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Innovative Housing Grants Program

THE POLY AIR DAM

A NEW PLASTIC GASKET TO IMPROVE AIRTIGHTNESS

November 15, 1987

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The views and conclusions expressed and the recommendations made in this report are entirely those of the authors and should not be construed as expressing the opinions of Alberta Municipal Affairs.

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FOREWORD

The project documented in this report received funding under the Innovative Housing Grants Program of Alberta Municipal Affairs. The Innovative Housing Grants Program is intended to encourage and assist housing research and development which will reduce housing costs, improve the quality and performance of dwelling units and subdivisions, or increase the long term viability and competitiveness of Alberta's housing industry.

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EXECUTIVE SUMMARY

Air leakage contributes significantly to the heating and cooling load in houses. Some of the major leakage pathways occur at:

1) bottom plate/subfloor junction,
2) rim joist/top of foundation wall junction and,
3) wall framing/window (door) jamb junction.

Conventional residential construction practice does attempt to reduce air leakage at the bottom plate/subfloor junction, but there are few effective ways to seal the other two pathways. Often no attempt is made to connect to the air/vapour barrier in any of these areas. Effective techniques to accomplish this air seal do exist, but they tend to be difficult and/or expensive.

The purpose of this project was to develop an effective, inexpensive, simple product and technique to seal these three pathways. The product is called the "Poly Air Dam" (PAD).

To establish profile shape and composition, a plastics manufacturer was contacted. Prototype production was initiated.

Laboratory testing, using an airtight chamber, compared the PAD to common methods of sealing the window and door jamb, and rim joist. Jamb and rim joist tests were conducted separately. The response of the construction community was assessed by providing product samples which were installed in several houses. Builders were interviewed

to assess installation procedures, training requirements, problems, and costs associated with the PAD approach.

The PAD system was found to be as effective as systems presently used in SEEH (Super Energy Efficient House) and R-2000 houses, but far less expensive and easier to install. Industry response indicated a market exists for the product.

1.0 INTRODUCTION

Air infiltration and exfiltration causes up to 60% of the heating load experienced in houses with higher insulation levels (1). In recent years, attempts have been made to minimize these loads. Leakage which occurs at the area between the framing members and the window or door jamb (Figure 1, Page 2), can account for 20% of total leakage (1). A second major leakage pathway at the bottom plate/subfloor, and top of foundation wall/rim joist junctions (Figure 2, Page 3), can account for up to 25% of total leakage (1,2). Conventional construction makes little attempt to address the problem of air infiltration in these areas.

Energy conserving techniques to accomplish this air seal have been developed in the past few years. Attributes of these techniques can be divided into three categories:

1) effective, difficult, expensive
2) effective, easy, expensive
3) limited effectivness, easy, relatively inexpensive

The ideal set of characteristics would be effective, inexpensive, and easy to install.

The Poly Air Dam (PAD) project is intended to address the problem of effectiveness, as well as to create a system which is inexpensive and easy to use. This project takes the product from the concept stage through to market readiness. An extensive literature search of present techniques indicates that technological improvements are wanting in this area. Canadian and American patent searches

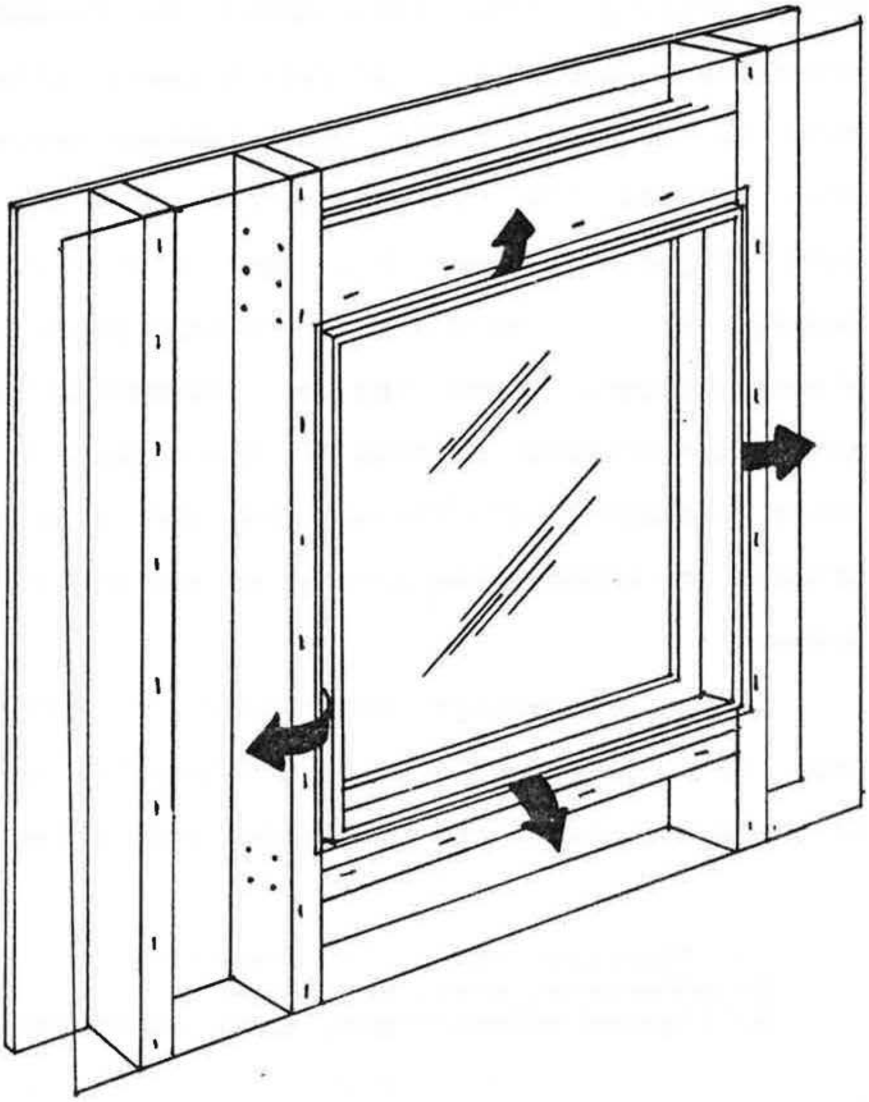


FIGURE 1: Leakage pathways at the window jamb (After "Air-Vapour Barriers", by D. Eyre and D. Jennings, Energy, Mines, and Resources Canada, Ottawa, 1984).

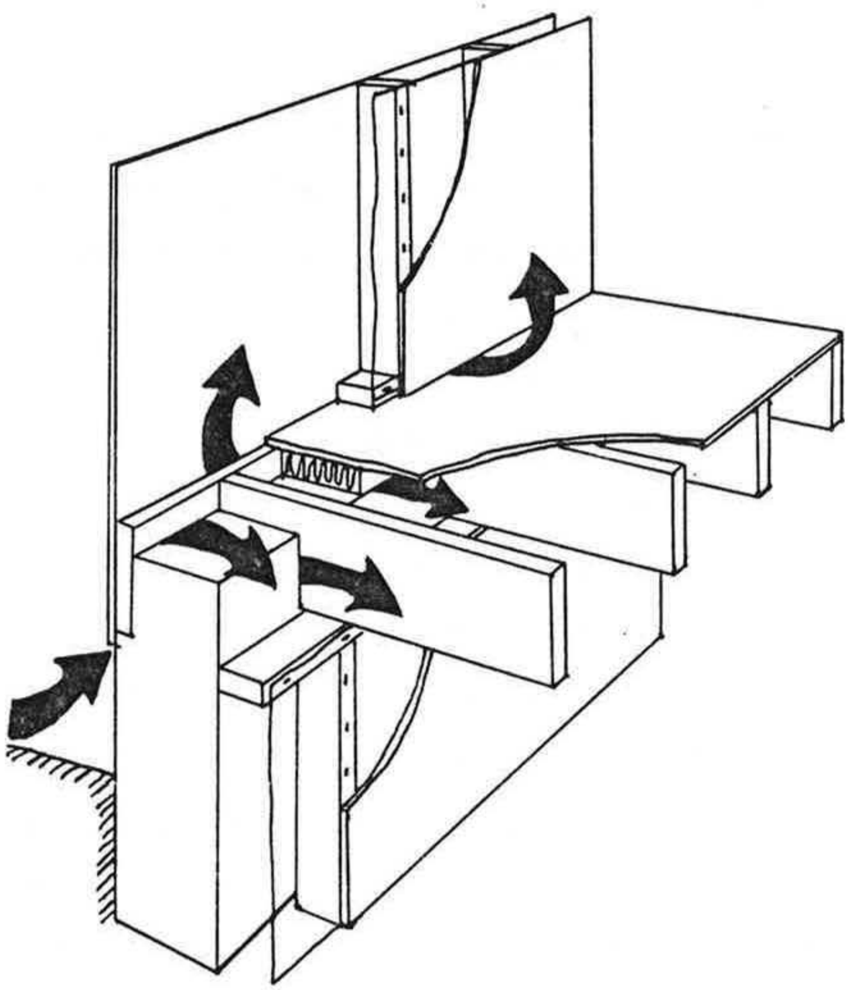


FIGURE 2: Leakage pathways at the rim joist: Joists cast into concrete foundation (After "Air-Vapour Barriers", by D. Eyre and D. Jennings, Energy, Mines, and Resources Canada, Ottawa, 1984).

were conducted, and have shown no existing patents for a similar product. Poly Air Dam patents are pending.

With the assistance of a plastics manufacturer, a suitable material and profile, based on a combination of price and performance, was selected for the PAD. Before any kind of market acceptance can be expected, a product with verifiable performance must exist.

The prototype was tested in a laboratory environment, as part of a system, to determine its ability to provide an air seal at the various junctions. Leakage was determined by creating an air pressure difference across the sealed junction and measuring the rate of air flow through the rim joist and the window assembly. Comparative tests were performed on several air leakage sealing techniques.

Successful laboratory testing would be of little general interest if the PAD were not commercially viable. The product was therefore installed in several houses. Upon completion of these trials, the participants were interviewed. These trials sought to assess training requirements, installation costs, and possible problem areas. Once these technical considerations were addressed, concerns associated with the PAD's commercial exploitation required examination to determine the potential of this product.

This report is organized to describe the development, testing, and field trials of the PAD, and concludes with sections describing the patents, certifications, and approvals which are required.

2.0 PROTOTYPE DEVELOPMENT AND COMPOSITION

An awareness of the difficulty of sealing window and door jambs to the air/vapour barrier in SEEH houses resulted in a desire to simplify the process. The new system had to meet R-2000 standards, and so had to perform well at a pressure of 50 Pascals. It was reasoned that an "L" shaped plastic moulding, stapled to the 1/2 inch projection of the extension jamb, and extending 1.5 inches onto the wall framing, should provide an effective (and simple to install) seal against air leakage. The shape also lent itself to eliminating the bulky plastic sheeting overlaps at corners, which caused finishing problems. During the development process, it became obvious that the size and shape of the PAD was also suited to sealing the air/vapour barrier to the subfloor. This alternate use resulted in adoption of the product to the rim joist sealing system which was tested.

As a result of working with Western Industrial Research and Training Centre (WIRTC) in Edmonton the original profile design of the PAD (Figure 3, Page 6) was changed to that in Figure 4 (Page 6) in order to minimize manufacturing difficulties related to uneven cooling. During profile development, it became obvious that adding a gasket to the 1/2 inch leg of the PAD (Figure 5, page 7), could eliminate the need to caulk the jamb.

The plastic moulding had to be semi-rigid, so PVC with a durometer value in the 110 range, was chosen for the prototype. Durometer refers to a measure of flexibility of

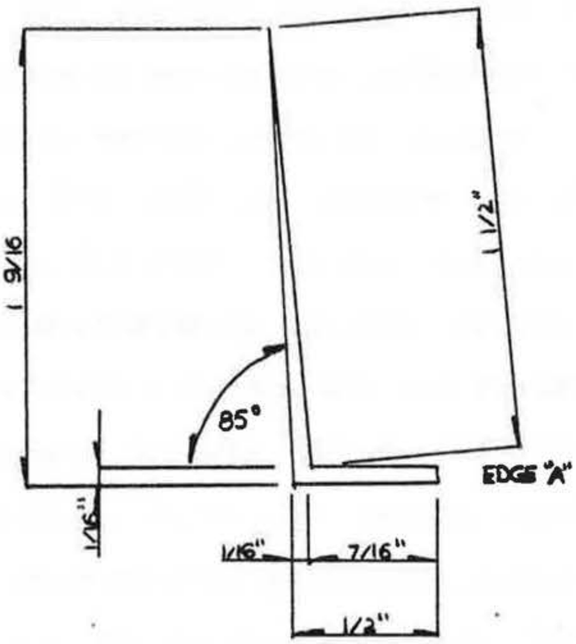


FIGURE 3: Original Poly Air Dam profile design.

