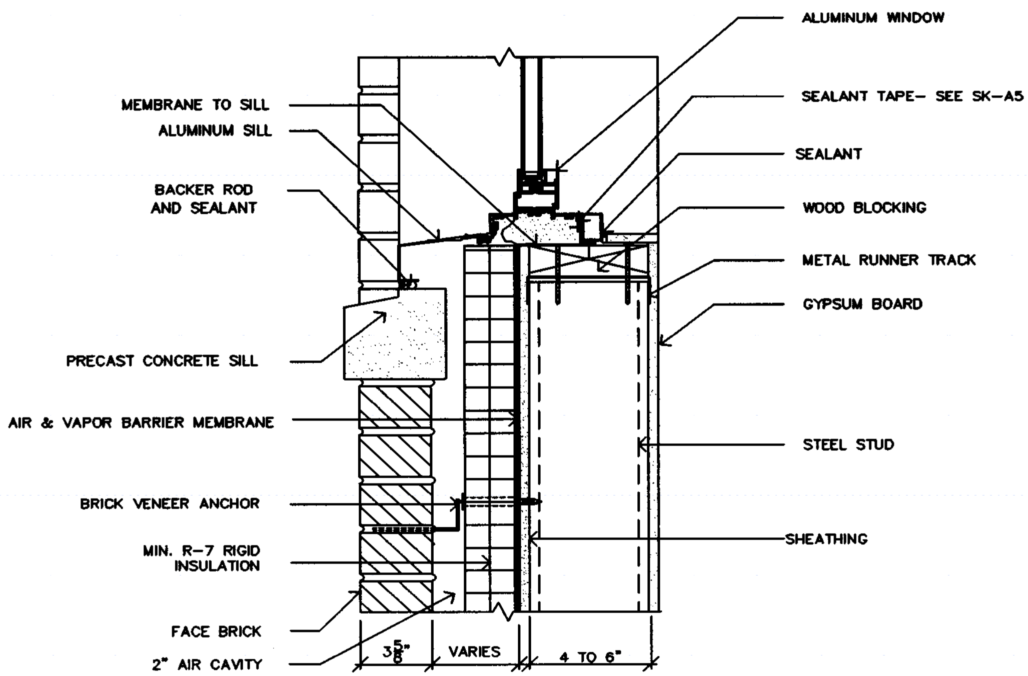
DETAIL AT FLOOR SLAB



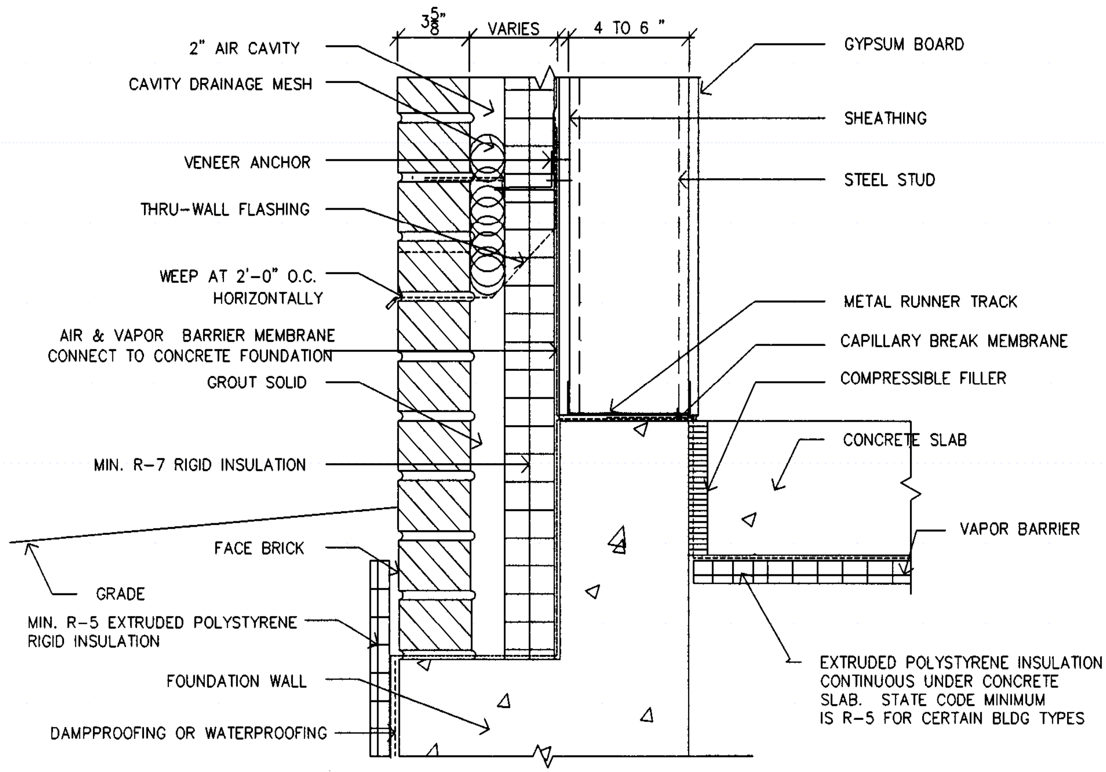
DETAIL AT WINDOW HEAD



