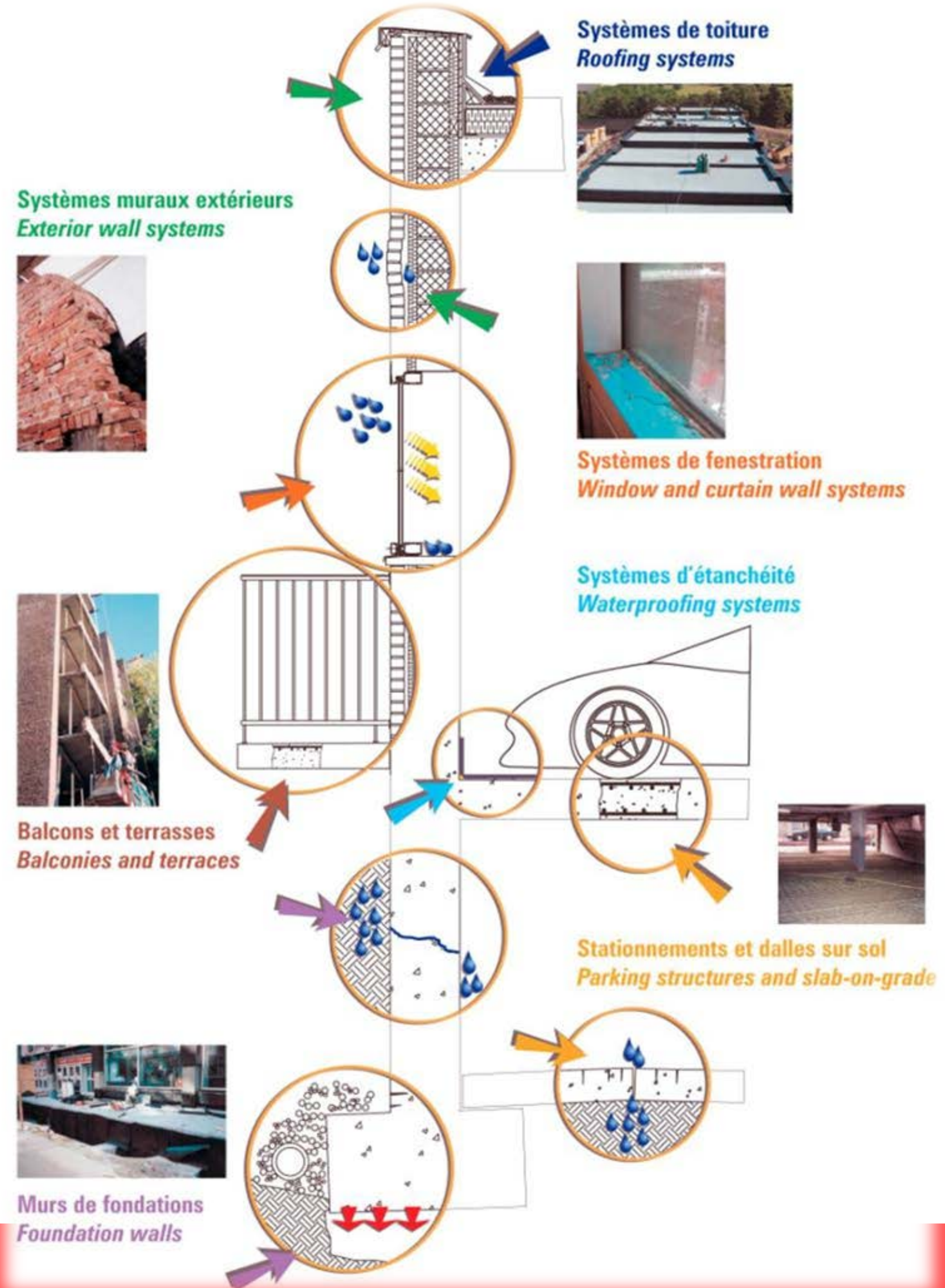
Building Science Revisited

Air Barriers vs. Vapour Barriers

It is the job of the building envelope to keep what is in, in, and what is out, out.



Keeping the outside, out...
and the inside, in…

Many building performance problems can be traced to air leakage through the building envelope. These problems range from high heating costs and poor temperature control in occupied spaces to rain penetration and the deterioration of brick on exterior walls.

Figure 1: View of severely corroded hot-dip galvanized structural members due to poultice corrosion from wet building sheathing. Metal loss exceeded 20% of original thickness.

exfiltration

When moisture inside the building escapes through defects in the building envelope, it condenses, freezes and causes damage inside of the wall.

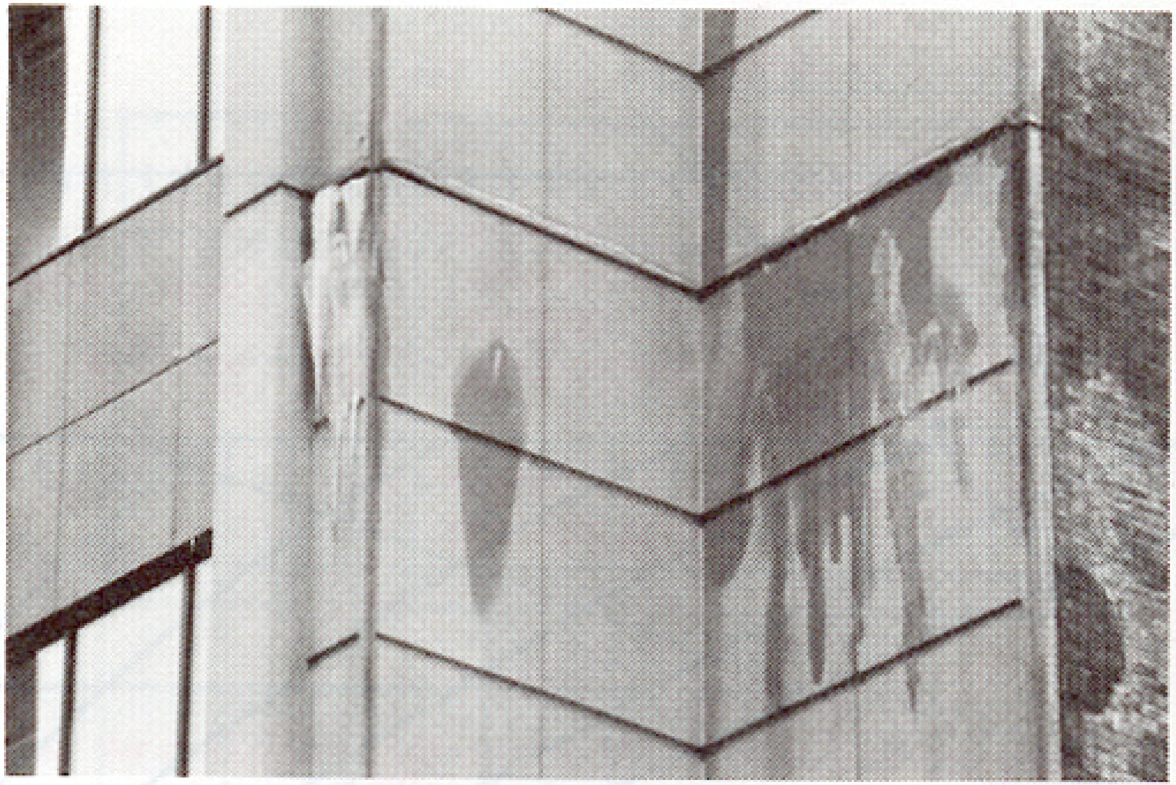


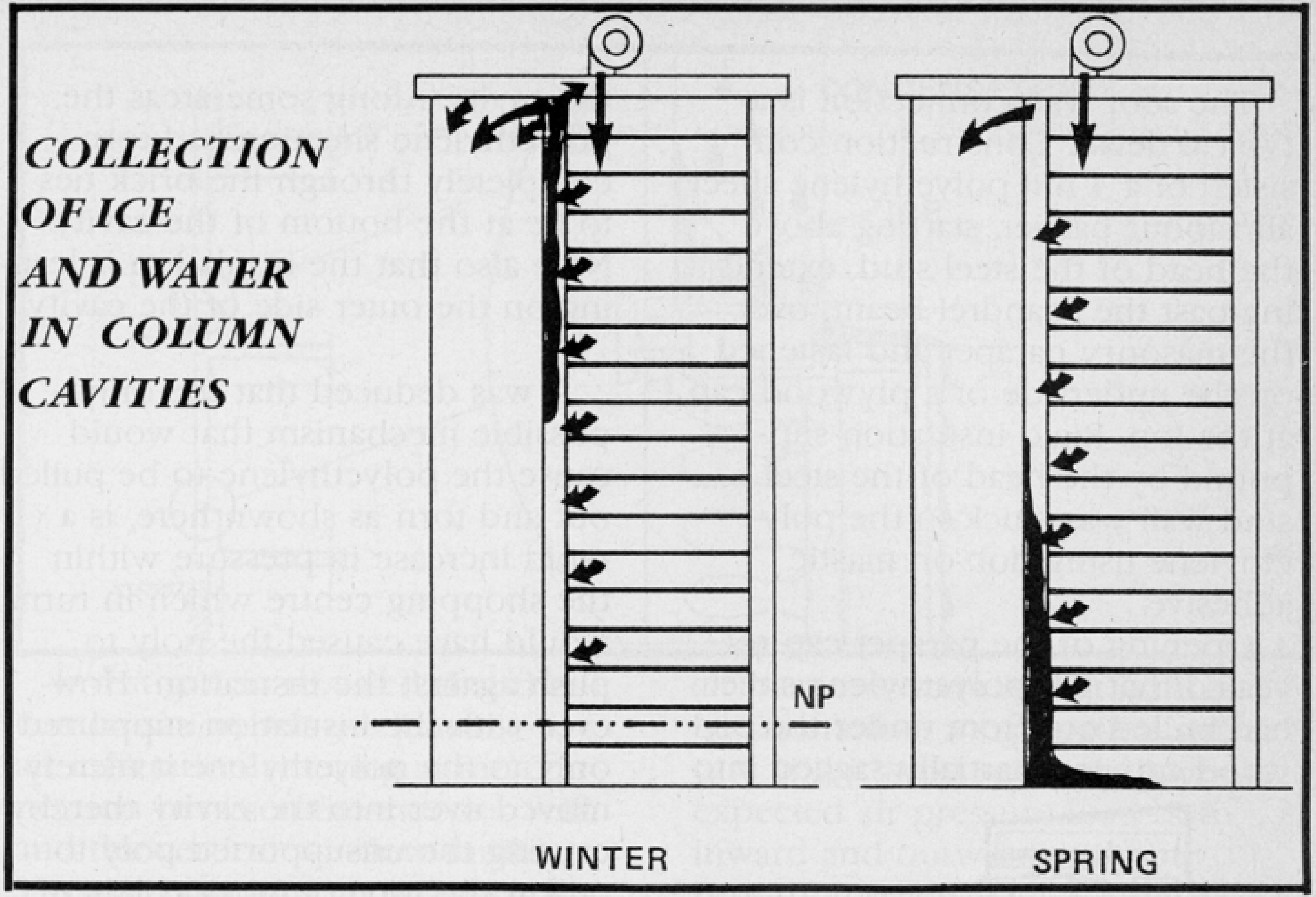
Figure 2.10 Exfiltration/Condensation

Air leakage on a masonry building

Fig. 15 Example of air leakage on the side of a building

Efflorescence, also a sign of air leakage

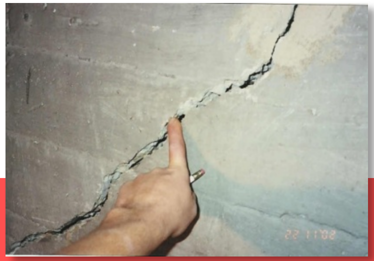
Fig. 16 An example of extensive wetness and efflorescence

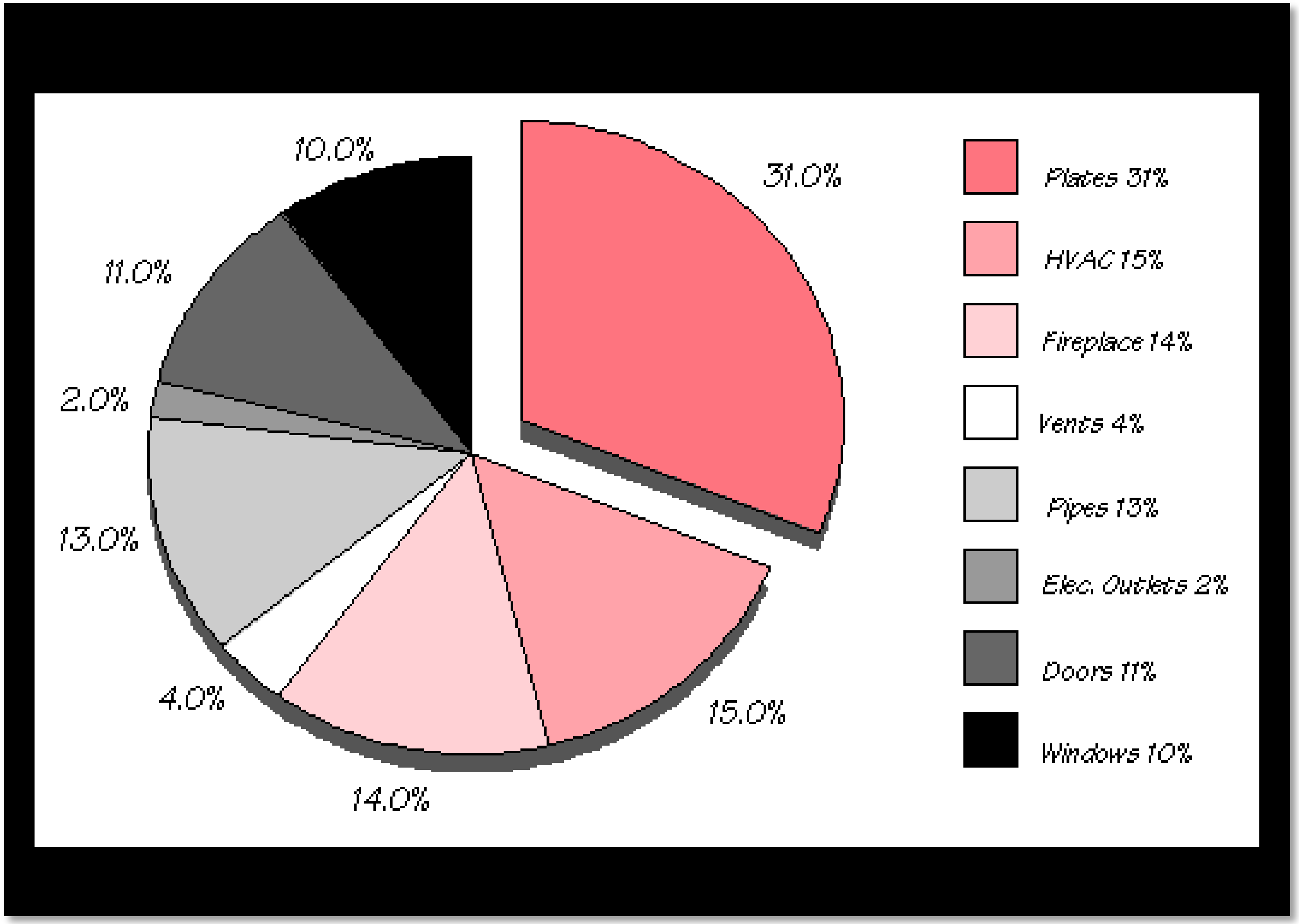

COLLECTION OF ICE AND WATER IN COLUMN CAVITIES
NP
WINTER
SPRING

Why does moisture move from inside to outside?

Moisture exists and hence can be moved in two forms. Most air has a certain moisture content referred to a relative humidity. Humans need a certain amount of humidity in heated indoor air to maintain a healthy environment (otherwise we get nosebleeds, etc.) So moisture exists as microscopic parts of the air itself. This moisture can be moved RIGHT THROUGH THE BUILDING ENVELOPE (like ghosts move through solids…), as well as THROUGH CRACKS IN THE BUILDING ENVELOPE.

Air pressure differential is the key force that drives both air leakage and vapour diffusion through the building envelope.



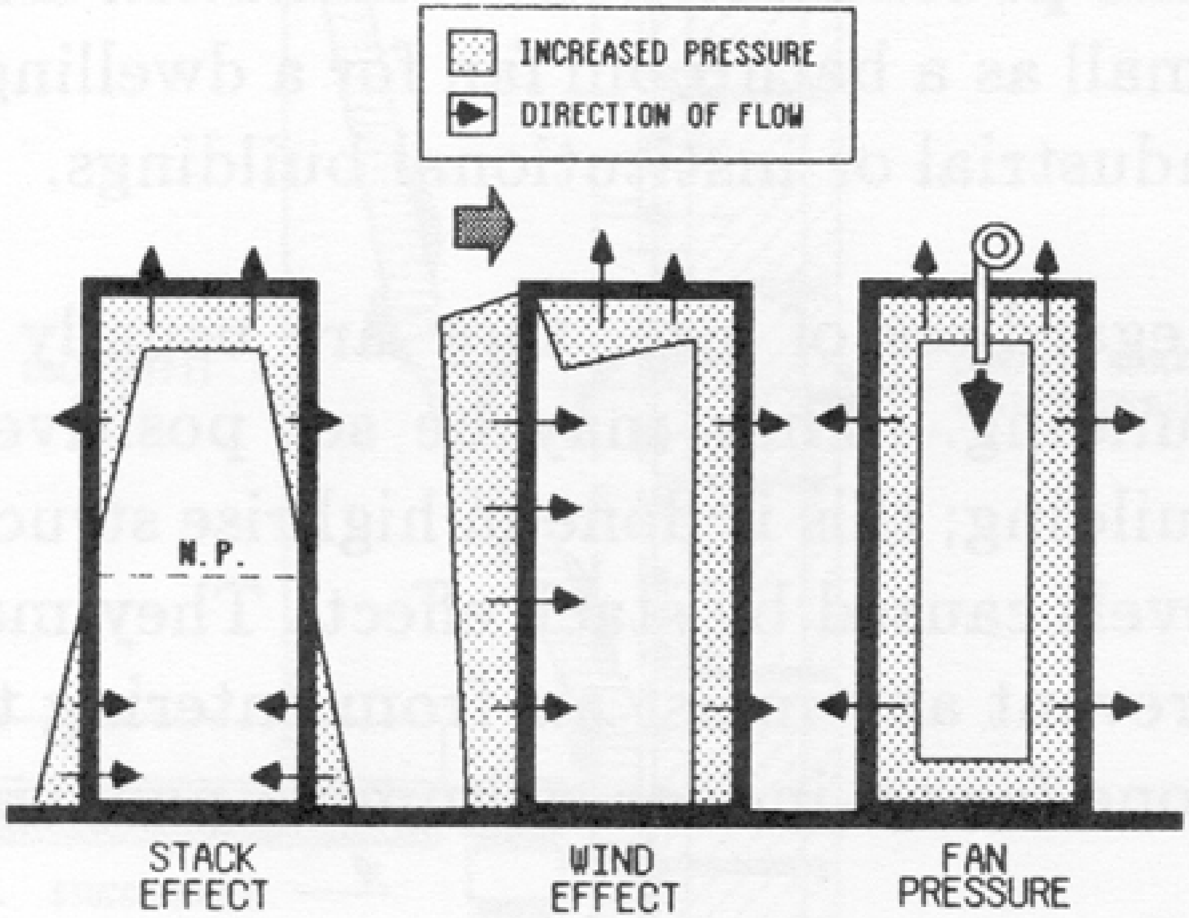


The Air Leakage Pie...

What drives pressure differential?

The air pressure differential is driven by, or relies on several key factors. If there is no pressure difference between the interior and exterior, there will not be air or vapour movement across the building envelope.

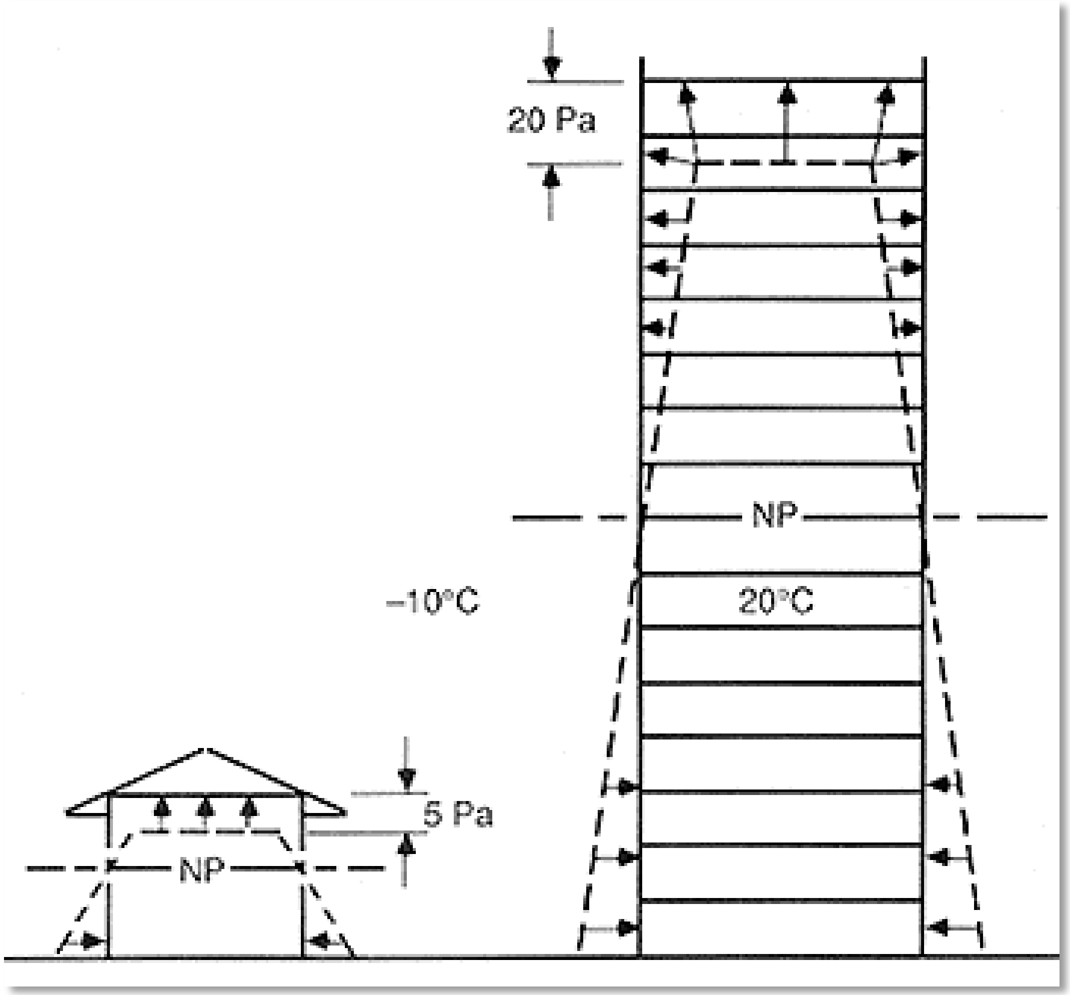
- temperature differential (hot inside, cold outside)
- stack effect (warm air rises)
- wind pressure (windward pressure, leeward suction)
- fan pressurization (kitchen, bathroom and furnace fans)



AIR PRESSURE DIFFERENCES ON THE BUILDING ENVELOPE

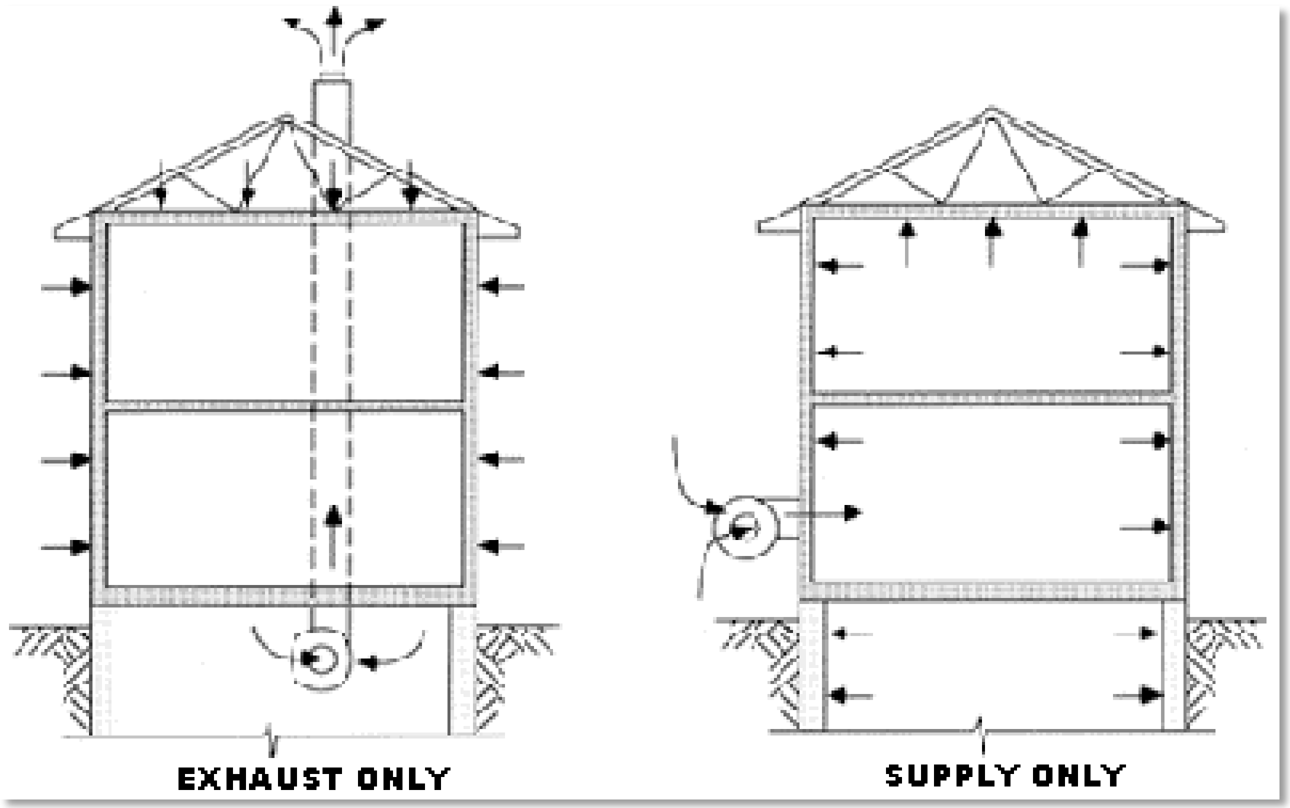
FIG. 3

Stack effect



Stack effect is a bigger problem the higher the building. Look at high rises with “problems”. Usually evidenced at the top floors of the building first as there is more driven warm moist air trying to escape through the upper part of walls.

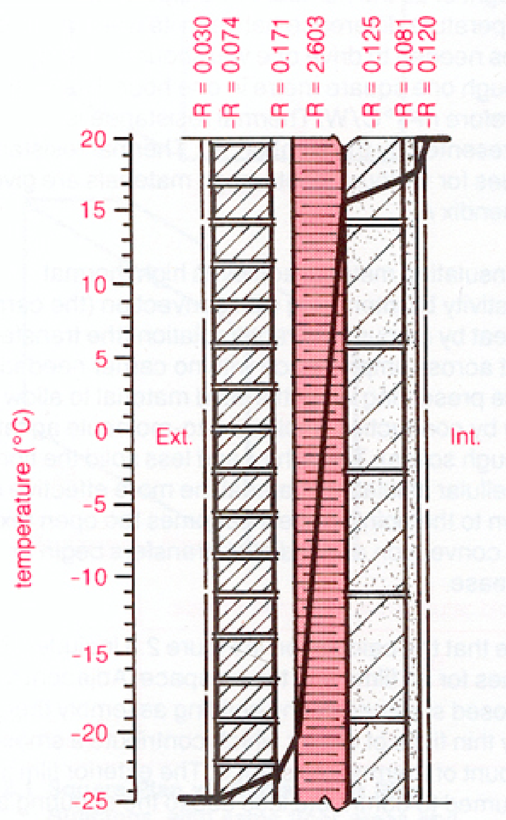
Fan pressurization



Depending on the direction of air movement from the fan, a house can either be pressurized or suck air in from outside.

Temperature differential

The larger the temperature difference, the more drive across a wall. Hence worse in the cold winter. Temperature drives air and vapour leakage as well as basic heat loss through the building envelope.



R_n ($m^2 \cdot °C/W$)	0.120	0.201	0.326	2.929	3.100	3.174
$\frac{R_n}{R_t}$	0.037	0.063	0.102	0.913	0.968	0.991
$T_n = T_i - (\frac{R_n}{R_t})\Delta T$ (°C)	18.3	17.2	15.4	-21.1	-23.5	-24.6

$\Delta T = T_i - T_o = 45°C$

$R_t = 3.20\ m^2 \cdot °C/W$

where R_n — total thermal resistance to outer edge of n'th component

R_t — total thermal resistance of wall

T_n — temperature of outer edge of n'th component

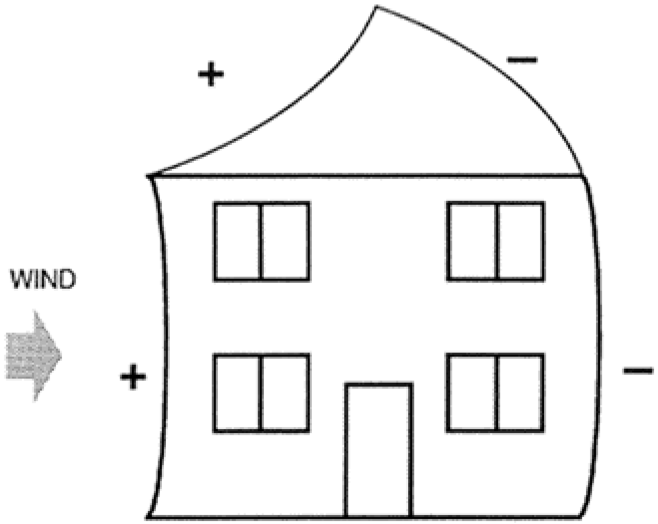
T_i — inside temperature

T_o — outside temperature

Figure 2.4 Calculation of Temperature Profile in a Building Assembly

wind

Depending on the wind direction, a high or low pressure area is created, pushing or pulling moisture through the building envelope.