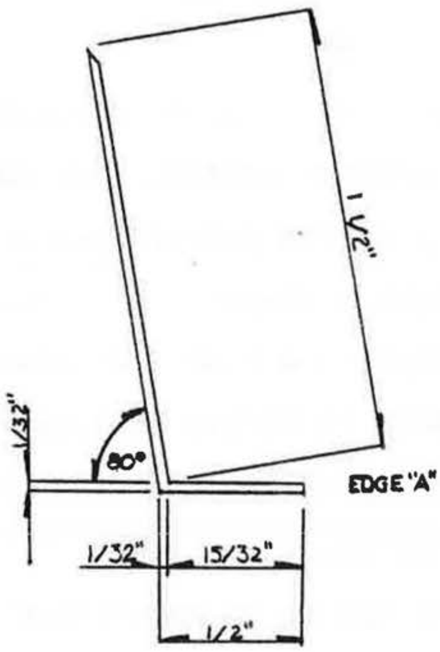


FIGURE 4: Preferred Poly Air Dam profile design.

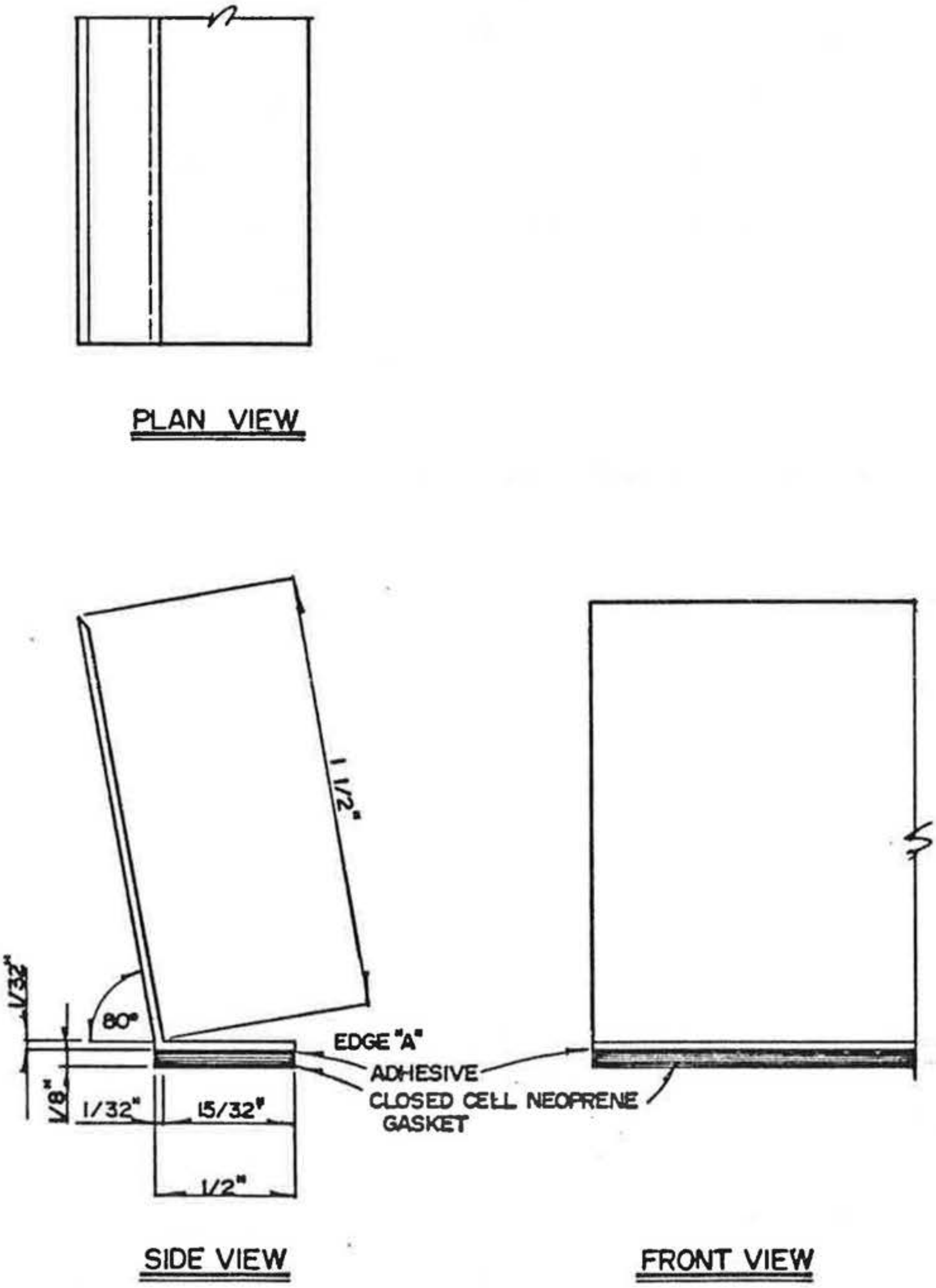


FIGURE 5: Poly Air Dam with neoprene gasket installed.

the manufactured product.

The PAD is produced by profile extrusion. Bulk polymer is heated and then forced through an opening, to take on the profile of the intended product. This requires the machining of a plate with a properly shaped orifice. Exact product dimensions are determined by the speed at which the product is pulled away from the extruder (eg- the faster the rate of pull, the smaller the profile). The profile is cooled in a water bath and cut to length. Adding the gasket in a factory setting requires specialized equipment, so during the testing this was done later by hand.

3.0 BASIC APPROACH TO LABORATORY TESTING

Hardy and Associates (1978) Ltd., consulting engineers, of Calgary conducted laboratory testing of the Poly Air Dam in conformance with ASTM Test Procedures E283 entitled "Standard Test Method For Rate of Air Leakage Through Exterior Windows, Curtain Walls, and Doors". Details of each test are presented later.

The same test equipment and airtight chamber were used for window and rim joist testing. The chamber was built with a 2x4 frame and plywood on a platform, and was completely sealed. It was 8 ft. high, 8 ft. wide, and 4 ft. deep. Typical framing was used to construct the test panel, except that the poly air/vapour barrier was deleted; it was considered desirable to have tests which could be related to the Airtight Drywall Approach.

The chamber had a removable panel into which a window was installed for testing. Typical wall framing was used to construct this panel. Window construction was of the standard fixed type, 21 in. by 56 in. (530 mm X 1430 mm), with glazing replaced by plywood. This unit was completely sealed. A removable gyproc panel surrounded the window location and acted as interior wall cladding. It was sealed to the test chamber by ducting tape.

The removable panel was changed for rim joist testing. It duplicated a 2X4 sill plate supporting a 2X8 rim joist with 1/2 inch subflooring. A 2X4 plate above this replicated the bottom plate of the exterior wall. When installed, the exterior of the rim joist component was capped with 3/8 inch plywood. A removable interior panel of gyproc, above the subfloor location, was sealed to the test chamber using ducting tape.

Airtightness of the chamber was confirmed using a smoke pencil and pressure differential.

Both pressurization and depressurization tests were run on each configuration. Recent research has indicated different leakage characteristics between the two pressure modes (3). For each test, pressure was increased past 50 Pa to reach the failure point of each configuration. A 140 cfm air pump with a two speed impellor produced the pressures, while air metering was accomplished using a sharp edged metering plate. Pressure was monitored with a Dwyer Incline Manometer. Checks with smoke pencils located actual leakage points.

Even though both infiltration and exfiltration tests were run, exfiltration only was chosen as an indication of performance because it is the most accurate (4). The tape used to create a temporary seal between the gyproc and the test panel performed poorly under infiltration conditions. When both results were plotted on the same graph, it became difficult to differentiate line locations; however, results from paired tests did follow the same general graphed slope.

4.0 REVIEW OF WINDOW AND DOOR JAMB SEALING TECHNIQUES AND TESTING DETAILS

4.1 INTRODUCTION

In conventional construction, the cavity between the rough opening and the jamb is filled with insulation, and a poly air/vapour barrier is installed, with no special attempt being made to seal it to the jamb. Some techniques, effective to varying degrees, do exist to correct this problem. A system developed in Canada for use in airtight houses utilizes a polyethylene collar attached to the window or door jamb before installation in the house frame. After installation, the polyethylene is sealed to the air/vapour barrier. This is the most effective system. Urethane foam spray, caulk, foam gaskets of various shapes, and mineral wool insulation enclosed in a poly bag are some of the other methods.

Except for the poly collar, all the systems in use are designed to be applied after the window or door is installed. With the exception of urethane foam spray, none can claim to be as effective as the poly collar. However, the two most effective systems are also the most expensive. A need exists for a functional product which is low in cost.

4.2 WINDOW AND DOOR JAMB SEALING TECHNIQUES

4.2.1 COSTING TECHNIQUES

Material costs which are quoted in this section are current prices which were obtained from building material supply houses. Poly Air Dam prices are actual prototype costs which are marked up to reflect distributor and retailer margins. The rough opening gap to be sealed was assumed to be 15 lineal feet. The labor rate used was $12.00 per hour except where noted otherwise. Supervisory personnel are often involved in the more specialized sealing procedures and this is reflected in the labor rate. Installation times were derived from a combination of subtrade interviews and the author's personal experience.

4.2.2 CONVENTIONAL NORTH AMERICAN PRACTICE

A gap between the window or door jamb and the adjacent framing members is filled with fibreglass insulation (5), but this is not an airtight joint (6). The polyethylene air/vapour barrier is installed on the interior wall surface, and the excess covering the window or door is trimmed away. It has been suggested that the polyethylene sheet can be stapled to the jamb (7) for improved leakage resistance, but recent testing has not confirmed this (3).

4.2.3 GLASS FIBRE ENCLOSED IN PLASTIC FILM

In Sweden, the gap left after the window/door is installed in the rough opening is partially filled with insulation. Glass fibre enclosed in a thin plastic film is pushed into the remaining gap (Figure 6, Page 14). A good air seal is achieved except at corners, where there is some leakage (6). An incremental cost could not be determined for this system as it is not available through the sources contacted.

4.2.4 TUBULAR OR ANGULAR STRIPS OF EPDM

EPDM is an acronym for ethylene propylene dien monomer, which is a synthetic rubber. Tubular or angular strips of EPDM are an alternative sealing method (Figure 7, Page 14). After partially filling the remaining gap with insulation, the strips are pushed in. They can achieve good airtighness under compression, but surfaces in contact with the strips must be smooth (6). The air/vapour barrier sheeting should be connected to the EPDM strip or sealed to the building structure. The cost per opening of caulk and EPDM would be $2.55. When labor is included (15 minutes), the incremental cost is $5.55 per opening.

4.2.5 CAULK

A combination of insulation and caulk, with or without a bottoming strip (Figure 8, Page 15), is another suggested method of achieving an air barrier (6). This method presents problems, due to possible building component movement and sealing of the air/vapour barrier to the caulk. Caulk cannot be used to create an effective seal across a gap of 1/4 inch, which is common. Incremental

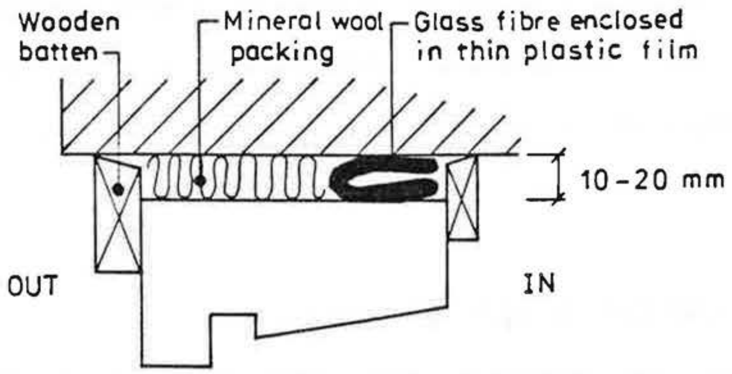


FIGURE 6: Jointing with glass fibre enclosed in a thin plastic film (Extracted from "Air Infiltration Control in Housing: A Guide to International Practice", by A. Elmroth and P. Levin, Swedish Council for Bulding Research, Stockholm, Sweden, 1983).