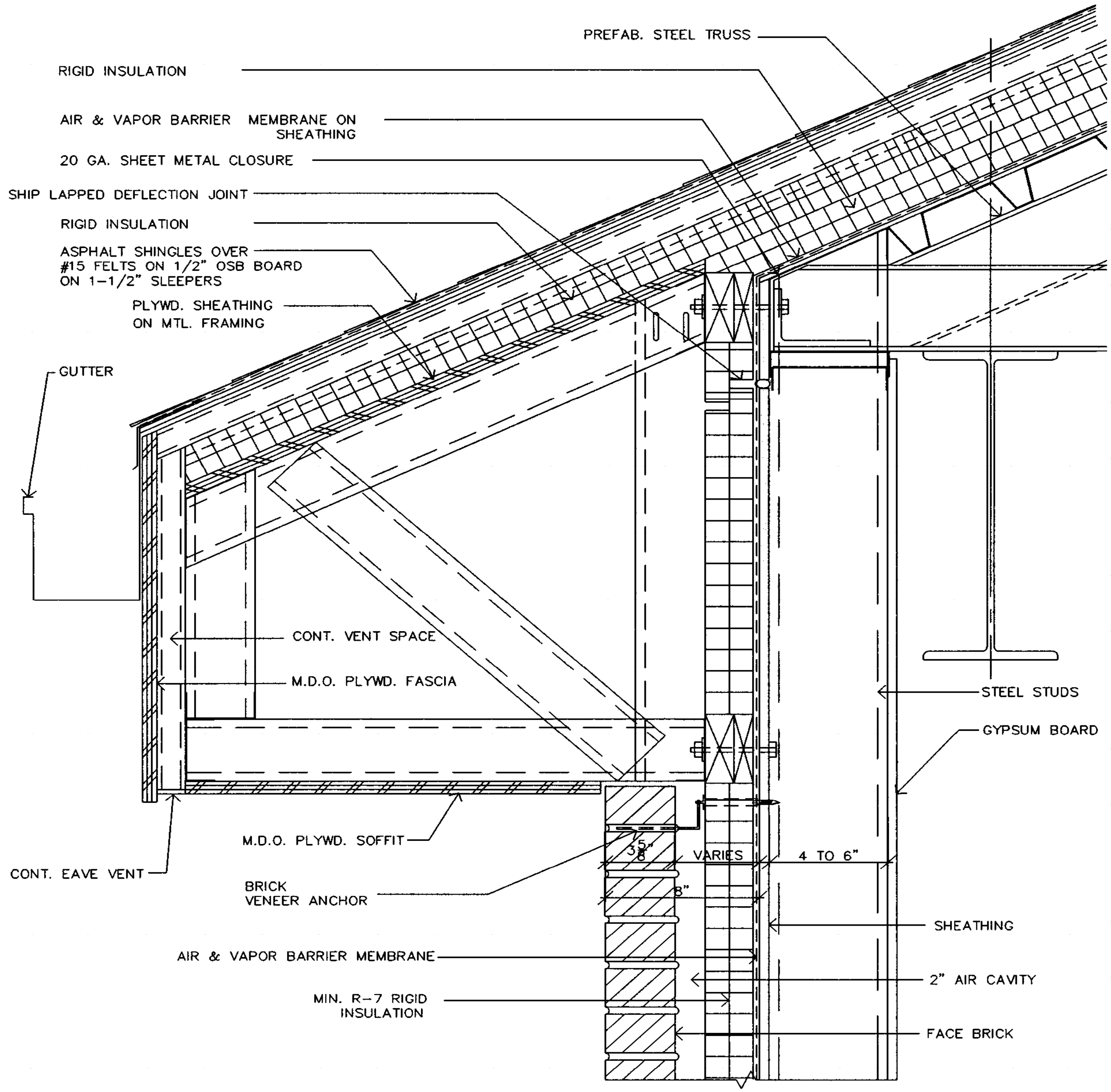
DETAIL AT WINDOW JAMB



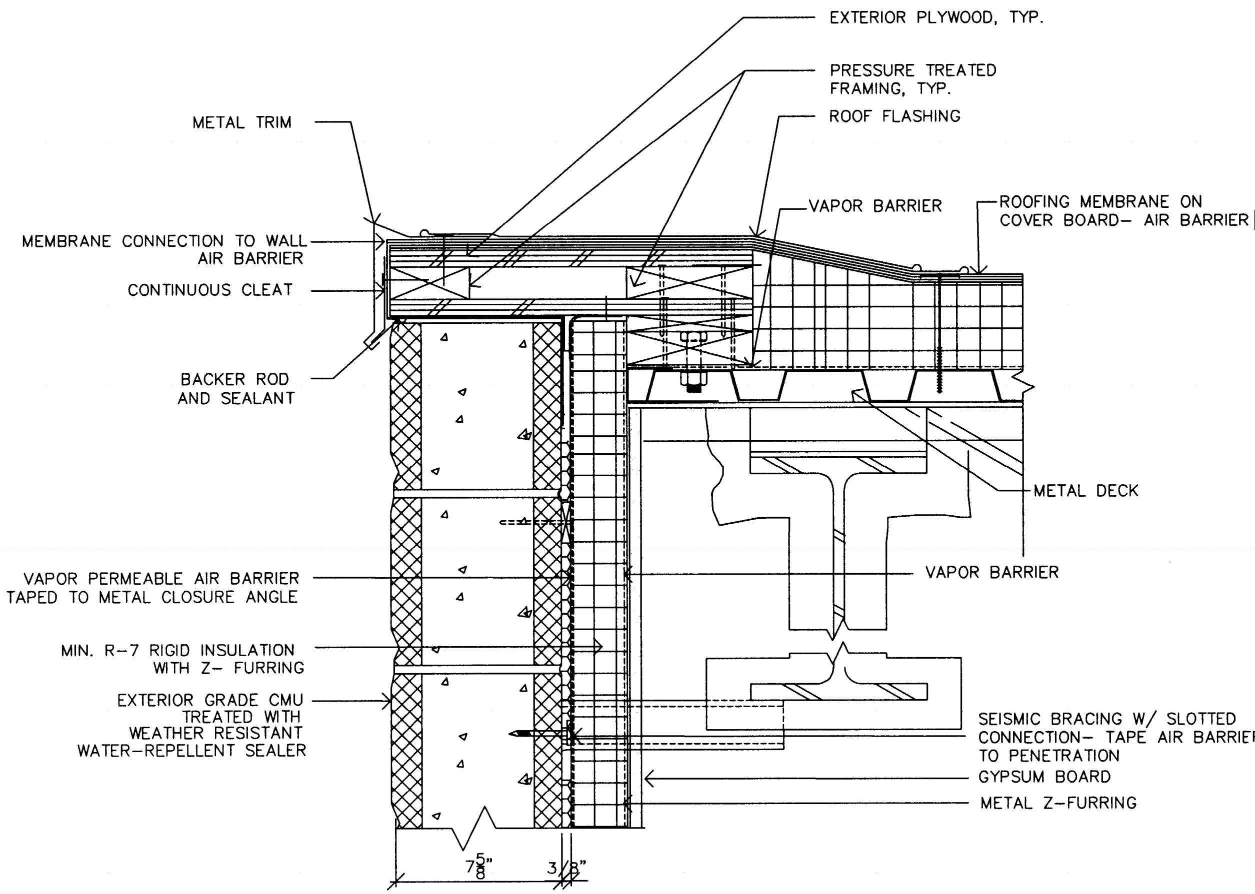
DETAIL AT WINDOW SILL



DETAIL AT FOUNDATION