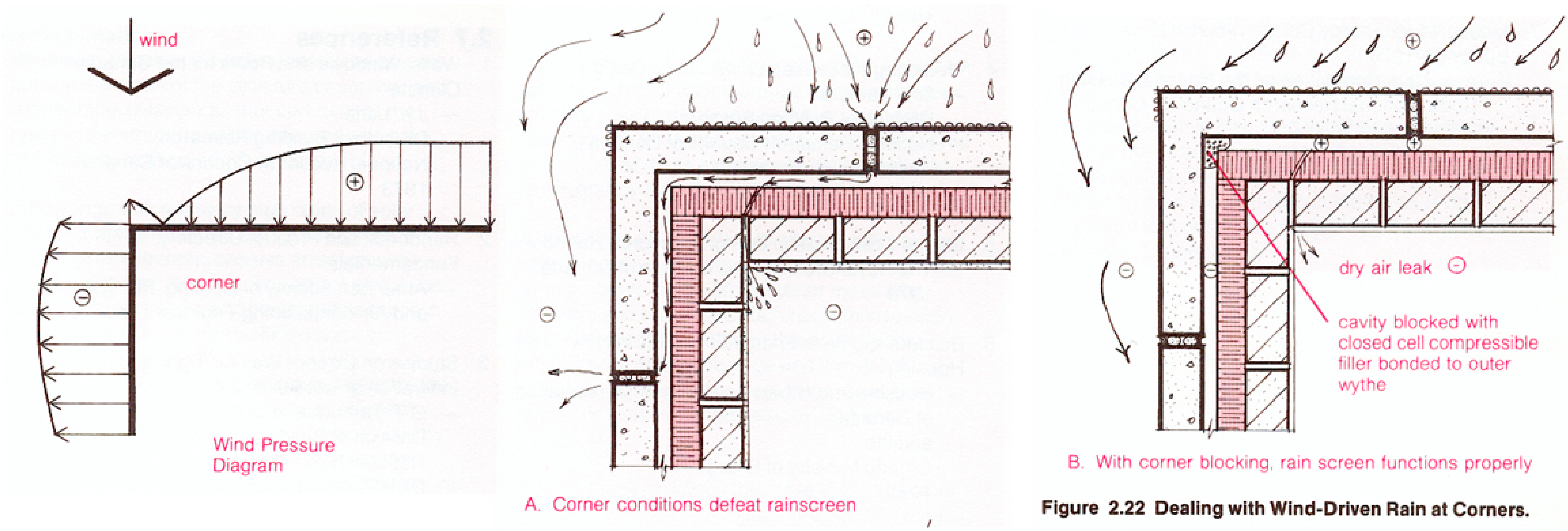
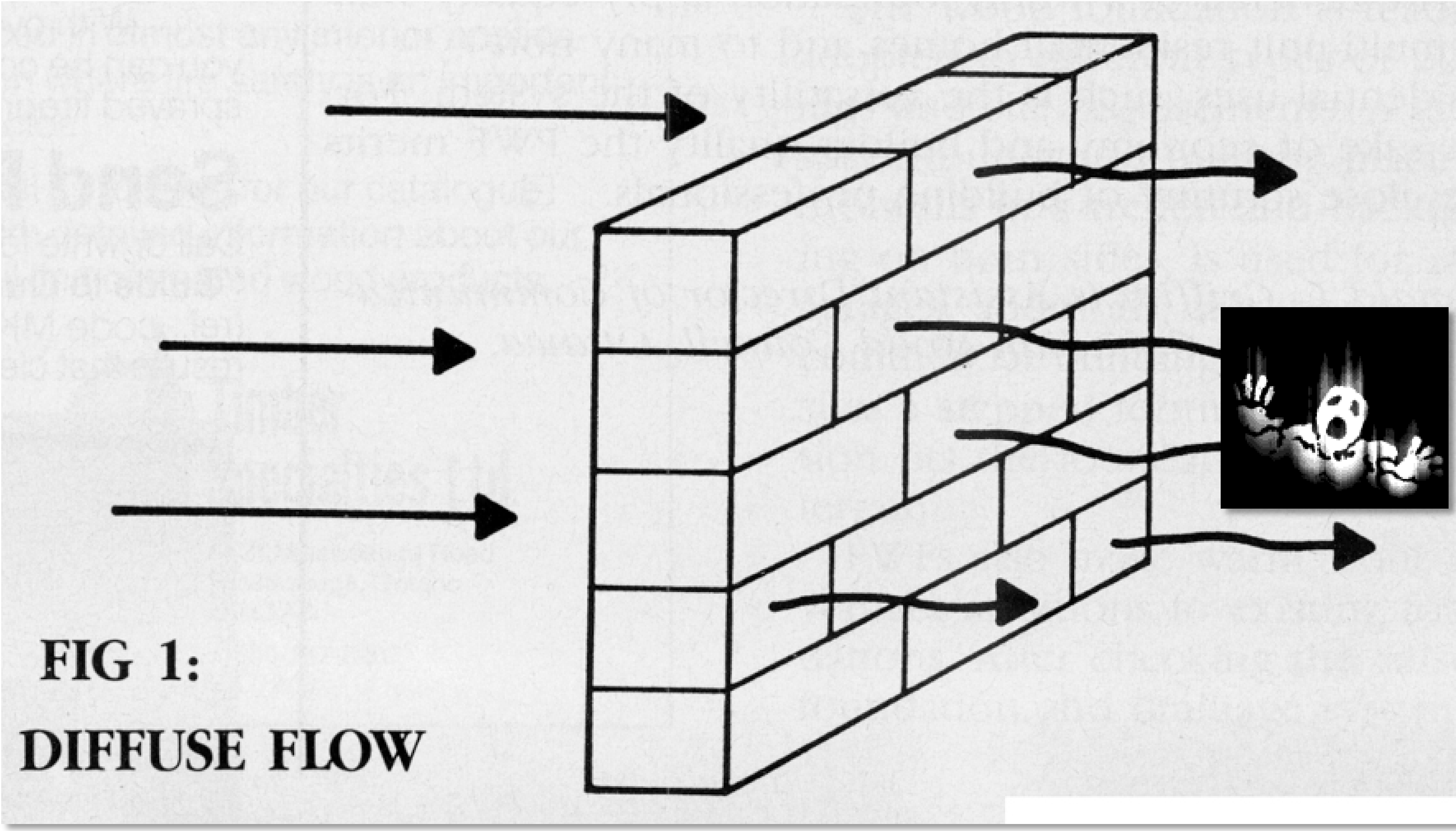
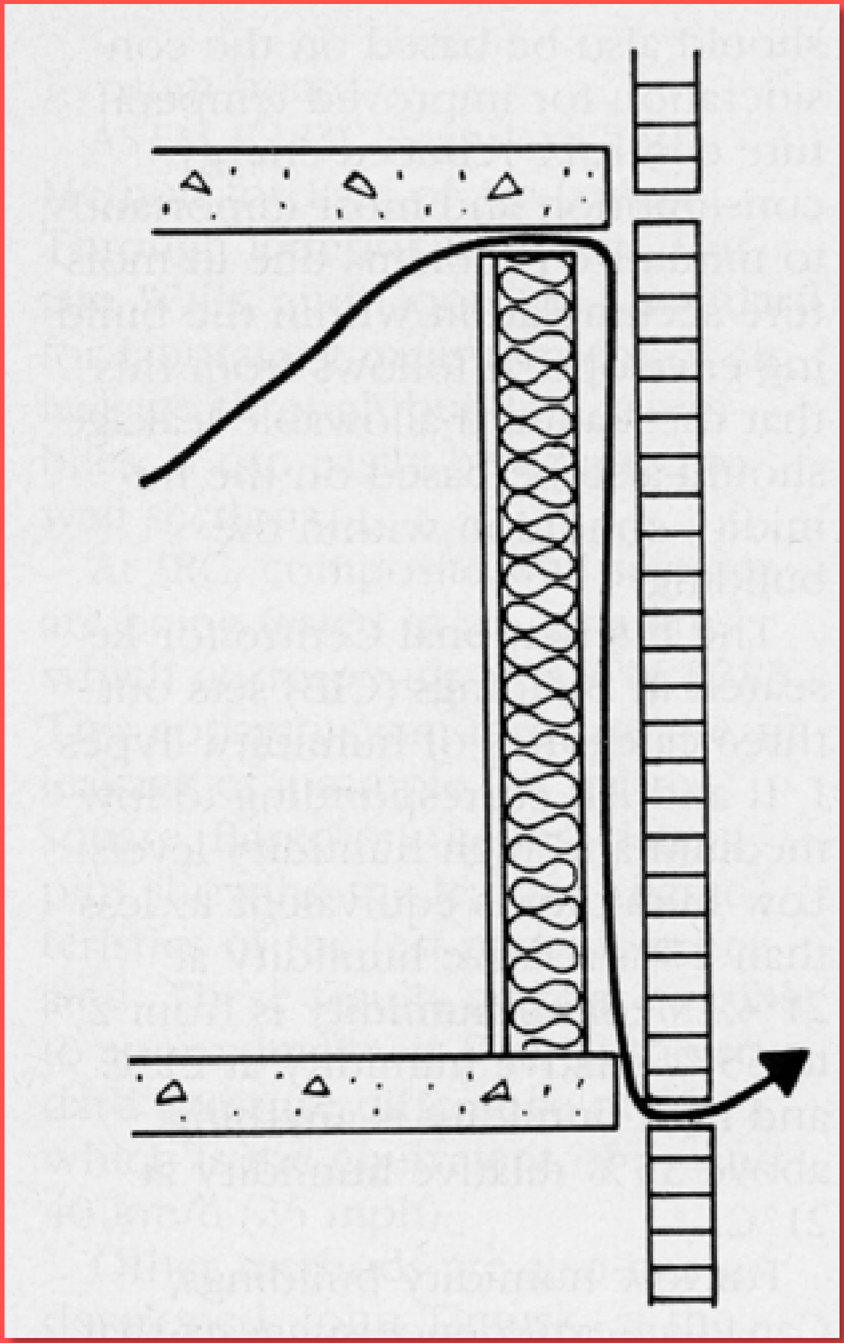


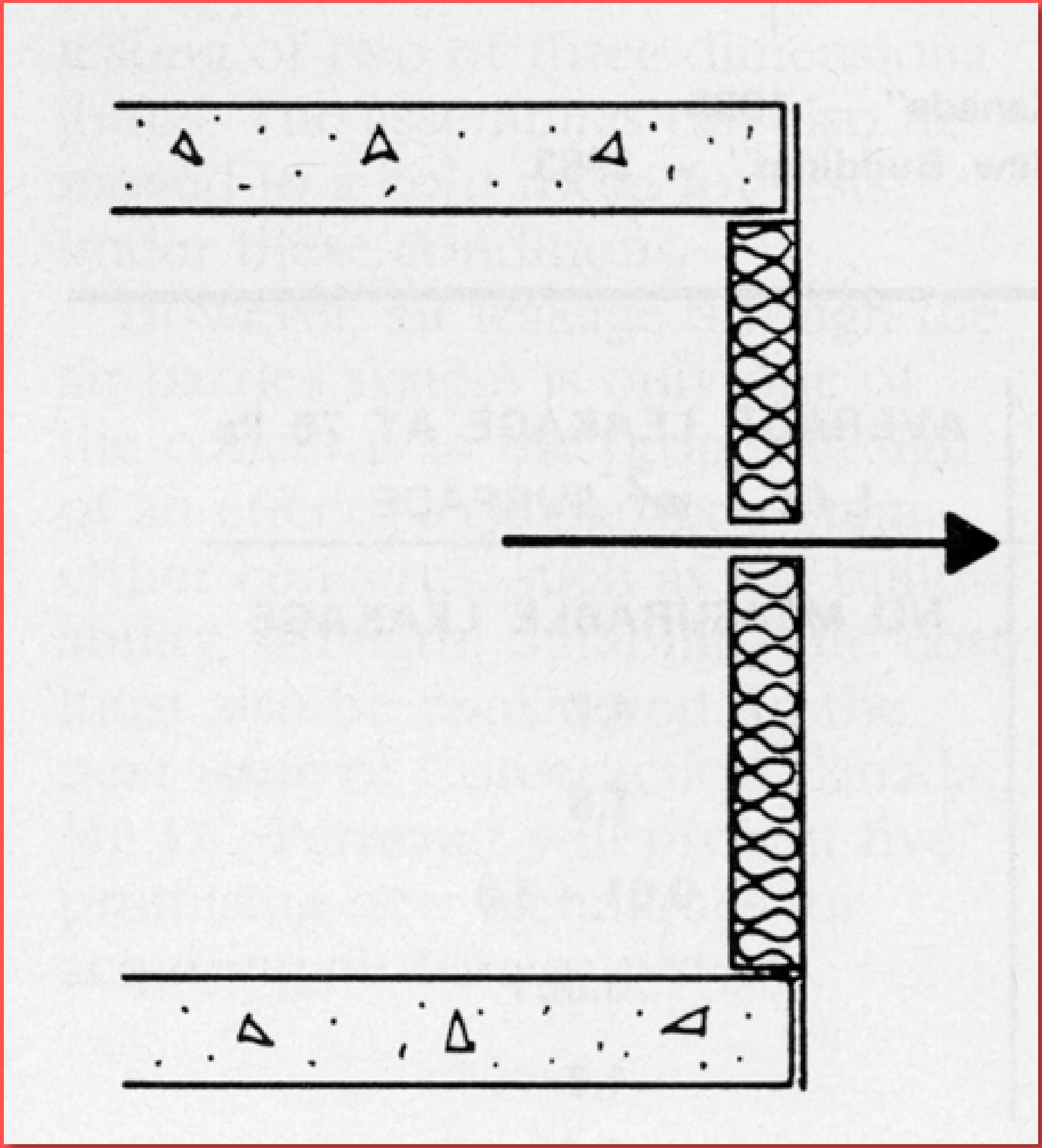
Figure 2.22 Dealing with Wind-Driven Rain at Corners.

Moisture moves through the envelope in 3 ways….



And by channel flow…



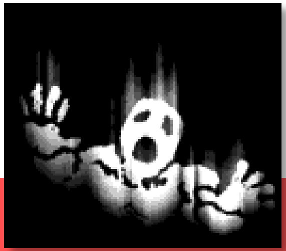


And through orifice flow...

The vapour barrier

For many years, designers were taught that the vapour barrier was a major requirement for insulated walls in order to control the diffusion of water vapour into the colder reaches of these walls, where it could condense and stain the finished surfaces or, worse, initiate the deterioration of the affected materials. When it became obvious to researchers in the 1960s that air leakage into the walls and roofs was a more important source of water migration, authorities began calling for a "continuous vapour barrier."

It was found to be close to impossible, considering the materials that were being used (mostly polyethylene and other not-so-durable products.)



A Vapour barrier is: *definition*

- a material that offers a high resistance to the diffusion of water vapour.
- is used to separate an environment which is at a high vapour pressure from an adjacent one at a lower vapour pressure.
- For best results, it is important that the vapour barrier be continuous, but it does not have to be perfectly continuous. Unsealed laps or minor cuts do not affect the overall resistance to diffusion significantly.
- The vapour barrier must also be located on the warm side of the insulation or at least in a location in the wall near enough to the warm side to remain above the dew point temperature of the indoor air during cold weather.

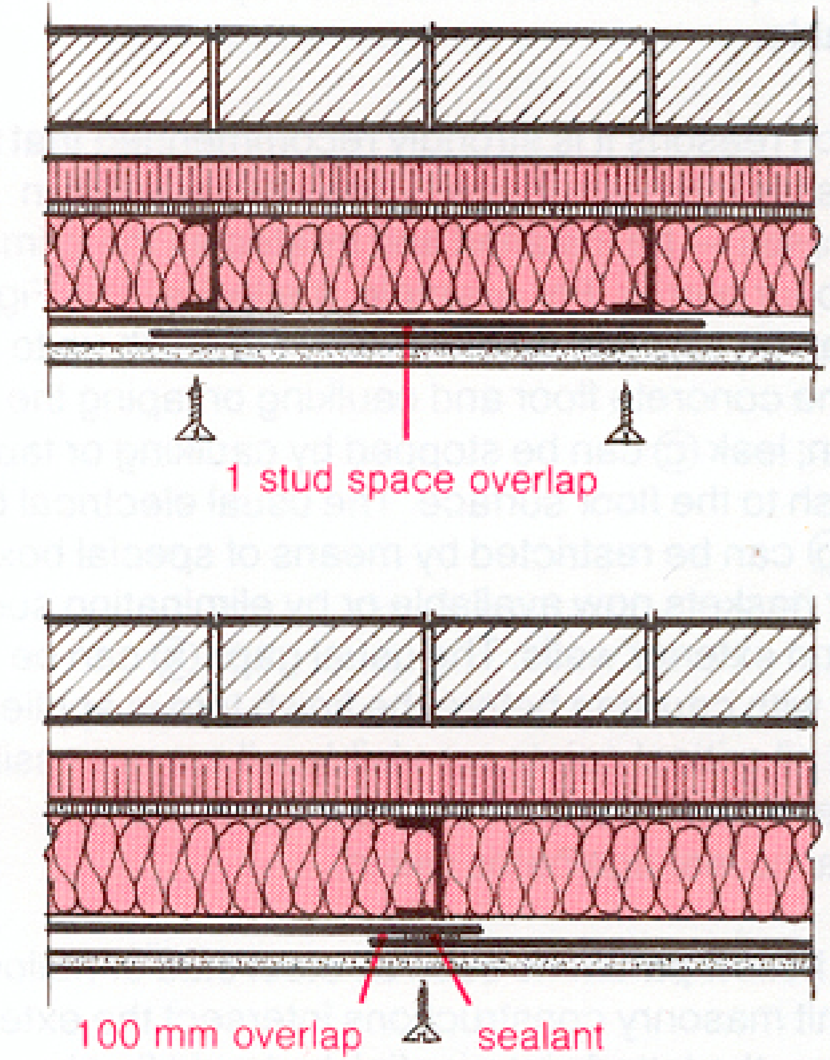
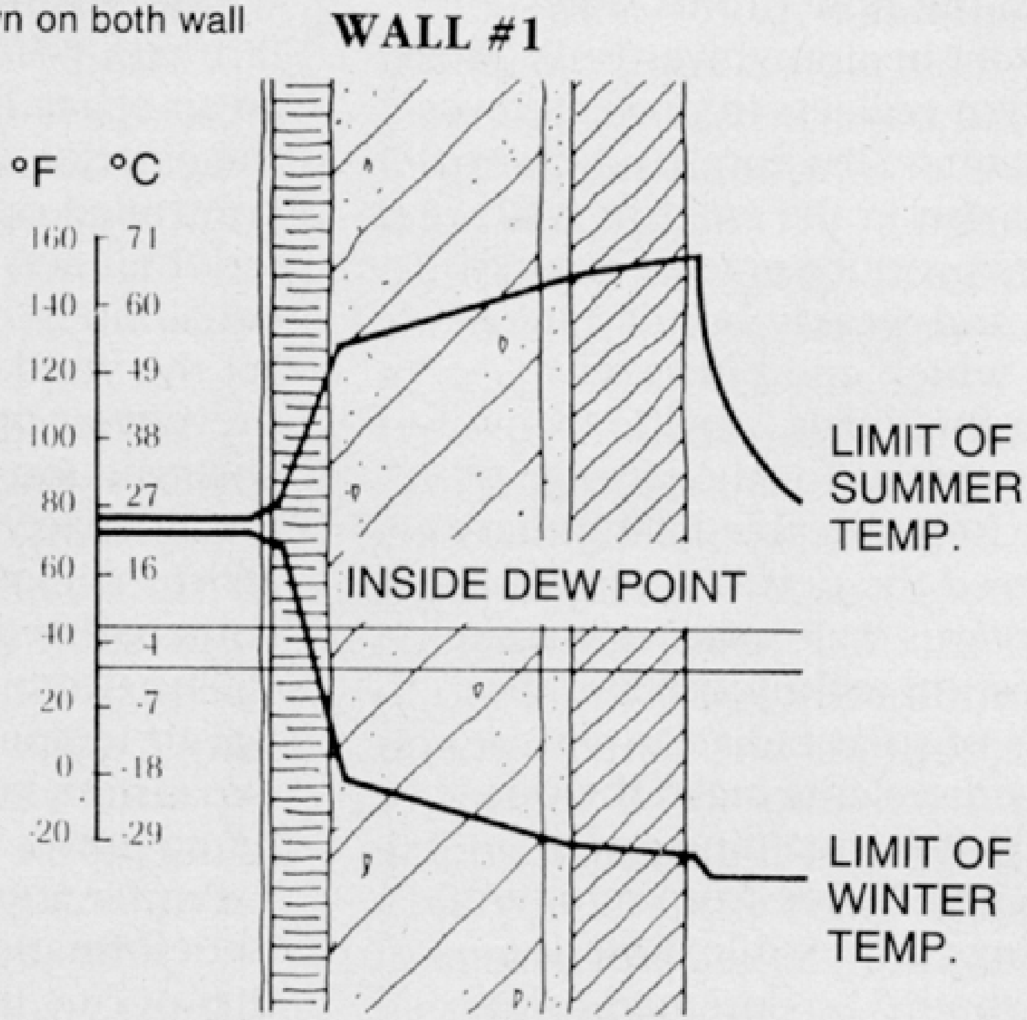


Figure 2.17 Recommended Joints in Polyethelene Air/ Vapour Barrier

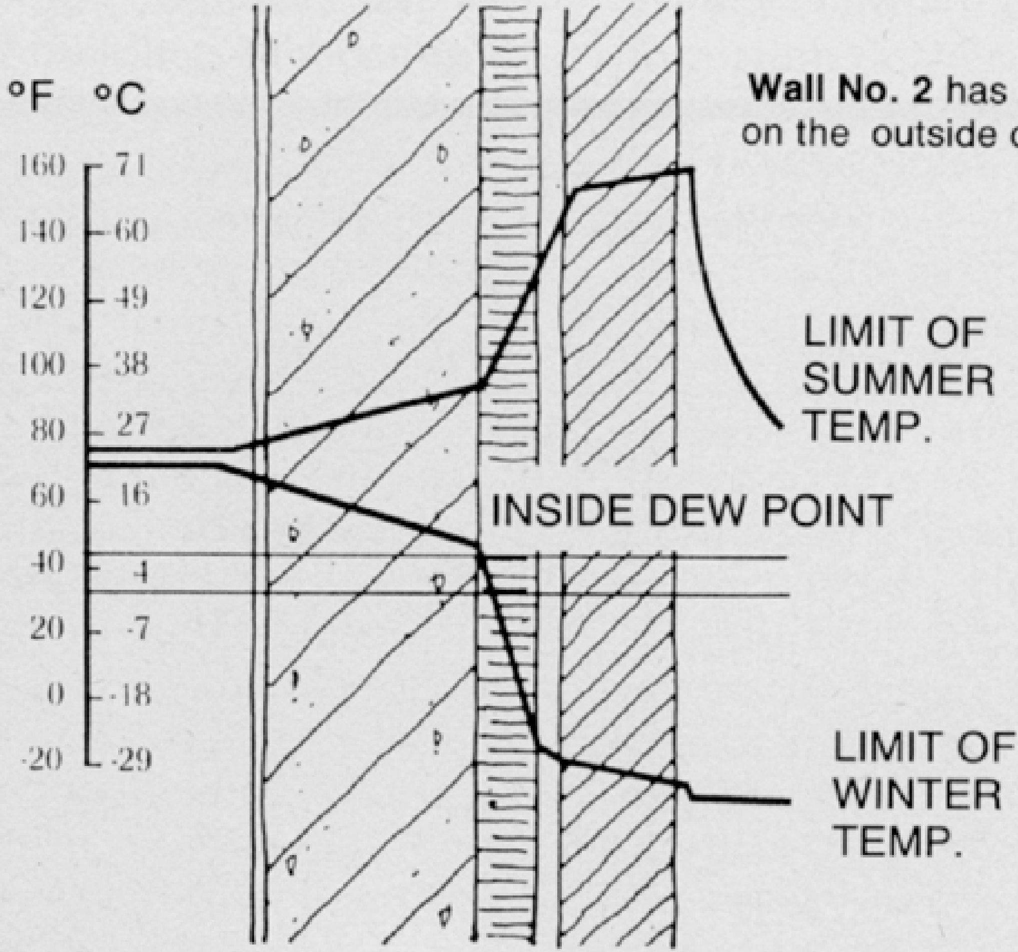
The calculated temperature gradients for winter and summer are shown on both wall sections.

Wall No. 1 has the insulation located on inner (or warm) side of the wall construction:



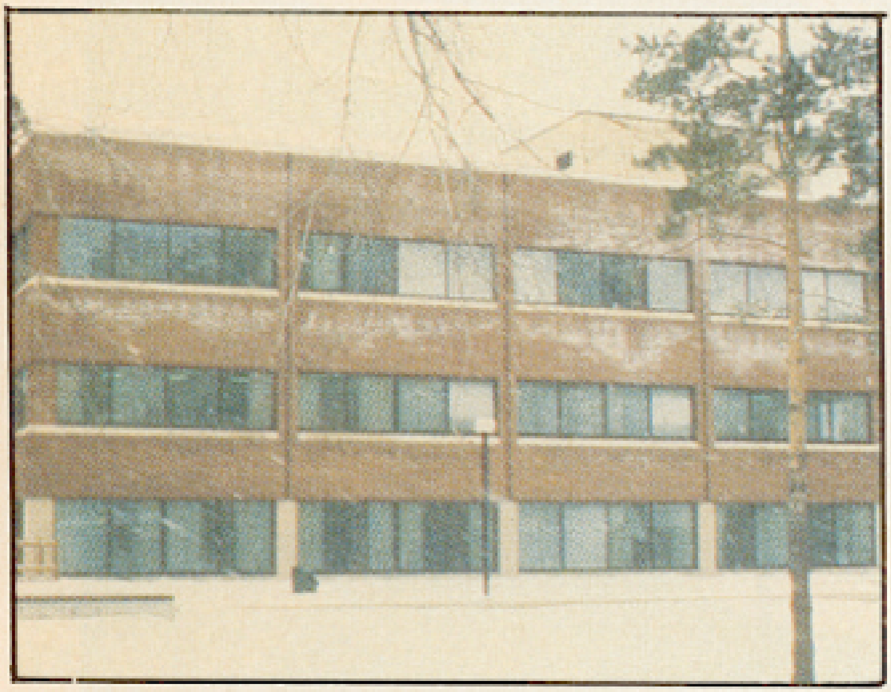
WALL #2

Wall No. 2 has the insulation located on the outside of the inner wythe.



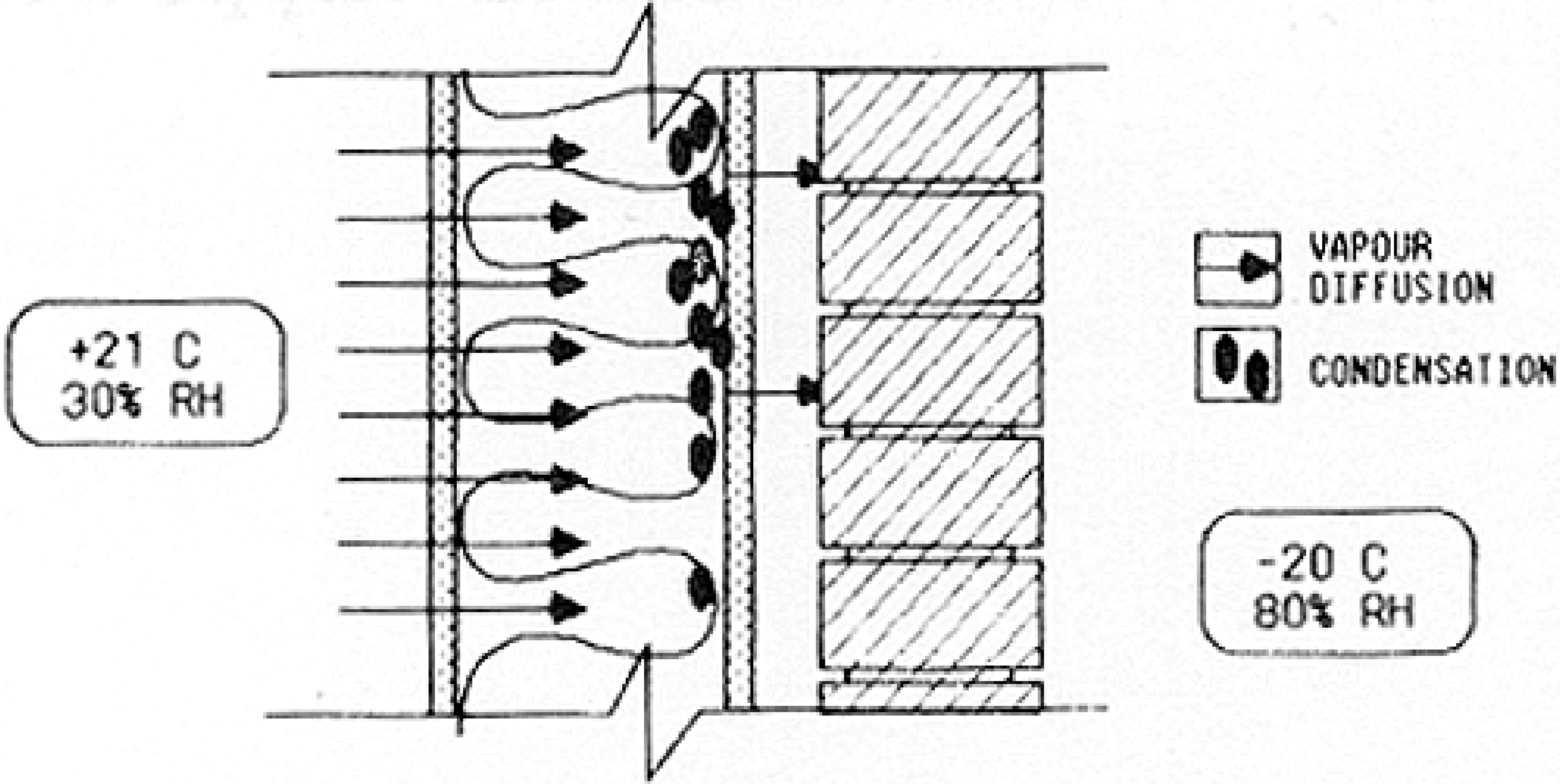
Air Barrier:

The principal function of the air barrier is to prevent both the infiltration of outdoor air into a building and the exfiltration of indoor air to the outside. This applies whether the air is humid or dry. Air leakage can cause problems other than the deposition of moisture in the walls, such as loss of energy and infiltration of rain.