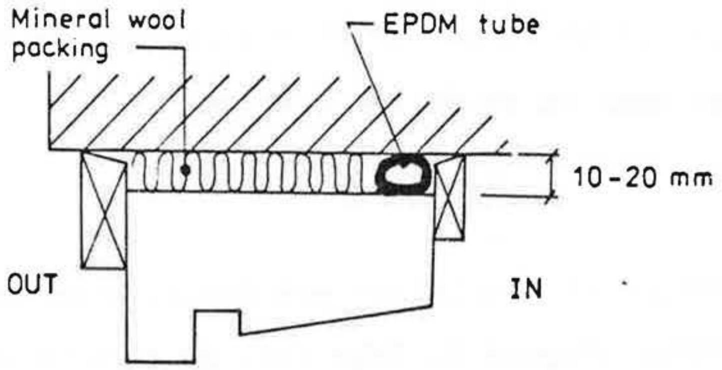


FIGURE 7: Jointing with tubular strip or angular strip of EPDM (Extracted from "Air Infiltration Control in Housing: A Guide to International Practice", by A. Elmroth and P. Levin, Swedish Council for Building Research, Stockholm, Sweden, 1983).

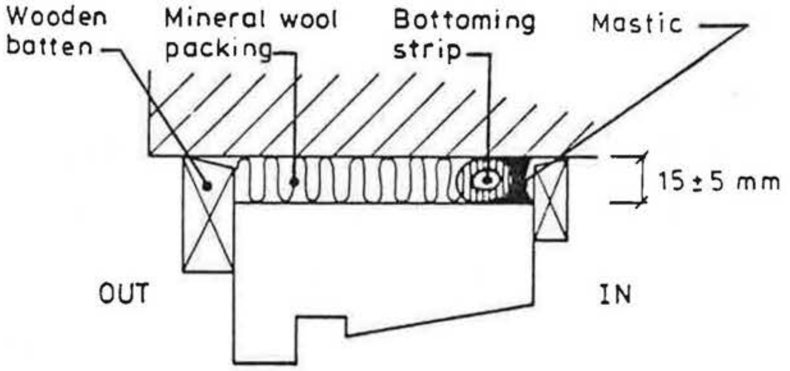


FIGURE 8: Internal sealing with mastic and mineral wool packing (Extracted from "Air Infiltration Control in Housing: A Guide to International Practice", by A. Elmroth and P. Levin, Swedish Council for Building Research, Stockholm, Sweden, 1983).

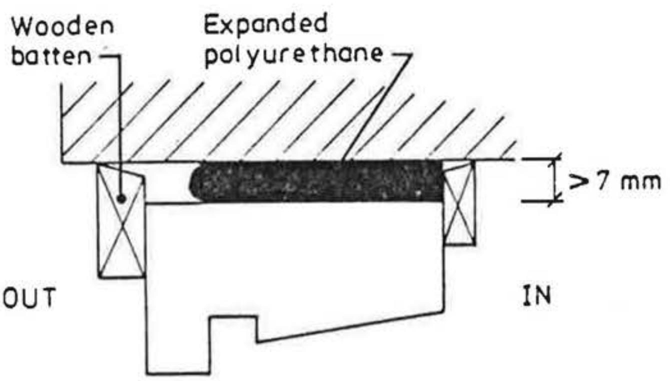


FIGURE 9: Jointing with polyurethane foam (Extracted from "Air Infiltration Control in Housing: A Guide to International Practice", by A. Elmroth and P. Levin, Swedish Council for Building Research, Stockholm, Sweden, 1983).

costs could vary considerably depending on the gap size, amount of time and caulk, and type of bottoming strip used, but would fall in the $5.00 to $7.00 range.

4.2.6 POLYURETHANE FOAM

Polyurethane foam (Figure 9, Page 15) can be sprayed into the rough opening gap to both insulate and seal the opening (6). When the foam is sprayed into place, the gap must be left partially empty to allow for expansion: if this is not done, windows and doors will be difficult to open. The excess must be trimmed to allow for gyproc and finishing. Some uneven filling may result and is a potential source of leakage. This product will tolerate a 10% movement factor (6). Beyond that point, the air seal is broken. The author has tried this product and found that a typical bedroom or dining room window, in a 2x6 wall, requires one spraycan of material (at $11.95 per can) and about 10 min. of labor. This yields a total incremental cost per opening of $13.95.

4.2.7 POLY WRAP COLLARS

This technique was developed in Canada (Figure 10, Page 17), and effectively prevents leakage in super energy efficient (SEEH) and R-2000 houses. Materials consist of poly, caulk, glass filament tape, and staples. Procedures are described in detail elsewhere (8,9,10), but briefly, a poly collar is attached to a window or door frame before installation in the rough opening. The window or door is

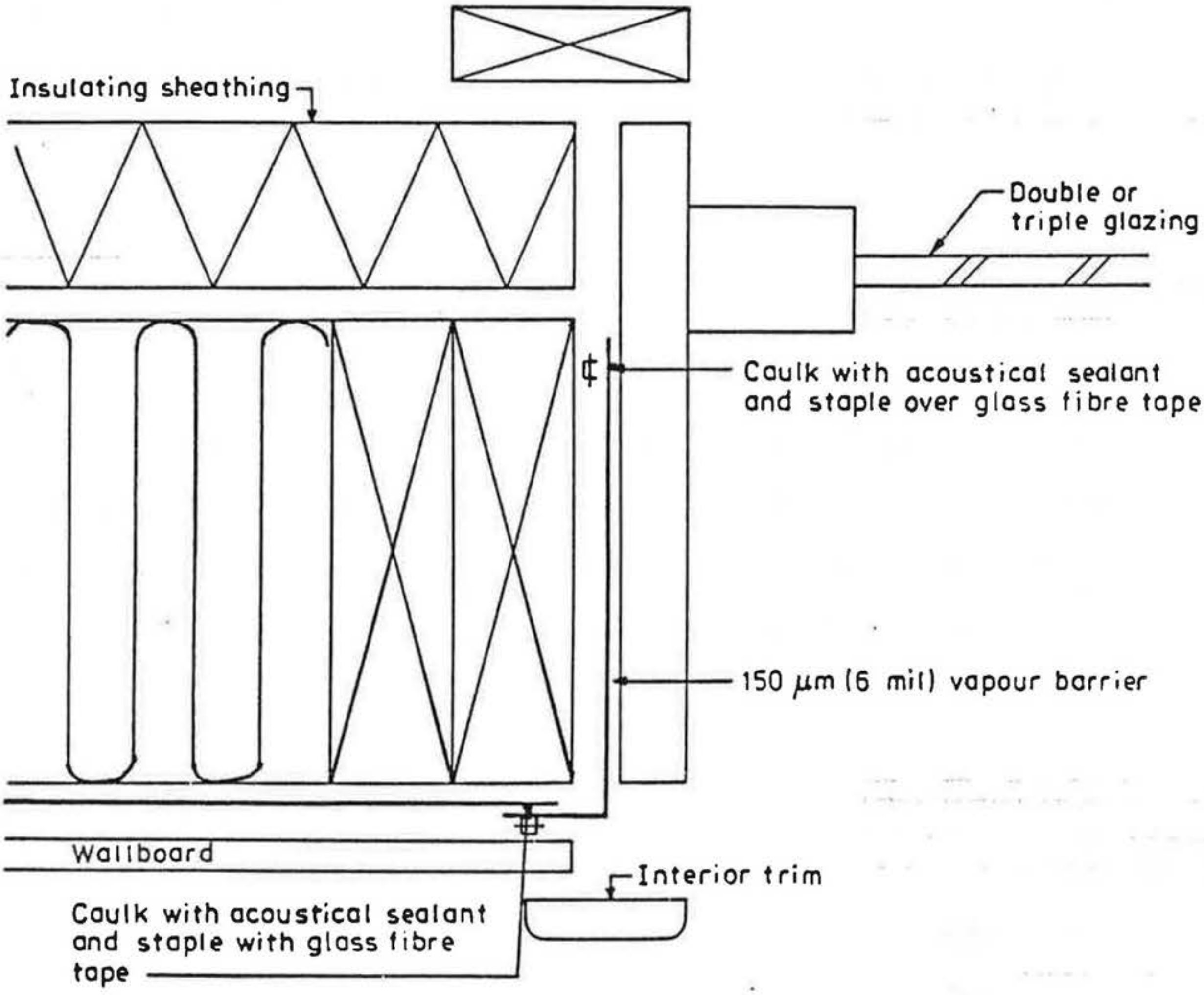


FIGURE 10: Jointing using polyethylene, caulking, and staples connected to poly air/vapour barrier system used in Canadian SEEH and R-2000 houses (Extracted from "Air Infiltration Control in Housing: A Guide to International Practice", by A. Elmroth and P. Levin, Swedish Council for Bulding Research, Stockholm, Sweden, 1983).

mounted in the framing and the poly collar is attached to the air/vapour barrier. An installation time of 40 minutes (including time to handle the window and attach to the air/vapour barrier) yields labor costs of $8.00, plus $3.00 for materials, gives an incremental cost of $11.00 per opening.

4.2.8 AIRTIGHT DRYWALL APPROACH

As an alternative to the polyethylene air/vapour barrier, the Airtight Drywall Approach (ADA) is currently being developed (11,12). Under this approach, a caulk bead is used to form an airtight joint between the jamb and drywall (Figure 11, Page 19). To do this effectively, the author has found that the drywall to jamb clearance must be tighter than is common construction practise, although once properly sealed, this can be an effective method. Problems can arise due to shifting of the structure and caulk performance (6). An installation time of 15 minutes plus caulk gives a current incremental cost of $4.20 per opening. This does not take into account extra charges a drywaller may want.

4.3 POLY AIR DAM INSTALLATION PROCEDURES: WINDOW/DOOR JAMB

The Poly Air Dam was tested in gasketed and ungasketed versions, and the same installation procedures apply to both. Figures 12 and 13 (Pages 20 and 21 respectively) show typical PAD installations between studs and rough sills or headers. These illustrations also show interior wall

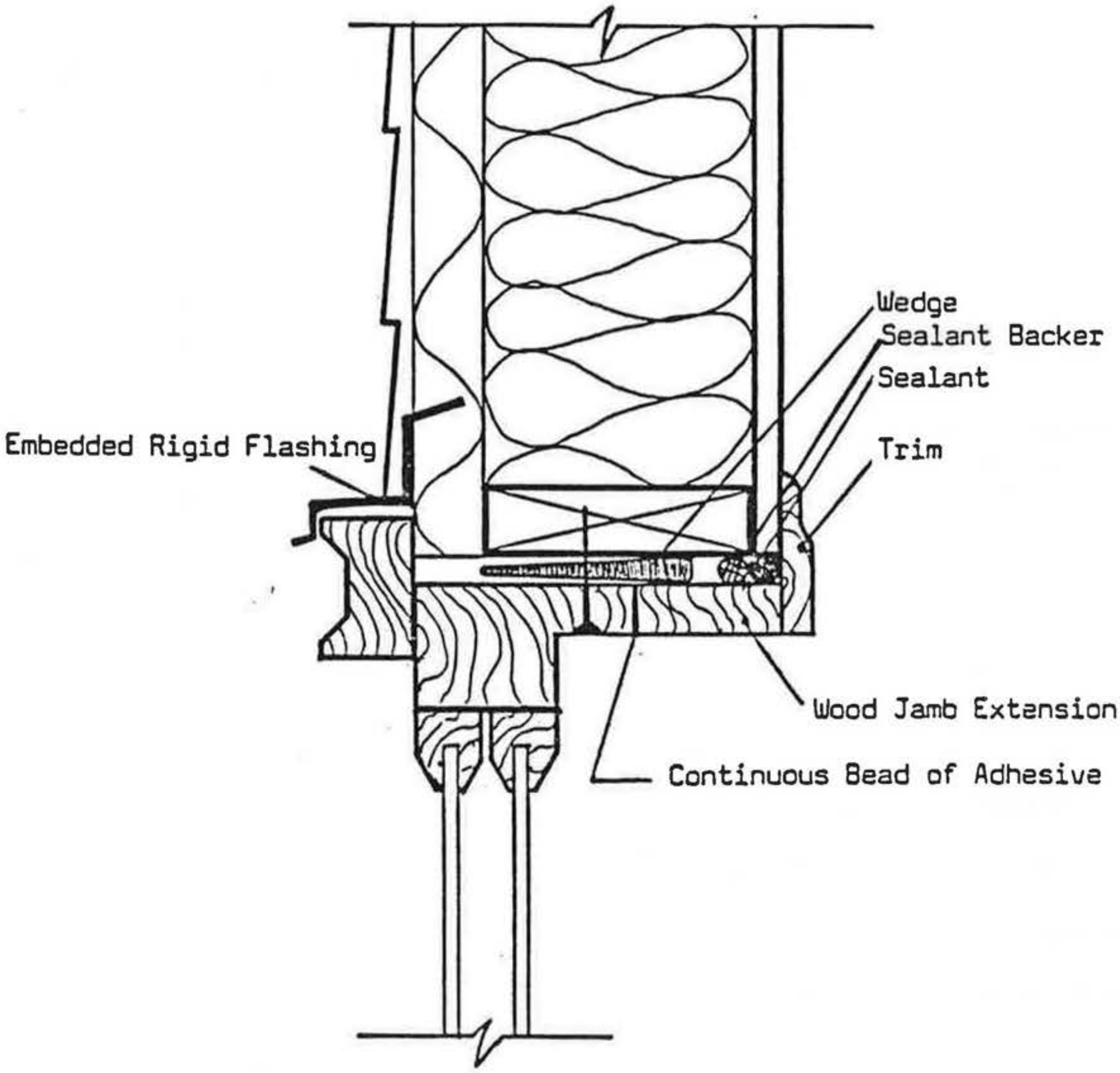


FIGURE 11: Jointing at window using ADA technique - wood extension jamb (Extracted from "Construction Experience Using the Airtight Drywall Approach", by J. Lstiburek, Alberta Department of Housing, Edmonton, 1985).