DETAIL AT BRICK VENEER WALL / ROOF



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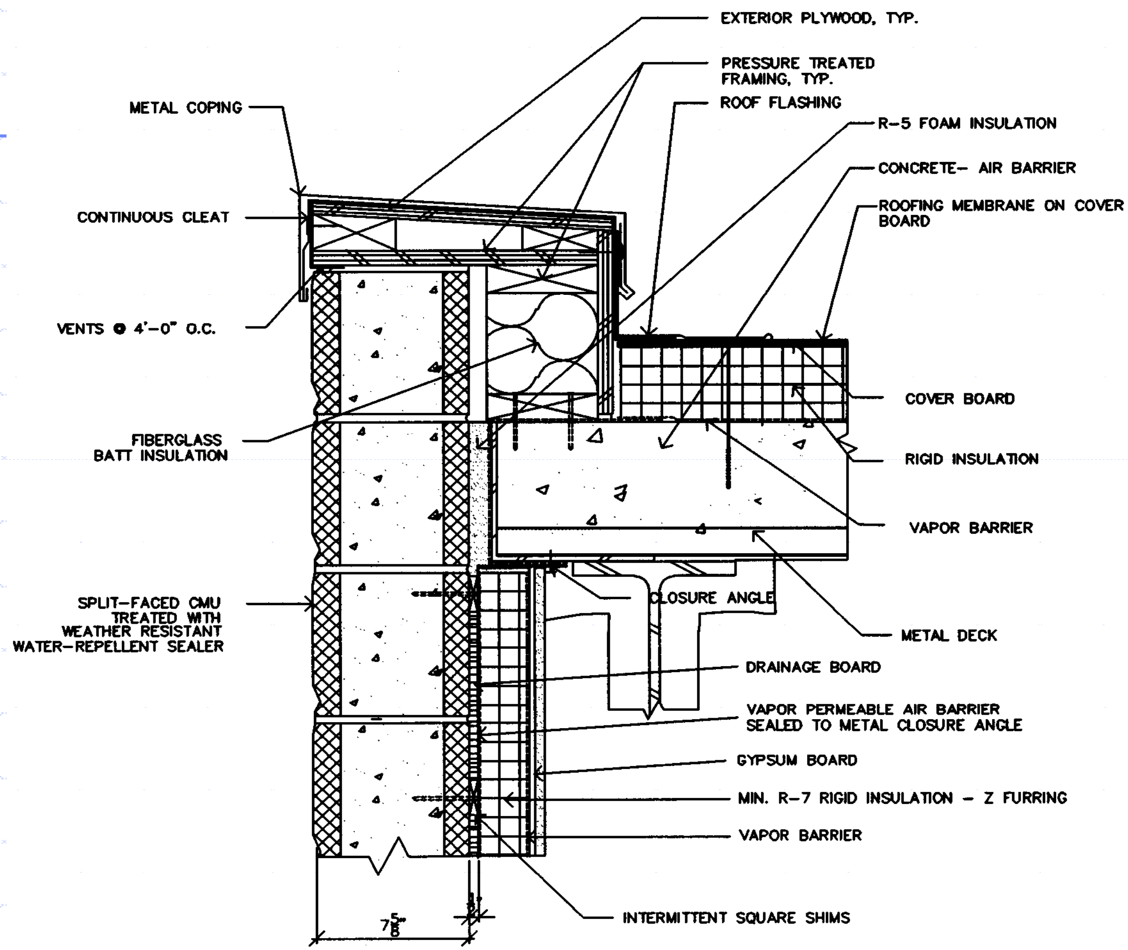