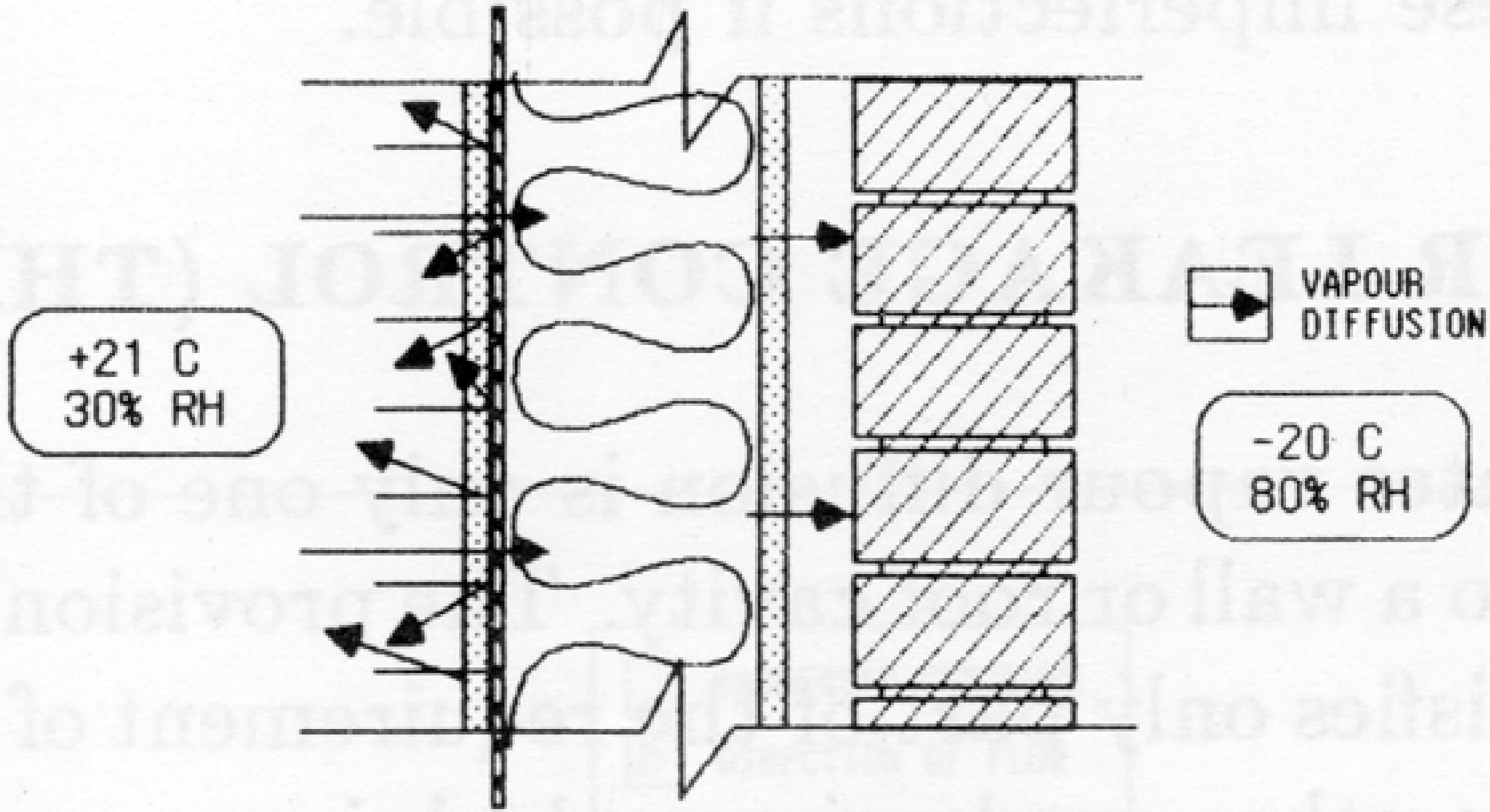
Efflorescence on masonry (Photo I)

In 1964, Mr. N. Hutcheon wrote in Technical Paper No. 188, Division of Building Research, NRCC:



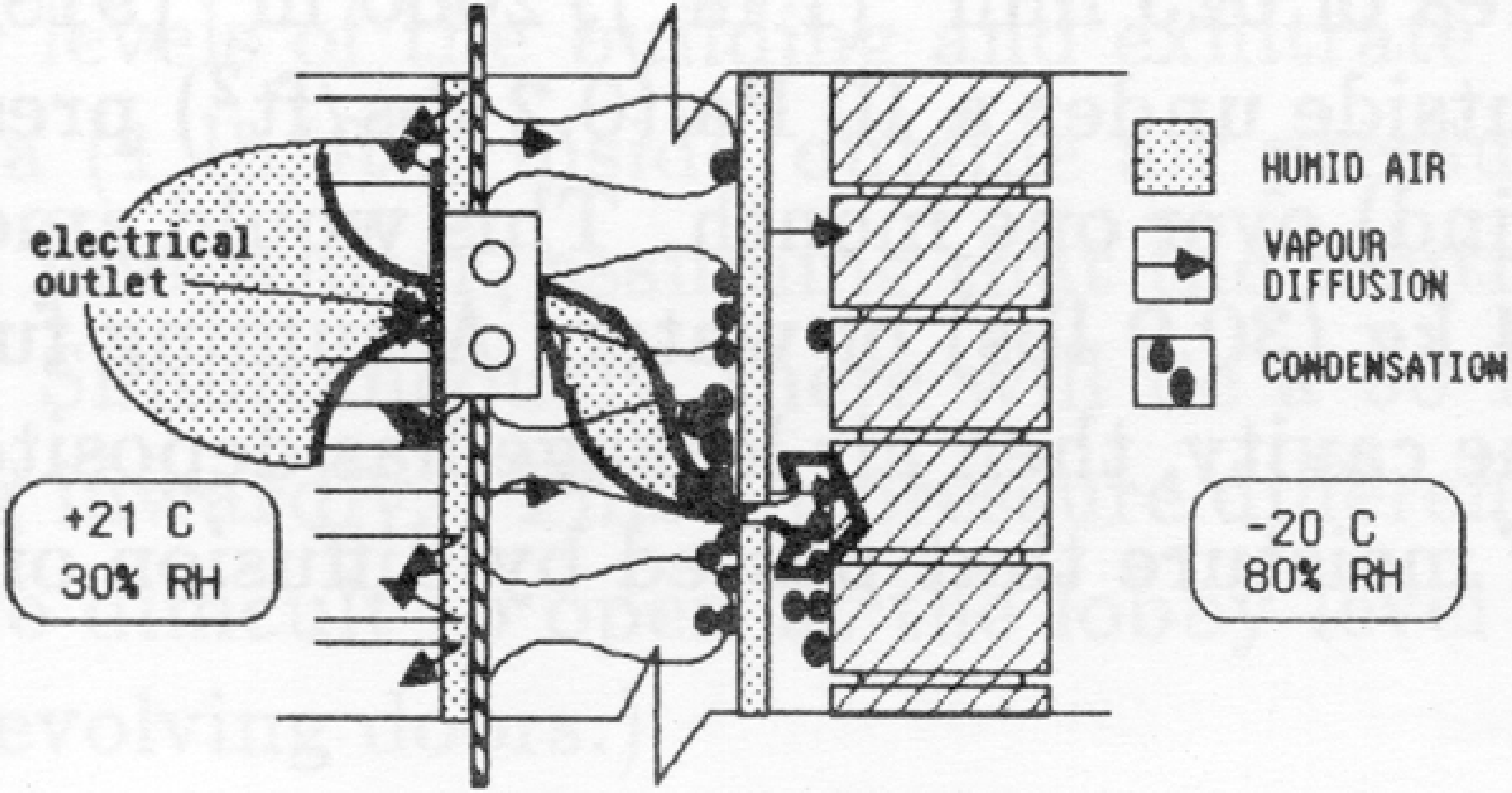
WALL WITHOUT A VAPOUR BARRIER

FIG. 1A



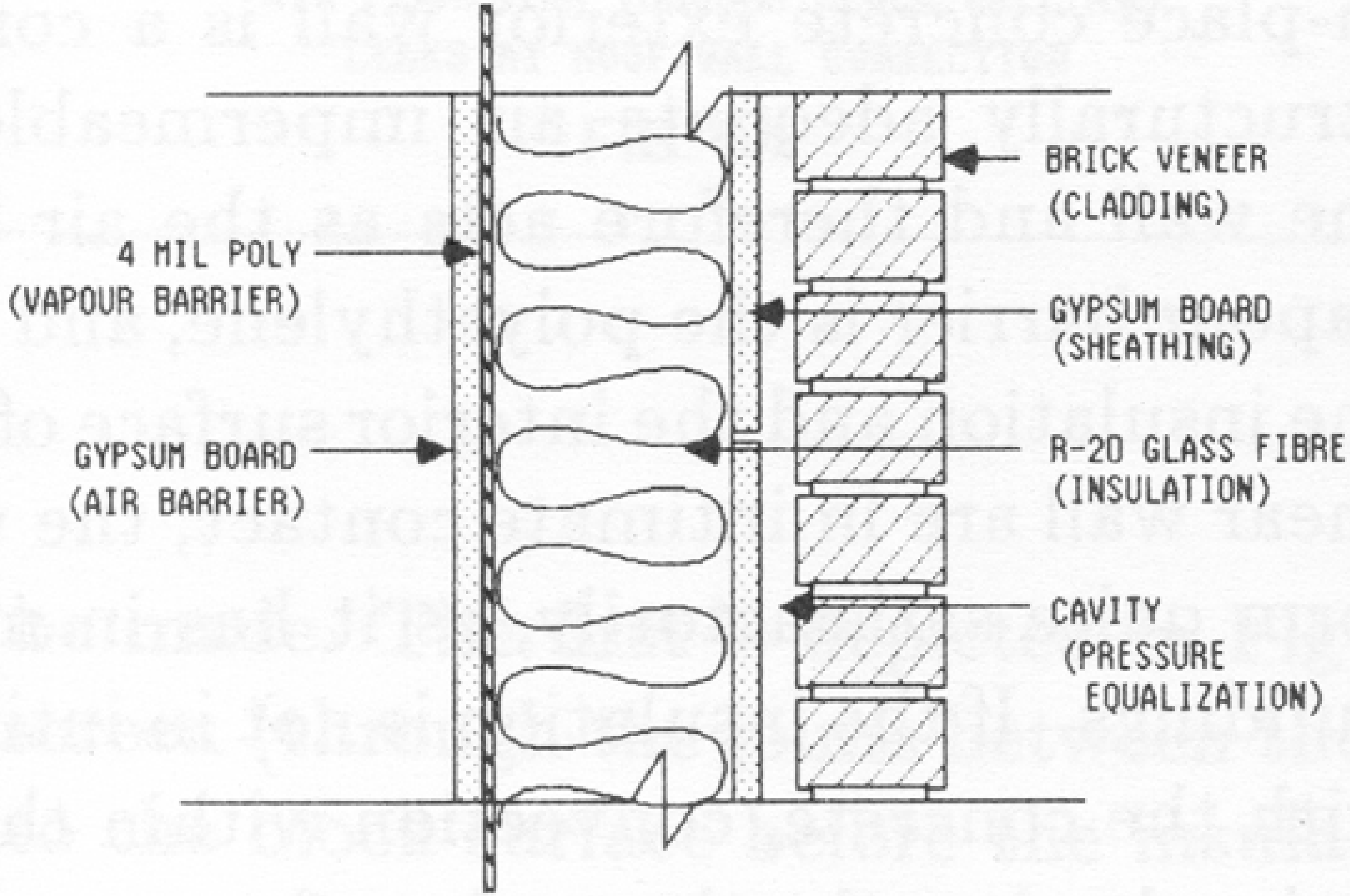
WALL WITH A VAPOUR BARRIER

FIG. 1B



WALL WITH VAPOUR BARRIER
PREVENTS VAPOUR DIFFUSION BUT NOT AIR LEAKAGE

FIG. 2



SEPARATE AIR AND VAPOUR BARRIERS

FIG. 7

DIFFERENCE BETWEEN VAPOUR AND AIR BARRIERS:

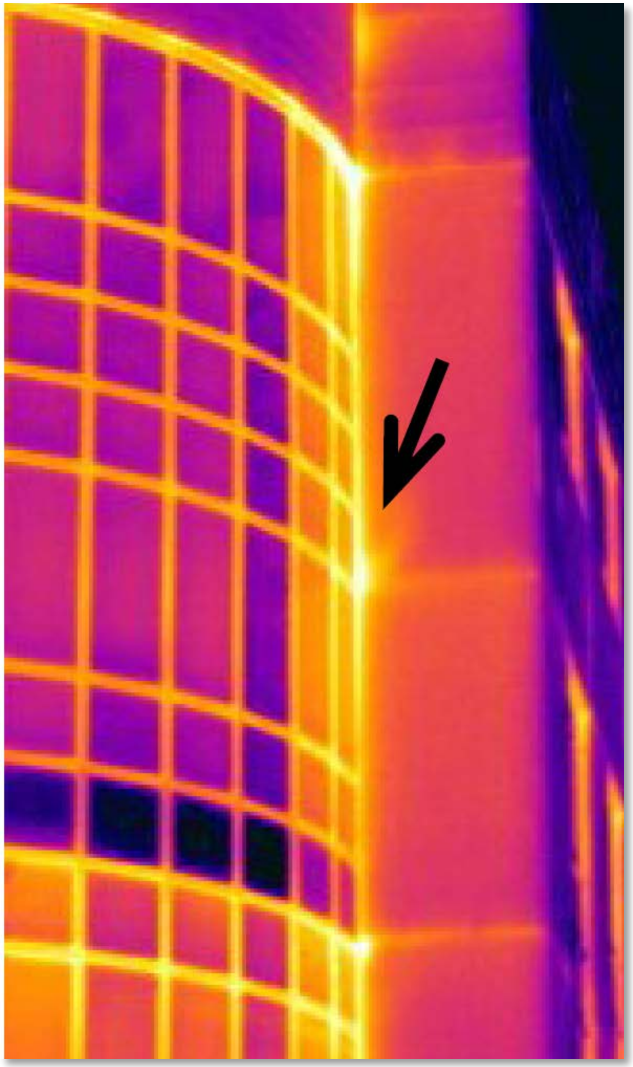
•vapour barrier stops air diffusion - movement THROUGH the wall	•air barrier stops air movement - movement through CRACKS in the wall
•vapour barrier is usually a PRODUCT (like poly film)	•air barrier is a SYSTEM
•joints are not a problem, ie. continuity not an issue	•air barrier must be CONTINUOUS and all joints between different materials SEALED
•not necessarily durable	•durability important

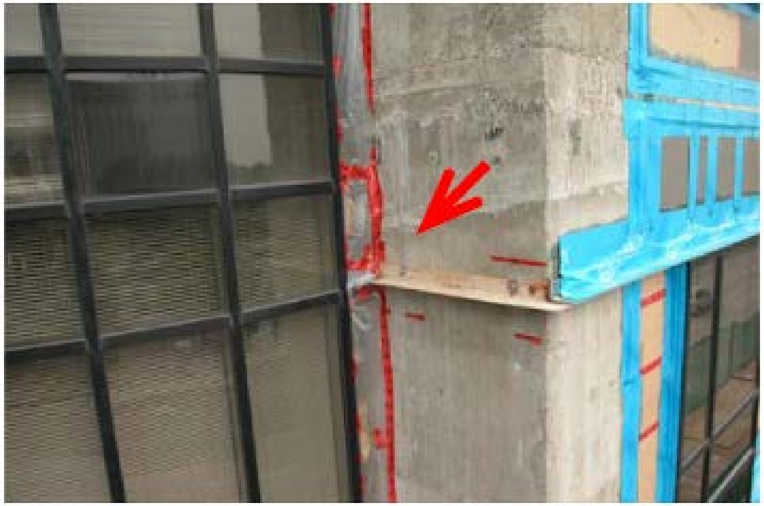
Air barrier design criteria: *Continuity:*

Continuity:

Continuity means more than being without holes. Because the component that performs the role of the air barrier changes from the wall to the window to the roof, continuity means that all these assemblies must be connected together so as to ensure that there is no break in the airtightness of the envelope.

AIR BARRIER CONTINUITY



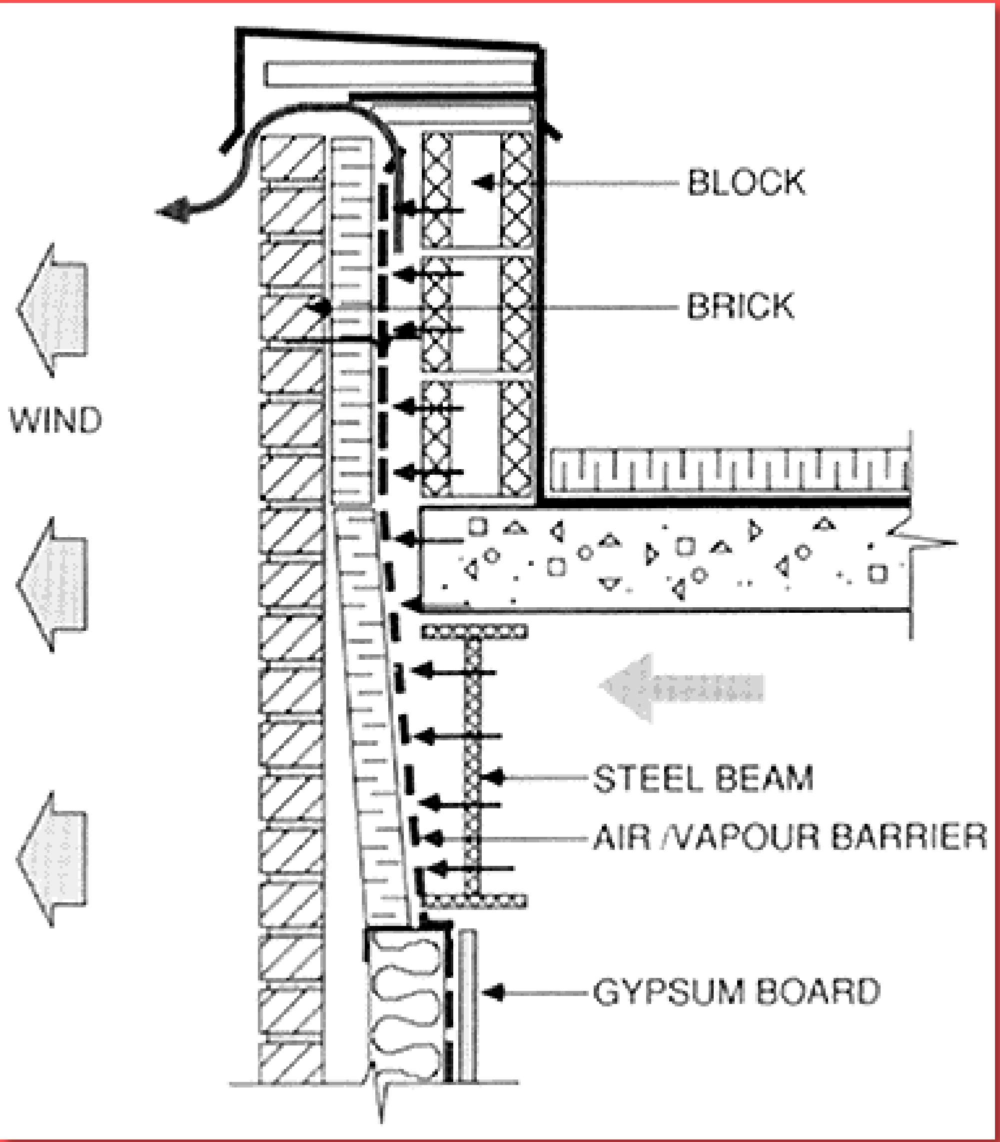


Air barrier design criteria: *Structural Integrity:*

Structural Integrity:

The component designed to be the air barrier must itself be capable of resisting the imposed load or must be supported by one that can. It must be capable of resisting the strongest wind load acting either as a pressure or suction without rupturing or breaking away from its support. The air barrier must not detach itself from its support or fail in creep under a sustained pressure resulting from stack effect or fan pressurization or exhaust. The air barrier and its support must be sufficiently rigid to resist displacement.

Structural Integrity:

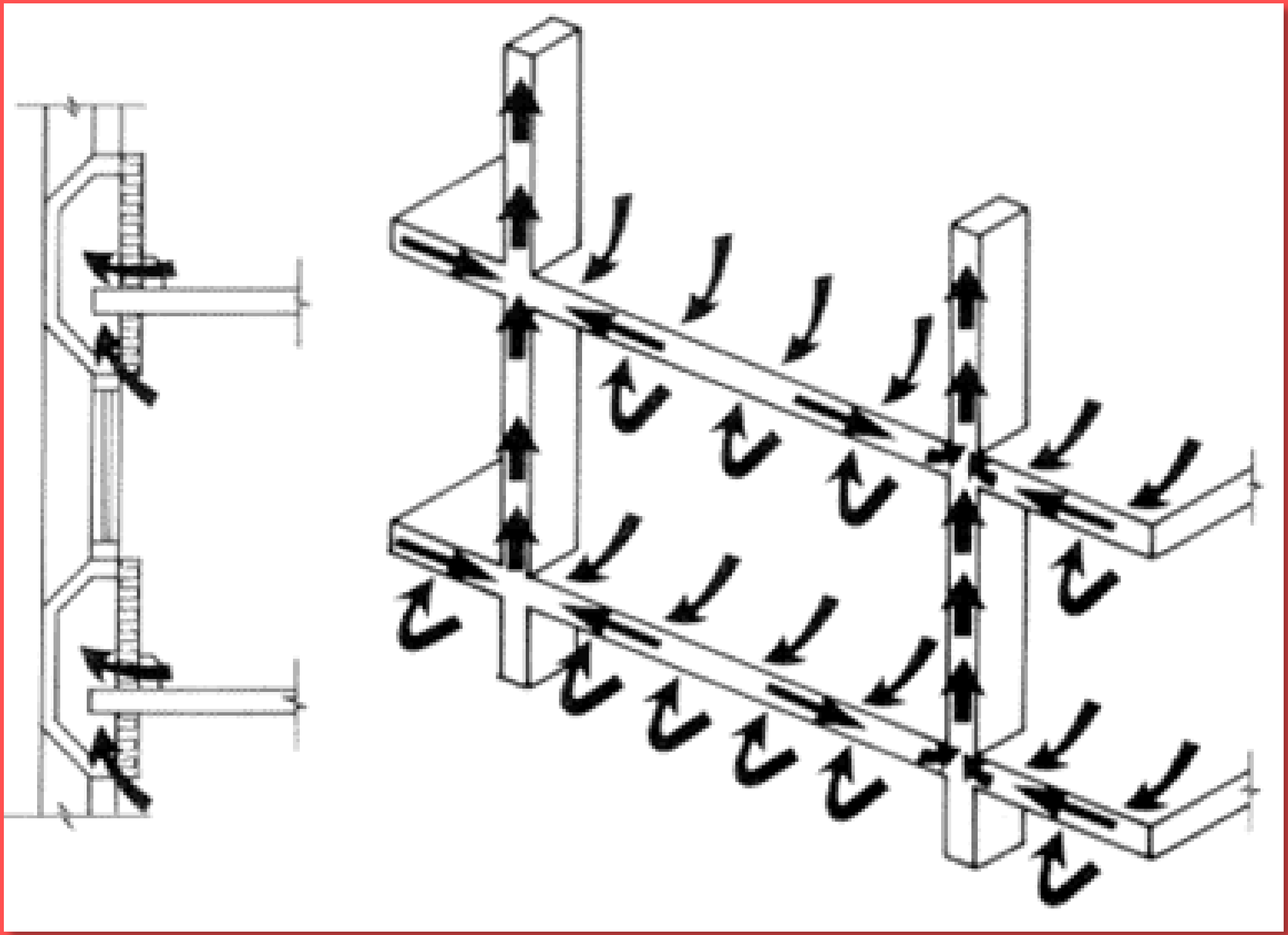


Air barrier design criteria: *Impermeability:*

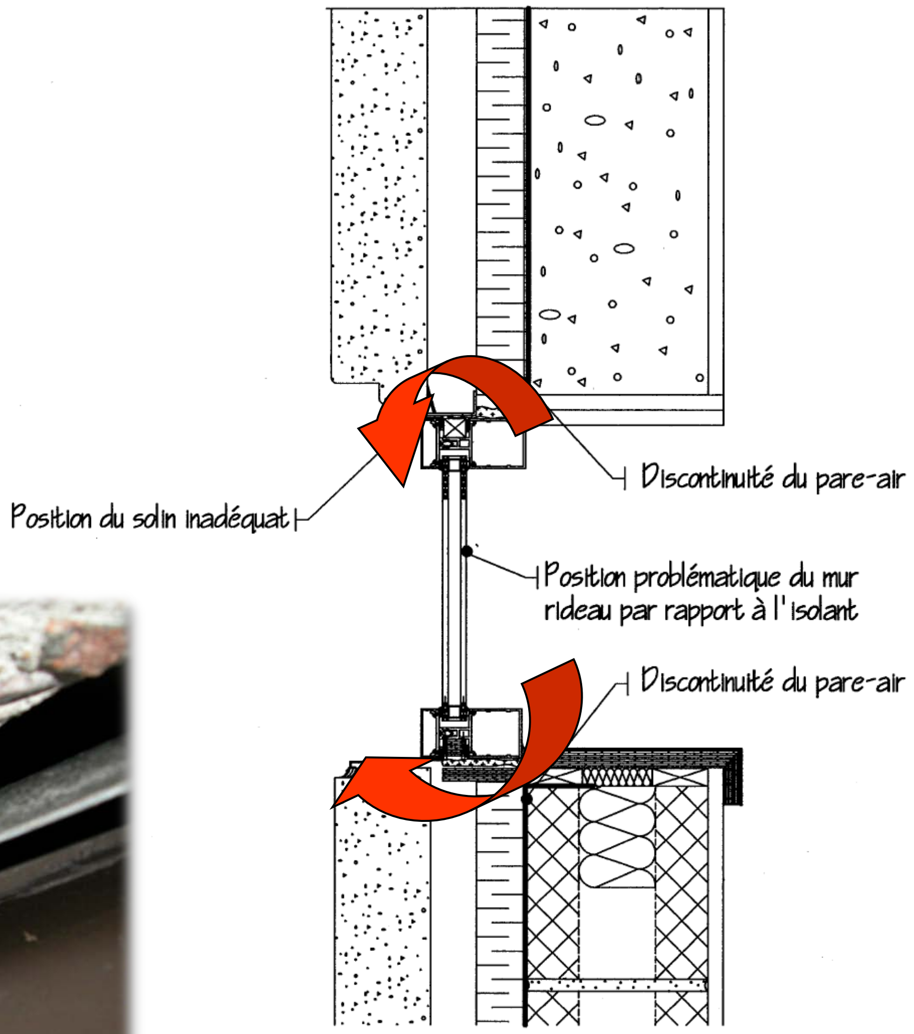
Air Impermeability

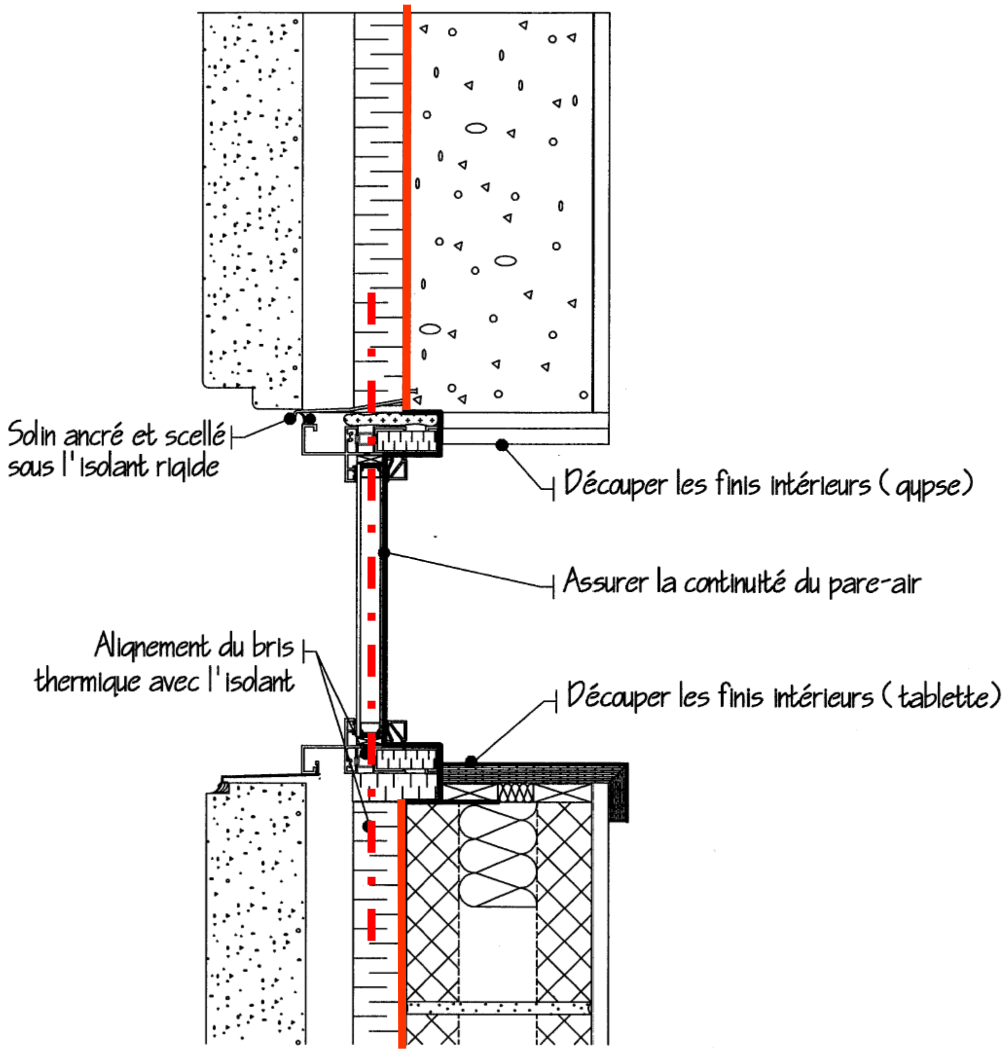
A major requirement of an air barrier is that it offer a high resistance to air flow. While absolute air impermeability may not be required, materials such as glass, sheet metal, gypsum board, cast-in-place concrete and a properly supported polyethylene sheet offer a much higher resistance to air flow than do more porous materials such as concrete blocks, fibre board sheathing, and expanded polystyrene insulation. A second major consideration is that individual panels be joined into an airtight assembly. The joints between gypsum boards can be taped quickly and effectively, sheet metal panels can be lapped with tape, precast panels can be sealed with rope and sealants, etc.

Impermeability:



Block air paths!





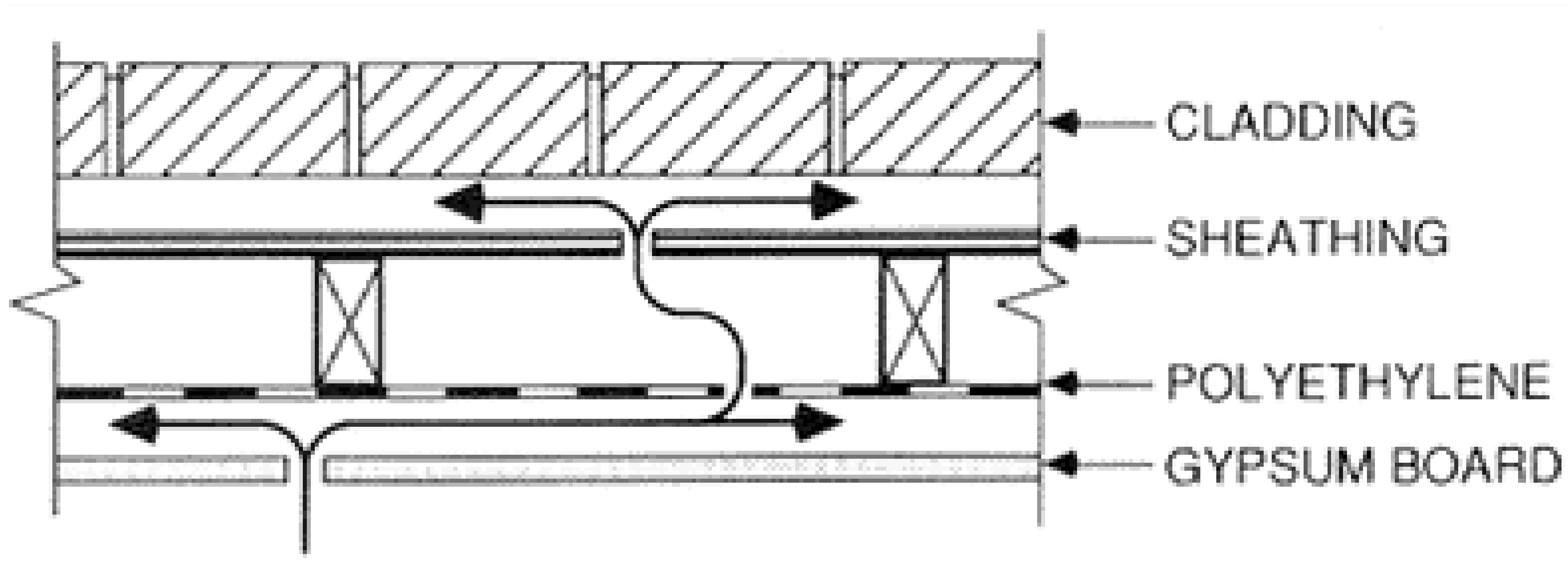
Solin ancré et scellé
sous l'isolant rigide
Découper les finis intérieurs (gypse)
Assurer la continuité du pare-air
Alignement du bris
thermique avec l'isolant
Découper les finis intérieurs (tablette)

Air barrier design criteria: *Durability:*

Durability

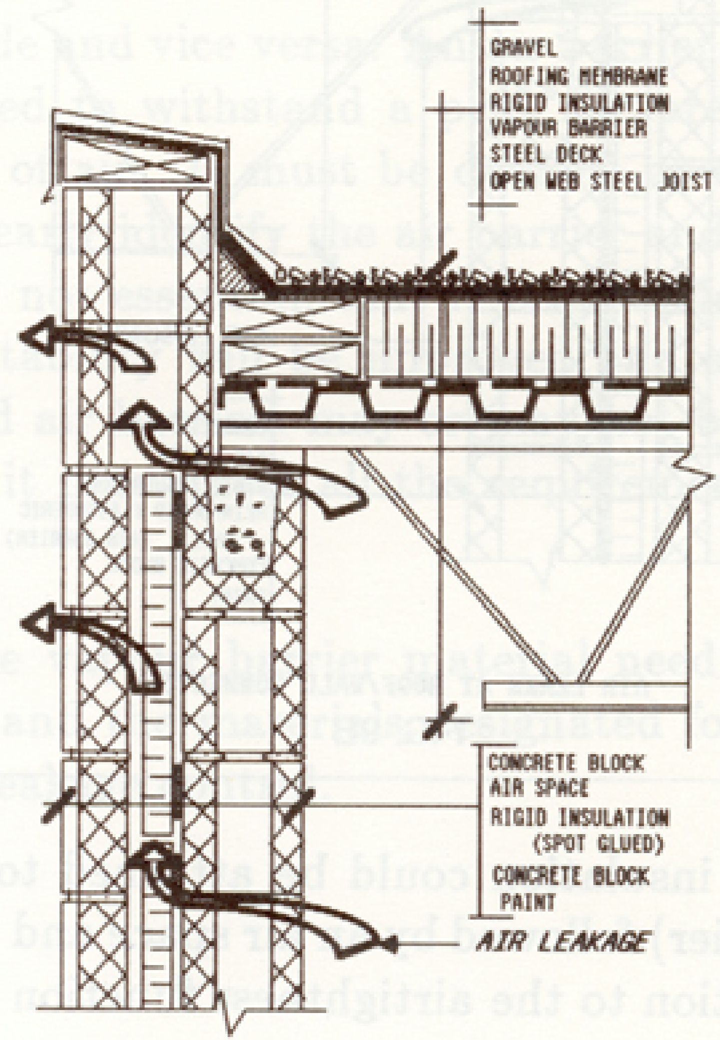
The airtightness system must outlast the building itself. For this to happen, the materials used must have a proven track record or the material should be positioned in such a way that it is accessible for inspection and maintenance.