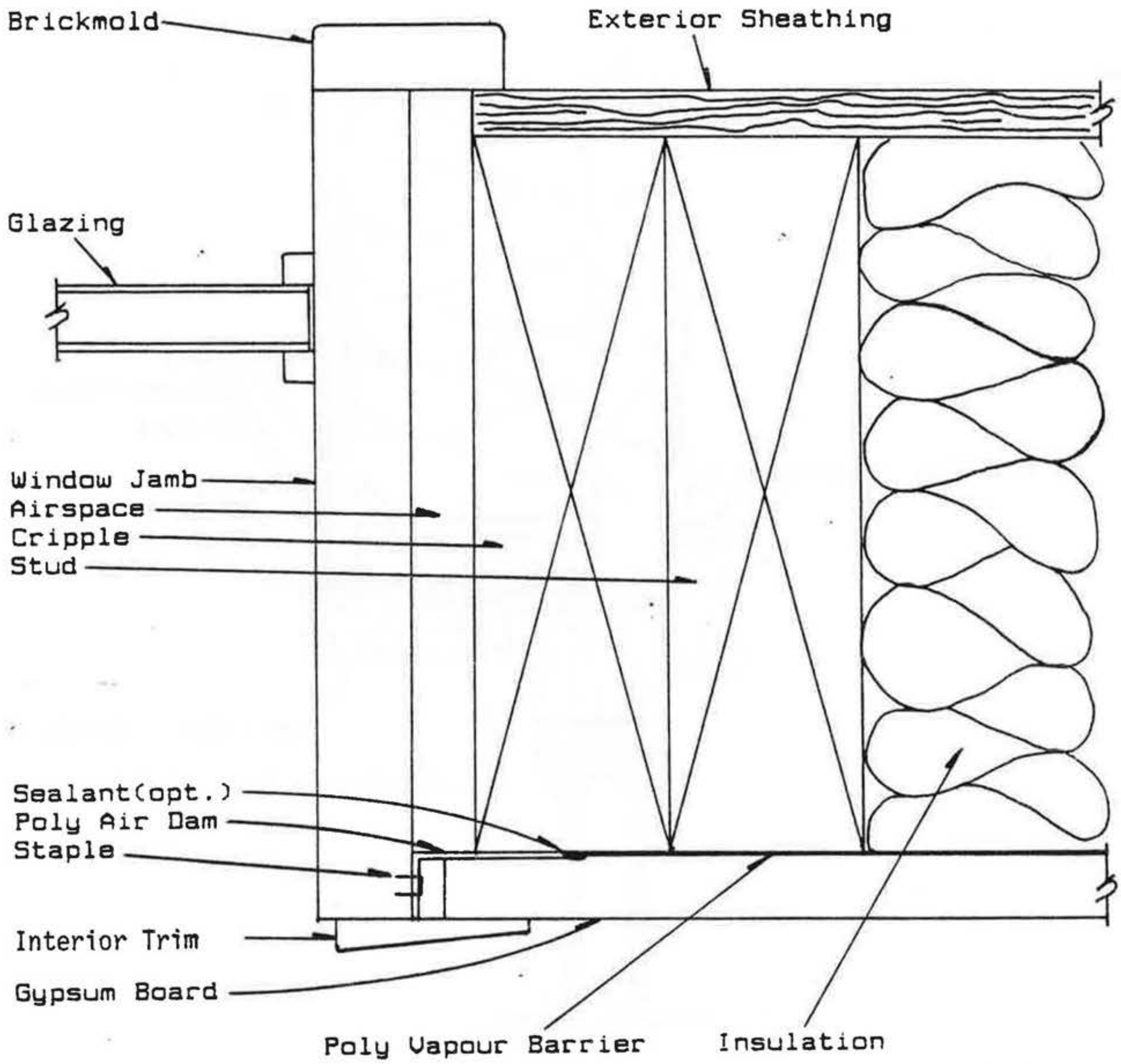


FIGURE 12: Top cross sectional view of Poly Air Dam installation at studs.

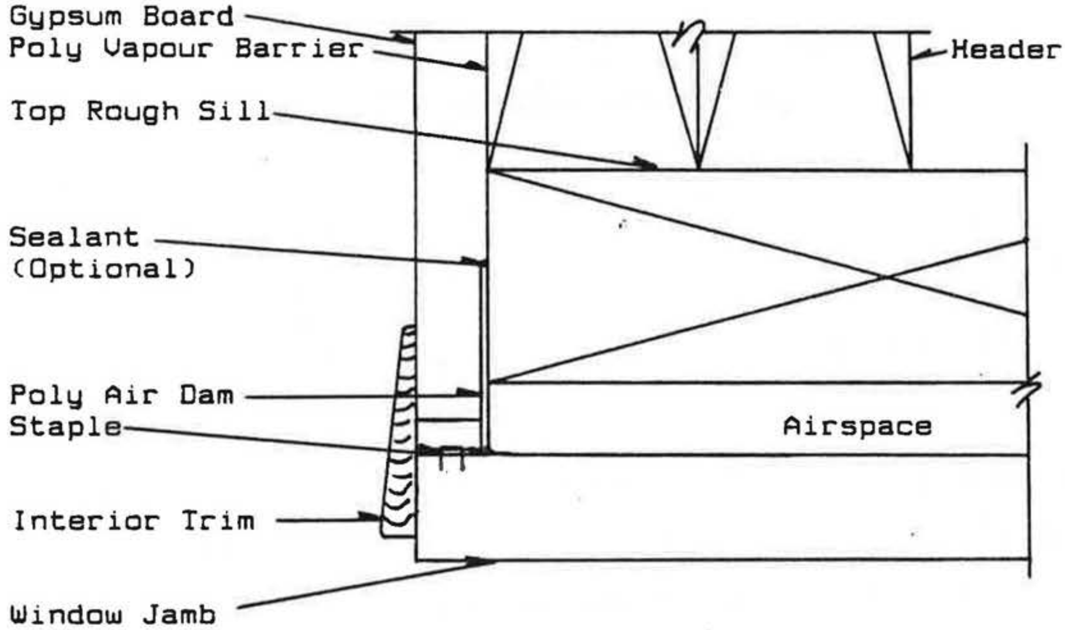


FIGURE 13: End cross sectional view of Poly Air Dam installation at header.

cladding (ie- gyproc) installed. The air dam must be installed before the interior cladding and, if applicable, the poly air/vapour barrier.

Once an exterior wall is framed, the doors and windows are installed in the conventional manner. Air dams are then applied, aligning edge "A" (Figure 5, Page 7) with the outside edge of the extension jamb. They are fixed into position using the appropriate length of staple spaced 6 inches on center. This application assumes the use of a wooden jamb. If the jamb is of some other material, an appropriate adhesive can be used.

Poly Air Dams are trimmed on site to a 45 degree angle at each corner. Each air dam is first cut 3 inches longer than the jamb length, to overhang 1.5 inches past each end of the jamb. Either both sides or the top and bottom air dam pieces MUST be installed first, and in pairs. The short legs of the PAD are trimmed from each overhanging portion of the first pair. The second pair of PADs are installed, and the angle formed where the long and short legs meet is cut for the length of the overhang. The short legs are bent around the corner and stapled (Figure 14, Page 23).

After installation, there is a double thickness of material at the corner overlaps. A wide chisel is held along line "BB" (Figure 15, Page 24), at each corner location, and a cut is made. Only hand pressure is required to make the cut. This procedure insures that the two cut surfaces and the corners will be matched. A bead of caulk can be applied to the perimeter and corner joints of each

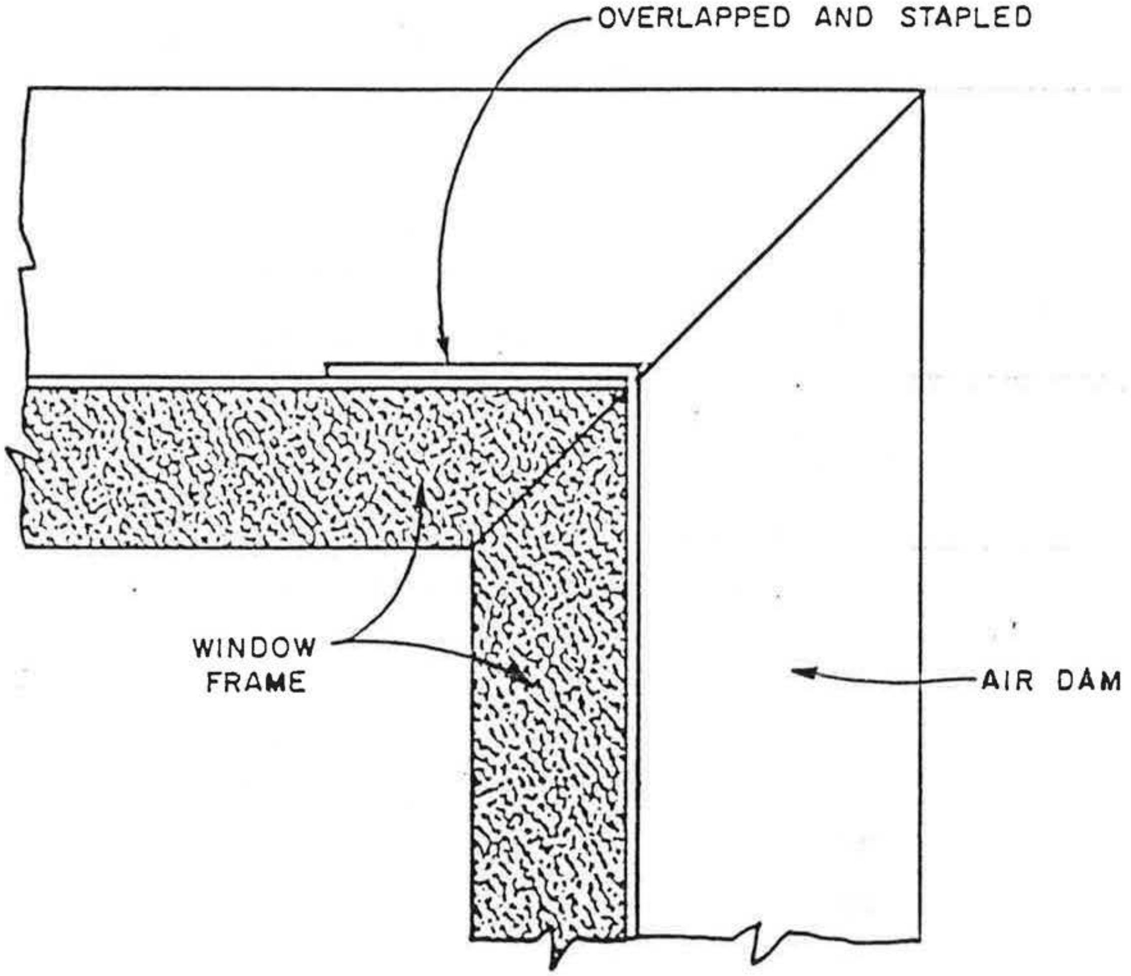


FIGURE 14: Corner detail of overlapped and stapled Poly Air Dam attaching strip.