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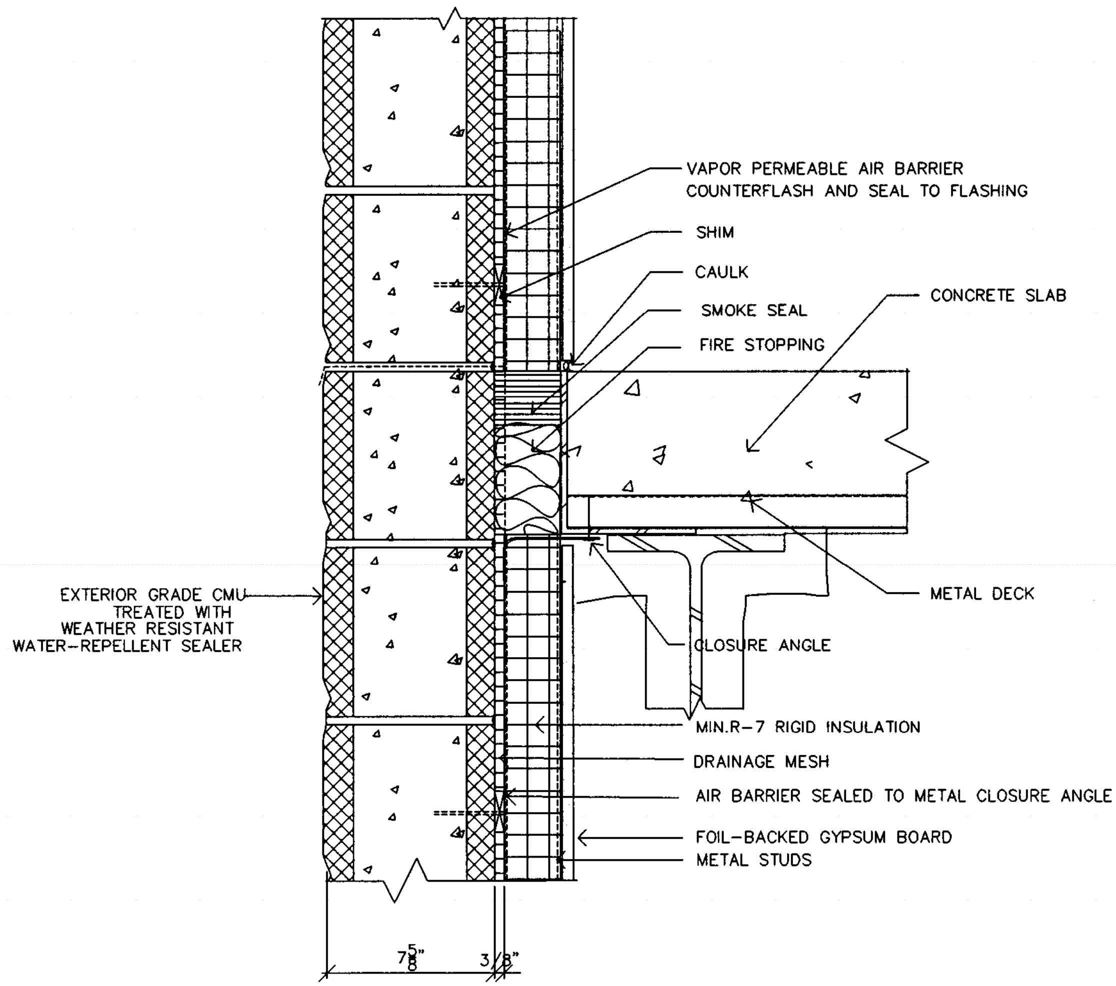
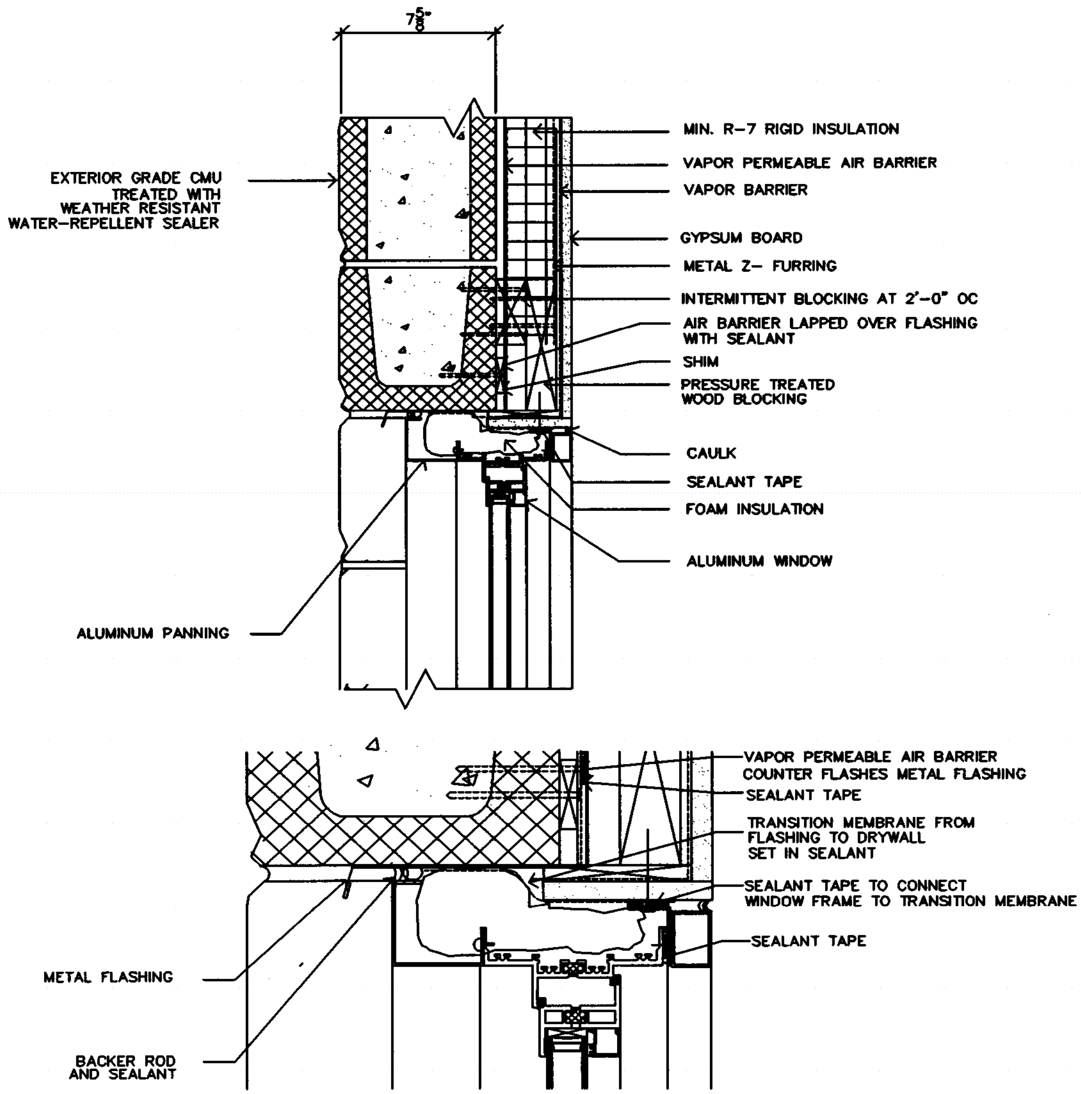