Durability is not an intrinsic property of a material but depends largely on how a material reacts to a specific environment such as moisture, temperature, ultra-violet radiation, and to the presence of other materials (incompatibility).



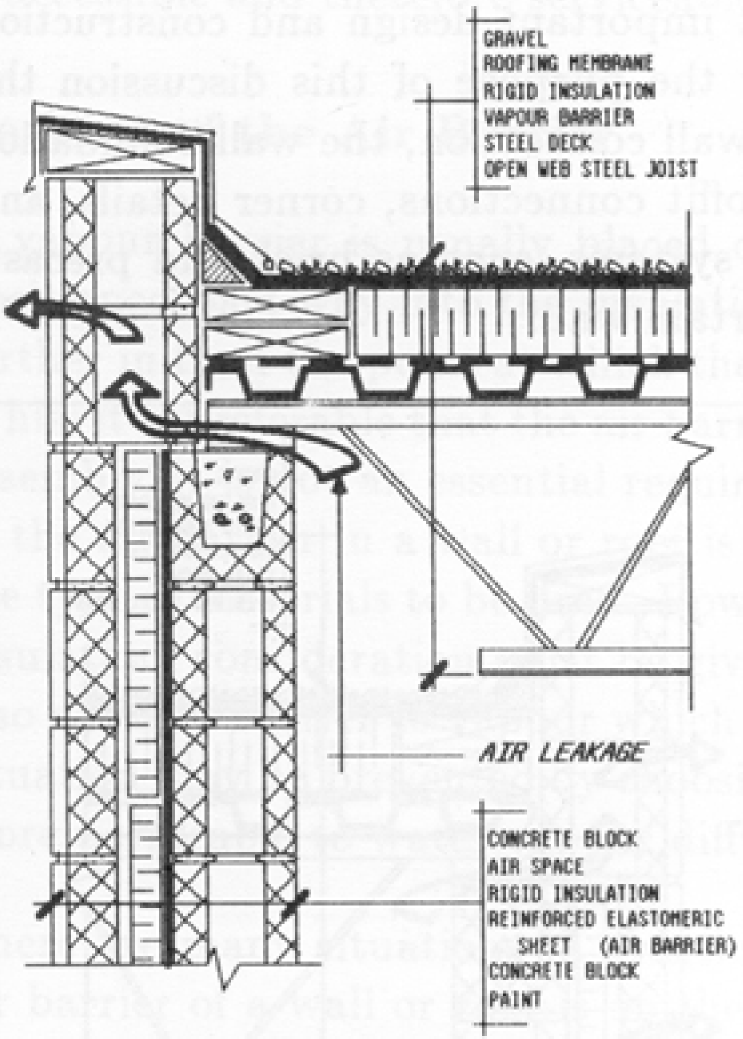
Air flow path: all of the joints in the system must be identified and sealed. Such seals must be of durable long lasting materials OR be in such a place as to be able to be inspected periodically and repaired.

You need to understand how air will flow via both diffuse and channel/orifice methods in order to begin to create the strategy for your air barrier detailing.



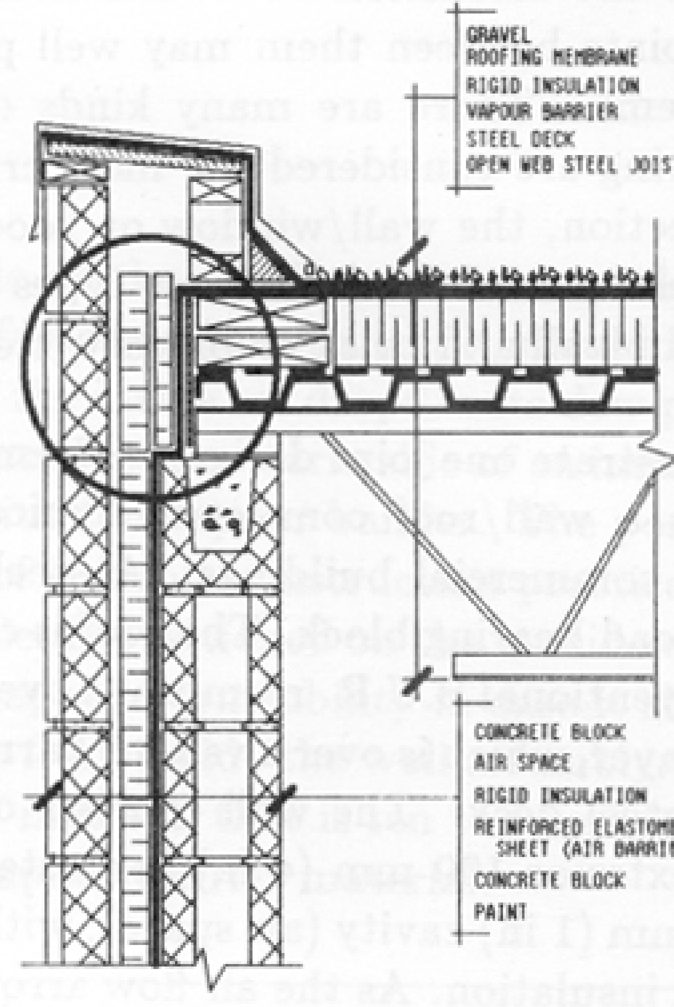
AIR PERMEATES THROUGH BLOCK WALL AND LEAKS AT ROOF/WALL CONNECTION

FIG. 9A



AIR LEAKS AT ROOF/WALL CONNECTION

FIG. 9B



ROOF MEMBRANE (AIR BARRIER) IS CONNECTED TO ELASTOMERIC SHEET (AIR BARRIER)

FIG. 9C

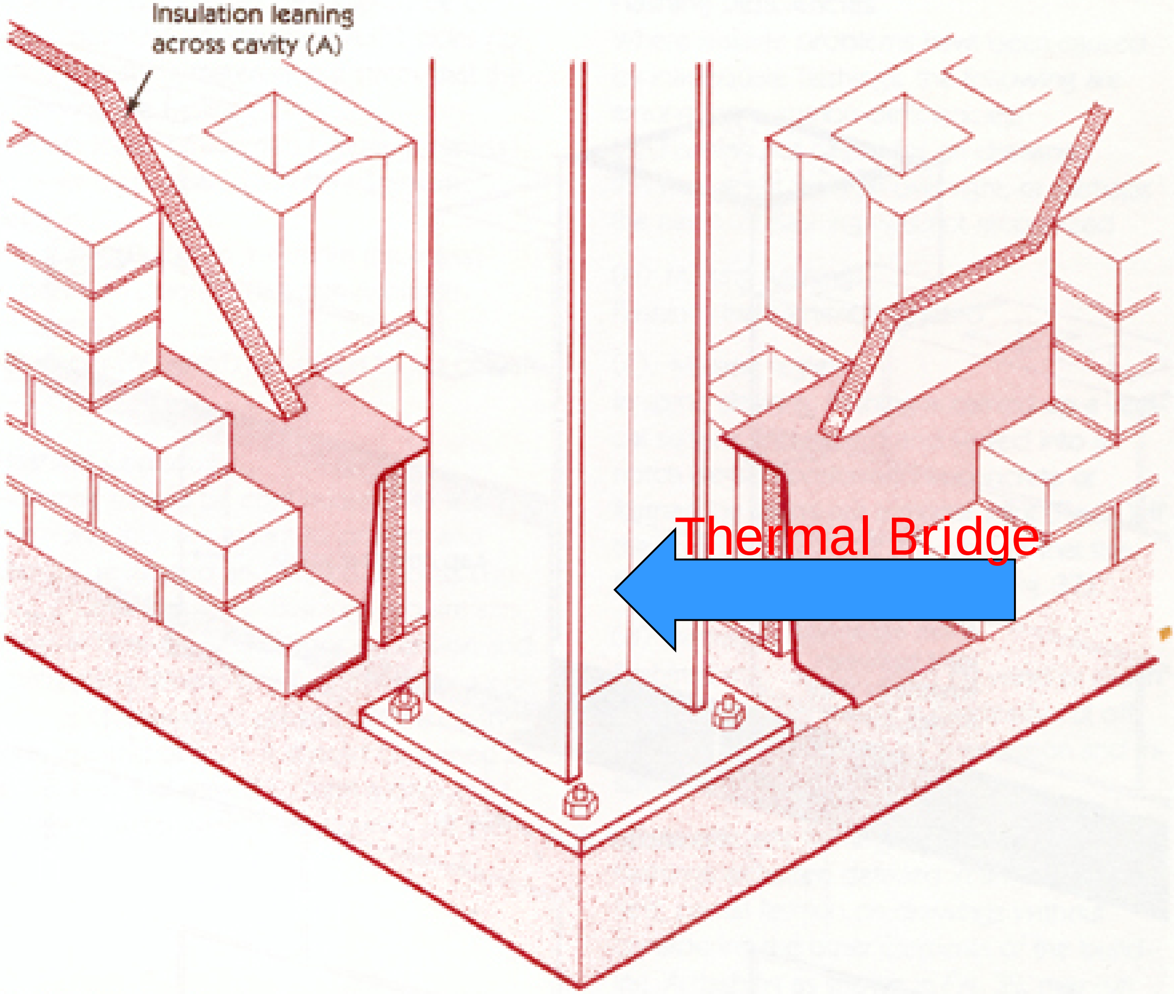
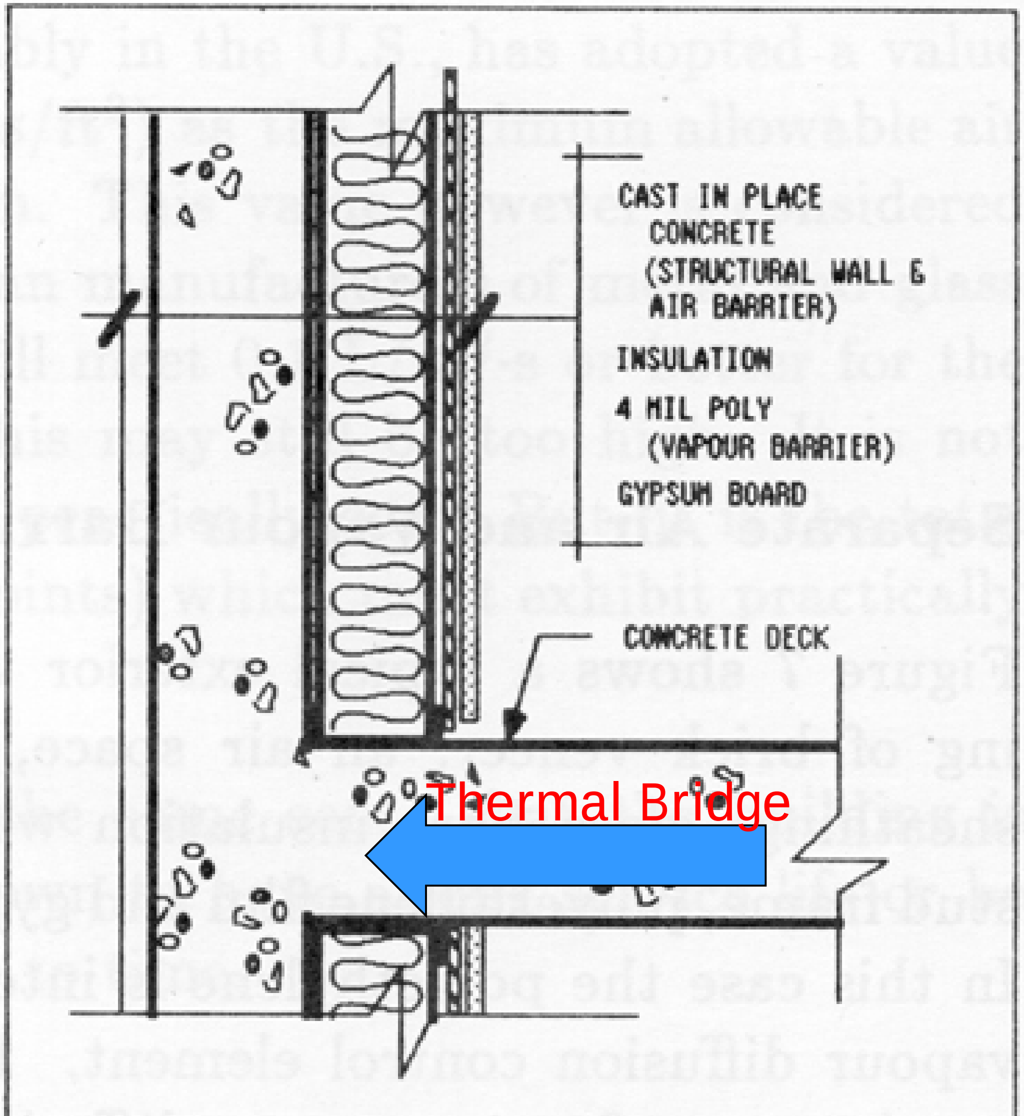


Fig. 39 It is easily visualized how leakage occurs where details like this are encountered.
It will be difficult to:

- flash around the column
- anchor the block
- obtain an air barrier
- maintain a cavity
- place the veneer
- maintain a continuous thermal barrier (Ref. 16).

It is always necessary to visualize details in 3-D in order to properly understand and design a continuous air barrier system.



AIR BARRIER ON THE EXTERIOR

FIG. 8

don't always trust what you see…read…think….be skeptical!

This image is from a Canadian government publication on air barriers. Concrete may be an excellent air barrier, *but what is wrong with this detail??*

Different material combinations will call for different products and methods of creating the air barrier **system**.

Masonry, for example…

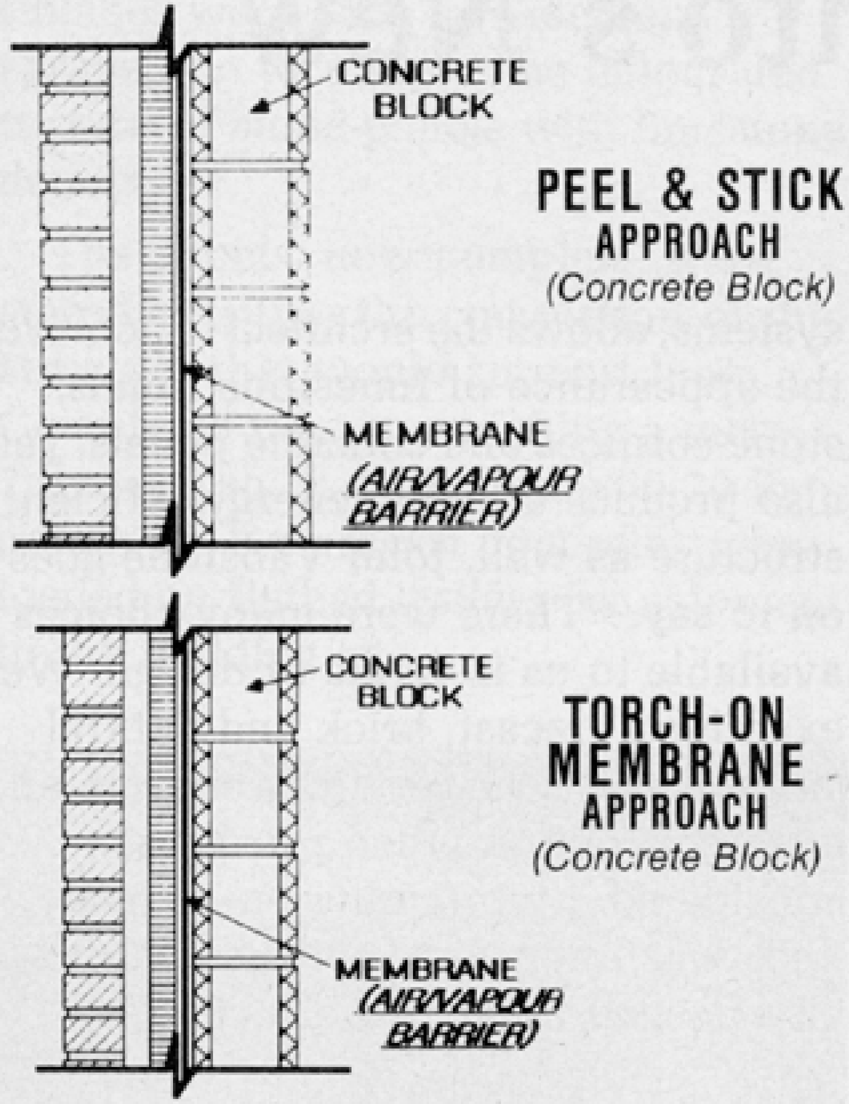
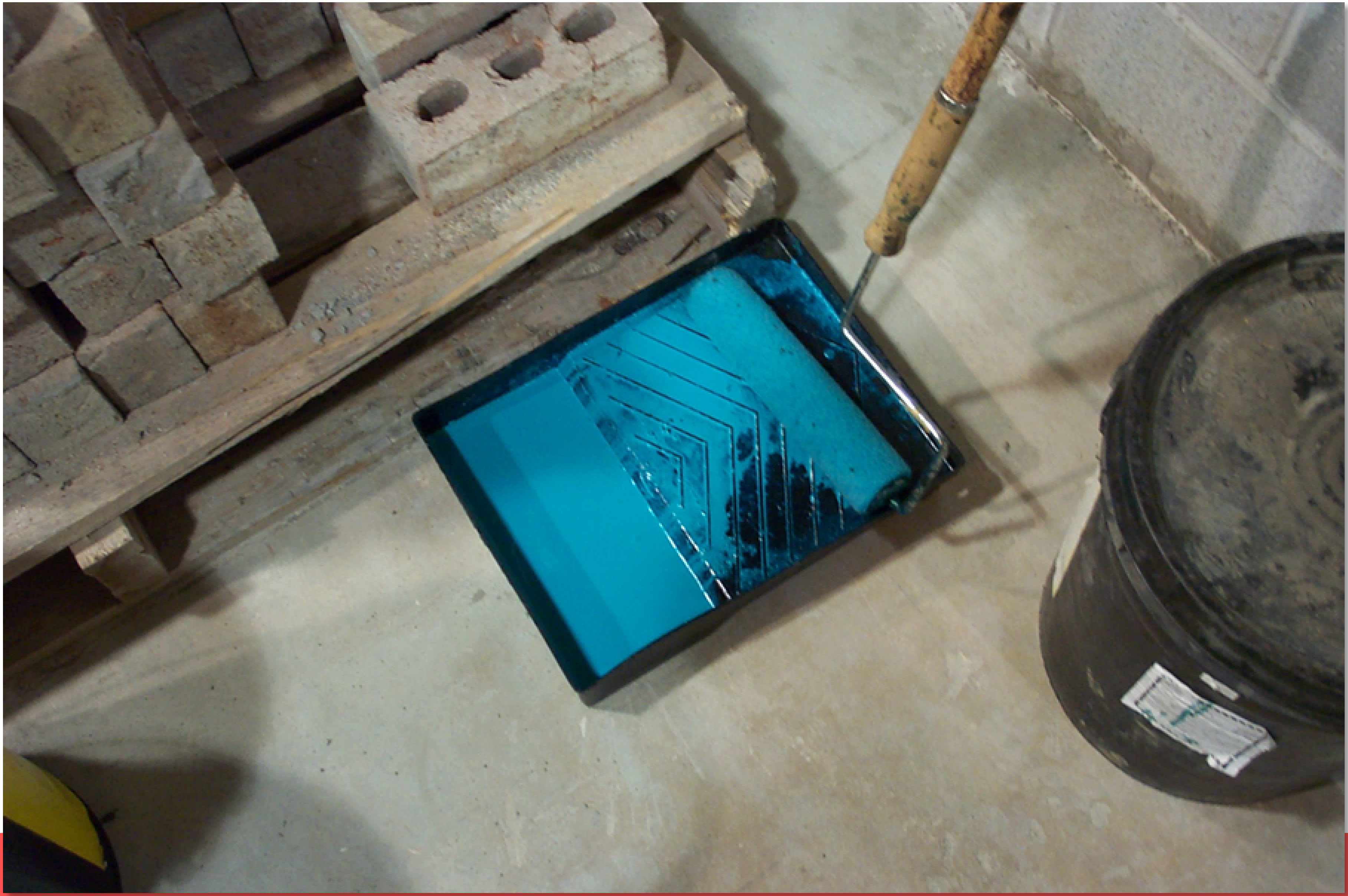


Fig. 7 & 8: Applied Membrane Air Barriers

Some of the rolled membranes that are bitumen based products are adhered via a torched (heat applied) application.

Peel and stick barriers require the application of a roll on base compound to seal the concrete block surface and help adhesion.



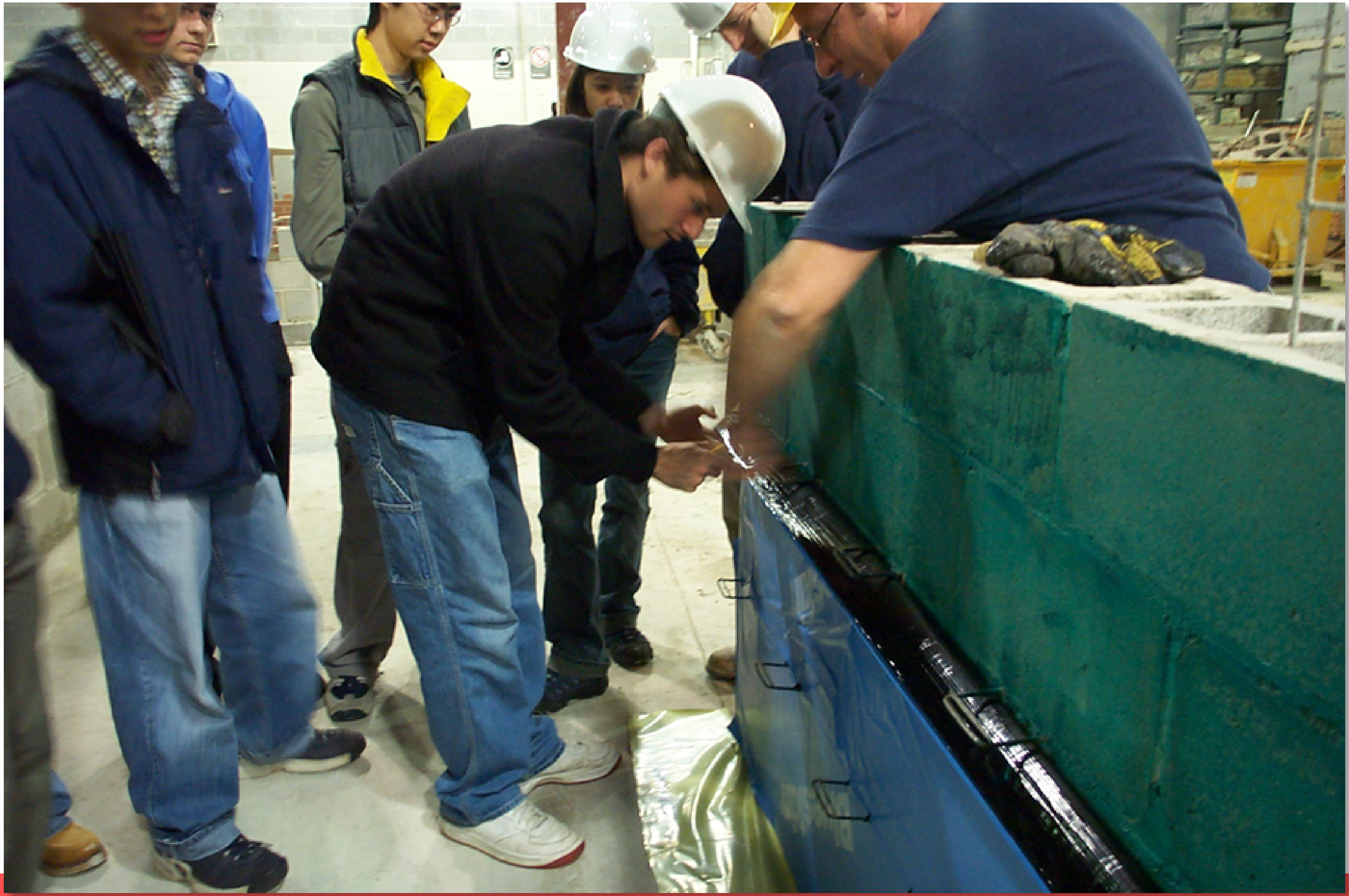
Base flashing also comes in peel and stick product types, but they are usually heavier in quality.

A roller is used on peel and stick membranes to smooth out the product and help to seal edges.

Care must be taken to make sure that material is added at joints for overlap so to ensure that no air/water leaks.

The wall product is lapped over the base flashing to ensure water runoff. The material is cut where it meets masonry ties. These junctions must be resealed to prevent air leakage.

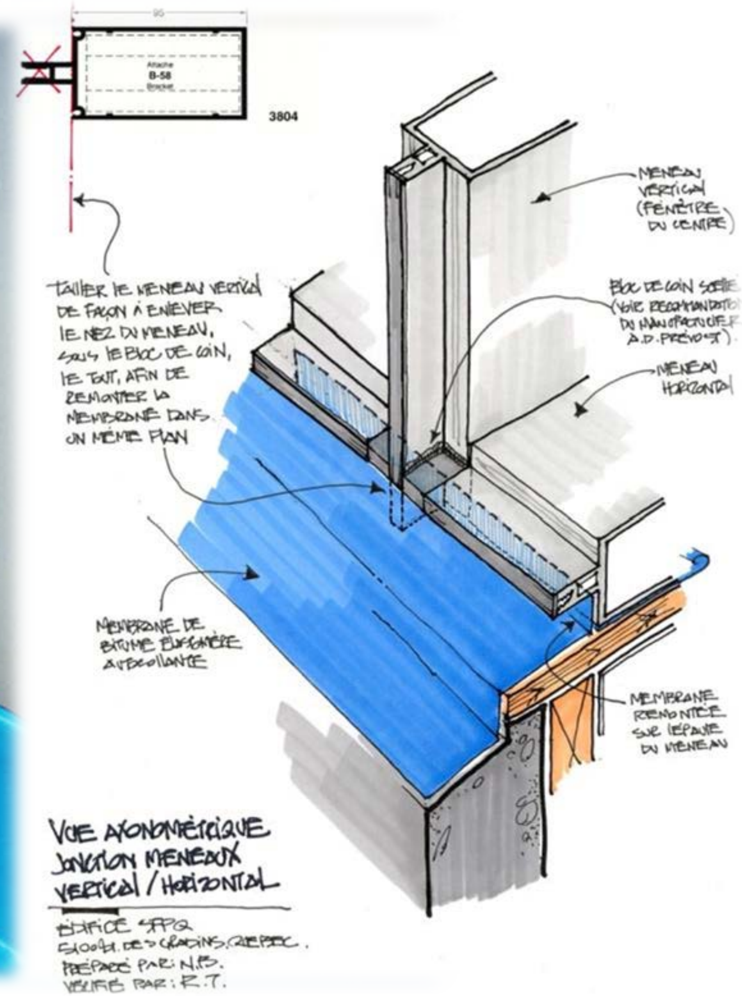
Each subsequent layer of material is lapped over the previous to prevent water from entering from the cavity, and to make for a tight air barrier preventing air leakage from the inside.



Installation of Blueskin on Mars in downtown Toronto.