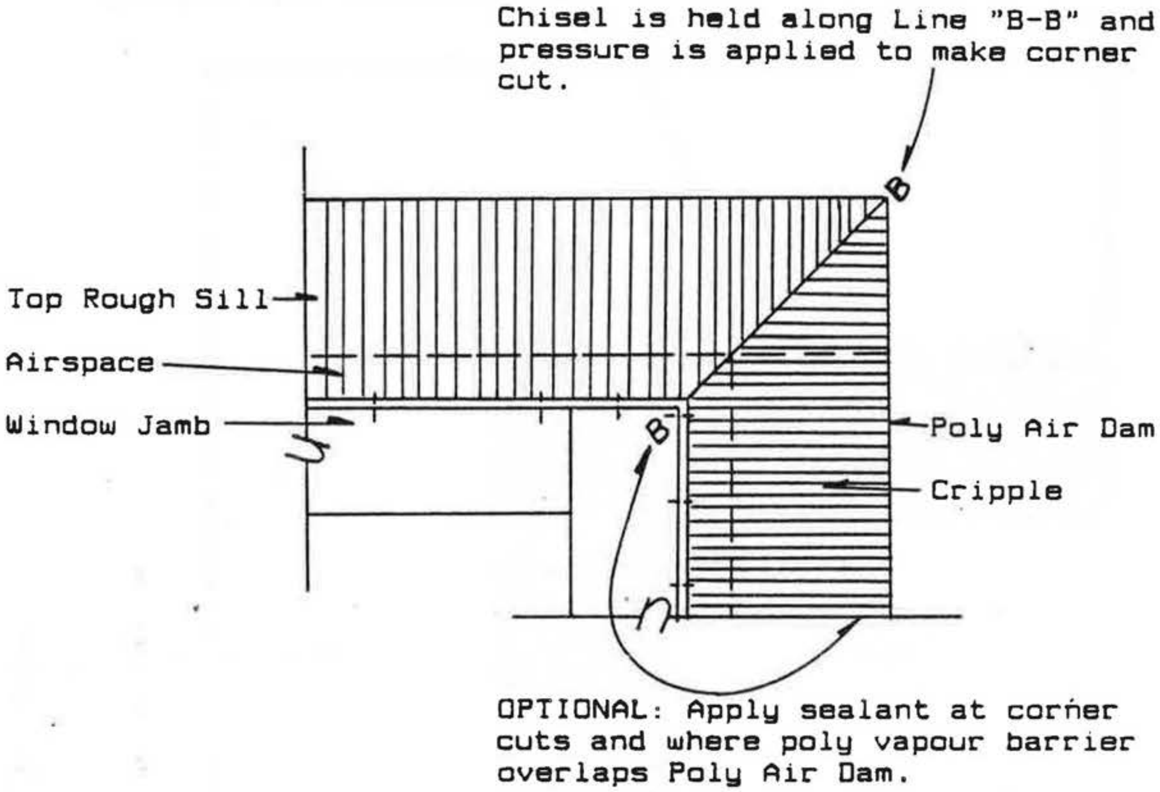


FIGURE 15: Cutting and caulking procedures at corners and for air/vapour barrier sealing to Poly Air Dam.

air dam, but this not essential to forming a good air seal. Insulation, air/vapour barrier, interior cladding, trim, and paint are now applied in the conventional manner.

Some drywallers have started using routers to cut the window and door openings while the gyproc sheets are held in place. There is potential for damage to the air/vapour barrier and damage to any air seal applied to the jamb, including the Poly Air Dam. This procedure MUST not be used for cutting window and door openings.

A simplified corner installation technique has been tried (Figure 16, Page 26). Opposite sides of the jamb are still put on in pairs, but the first pair is cut to the length of the jamb. The remaining pair is installed with an overhang, and the short legs are cut and stapled around the corner as before. This gives a butt joint rather than a mitre joint. This procedure is not recommended, as a gap remains that is the thickness of the PAD gasket. It performed poorly in Lab tests.

Tools commonly available on any jobsite are used to install PADs. Cutting and trimming are accomplished with a utility knife, chisel, and side cutters. A hand, electric, or air powered stapler capable of handling 1/4 to 3/8 X 3/8 inch staples is used for attachment. Caution should be used to insure that the stapler does not drive the staples entirely through the PAD material.

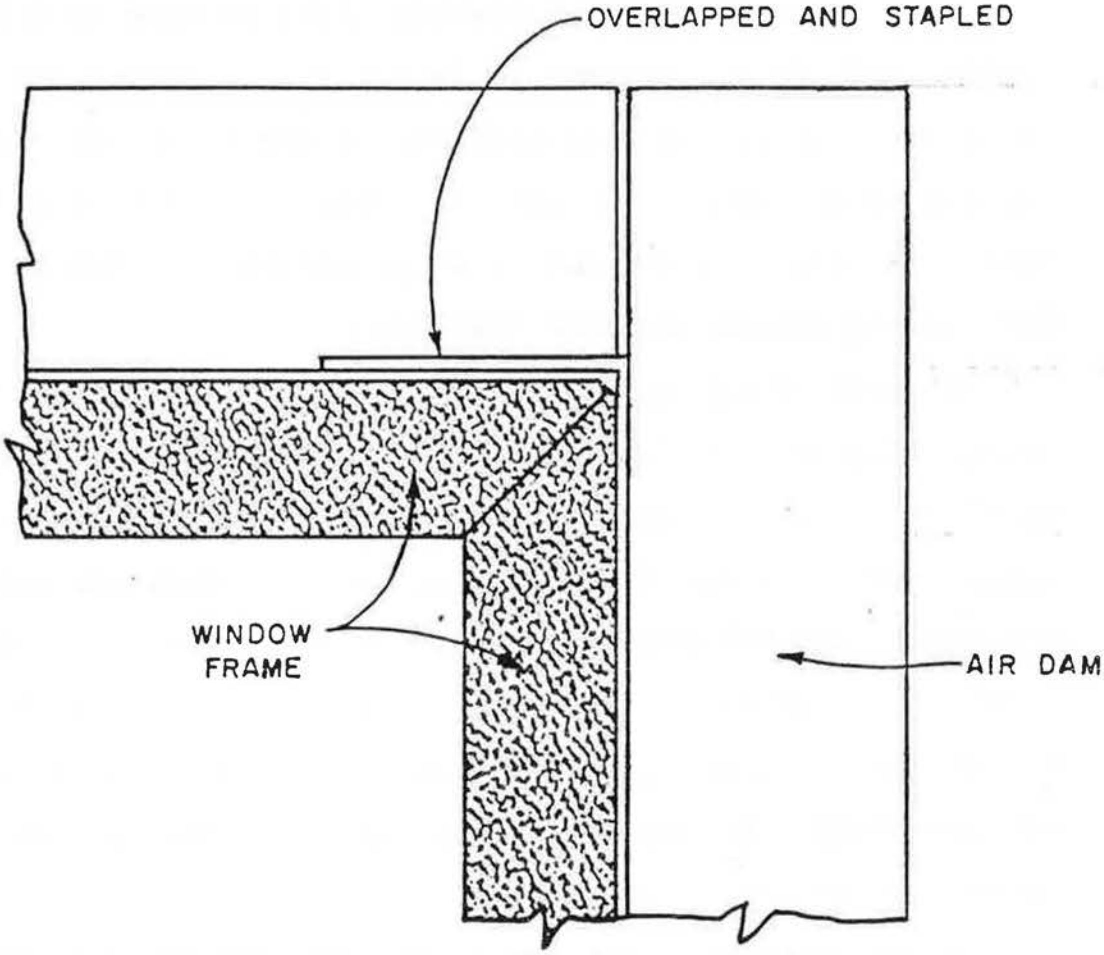
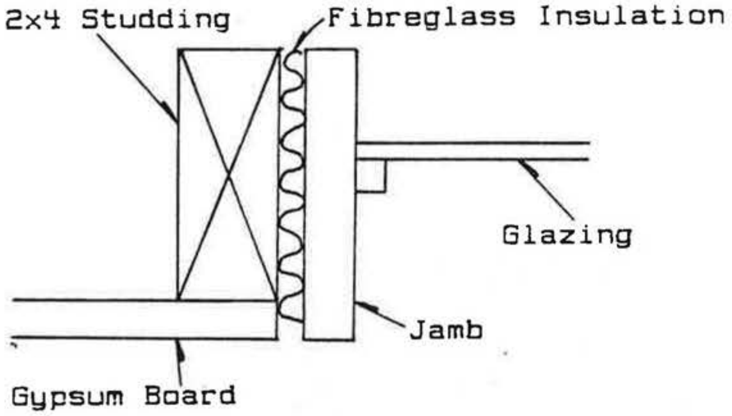


FIGURE 16: Corner detail of overlapped and stapled Poly Air Dam attaching strip using butt joint procedure.

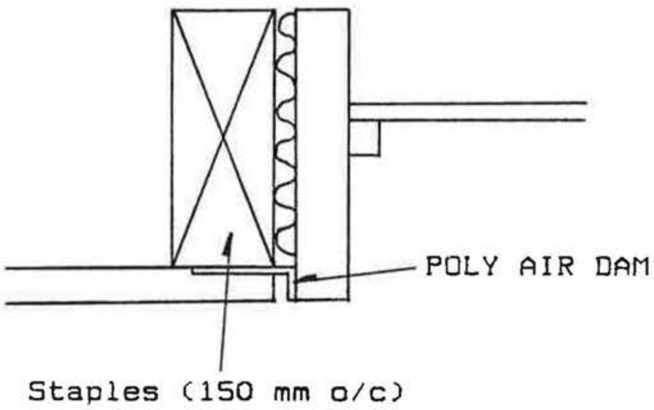
4.4 LABORATORY TESTING OF WINDOW AND DOOR JAMB SEALING TECHNIQUES

Eleven window jamb sealing techniques were tested:

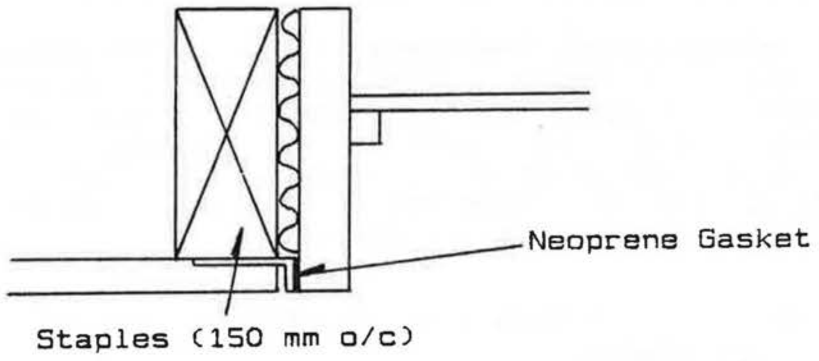
1) The conventional technique, in which the cavity is filled with insulation (Test Section #1). No attempt is made to seal an air/vapour barrier to the window/door jamb. Two methods of sealing this gap which could be considered conventional in Europe (Figures 6 and 7, Page 14) are not included in this test, as the product was not available.



2) PAD stapled to framing members at 6 inch (150 mm) centers (Test Section #2).

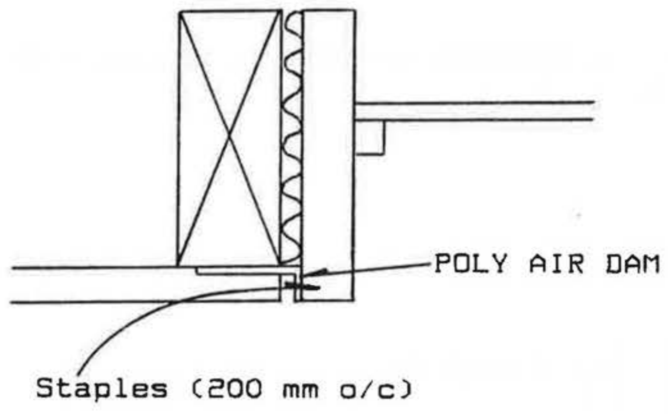


3) PAD with closed cell neoprene gasket applied to jamb contact surface, then stapled to wall framing members (Test Section #3).

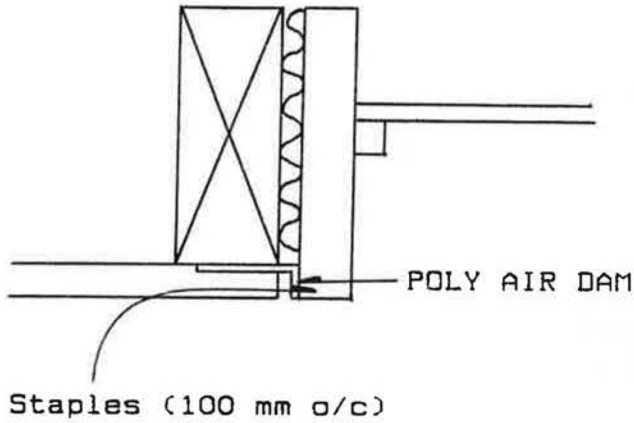


4) Gasketted PAD stapled to wall framing with an overlap of taped section around corner (Test Section #4). This was the corner installation technique used in subsequent tests #'s 5 to 11 (Figure 14, Page 23).