DETAIL AT FLOOR SLAB



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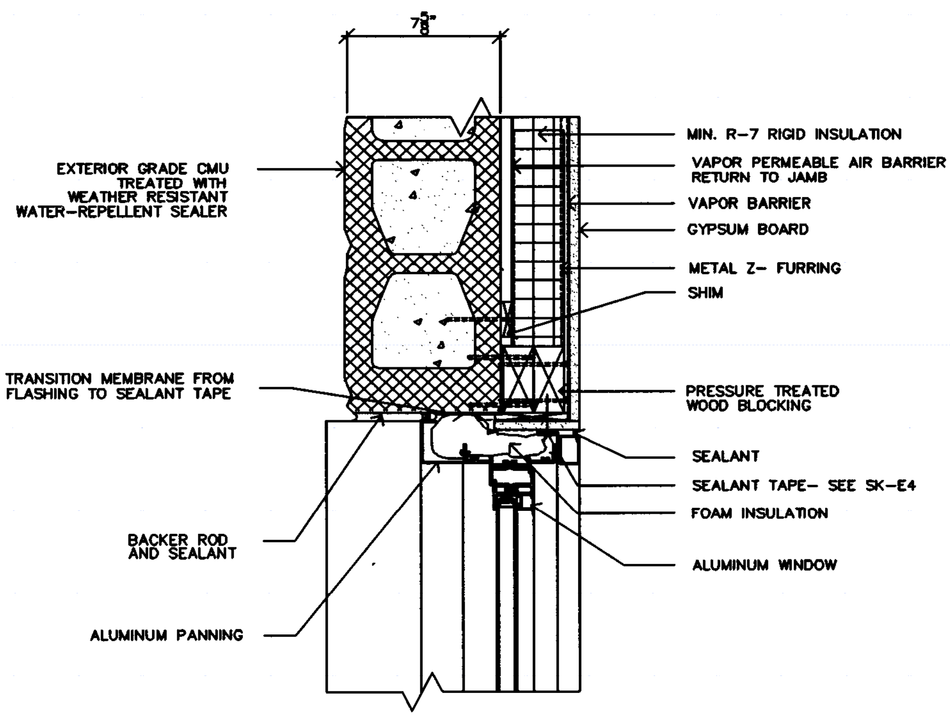