Blueskin

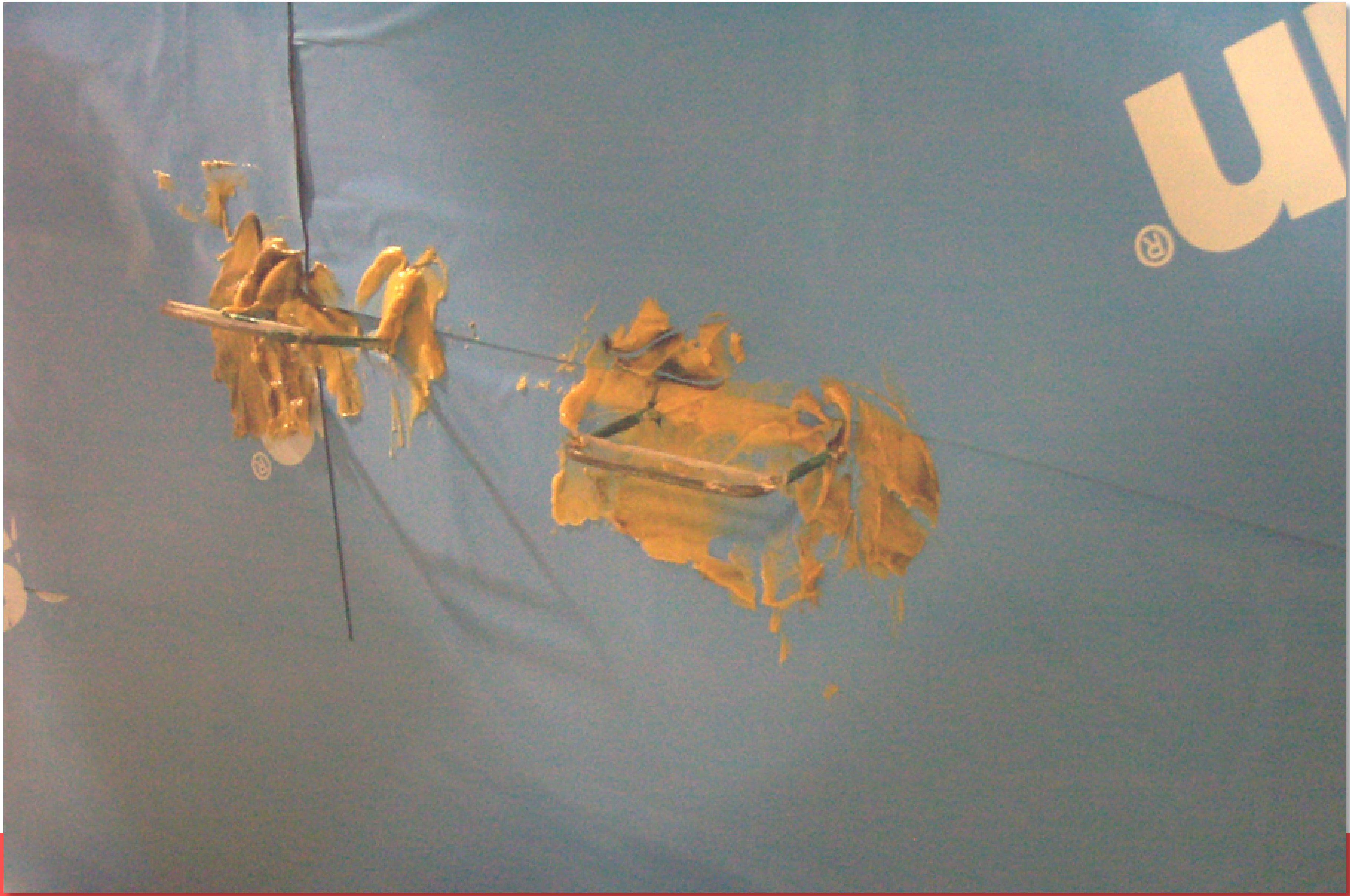
Be sure to properly join and flash openings to prevent leakage.



Air barrier membrane also comes in trowel applied applications.


12/19/2005

The trowel applied material can be used in conjunction with stick on membranes to seal around form tie cuts.



Other devices can be used to flatten out any bubbles or wrinkles in the material.

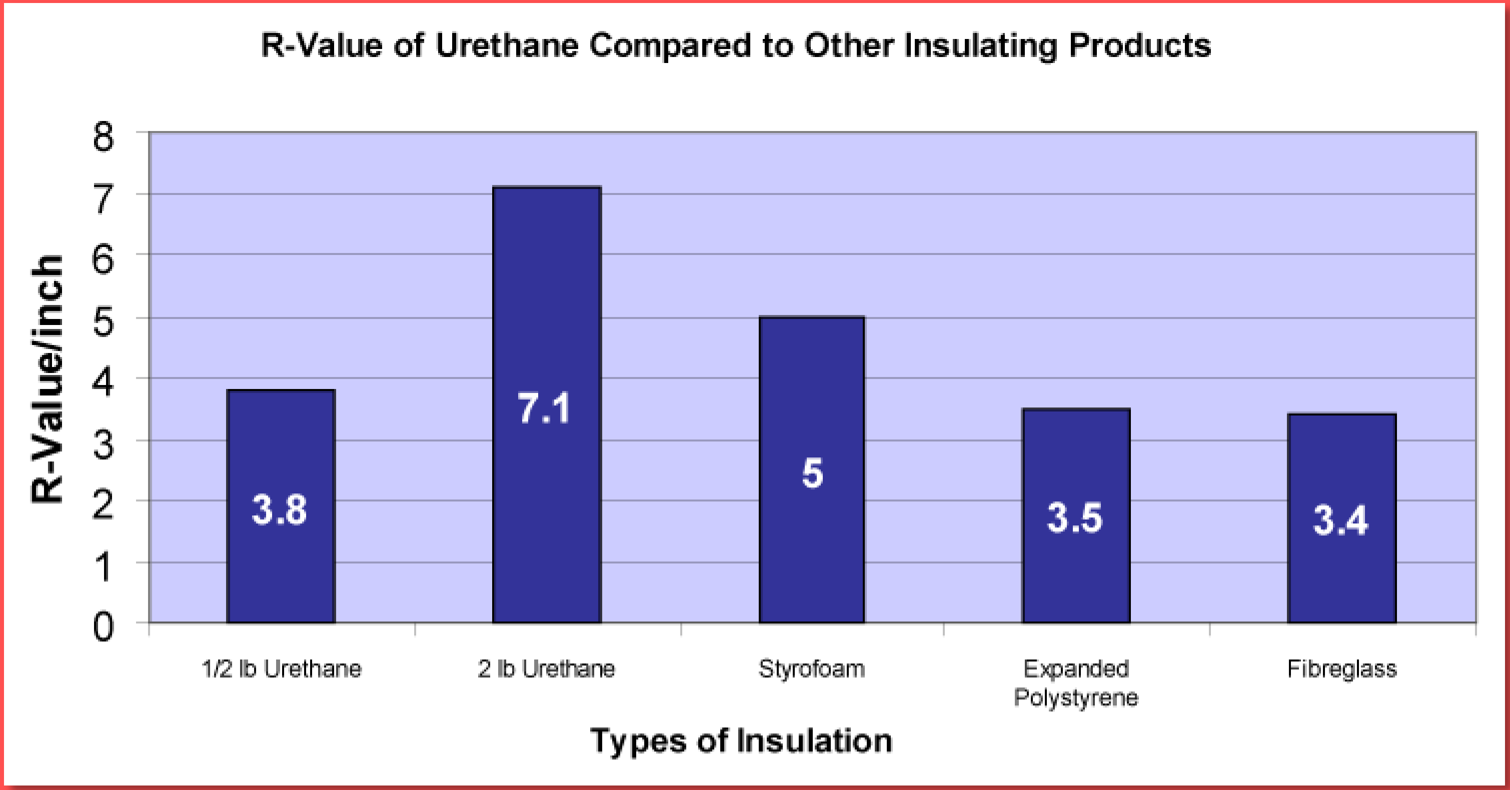
Polyurethane foam insulation (PUFI) can also be used on masonry and other base materials as a combined insulation and air barrier system.

Tohu, permanent circus bigtop, Montreal



Polyurethane foam insulation – which also acts as an air barrier – is termed a “closed cell” insulation. i.e. it will not absorb moisture.

They need to trim the excess before installing the drywall.


R-Value of Urethane Compared to Other Insulating Products
R-Value/inch
8
7
6
5
4
3
2
1
0
3.8
7.1
5
3.5
3.4
1/2 lb Urethane
2 lb Urethane
Styrofoam
Expanded Polystyrene
Fibreglass
Types of Insulation

More than just food!

Soy beans are being used to make more environmentally friendly spray foam insulation that also acts as an air barrier!

This type of application is particularly useful in attics as you do not have to provide a vent space!

Early methods relied solely on polyethylene film to act as a combined air and vapour barrier.

This did not prove highly effective as the poly was not durable enough.

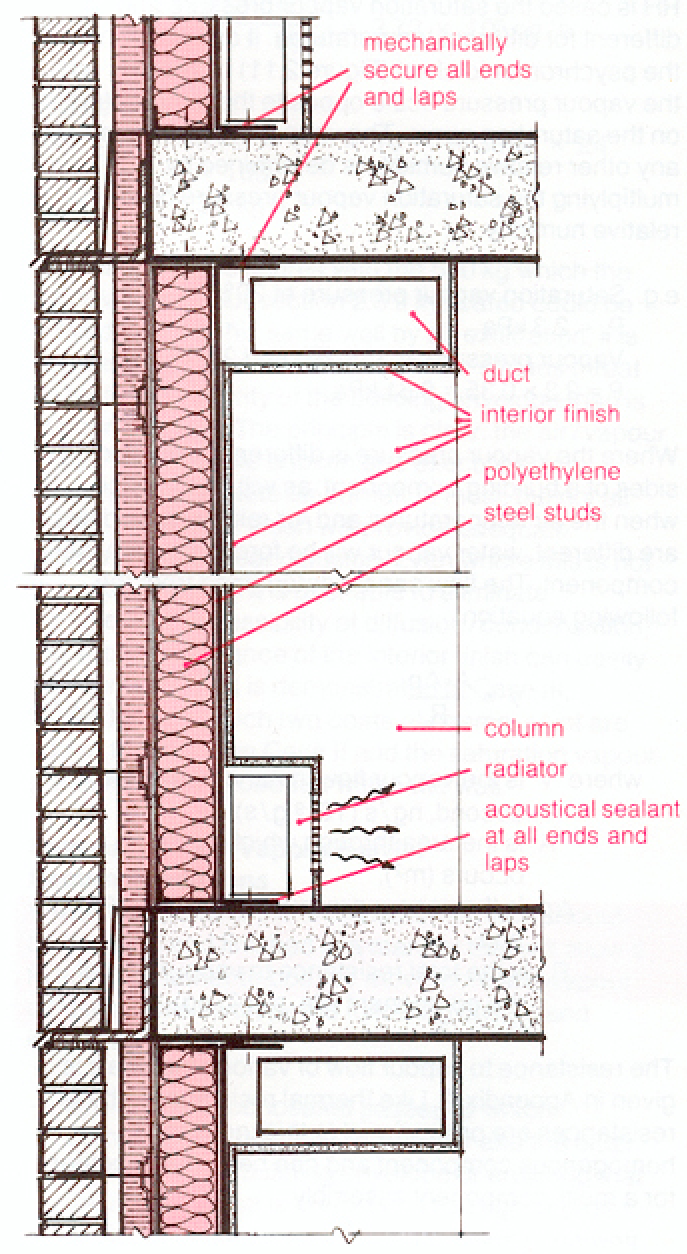
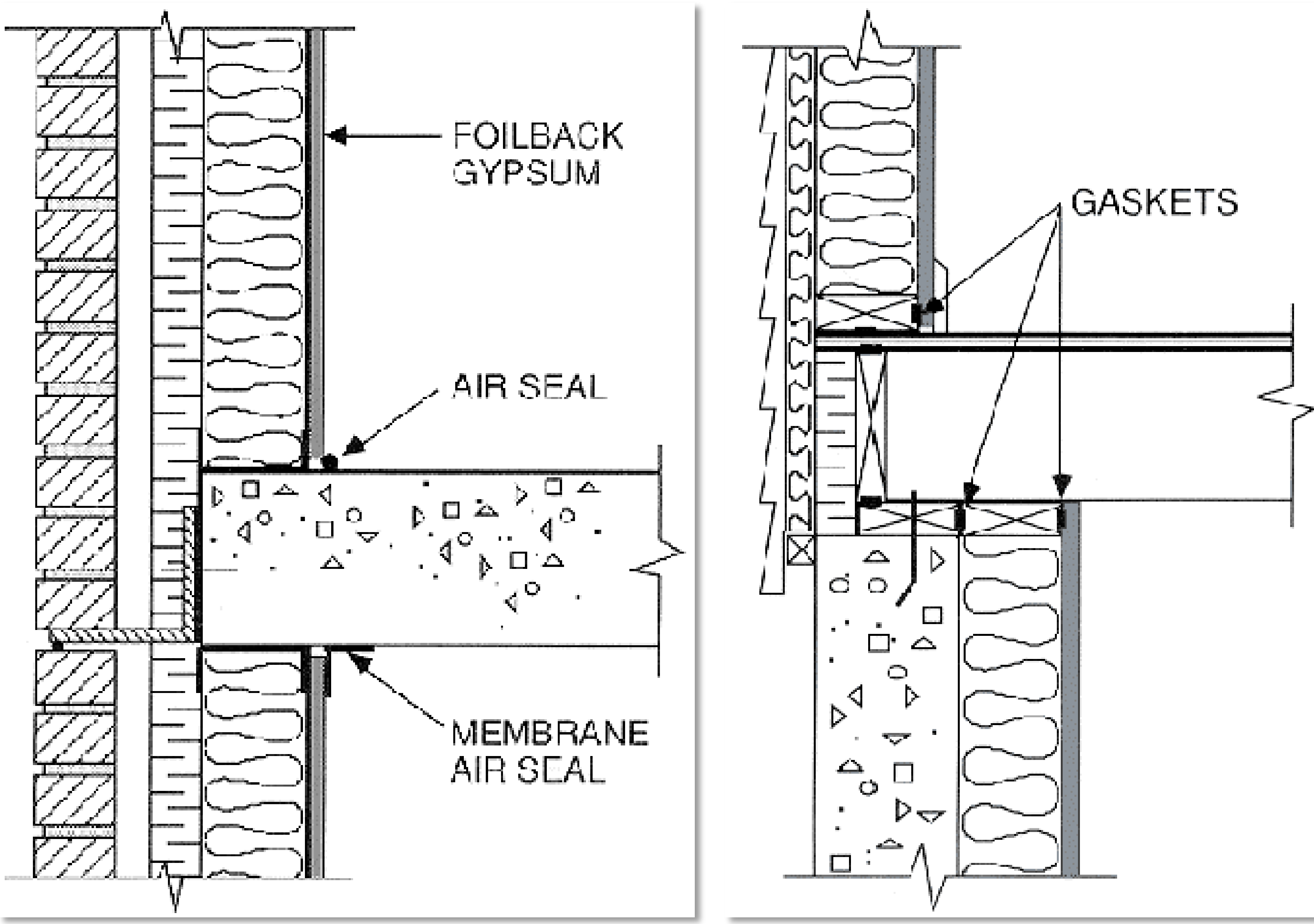
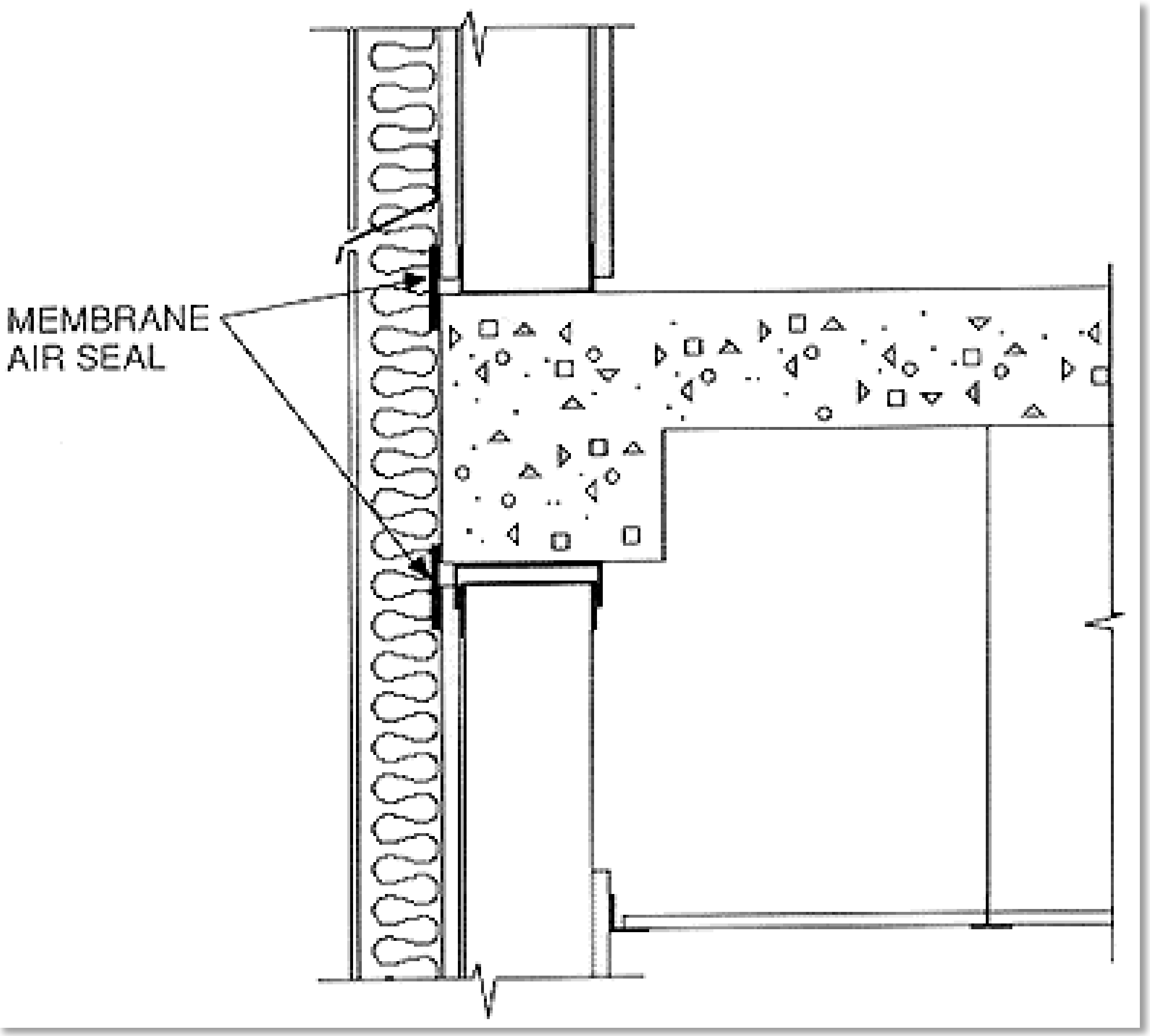


Figure 2.16 Polyethylene Film Used as Air/Vapour Barrier

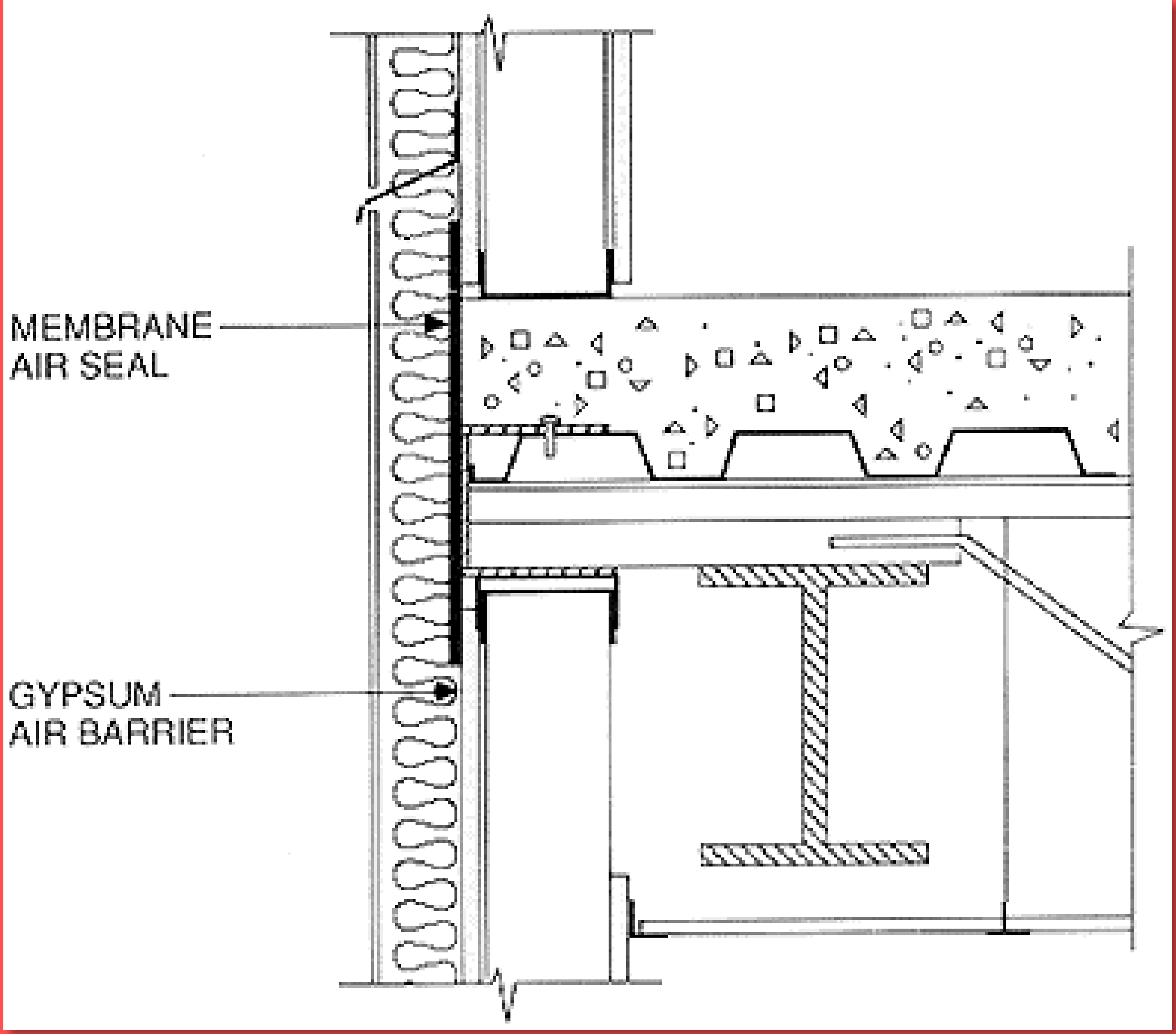
The exposed drywall approach replaced reliance on polyethylene:

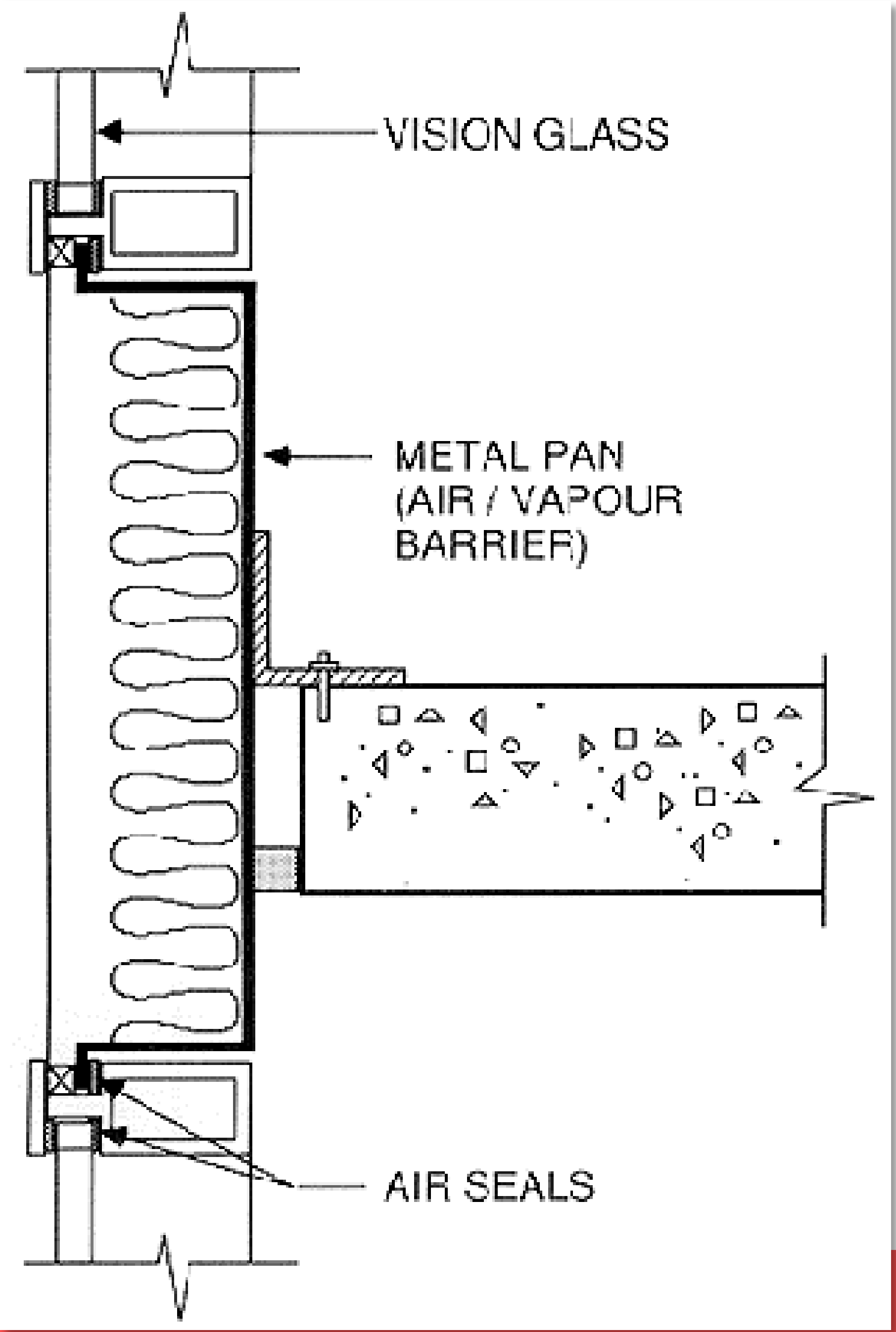


Drywall as Air Barrier, must have joints sealed with gaskets or inspectable caulking



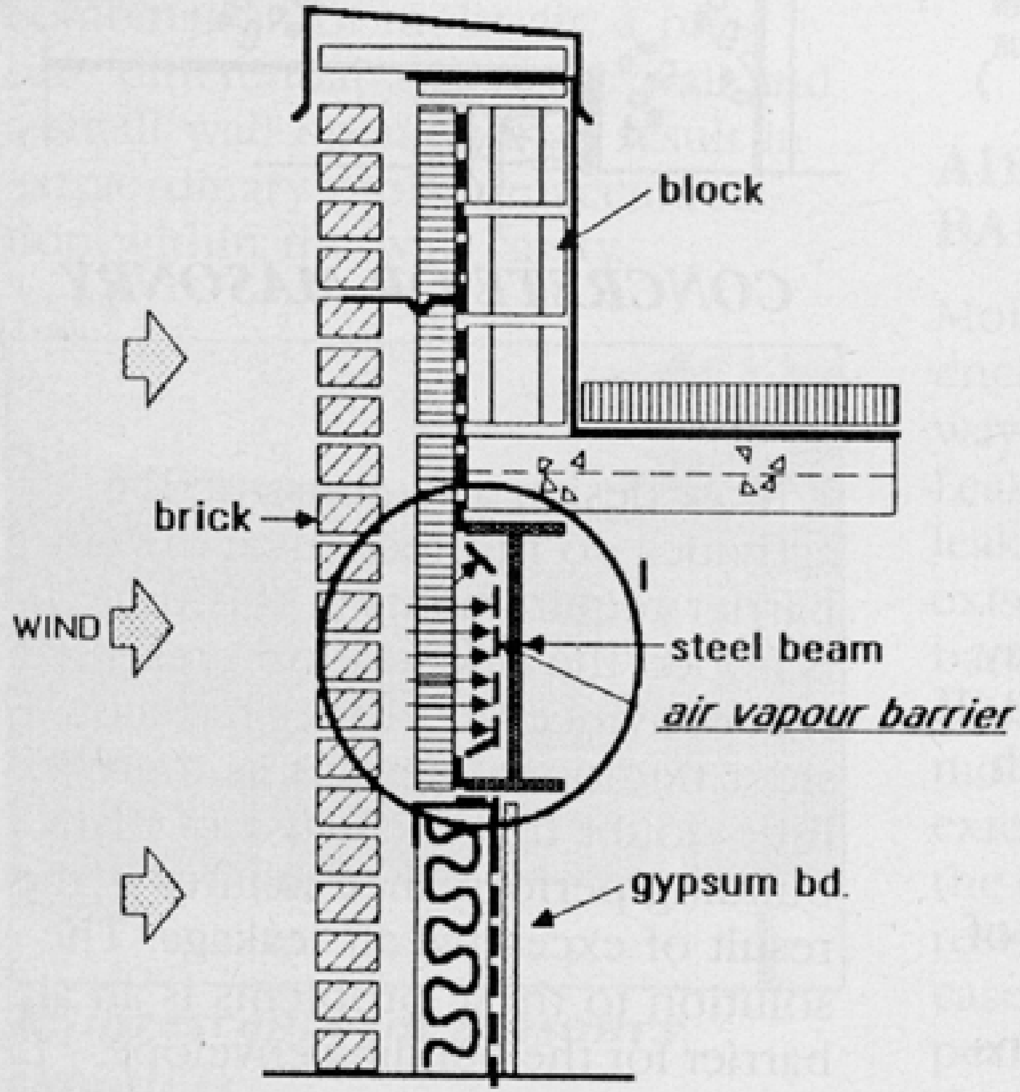
If drywall is not used as the air barrier, then membrane air seals (like those used in block construction) can be used on the warm side of the insulation.


MEMBRANE
AIR SEAL
GYPSUM
AIR BARRIER

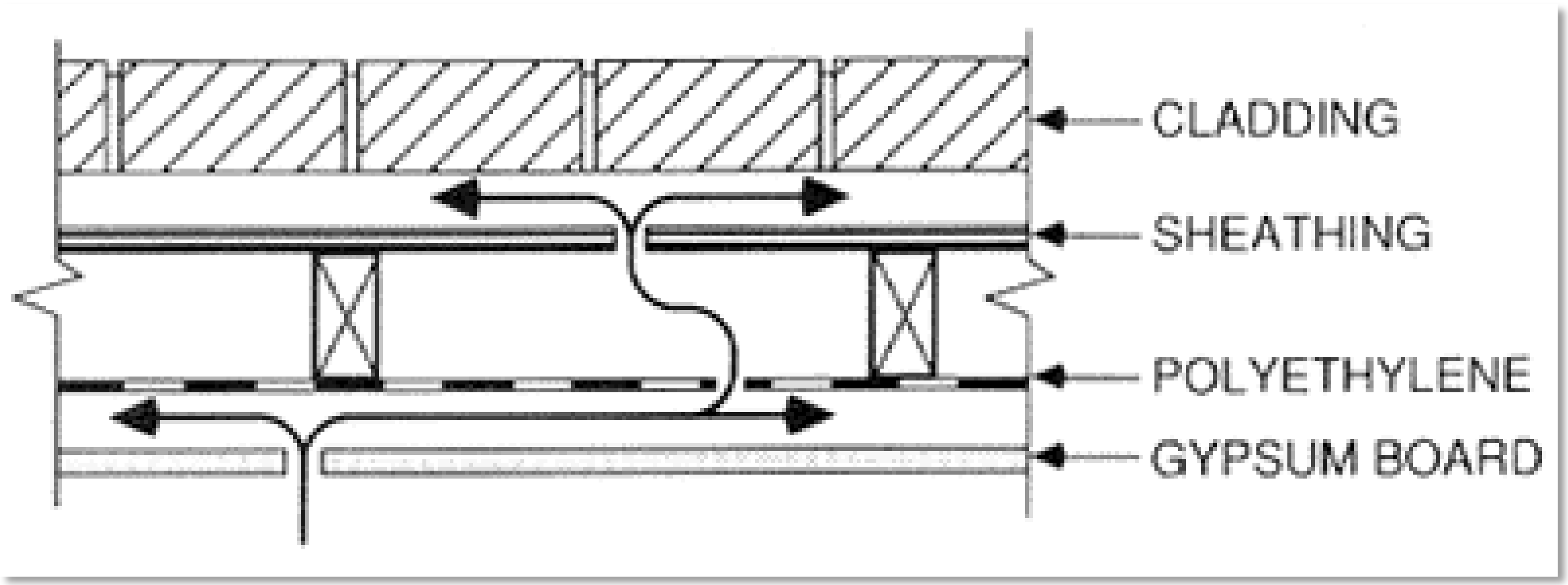


For curtain walls the metal backer pan can function as the air and vapour barrier, provided that seals are provided at the junction with the aluminum frame.