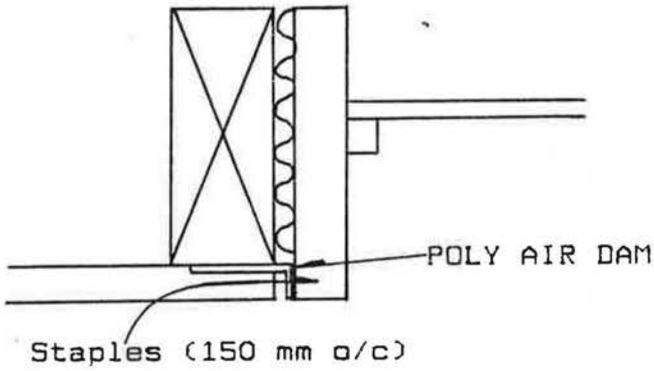
5) PAD stapled to window jamb at 8 inch (200 mm) centers (Test Section #5).



6) Repeat test #5 with staples at 4 inch (100 mm) centers (Test Section #6).

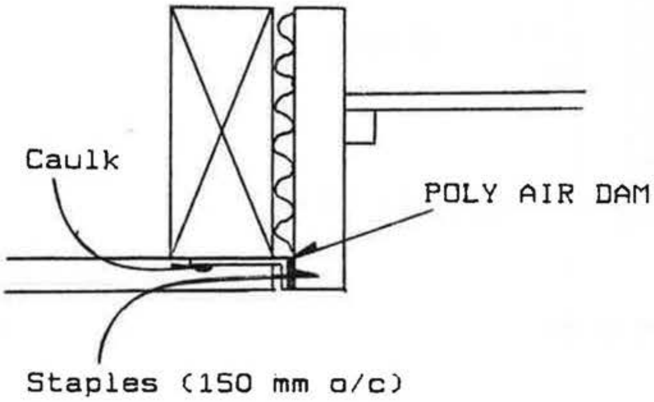


7) Gasketted PAD stapled to window jamb at 6 inch (150 mm) centers (Test Section #7).

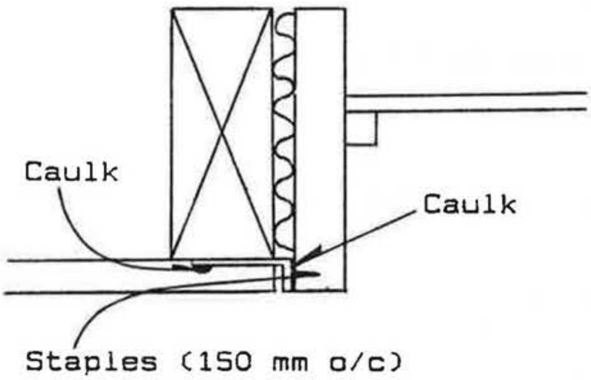


8) Gasketted PAD with caulk applied only to the corner cuts, line 'B-B' (Figure 15, Page 24) (Test Section #8).

9) Gasketted PAD with caulk applied to corner cuts and air/vapour barrier contact surface (Test Section #9).



10) PAD as in installation #9, but replacing the gasket with caulk (Test Section #10).



11) Poly collars as used in R-2000 houses (Figure 10, Page 17) (Test Section #11).

Once the above test procedures were completed, a separate leakage test was performed to determine the effect of drying of framing members on the seal provided by the PAD (Test Sections #12A and #12B). The test panel was stripped of the window and rough opening framing members. These framing members were soaked in a water bath for five days, until the moisture content had risen to 20%. At this point the wood appeared to be saturated, as no further increases in moisture content were noted. Reassembly and leakage testing of configuration #7 was carried out. Corner cuts were made following the butt joint procedure mentioned earlier. After the wood dried to 12%, this test was repeated (moisture content was established using a Delmorst moisture gage). The wetting and drying cycle showed no significant effect as the test results were within the experimental range of error (4).

4.5 TEST RESULTS: WINDOW/DOOR JAMB

Exfiltration test results are illustrated in the graph on page 32 (Figure 17) and Table 1 (Page 33). Each line number on the graph relates to the appropriate test section number (eg: Line #11 - Test Section #11, poly collar). Percentage leakage reduction was compared to Test Section #1 and was tested at 50 Pa, as this is the R-2000 standard testing pressure.

Laboratory test results were as follows:

1) Stapling the PAD to the framing members and not the jamb (Lines #2, #3, and #4) is not particularly

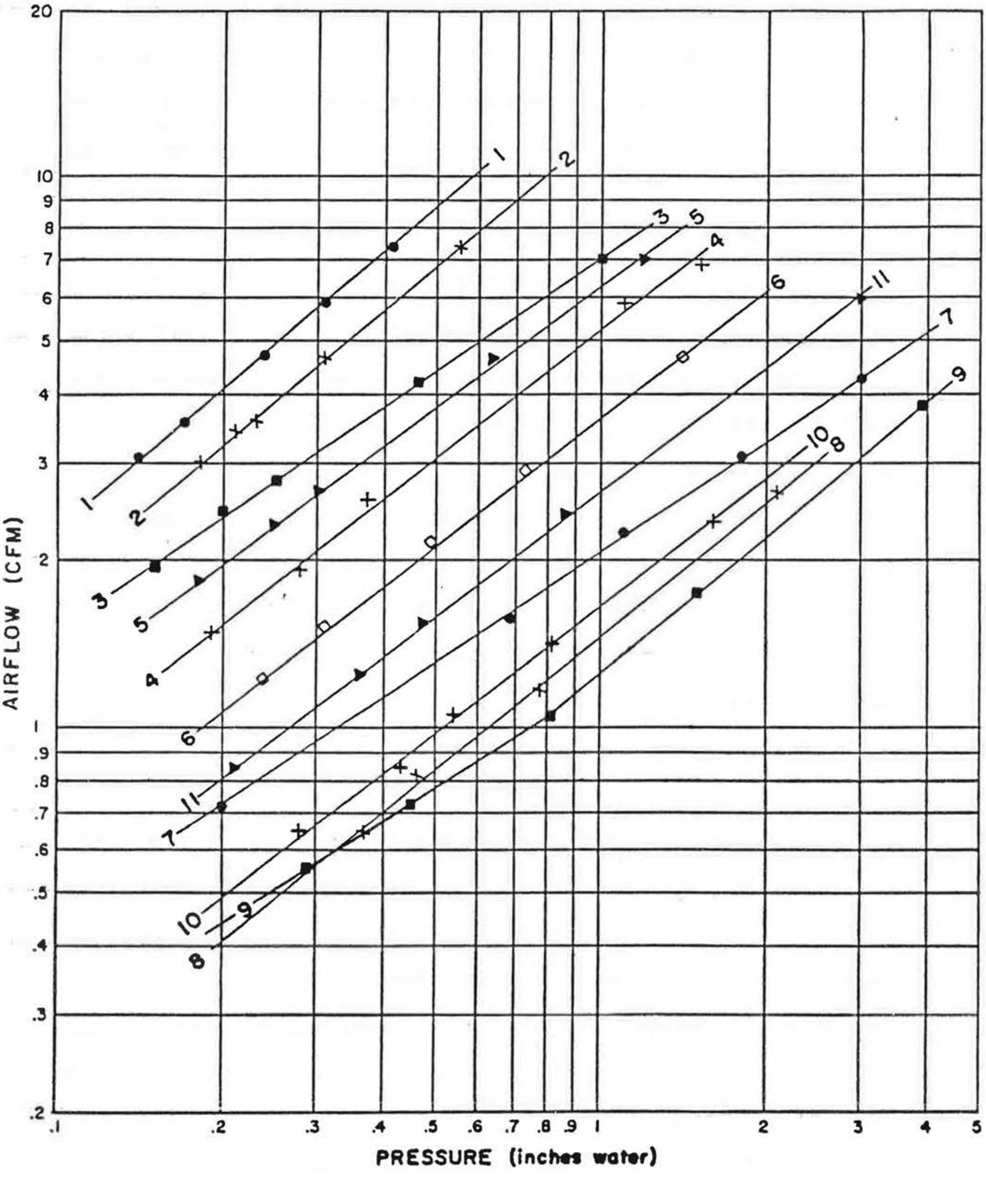


FIGURE 17: Exfiltration test results: window/door jamb.
(0.2 inches of water column = 50 Pa)

TEST SECTION NUMBER	DESCRIPTION	AIR LEAKAGE (CUBIC M/HR/M CRACK LENGTH)	AIR LEAKAGE REDUCTION AS COMPARED TO CONVENTIONAL PRACTISE: TEST SECTION #1 (PER CENT)
1	CONVENTIONAL: R/O SPACE FILLED WITH INSULATION	1.80	-
2	PAD: STAPLED TO WALL FRAME 150 MM O/C, NO CAULK	1.41	21.7
3	PAD WITH GASKET: STAPLED TO WALL FRAME ON 150 MM O/C, NO CAULK	1.06	41.0
4	PAD AS PER #3: WRAPPED AND STAPLED CORNERS, NO CAULK	0.67	62.8
5	PAD: STAPLED TO JAMB 200 MM O/C NO CAULK	0.86	52.2
6	AS PER #5: 100 MM O/C	0.48	73.3
7	PAD WITH GASKET: STAPLED TO JAMB 150 MM O/C, NO CAULK	0.32	82.2
8	AS PER #7: CORNER CUTS CAULKED	0.18	90.0
9	AS PER #8: OUTER EDGE OF PAD CAULKED	0.19	89.4
10	PAD: STAPLED TO JAMB ON 150 MM O/C JAMB CONTACT SURFACE, CORNER CUTS, AND OUTER EDGE OF PAD CAULKED	0.22	87.9
11	POLY COLLAR AS PER R-2000 LITERATURE	0.36	80.0
12A	WET TEST: WOOD MOISTURE CONTENT AT 20 %, PAD AS PER #7: MITRE CORNER JOINT REPLACED BY BUTT JOINT	0.66	63.3
12B	REPEAT 12A: WOOD MOISTURE CONTENT AT 12 %	0.75	58.3

ALL PAD TESTS SUBSEQUENT TO #4 INCORPORATED WRAPPED AND STAPLED CORNERS

TABLE 1: Air leakage test results of test sections at 50 Pa as compared to conventional practice: window jamb.

effective compared to the poly collar (Line #11), but yielded a minimum reduction in air leakage of 21.7% over conventional practice (Line #1).

2) The addition of the neoprene gasket (Line #3) produced a 41% reduction and the corner treatment (Line #4) produced 62.8% reduction. The 21.8% improvement between Lines #3 and #4, due to the corner treatment, is consistent with smoke pencil findings: that no matter what the configuration, considerable leakage took place at corners.

3) The improvement achieved by stapling an ungasketted air dam to the jamb, at 8 inch (200 mm) centres, is shown by Line #5 (52.2% leakage reduction), and performance approaching that of the poly collar was achieved by placing the staples at 4 inch (100 mm) centers (Line #6). Both these findings were duplicated by results of the rim joist testing which is reported on page 56.

4) Using no caulking, the gasketted PAD, at 82.2% leakage reduction, surpassed poly collar effectiveness (Line #7).

5) Caulking the corner cuts only (Line #8) points clearly to the role of that location in air leakage, with airtightness levels improving a further 7.8%.

6) The butt joint style corner showed poor performance, as a tight corner joint could not be obtained. The corner gap was the thickness of the PAD gasket, and to eliminate this opening would require considerable effort.

7) Line #9 illustrates a marginal loss of 0.6% from the addition of caulk to the outside edges of the Poly Air Dam, and was replicated in the rim joist testing. The 1.5% improvement offered by a gasket, as opposed to caulk, can be seen in a comparison between Lines #9 and #10. Further, the gasket may be only marginally better than caulk at controlling leakage but there is concern about the service life of caulk (6,8).

4.6 CONCLUSIONS

It is well known that the poly collar is an effective way to seal the window or door jamb to the air/vapour barrier. However, this is a time consuming, expensive job that must be accomplished before the window or door is installed in the wall frame. Extensive caulking is required both before and after the window or door is in position. The gasketed PAD installed without caulking surpasses the poly collar in performance for a lower incremental cost ($6.30 as compared to $11.00 per opening).

5.0 REVIEW OF FLOOR FRAME SEALING TECHNIQUES AND TESTING

5.1 INTRODUCTION

Urethane foam spray, caulk, foam gaskets of various shapes, and strips of mineral wool insulation enclosed in plastic film are used in different parts of the world to seal the bottom plate of the exterior wall to the subfloor. This does nothing to seal the air/vapour barrier to the wall frame, or to stop leakage at the top of the foundation wall/rim joist junction. A system developed for use in SEE houses, utilizes a poly wrap installed around the rim joist and sealed to the air/vapour barrier. This is the most effective system, but is also the most expensive to use. A market niche appears to exist for a system which is low in cost, but is capable of providing a seal comparable to the poly wrapped rim joist.

5.2 RIM JOIST SEALING TECHNIQUES

5.2.1 COSTING TECHNIQUES

Comments in Section 4.2.1 (Page 12) which relate to material and PAD costs, labor rates, and installation times also apply to this section. Where specific quantities are used, they are indicated.