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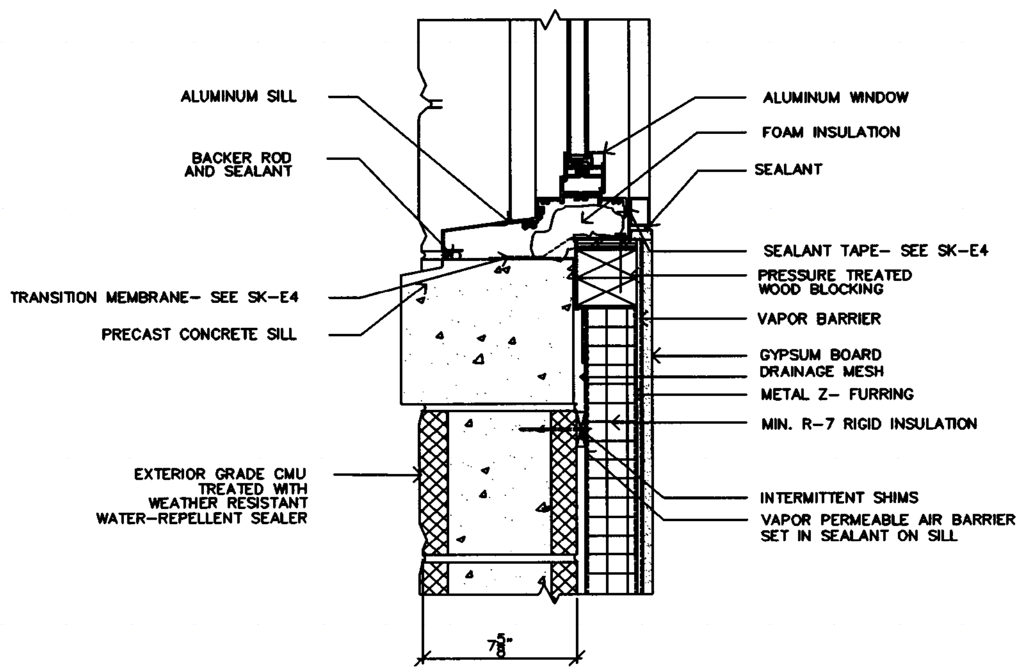
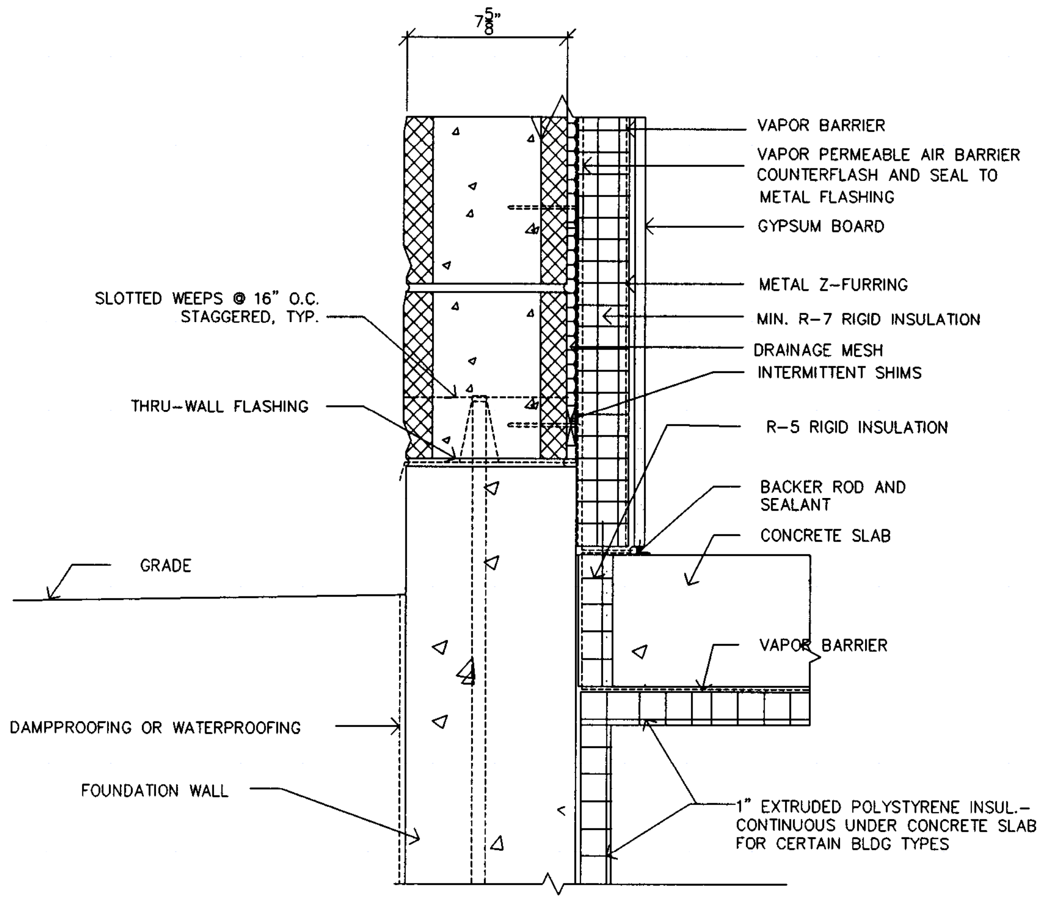