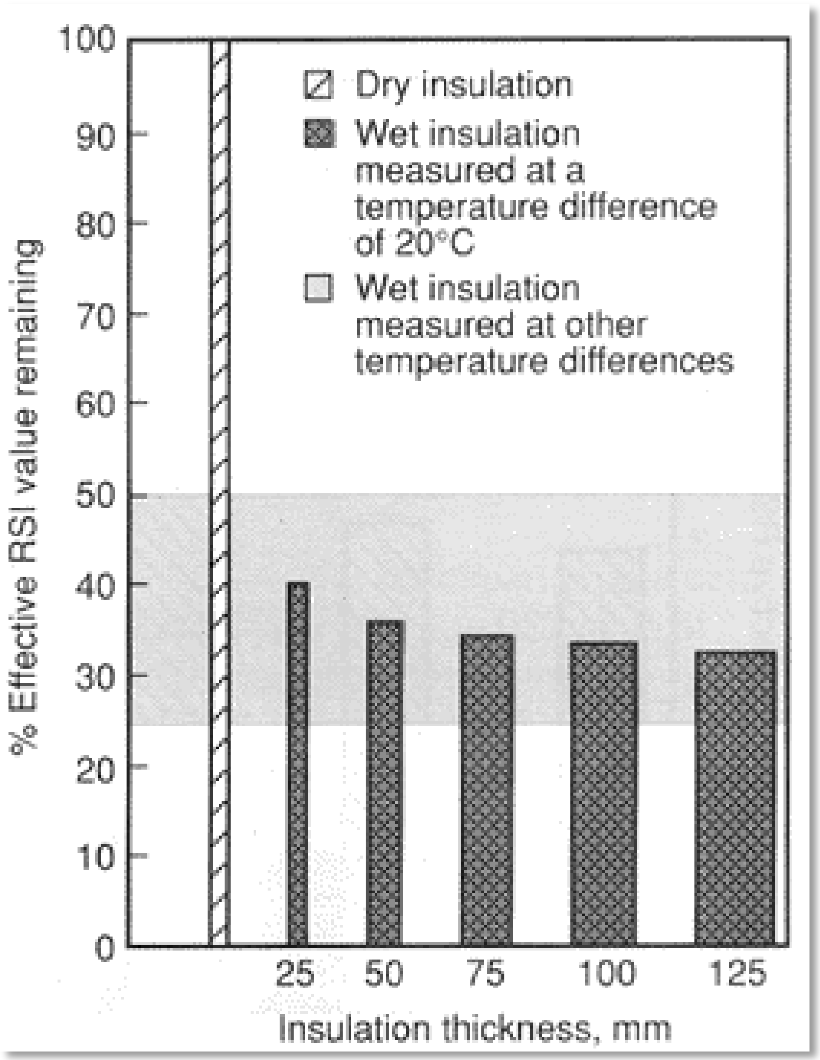
The glazing also acts as an air/vapour barrier.



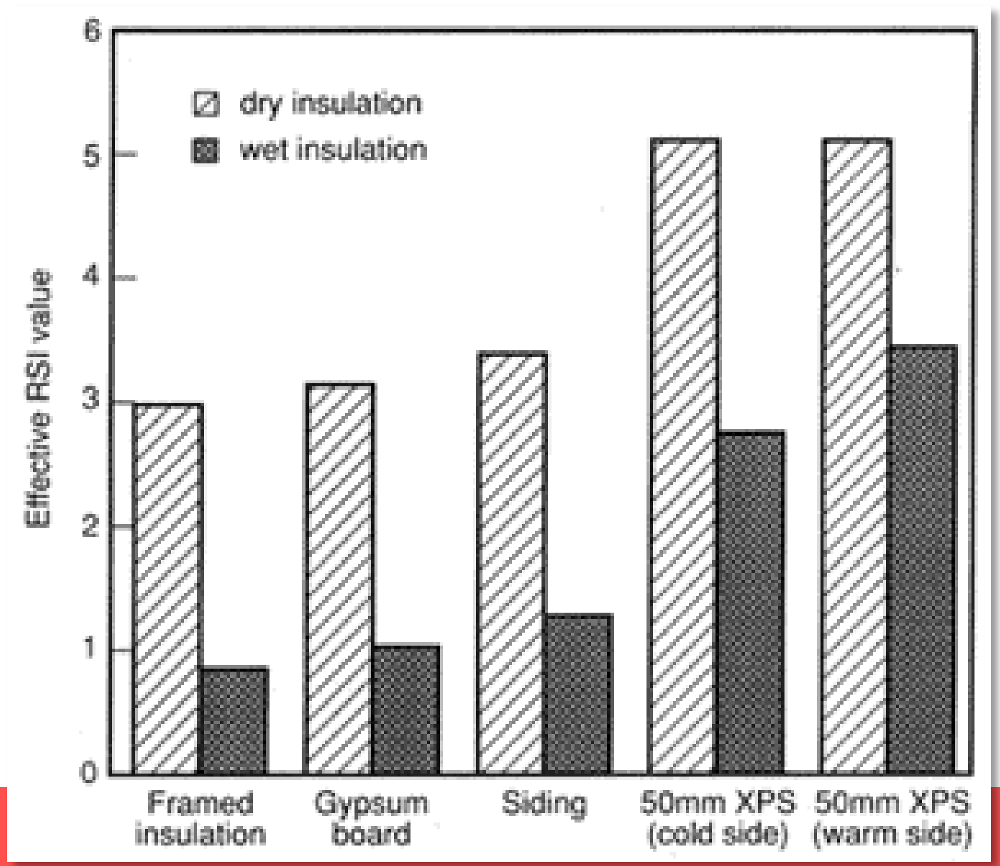
AIR BARRIER RESISTS DISPLACEMENT

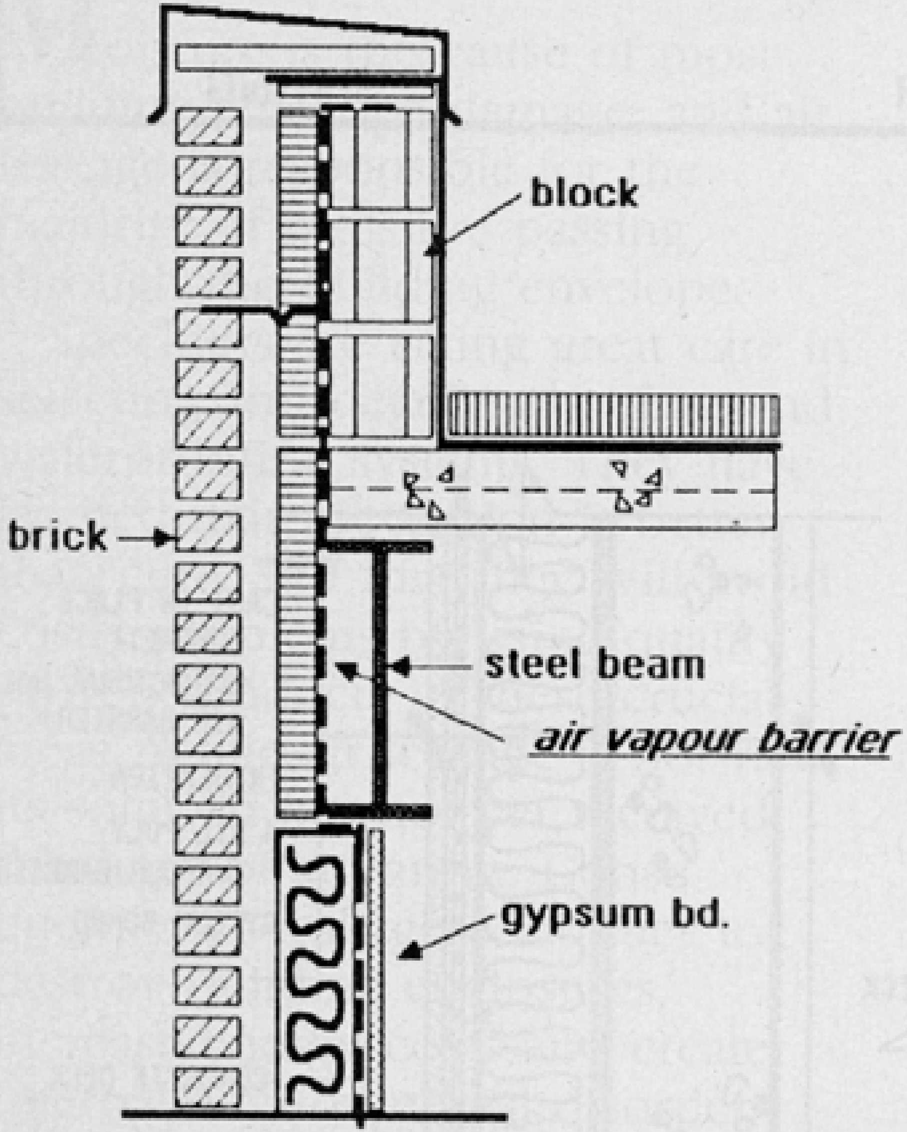


The gypsum system must ensure that all cracks are sealed, not only those at the base and top of the wall system.

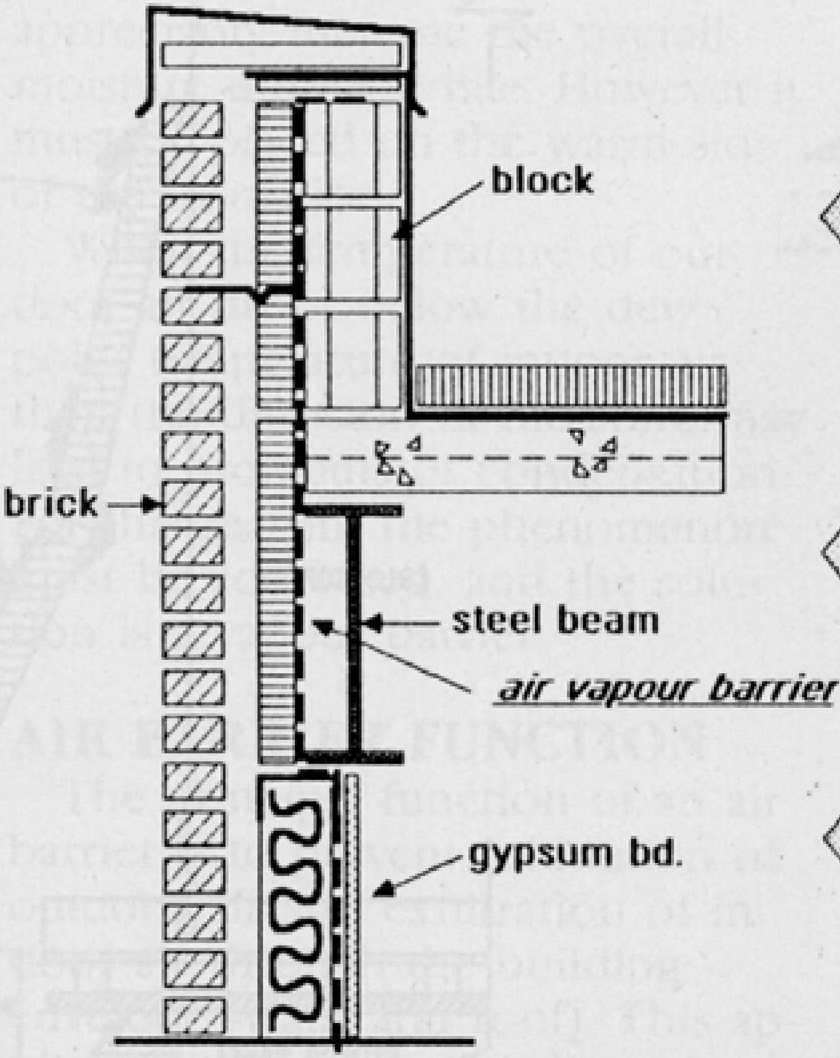


The air and vapour barriers are greatly important in keeping moisture out of the envelope so to keep the insulation DRY.

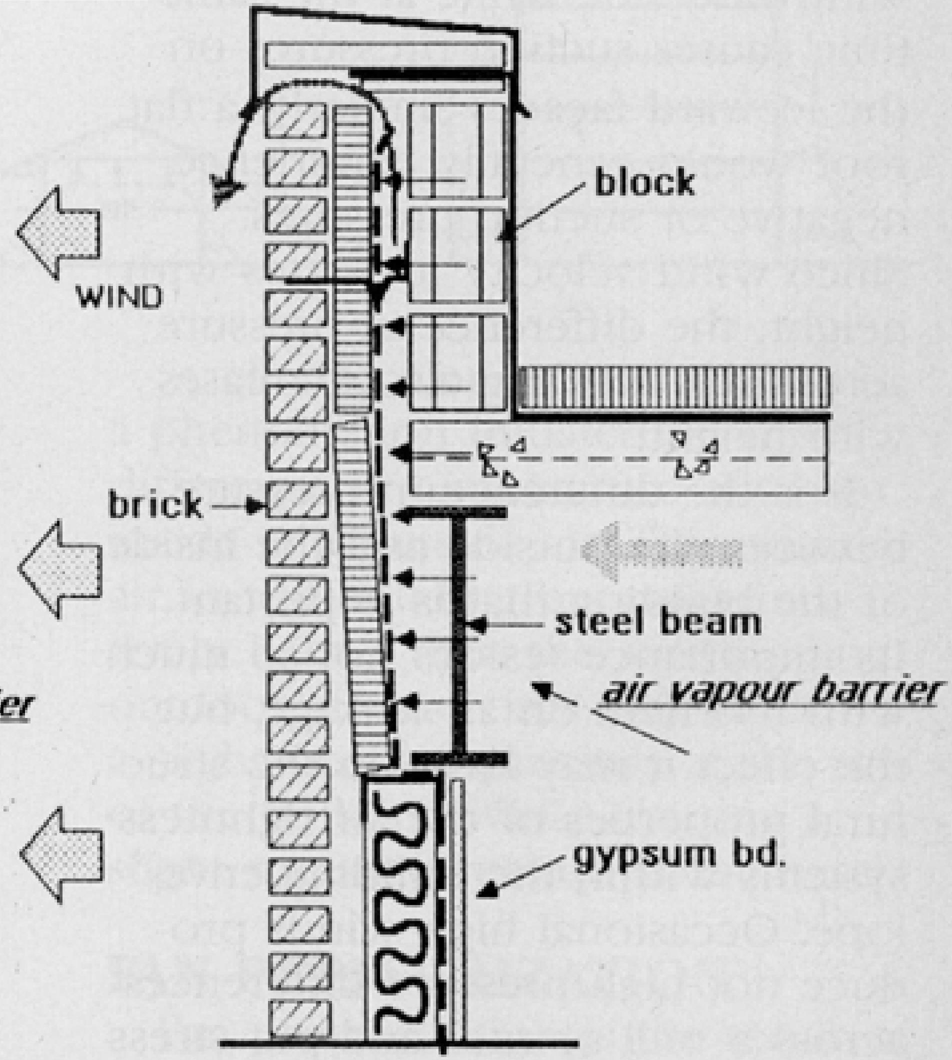




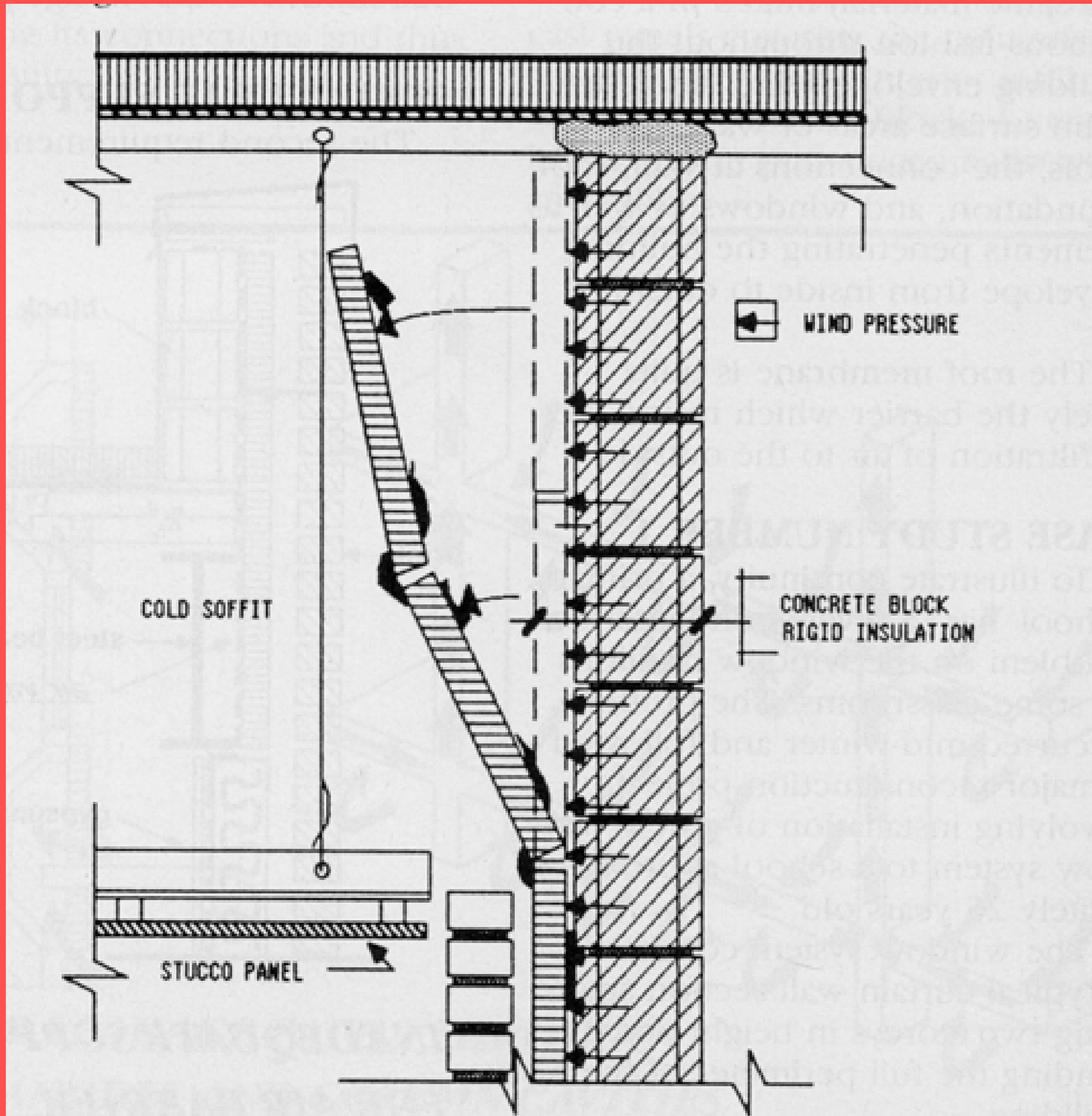
PROPER SUPPORT FOR AIR BARRIER

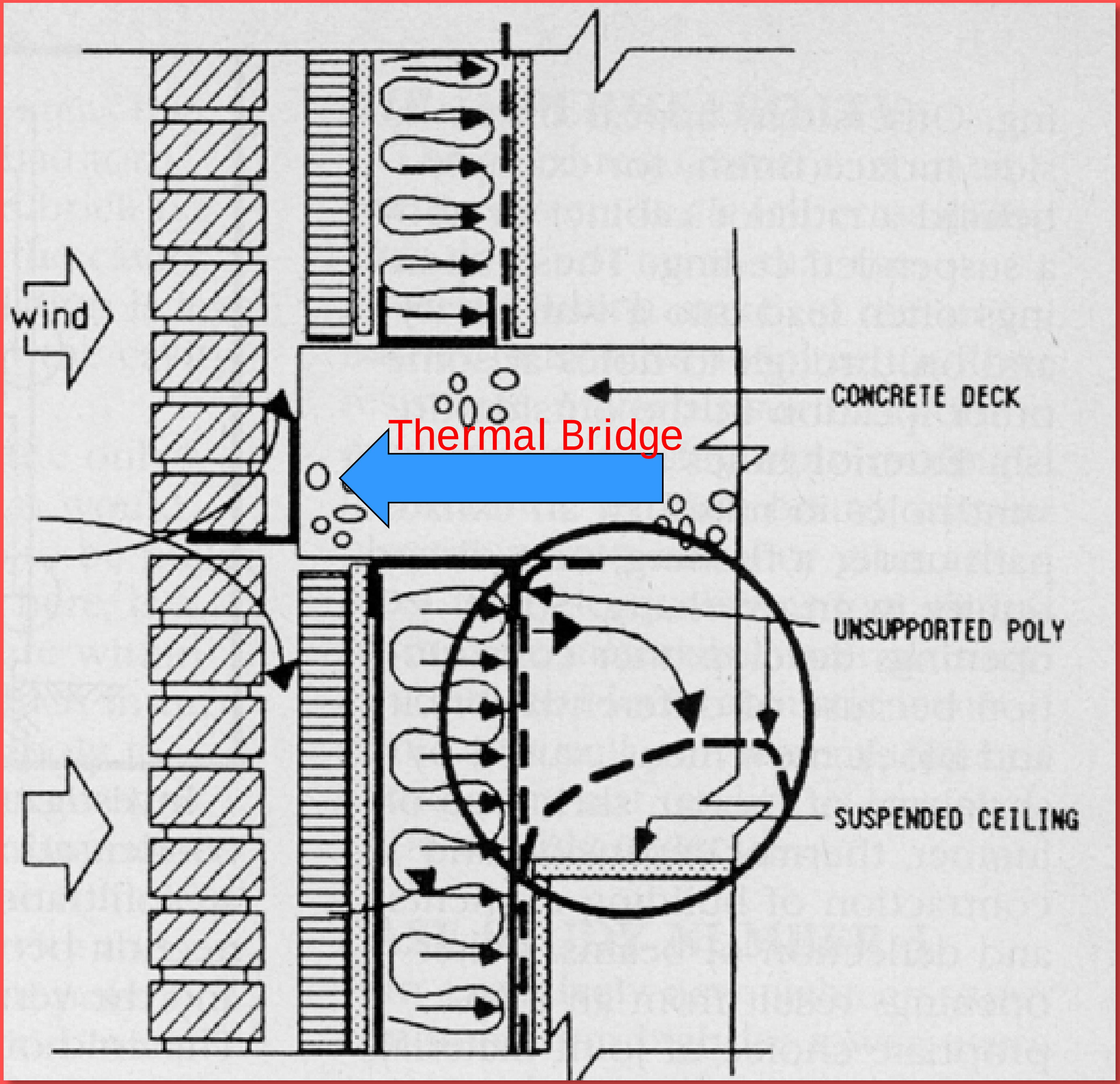


INADEQUATE SUPPORT FOR AIR BARRIER



AIR BARRIER DISPLACEMENT


WIND PRESSURE
CONCRETE BLOCK
RIGID INSULATION
COLD SOFFIT
STUCCO PANEL



wind
Thermal Bridge
CONCRETE DECK
UNSUPPORTED POLY
SUSPENDED CEILING

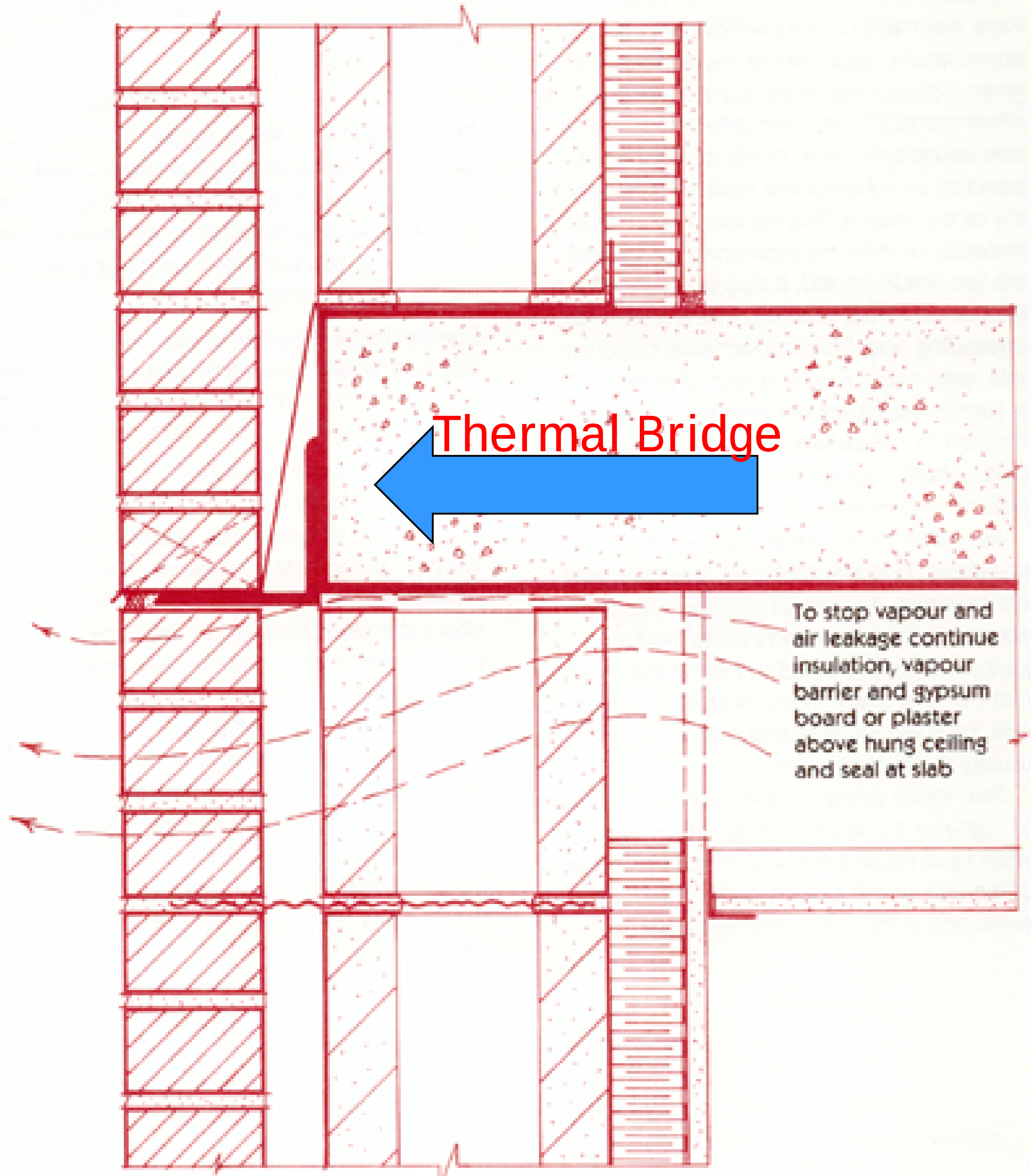


Fig. 22 Potential condensation zone above hung ceiling

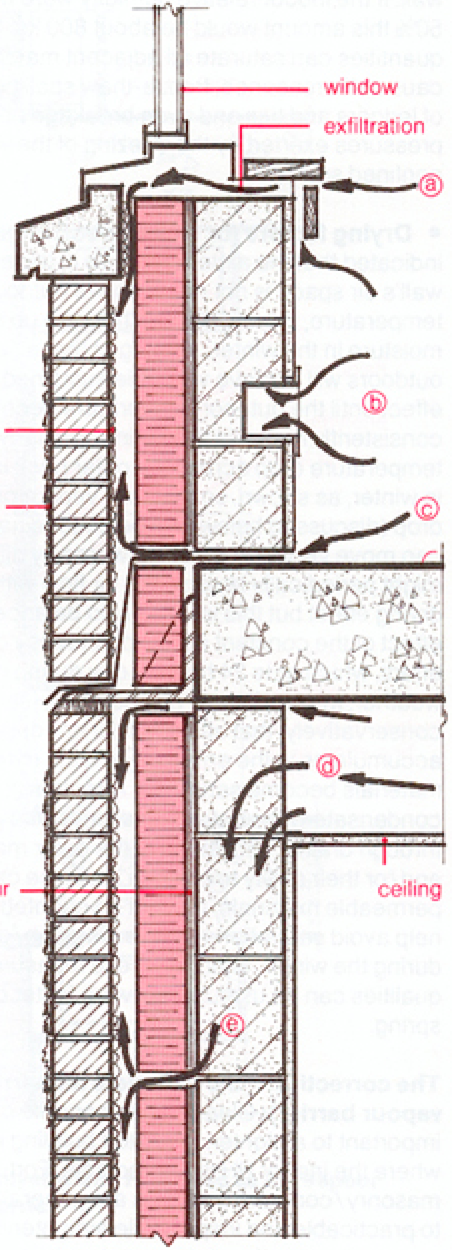


Figure 2.15 Exfiltration/Condensation Example Pattern (leakages ⓐ to ⓔ are discussed in the text)

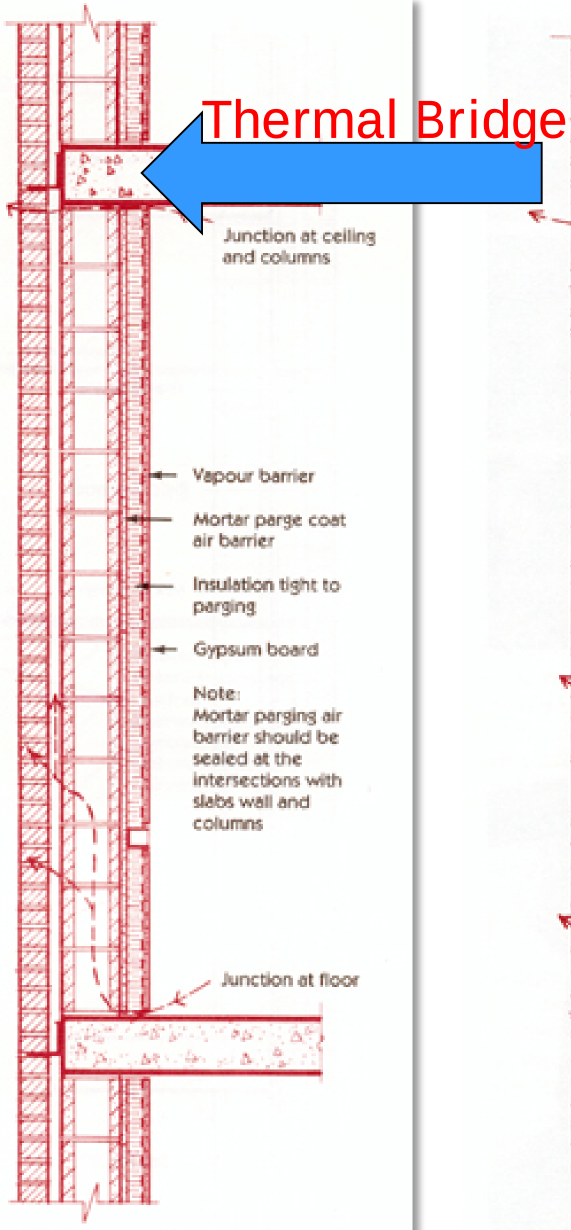


Fig. 18 Parge coat air barrier requires sealing at junctions with ceiling floor slabs and columns (ties, flashings and weepholes not shown)