5.2.2 CAULK

Caulk is often used to seal the subfloor to the bottom plate of the wall frame. It can usually be accomplished for incremental cost in the $44.00 range (1 hour plus $32.00 for 4 tubes of acoustical sealant). This can provide an effective seal, but does nothing to stop air flow at the other places indicated. Extensive caulking can be undertaken which can virtually eliminate leakage (Figure 18, Page 38), but this is time consuming and expensive. Caulk drying and hardening and building component movement can drastically reduce the effectiveness of this seal. This extensive caulking is uncommon.

5.2.3 POLYURETHANE FOAM

Polyurethane foam (Figure 19, Page 39) can be sprayed into the gap between the bottom plate and the subfloor to both insulate and seal the opening (6). This requires blocking up the bottom plate, making the labor cost high. This technique is uncommon in North America.

5.2.4 RUBBER AND PLASTIC GASKETS

Gaskets and rods of various materials are widely used to seal the subfloor to the bottom plate (6). Their incremental costs are low and installation is generally easy (Figure 20, Page 39). Foam sill plate gaskets are priced in the $0.10 to $0.14 per lineal foot range. Since they must be placed before the wall is erected, there is potential for damage.

5.2.5 FIBREGLASS STRIP ENCLOSED IN PLASTIC FILM

This product (Figure 21, Page 39) is available in

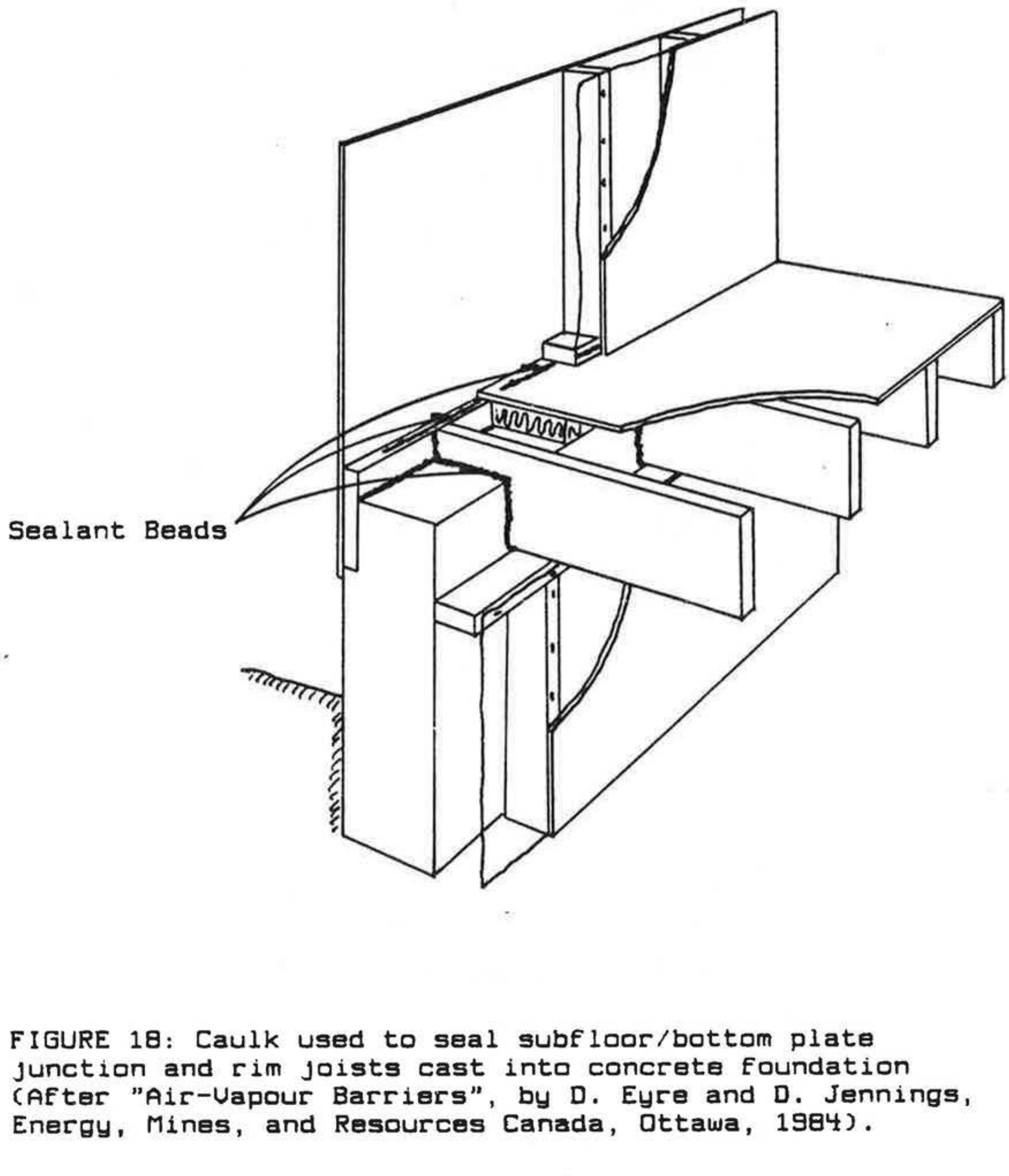


FIGURE 18: Caulk used to seal subfloor/bottom plate junction and rim joists cast into concrete foundation (After "Air-Vapour Barriers", by D. Eyre and D. Jennings, Energy, Mines, and Resources Canada, Ottawa, 1984).

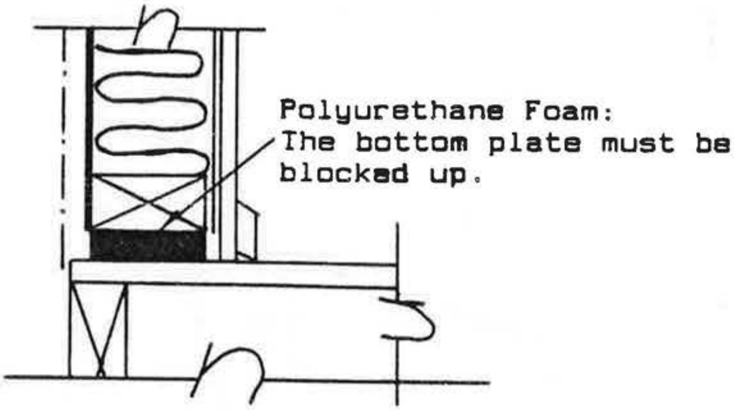


FIGURE 19: Sealing subfloor/bottom plate junction with polyurethane foam. **

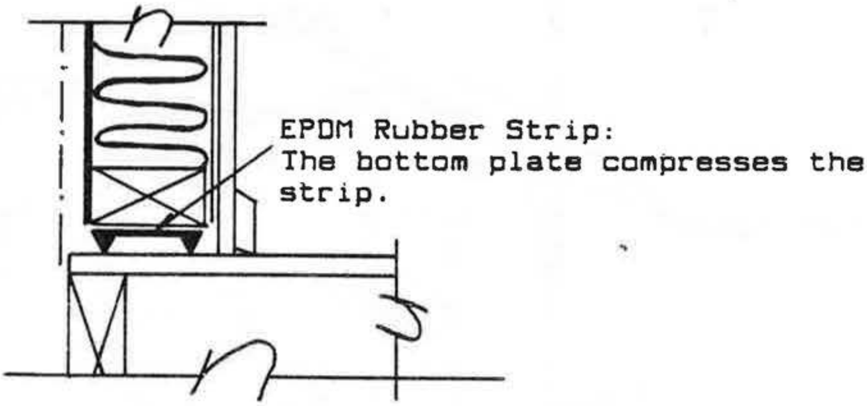


FIGURE 20: Sealing subfloor/bottom plate junction with plastic or rubber gasket. **

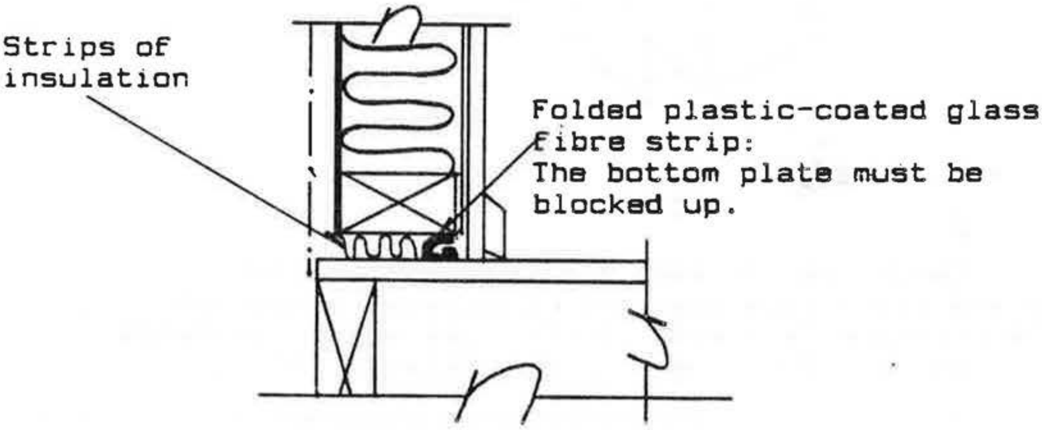


FIGURE 21: Sealing subfloor/bottom plate junction with glass fibre enclosed in plastic film.**

** : After "Air Infiltration Control in Housing: A Guide to International Practice", by A. Elmroth and P. Levin, Swedish Council for Bulding Research, Stockholm, Sweden, 1983.

Europe and provides reasonably good performance (6). The wall must be blocked up to allow for installation. Blocking creates some problems for sealing.

5.2.6 POLY WRAPPED RIM JOISTS

This technique, used in super energy efficient (SEEH) and R-2000 houses, effectively prevents leakage at both the subfloor and top of the foundation wall (Figure 22, Page 41). Materials consist of poly, caulk, and staples. Procedures are described in detail elsewhere (8,9,10), but are essentially as follows: a poly strip is attached to the top of the foundation wall and the floor framing is installed. The poly strip is wrapped around the rim joist, and the exterior walls are erected and placed on top of the strip. This poly strip is then attached to the air/vapour barriers on the foundation and exterior frame walls. The poly is prone to damage during construction, and it inhibits water vapour transfer. A vapour barrier should be located on the warm side of insulation, so rigid insulation is normally placed outside the poly. An installation, including labor (2 men) and materials (caulk, staples, and poly), in a 1270 square foot house (145 LF of rim joist) has an incremental cost of $264.00, not including insulation. Styrofoam insulation adds $90.00, making the incremental cost $354.00. The poly and insulation combination can be replaced with Tyvek, which is permeable to water vapour, for $302.00.