DETAIL AT WINDOW SILL



DETAIL AT FOUNDATION

Electro-Osmotic Pulse Technology

Electro-osmotic pulse (EOP) technology is used to prevent moisture intrusion through concrete and masonry into below grade spaces and is now being applied to historic buildings.

The positive-voltage pulse has the longest interval, and the negative-voltage pulse has the shortest interval. The positive electrical pulse causes the positive ions and associated water molecules to move from the anode (interior or dry side) toward the cathode (exterior or wet side), against the direction of flow induced by the hydraulic gradient, thus preventing water penetration through the structure.

One of the most critical aspects of this technology is the negative-voltage pulse (polarity reversal). The negative pulse is of very short duration as compared to the positive pulse. During the time of the negative pulse, the water flows in the opposite direction.

Thus some moisture is retained in the application matrix between the anode and cathode, preventing over-drying of the material and maintaining the structural integrity of the matrix. Another advantage of the short negative pulse is the reversal in the chemical reactions at the electrodes (the anode becomes the cathode for an instant and vice versa), thereby eliminating electrode polarization and guaranteeing that the system will continue to operate efficiently.

An EOP system is installed by inserting anodes into the wall and/or floor on the inside of the structure and by placing cathodes in the soil directly outside the structure. The number of anodes and cathodes and their placement are determined from an initial electrical resistivity test of the material and soil. The objective is to achieve a certain current density and thus create an electric field in the material that is sufficiently strong to overcome the force exerted on the water molecules by the hydraulic gradient from outside the structure.

By combining EOP with standard repair techniques that seal cracks and other defects, EOP can solve the problems of active water intrusion (high water table) and saturation (rising damp). EOP can extend the life of the repairs to cracks or voids by controlling the amount of water reaching the repair material. For more information: <http://www.moisture-solutions.com/home.asp>

Design Strategies For Moisture Control

Keeping Water Out

- Flash all windows and doors
- Provide continuous drainage plain
- Provide water screen behind siding
- Seal wood and fiber-cement siding
- Provide capillary break above footings
- Provide drainage layer and poly vapor barrier under concrete slabs (without a layer of sand between the poly and slab).

- Provide perimeter drain tile
- Provide water-proofing on the outside of foundation walls
- Slope ground away from building (minimum pitch of 5%) and provide impermeable cap (high clay content).
- Provide roof overhang to keep rainwater away from building
- Provide self-sealing ice and water barrier on roof.

Design Building Assemblies to Dry Out

- Provide wall cavity potential for drying to the exterior
- Design below grade spaces to dry to the interior
- Use plywood instead of OSB
- Provide vented roof assembly
- Provide encapsulated crawl spaces
- Avoid thermal bridges

Basements

Wall systems that tolerate an occasional wall leak or flood are advantageous in finished basements with uncertain moisture performance should include the following characteristics:

- External moisture barrier
- Steel framings; held out from wall 3/4".
- Fiberglass insulation w/o vapor retarder or extruded polystyrene
- Bottom channel raised above floor
- Polystyrene foamed insulation appears to seal very well against concrete

Ref: ASHRAE IAQ Conference paper

HEPA Filtration

- Use of HEPA (High Efficiency Particulate Arrestor) air filter to control air borne indoor air fungi was successful in an ASHRAE study.
- Portable HEPA filters influenced the indoor air quality of bedrooms of asthmatic children by reducing fungal levels 70% and particulate matter 38%. The reason for the disparity between the reduction is that the particulate matter refers to fine particulates measured in the range of 0.02 to 1.0 micron.

Bathroom Exhaust Fans

- Moisture in attics can be exacerbated by bathroom exhaust fans that do not discharge to atmosphere with a direct connection. Improper installation can cause localized damage to roof sheathing or contribute to higher moisture levels, which impacts the complete attic.
- Most bathroom exhaust fans do not exhaust much air and as a consequence, the room’s relative humidity is elevated for extensive periods. For residential applications an exhaust fan should have an external static pressure rating of not less than 0.20 inches.

Discharge of bathroom exhaust fans should not be in soffits. Michigan Mechanical Code (MMC) 2000, 501.3 states in part, "…shall be discharged outdoors at a point where it will not cause a nuisance…" Drawing hot moist air into an attic can create a nuisance if mold starts to grow on the sheathing.

Avoid interior condensation by specifying a light/fan switch that with a single switch combination allow the exhaust fan to operate from 5 to 60 minutes after the light is turned off.