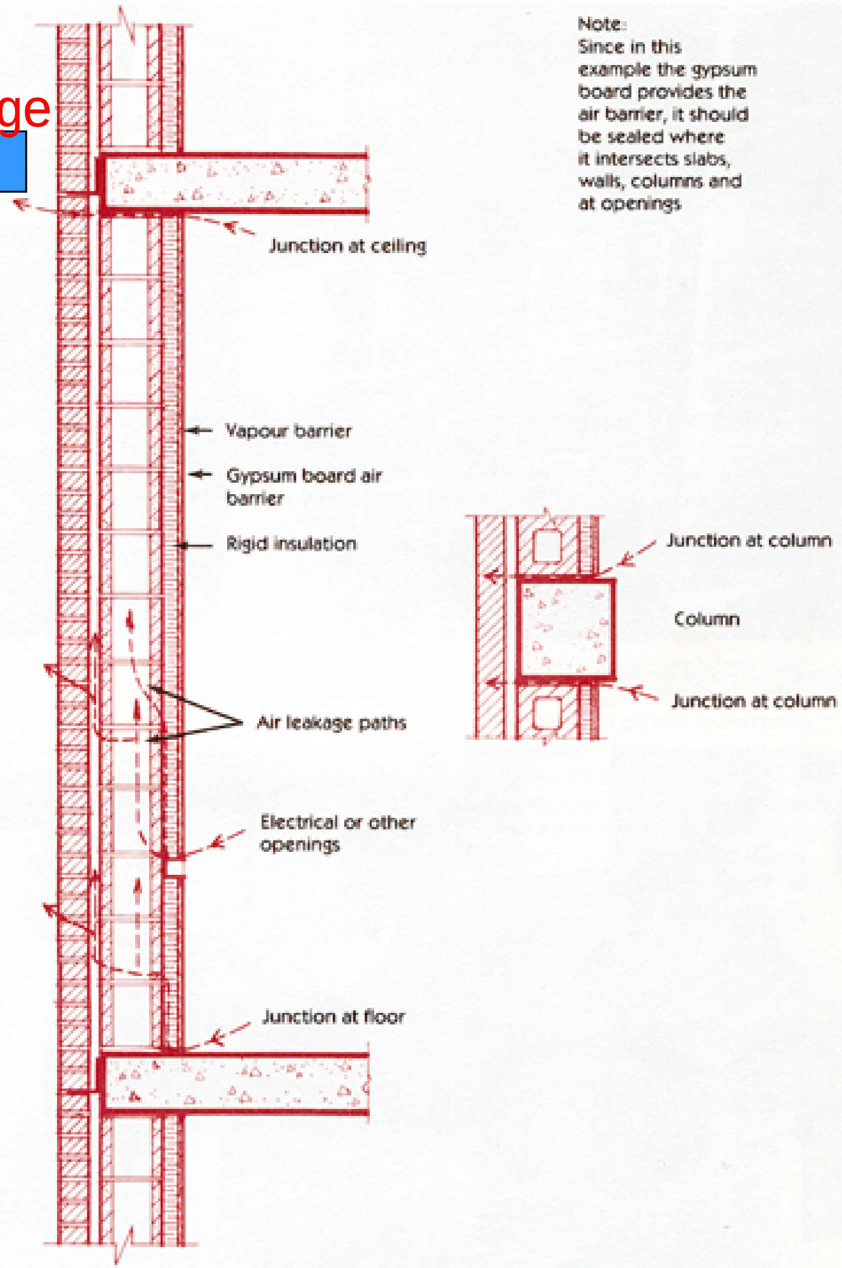
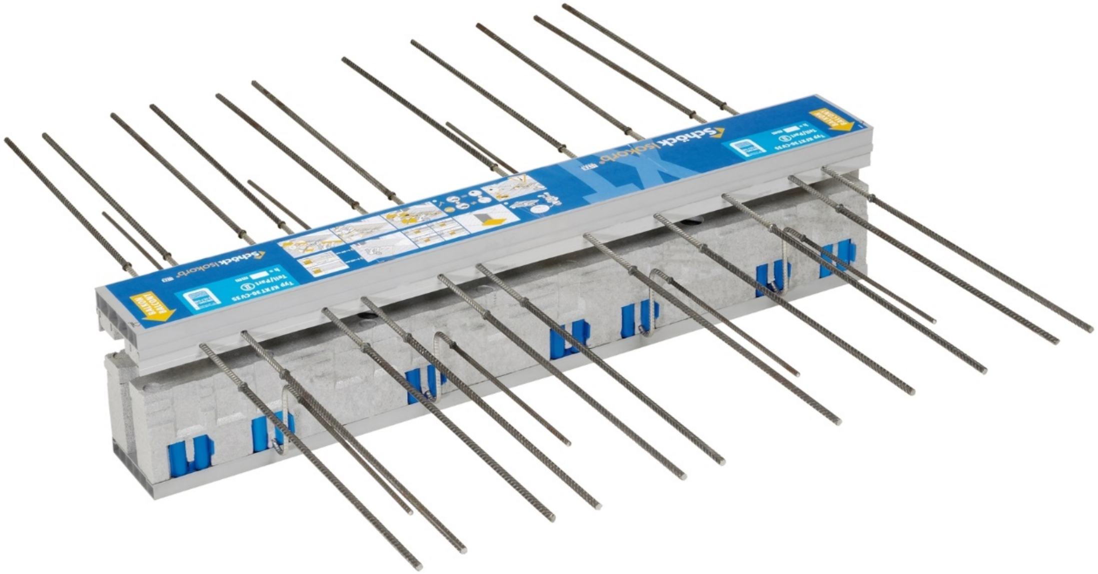


Fig. 17 Air leakage paths in brick veneer on concrete block backup to be taped or otherwise sealed (ties, flashings and weepholes not shown)

New product to prevent thermal bridging in cantilevered concrete slab (balconies).



http://www.schoeck.co.uk/en_gb/solutions-uk/cantilever-structural-components-7c

Detailing around junctures in the wall, where windows and other openings occur, becomes an important aspect of wall design as much leakage can occur at these “weak” points in the wall assembly.

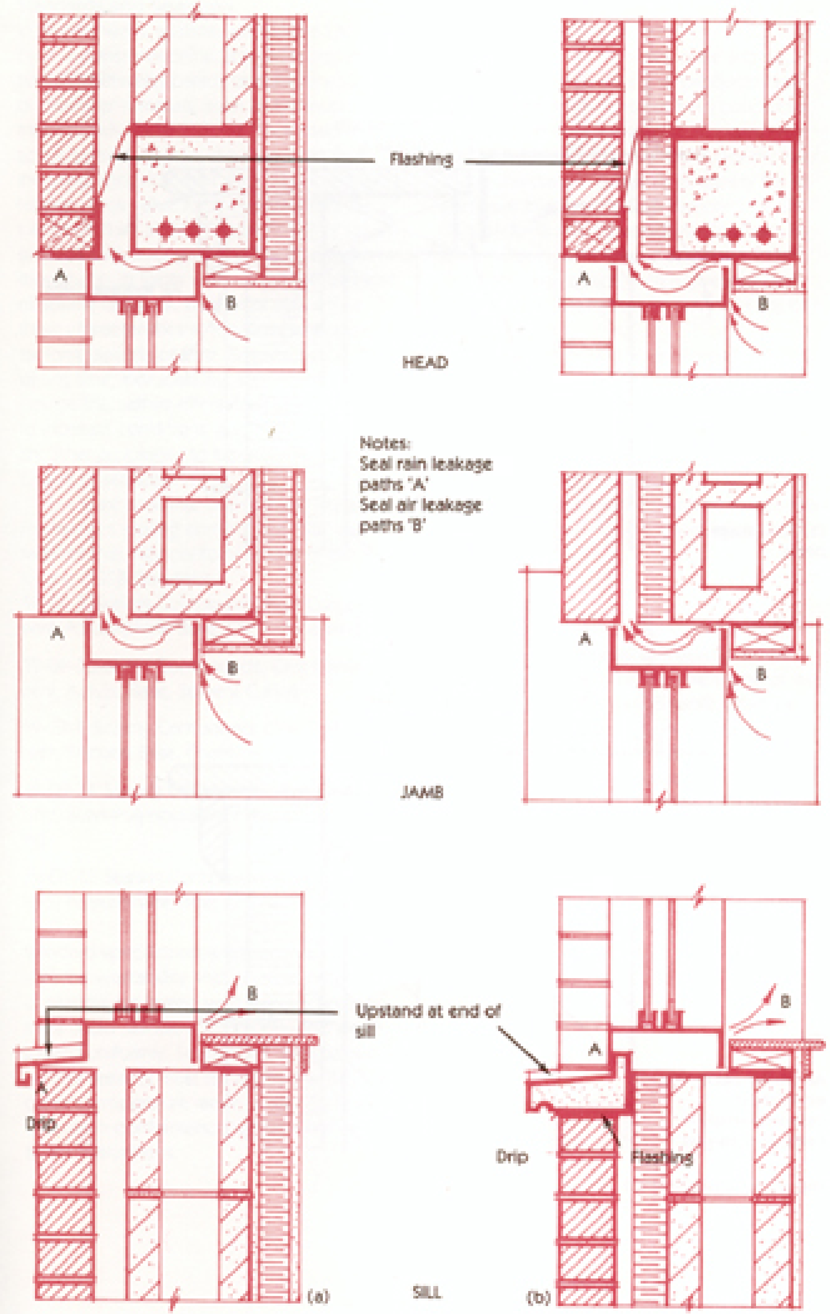


Fig. 44 Air leakage at window to wall connection

Not only insulation should be continuous in the unending battle against thermal bridges, but all material intersections must be sealed with materials that are both durable and inspectable/repairable

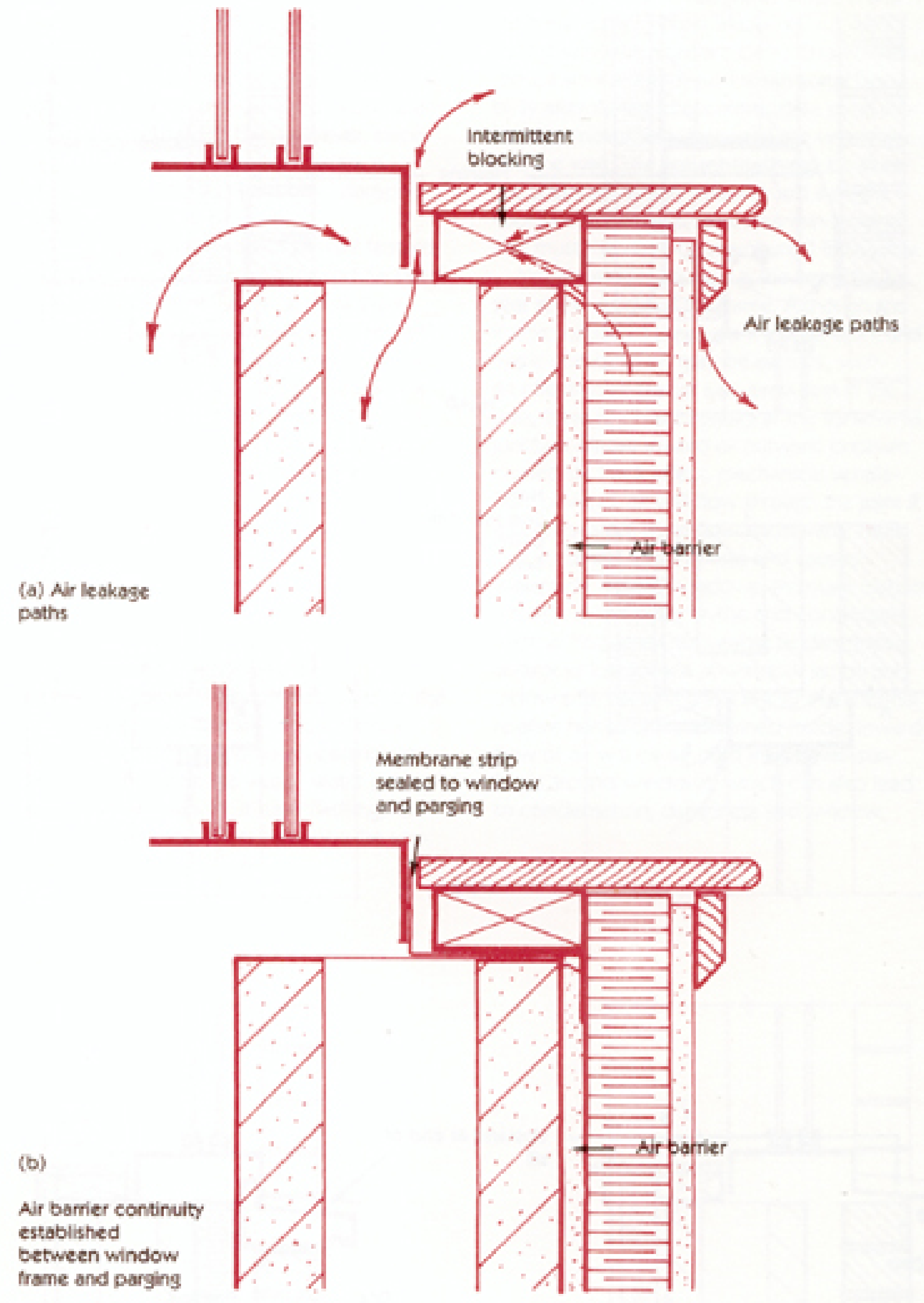
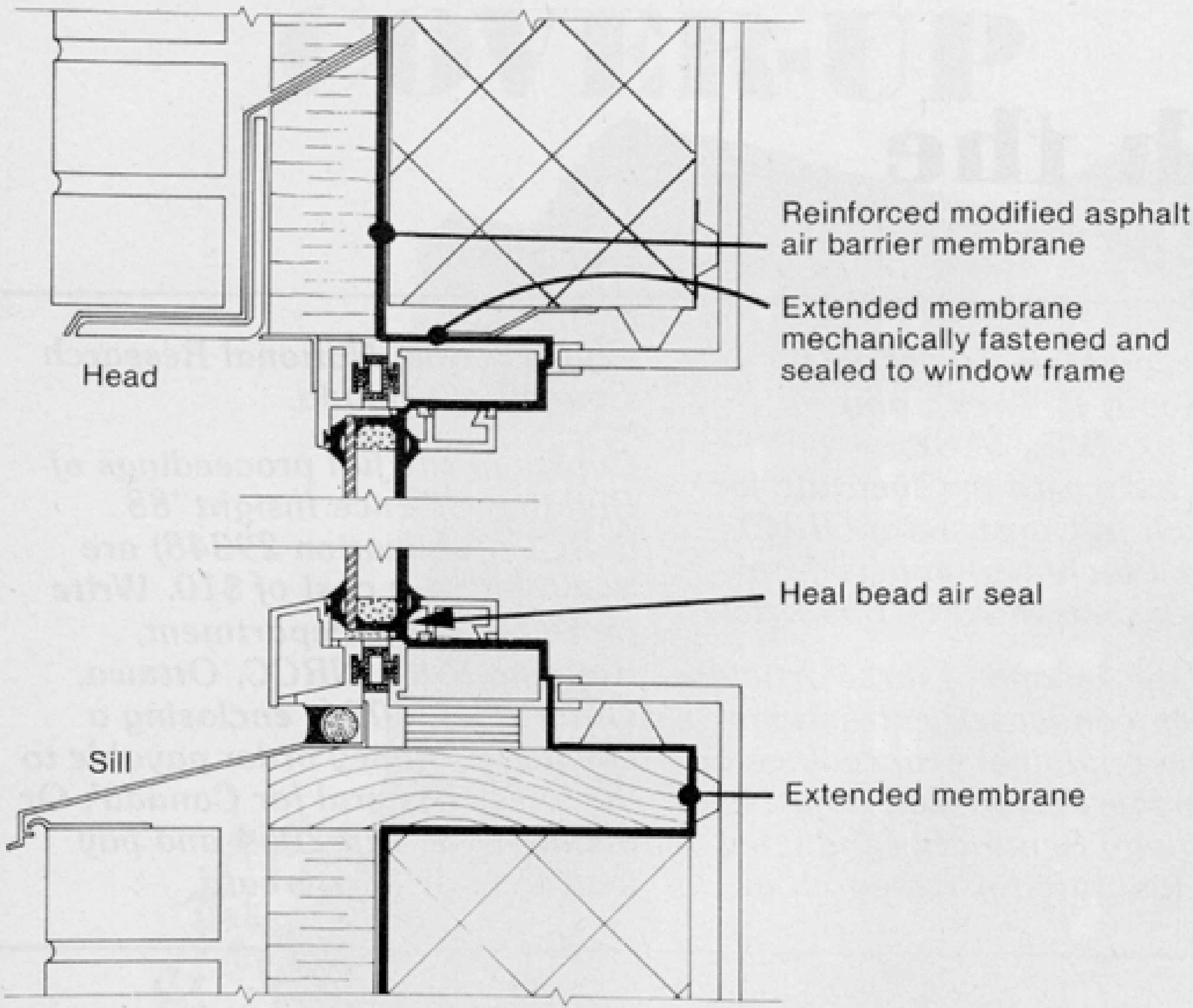
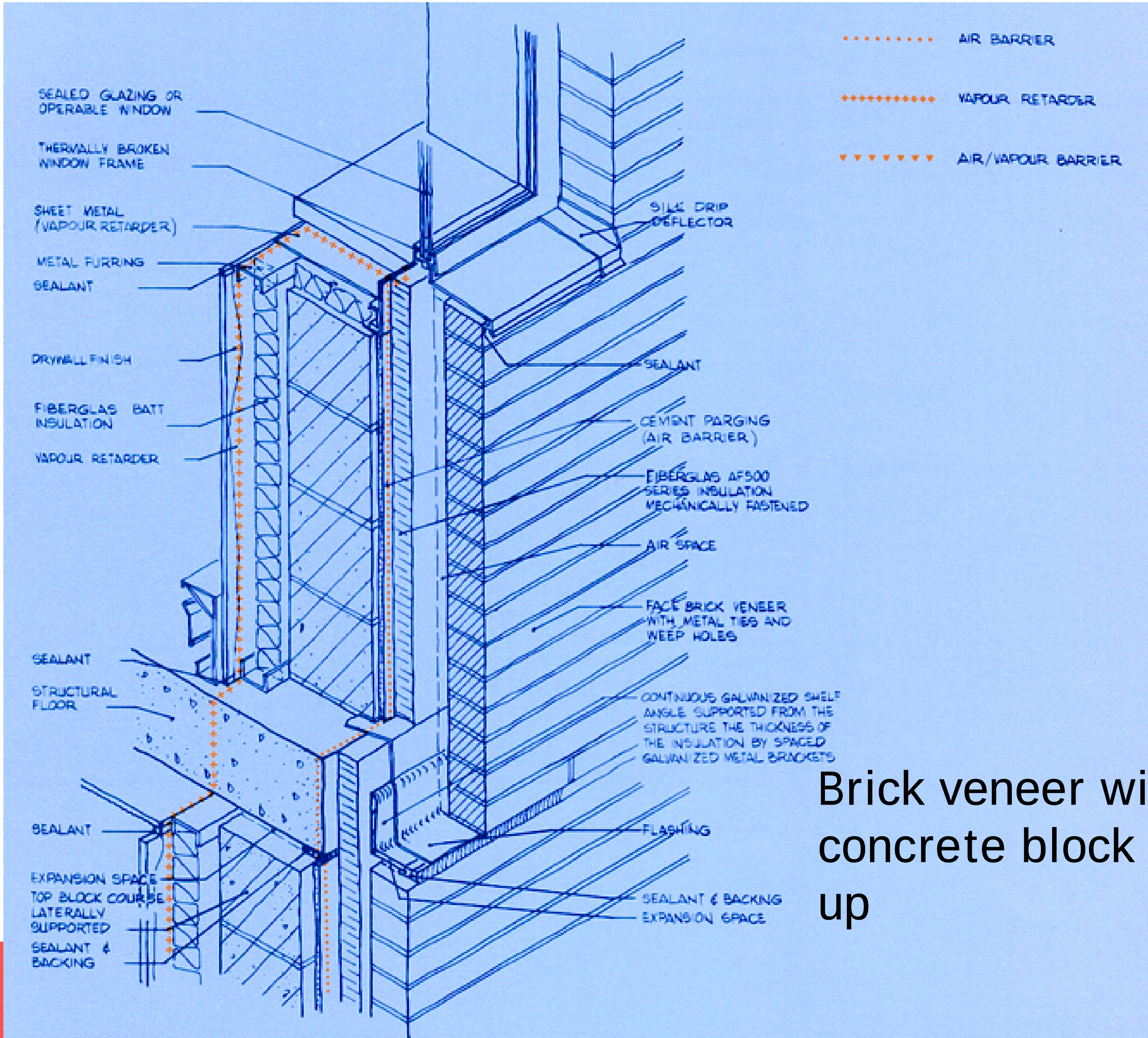


Fig. 45 Air leakage at sill

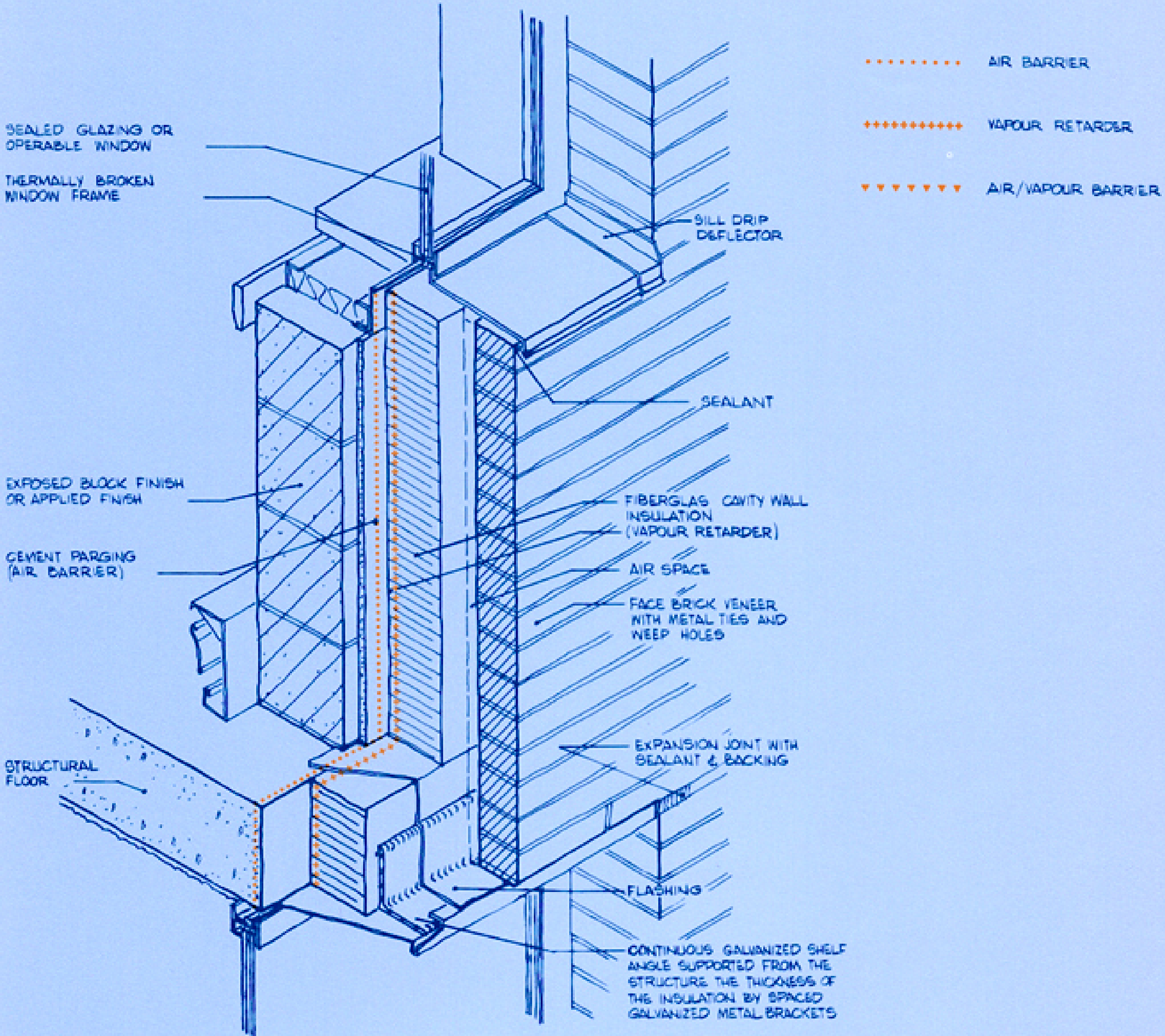
Fig. 1 Commercial Window



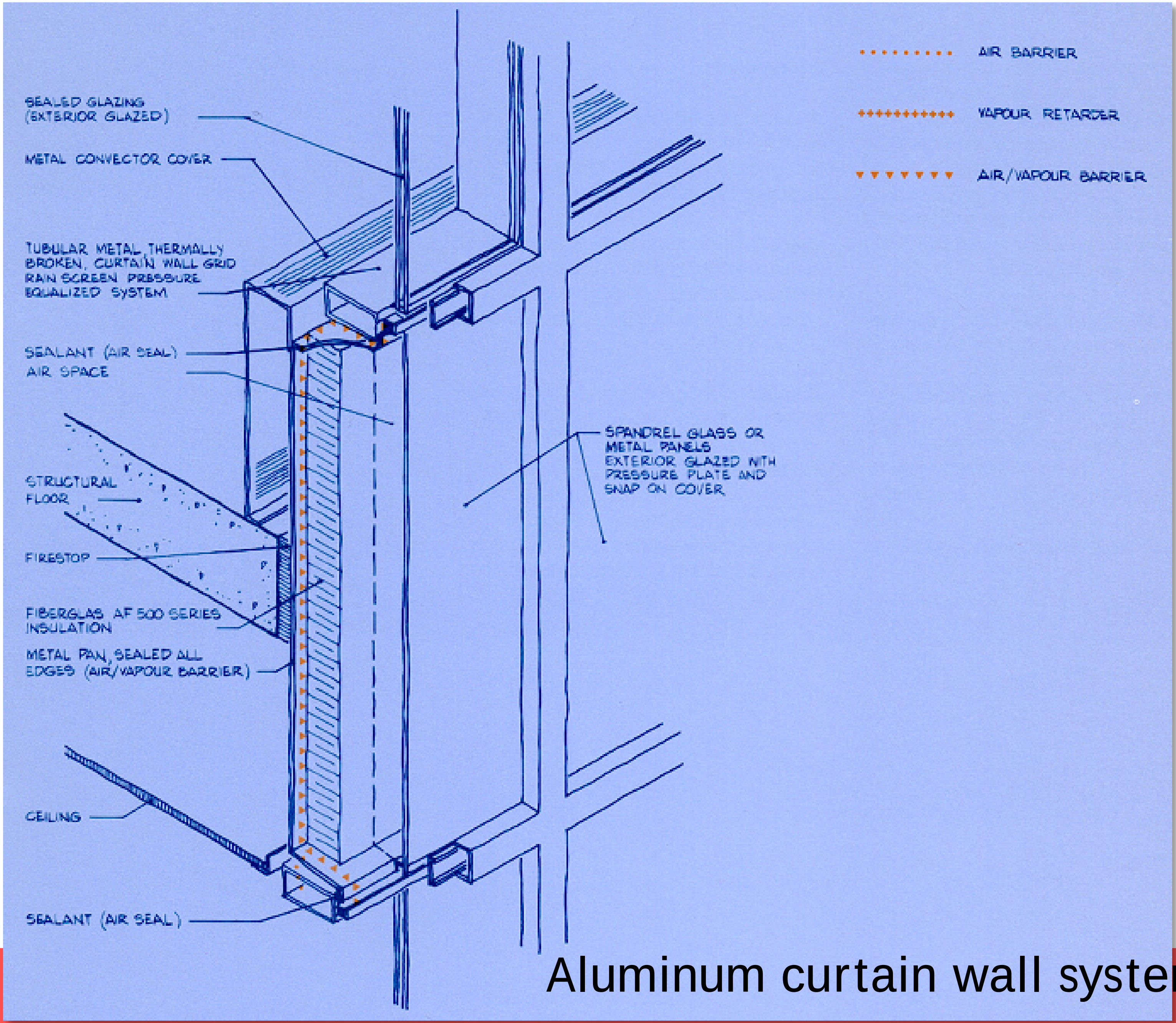
Examples of air and vapour barrier systems:



Brick veneer with concrete block back-up



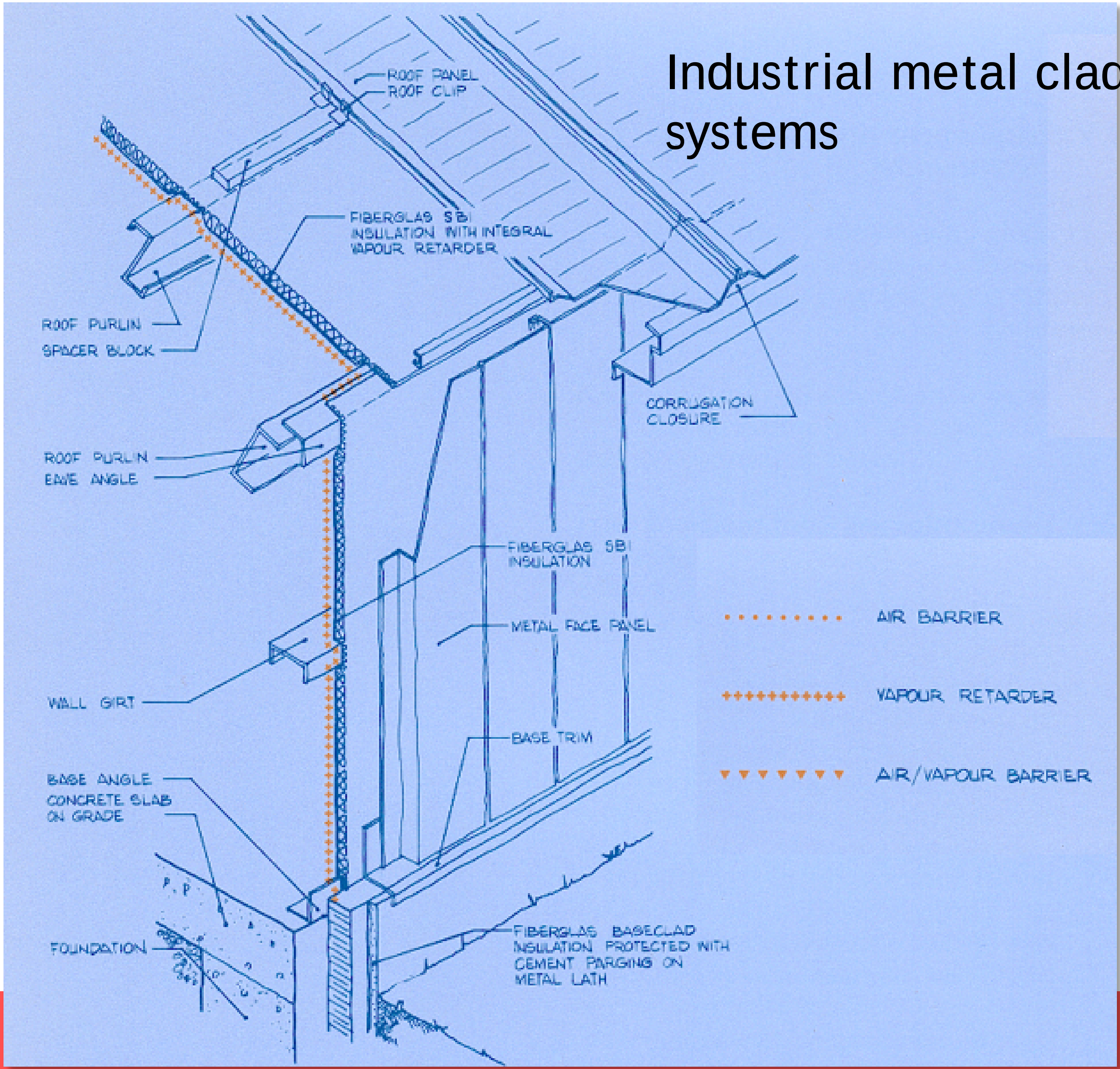
AIR BARRIER
VAPOUR RETARDER
AIR/VAPOUR BARRIER
SEALED GLAZING OR OPERABLE WINDOW
THERMALLY BROKEN WINDOW FRAME
SILL DRIP DEFLECTOR
SEALANT
EXPOSED BLOCK FINISH OR APPLIED FINISH
FIBERGLAS CAVITY WALL INSULATION (VAPOUR RETARDER)
CEMENT PARGING (AIR BARRIER)
AIR SPACE
FACE BRICK VENEER WITH METAL TIES AND WEEP HOLES
EXPANSION JOINT WITH SEALANT & BACKING
STRUCTURAL FLOOR
FLASHING
CONTINUOUS GALVANIZED SHELF ANGLE SUPPORTED FROM THE STRUCTURE THE THICKNESS OF THE INSULATION BY SPACED GALVANIZED METAL BRACKETS



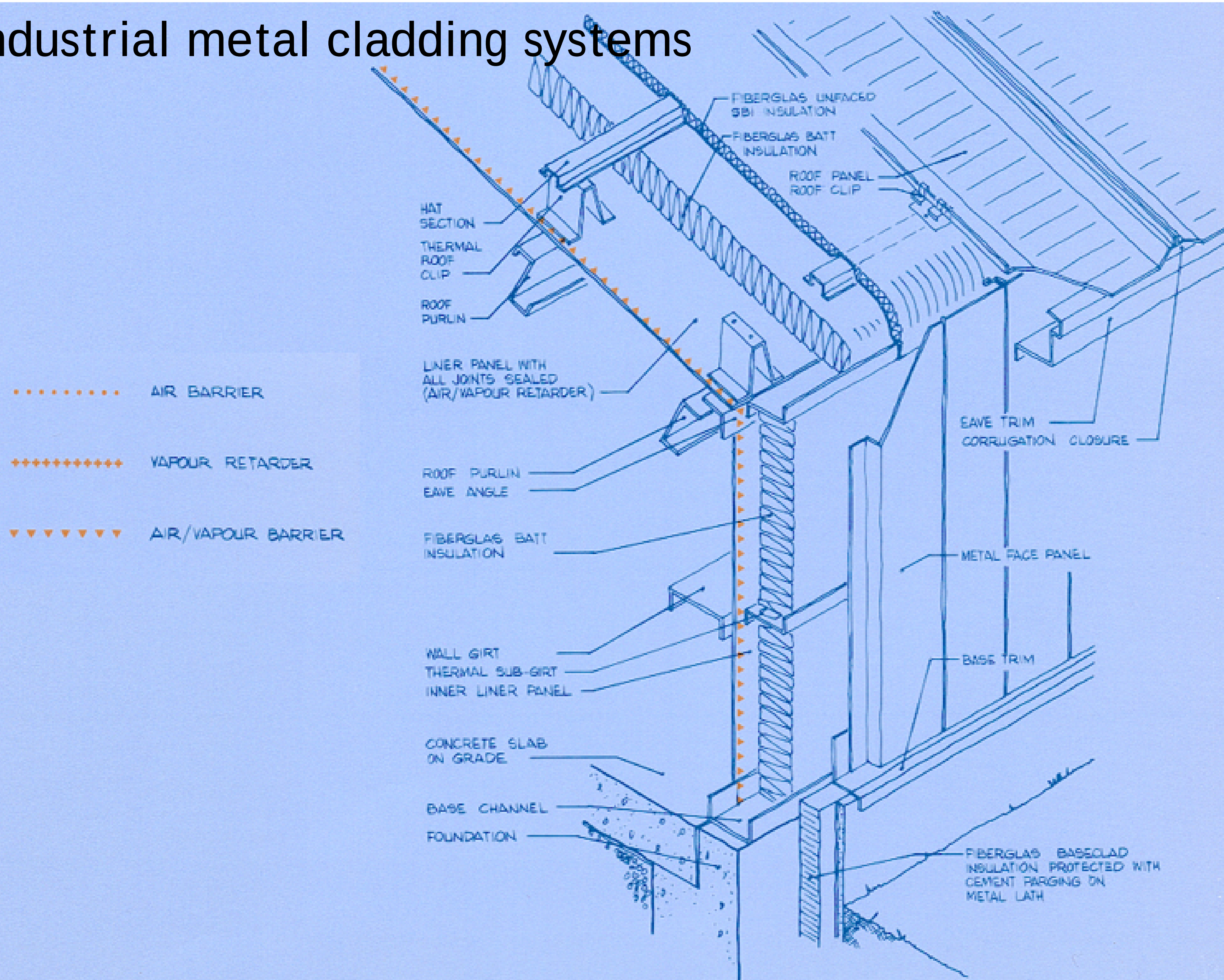
Aluminum curtain wall systems

In curtain wall the glass can be acting as the air/vapour barrier, or in the case of solid looking walls, the metal backer panel behind the insulation.

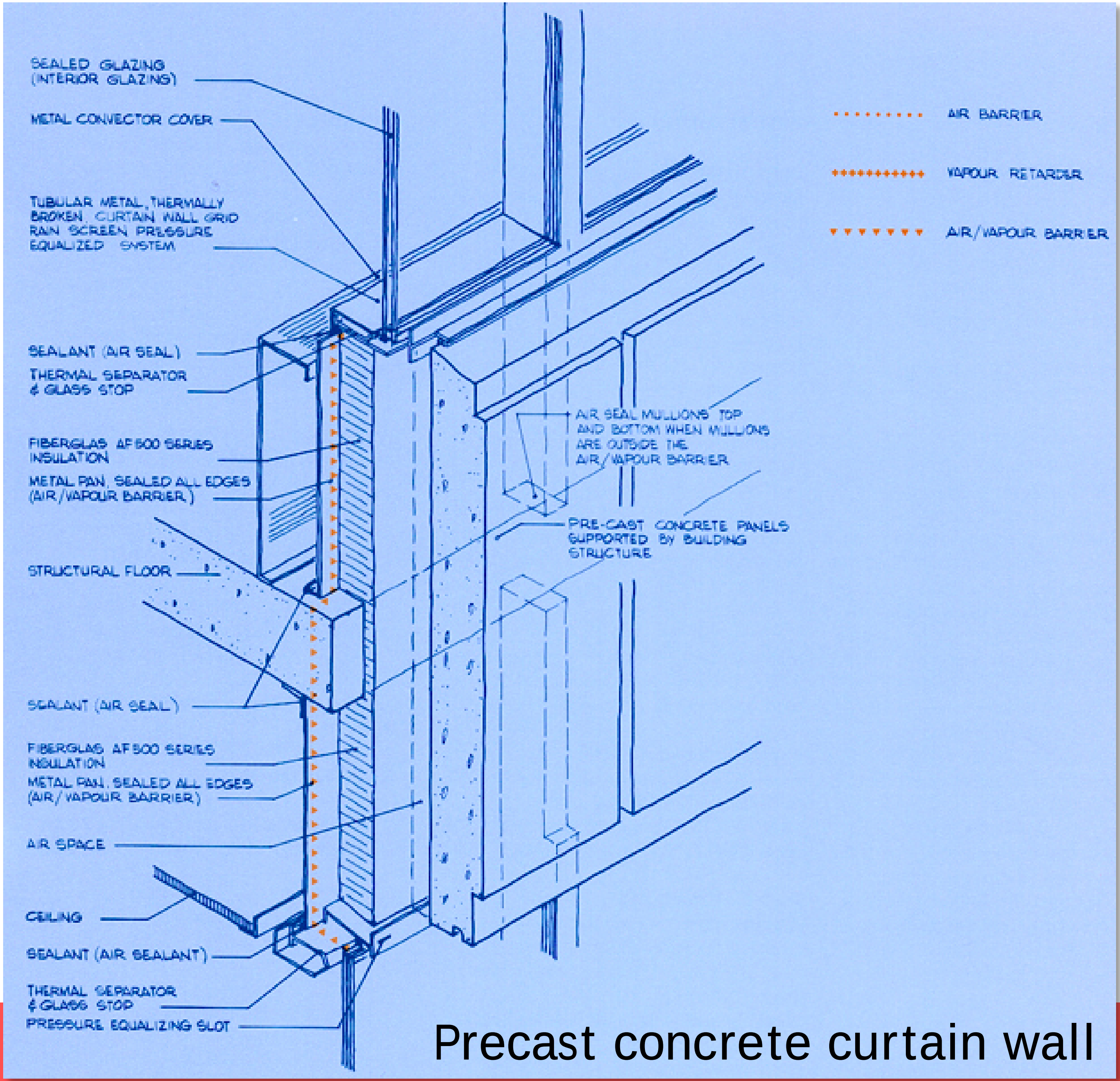
Industrial metal cladding systems



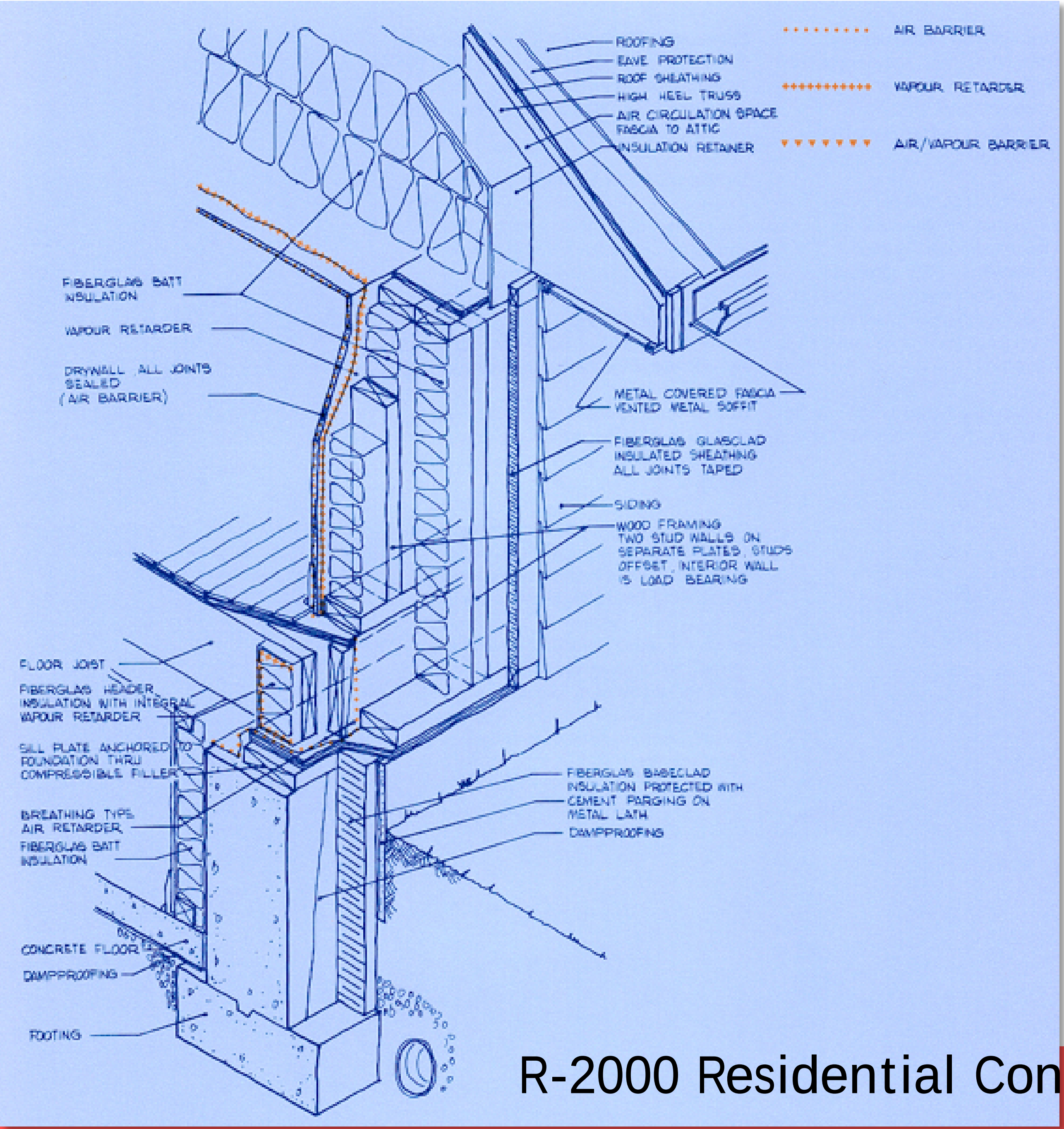
Industrial metal cladding systems



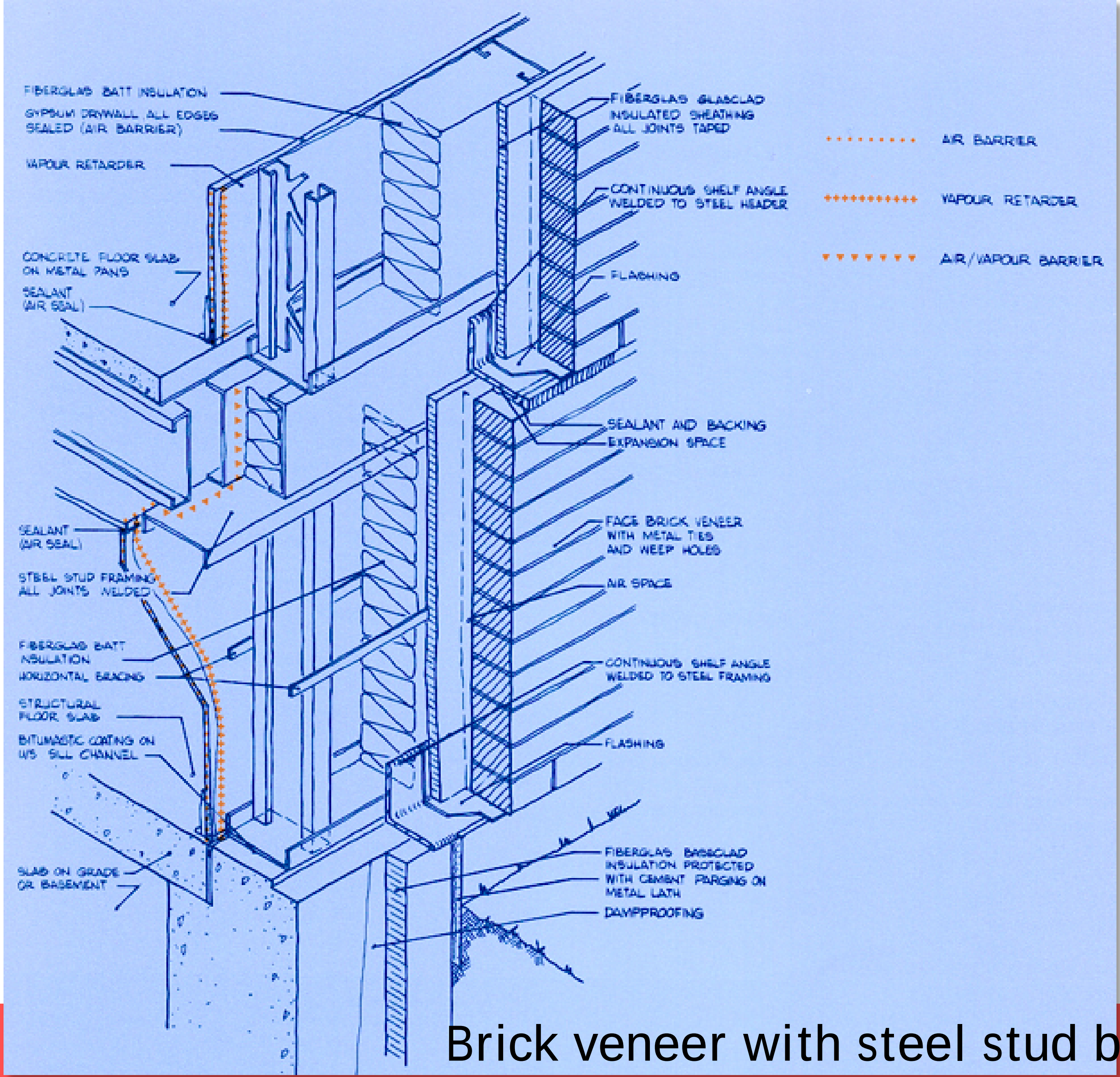
Ontario College of Art and Design



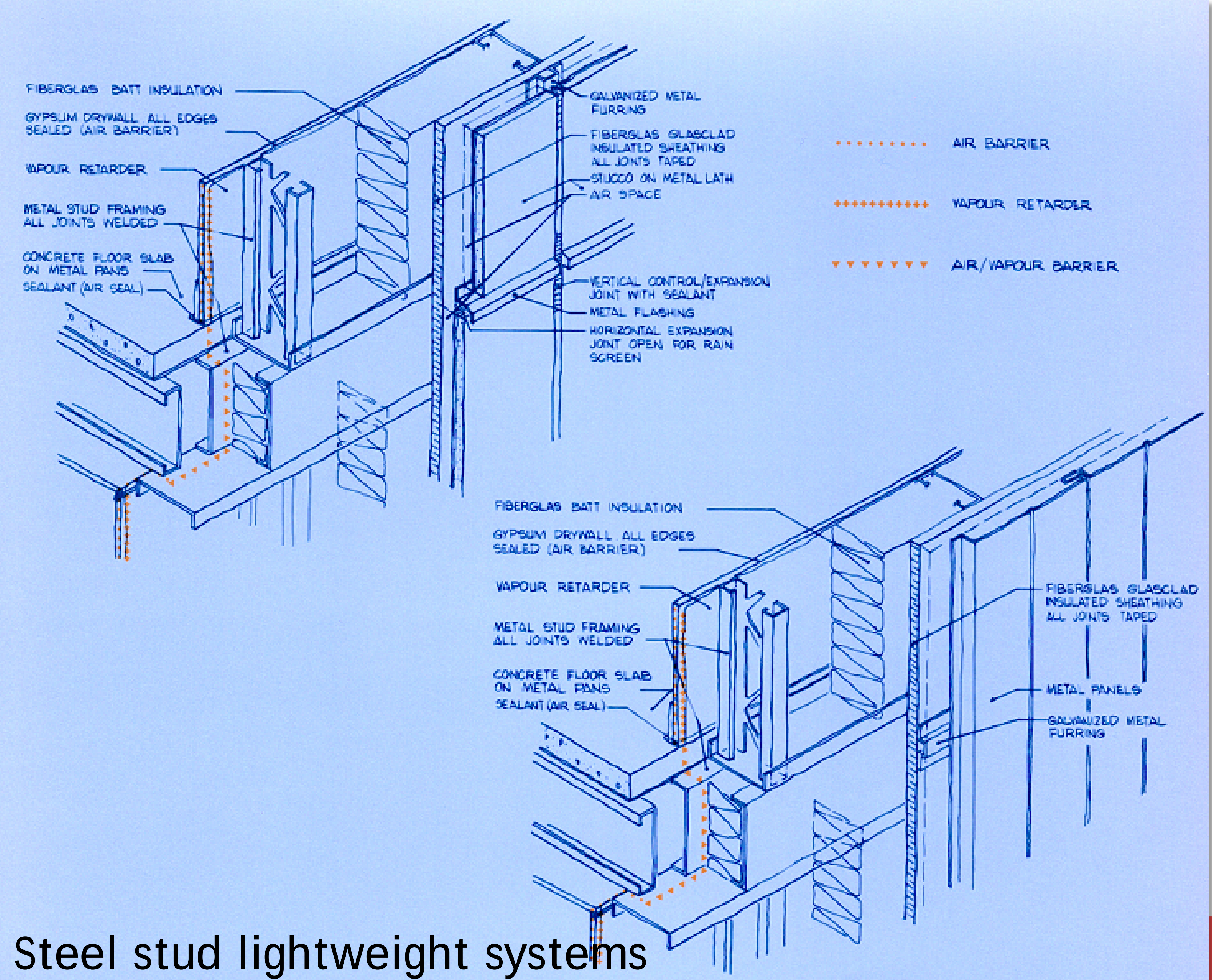
Precast concrete curtain wall



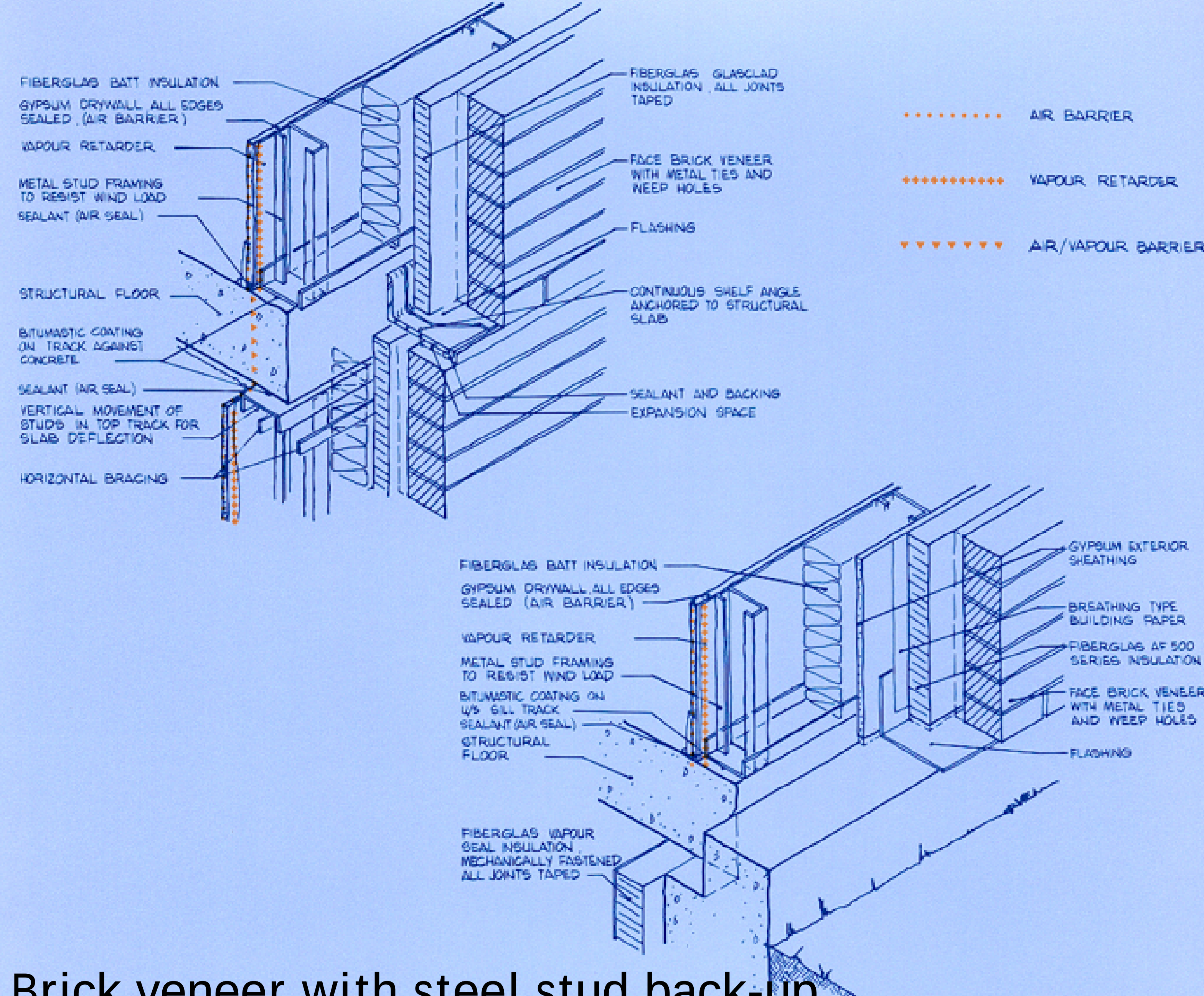
R-2000 Residential Construction



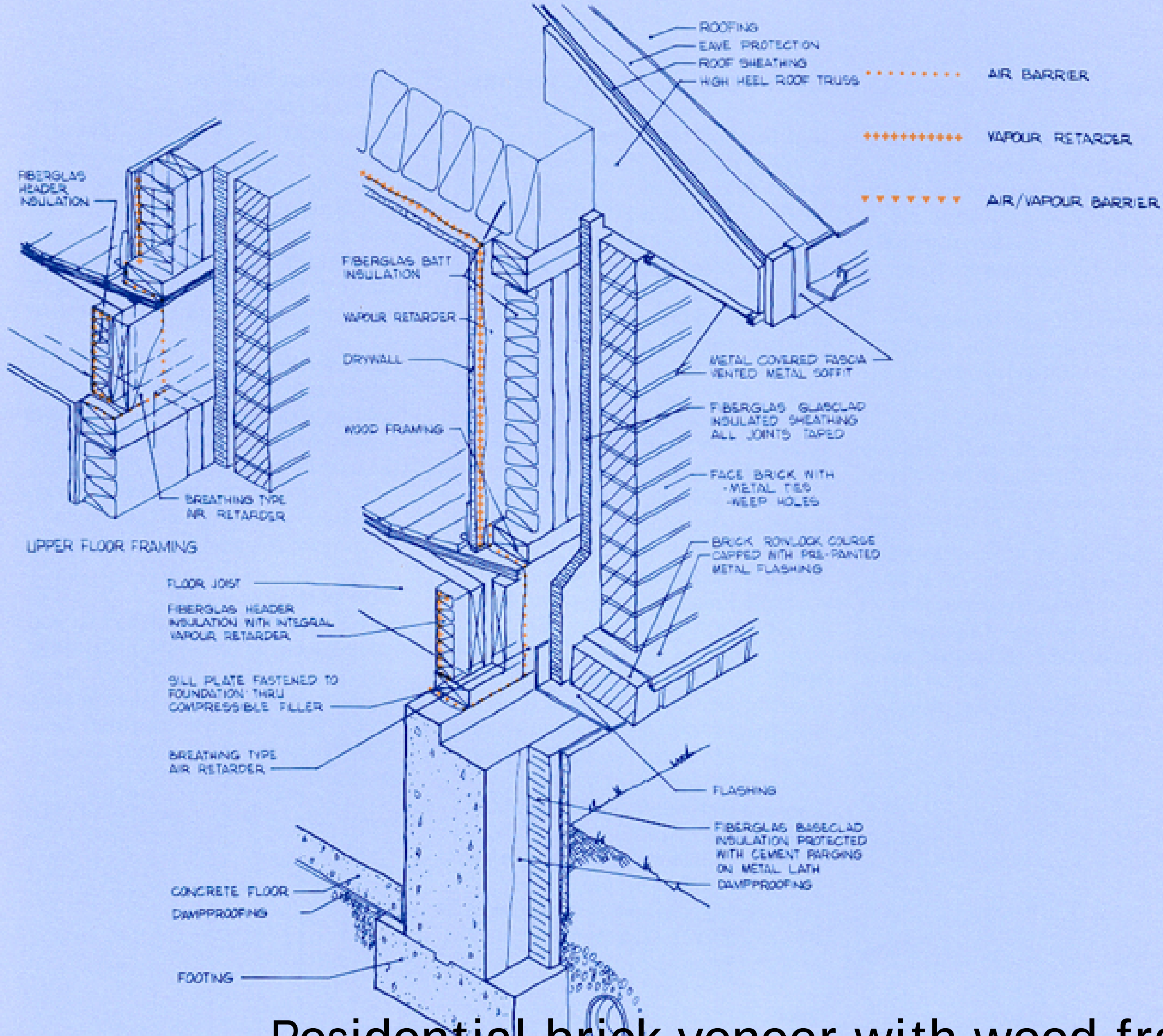
Brick veneer with steel stud back-up



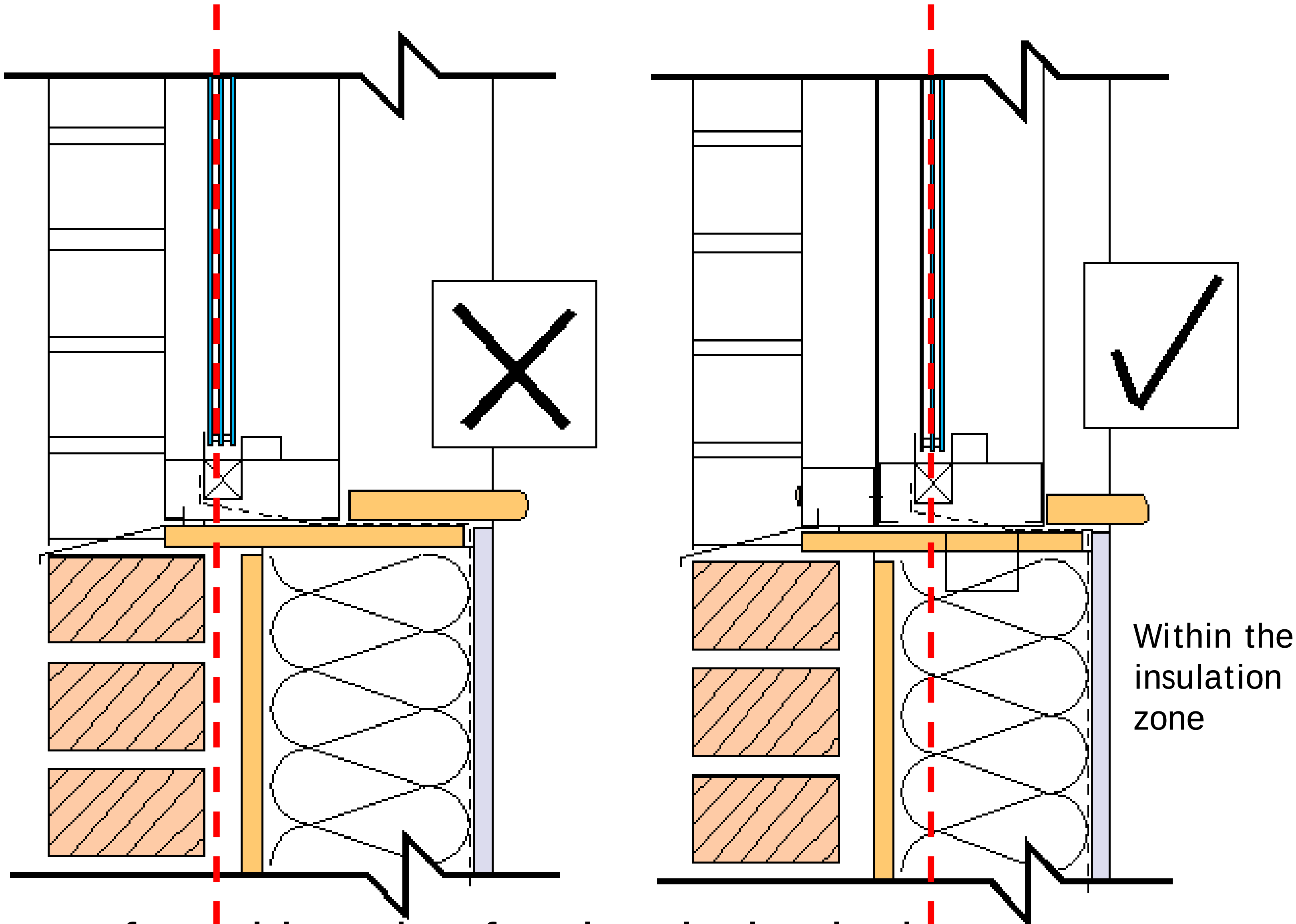
Steel stud lightweight systems



Brick veneer with steel stud back-up



Residential brick veneer with wood framing



The preferred location for the glazing is shown.


UW Coop Services Building


Look closer…


And closer.
What is wrong?
Why?