Structural Drying

Mold forms in 4 days if elevation moisture levels exist as a consequence of structural wetting during construction.

Desiccant materials attract water of the air as a vapor. Humid air has a high vapor pressure. Dry desiccant has a low vapor pressure.

Propelled by this vapor pressure difference, water molecules (as a vapor) move out of the humid air to the desiccant which captures the water molecules onto the surface of the desiccant medium by a process called adsorption.

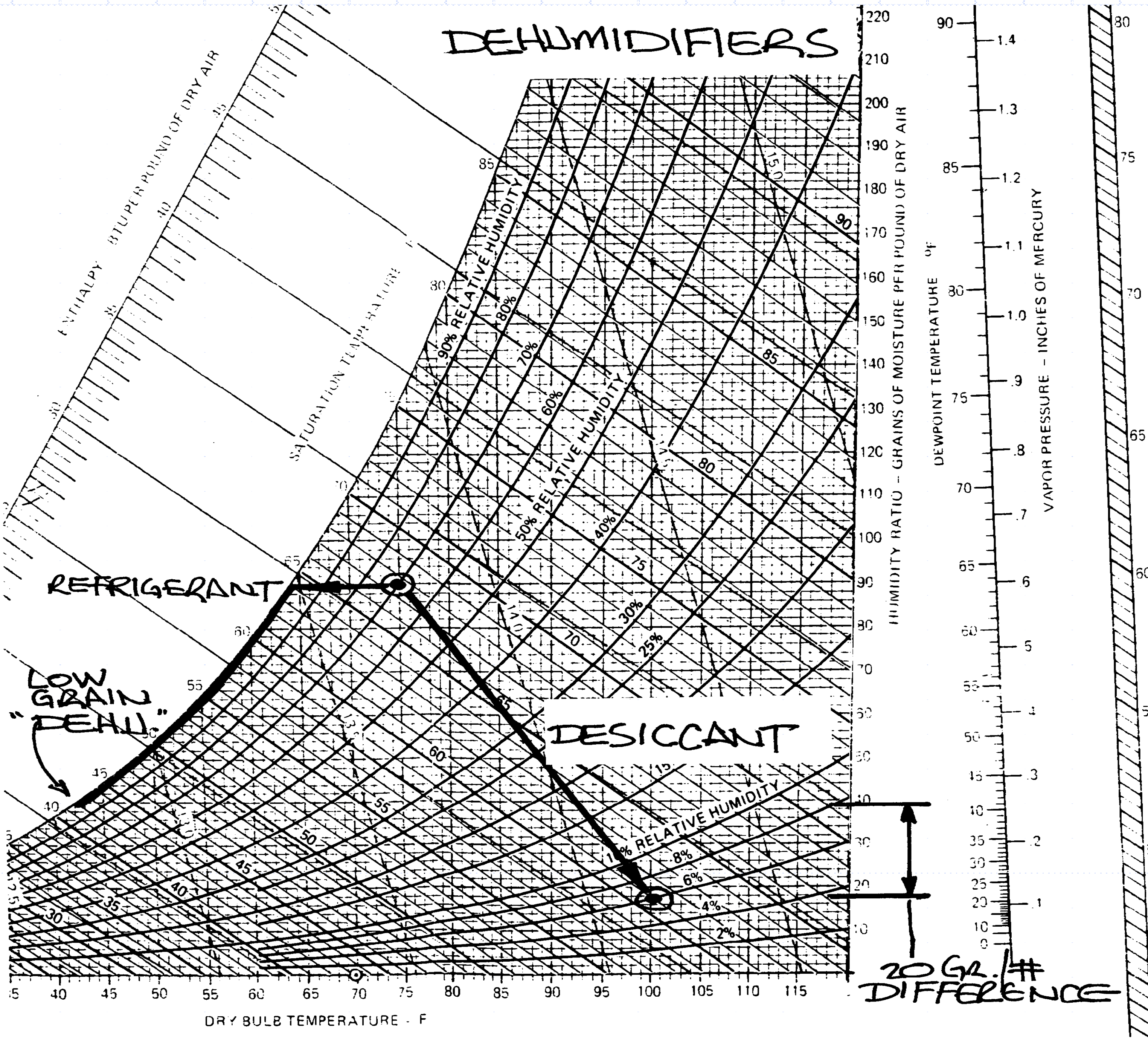
Solid desiccant materials are adsorbents with a tremendous internal surface area providing for the capacity to handle large volumes of water.

A single gram (less than one teaspoon) of dry desiccant can have more than 50,000 square feet of surface area (equivalent to the size of a football field).

After being loaded with water molecules the desiccant is reactivated (dried out) by heating, which raises the vapor pressure of the material above that of the surrounding air.

Desiccant drying controls mold formation.

DEHUMIDIFIERS



Final Thoughts

Using the best building science we can not only design and construct buildings that will last but also reduce the risk of moisture-related health problems, including exposure to molds and other allergens. To apply building science, we have to address the interactions among components in a building—looking to manufacturers for solutions at the level of the individual product isn't enough.

Rarely is anyone filling the role of building scientist on design teams today. It's up to architects to either learn to play that role, or hire consultants who can work through details of the envelope and mechanical and plumbing systems with them.

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