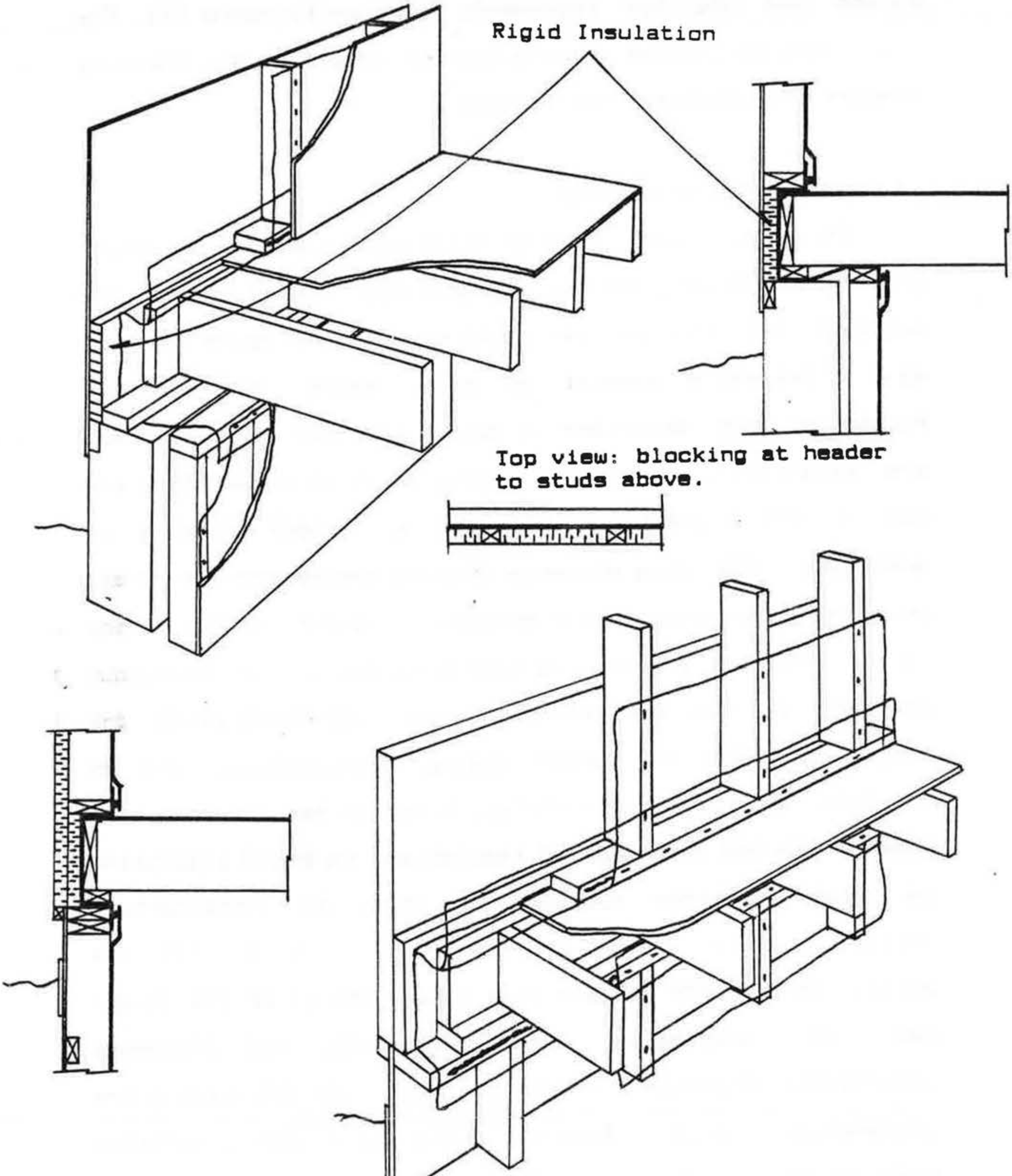


FIGURE 22: Poly wrapped rim joist used to seal subfloor/bottom plate and top of foundation wall to rim joist: as used in R-2000 houses (After "Air-Vapour Barriers", by D. Eyre and D. Jennings, Energy, Mines, and Resources Canada, Ottawa, 1984).

5.2.7 AIRTIGHT DRYWALL APPROACH

As an alternative to the polyethylene air/vapor barrier, the Airtight Drywall Approach (ADA) is being tested (11,12). Using this approach, a foam plastic gasket or rod is used to form an airtight joint between the framing members and drywall (Figure 23, Page 43). A gasket is installed beneath the bottom plate to contact the subfloor and on the face of the plate to contact the drywall. This forms an effective seal and the incremental costs for material are about $0.14 per lineal foot. Achieving a good seal between the foundation and the rim joist can be more difficult. This seal can either be accomplished with gaskets or by notching drywall sheets to fit between the floor joists and to make contact with the bottom of the subfloor (Figure 24, Page 44). The gyproc is then caulked to the floor joists. This requires tighter than usual tolerances for the gyproc installation. If gaskets are used at the 6 locations as shown in Figure 23 (Page 43), an incremental cost of $109.00 for material ($61.00) and labor (4 hours) is estimated. If the notched drywall approach is used, an incremental cost of $427.00 for materials ($268.00 for gyproc gaskets and caulk) and labor ($159.00: hanging and extra cutting) is estimated. This approach does yield a drywalled basement area, which is marketable. There is some concern as to the overall effectiveness and longevity of this ADA Approach (6).

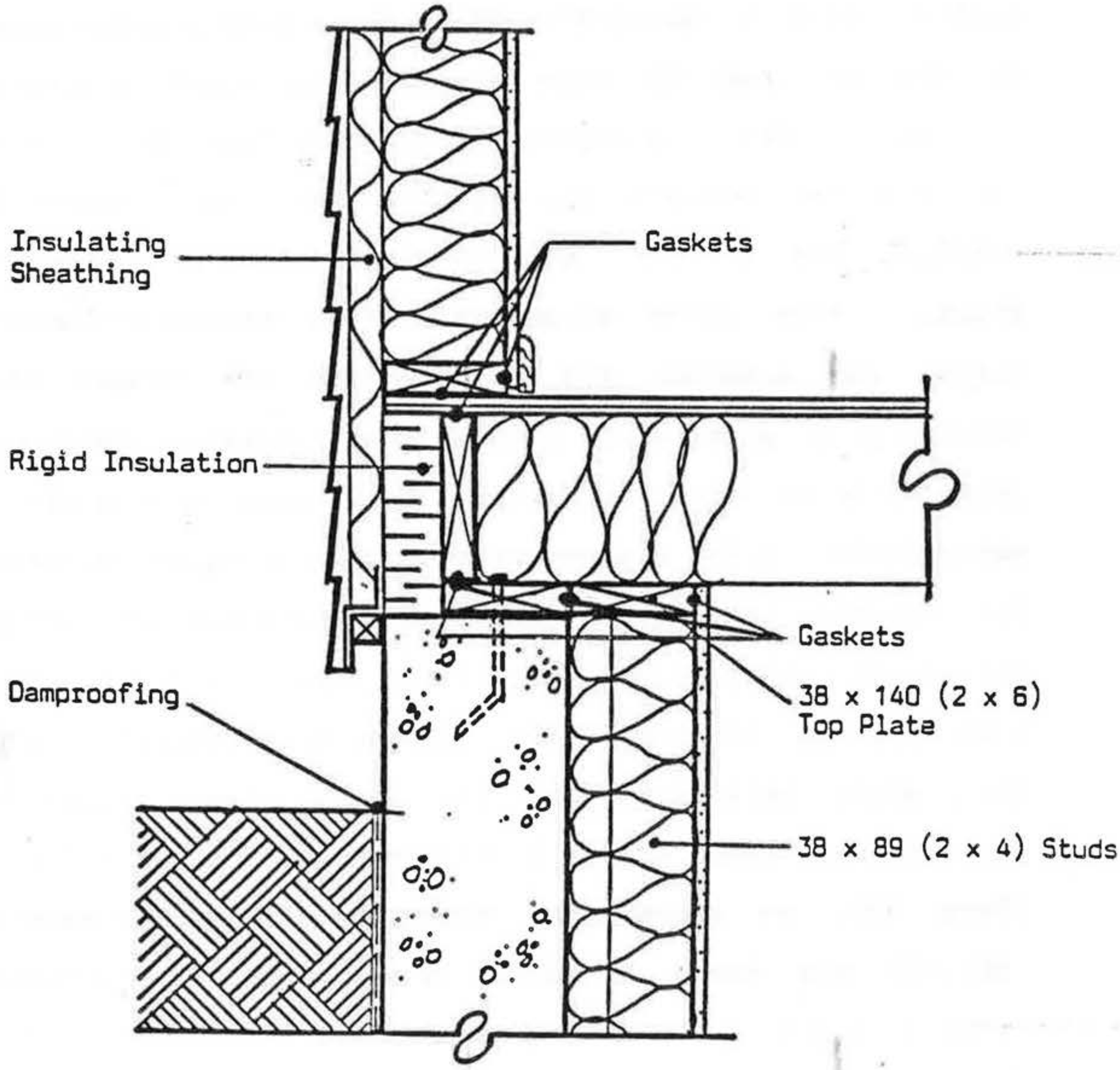


FIGURE 23: Airtight Drywall Approach to sealing rim joist using gaskets (Extracted from "Construction Experience Using the Airtight Drywall Approach", by J. Lstiburek, Alberta Department of Housing, Edmonton, 1985).

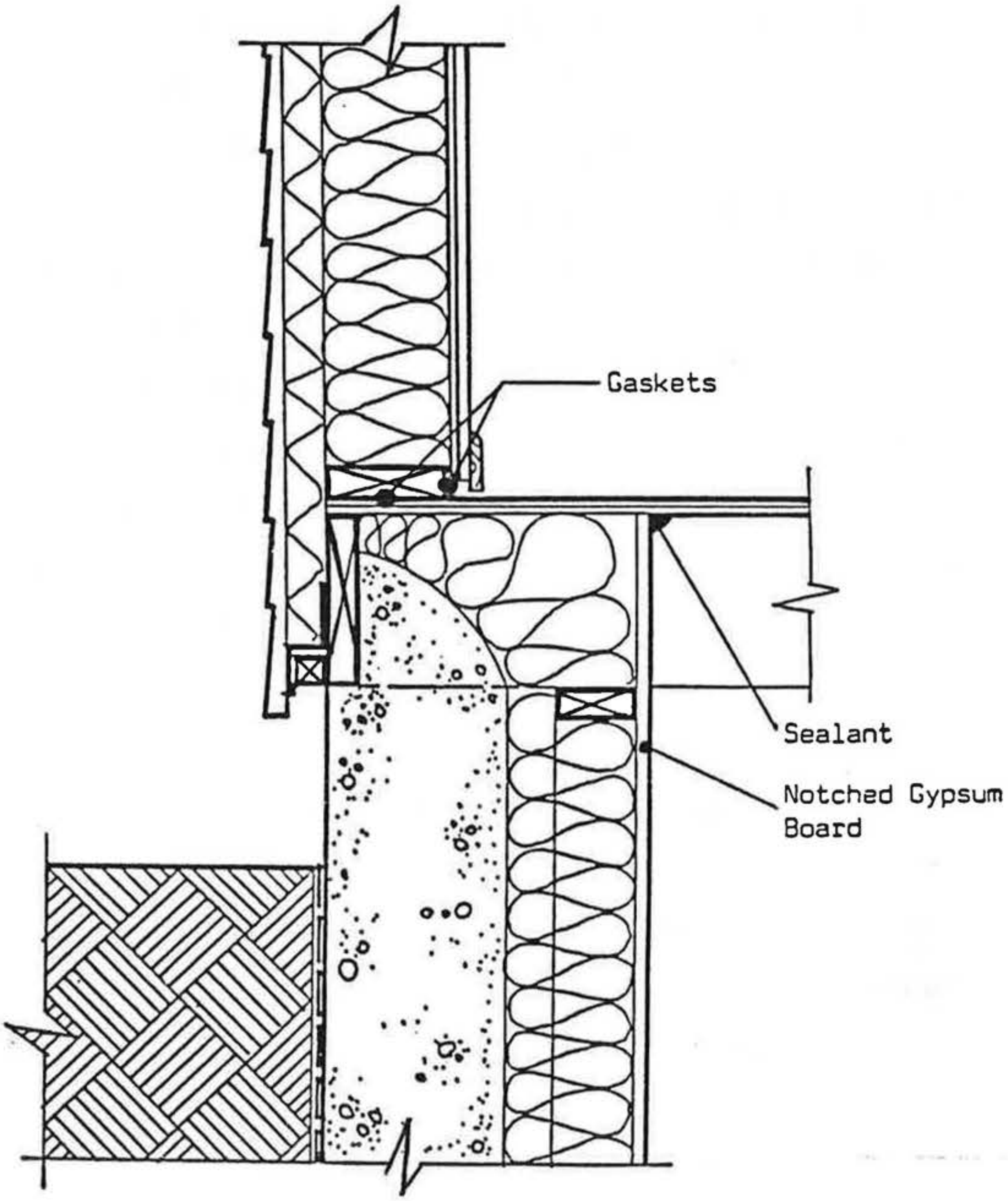


FIGURE 24: Airtight Drywall Approach to sealing rim joist using gaskets and notched drywall (Extracted from "Construction Experience Using the Airtight Drywall Approach", by J. Lstiburek, Alberta Department of Housing, Edmonton, 1985).

5.3 POLY AIR DAM INSTALLATION PROCEDURES: RIM JOIST

Figure 25 (Page 46) shows typical installations at the rim joist. The air dam must be installed prior to application of interior cladding and, if applicable, the poly air/vapour barrier.

Floor framing and exterior wall construction proceed in the conventional manner. Once walls are erected, the PAD is placed along the bottom plate and stapled to the subfloor (Figure 26, Page 47). Staples are placed 6 inches (150 mm) on center. This application assumes a wooden subfloor, but if the floor is concrete, staples are driven into the bottom plate (Figure 27, Page 47).

An air dam is butted into a corner and fastened as described. A second air dam is butted into the same corner, but perpendicular to the first PAD length. After installation, there is a double thickness of material at the corner which overlaps. Using a chisel, a cut is made through both thicknesses of material at a 45 degree angle, and the excess discarded. Only hand pressure is required to make the cut. This procedure insures the two cut surfaces will match and the corners will be flush. Ends are butted together along straight wall runs. Interior cladding, trim, and paint are now applied in the conventional manner.

Tools commonly available on any jobsite are used to install PADs. Cutting and trimming are accomplished with a utility knife, chisel, and side cutters. A hand, electric, or air powered stapler capable of handling 1/4 to 3/8 X 3/8 inch staples is used for attachment. Caution should be used

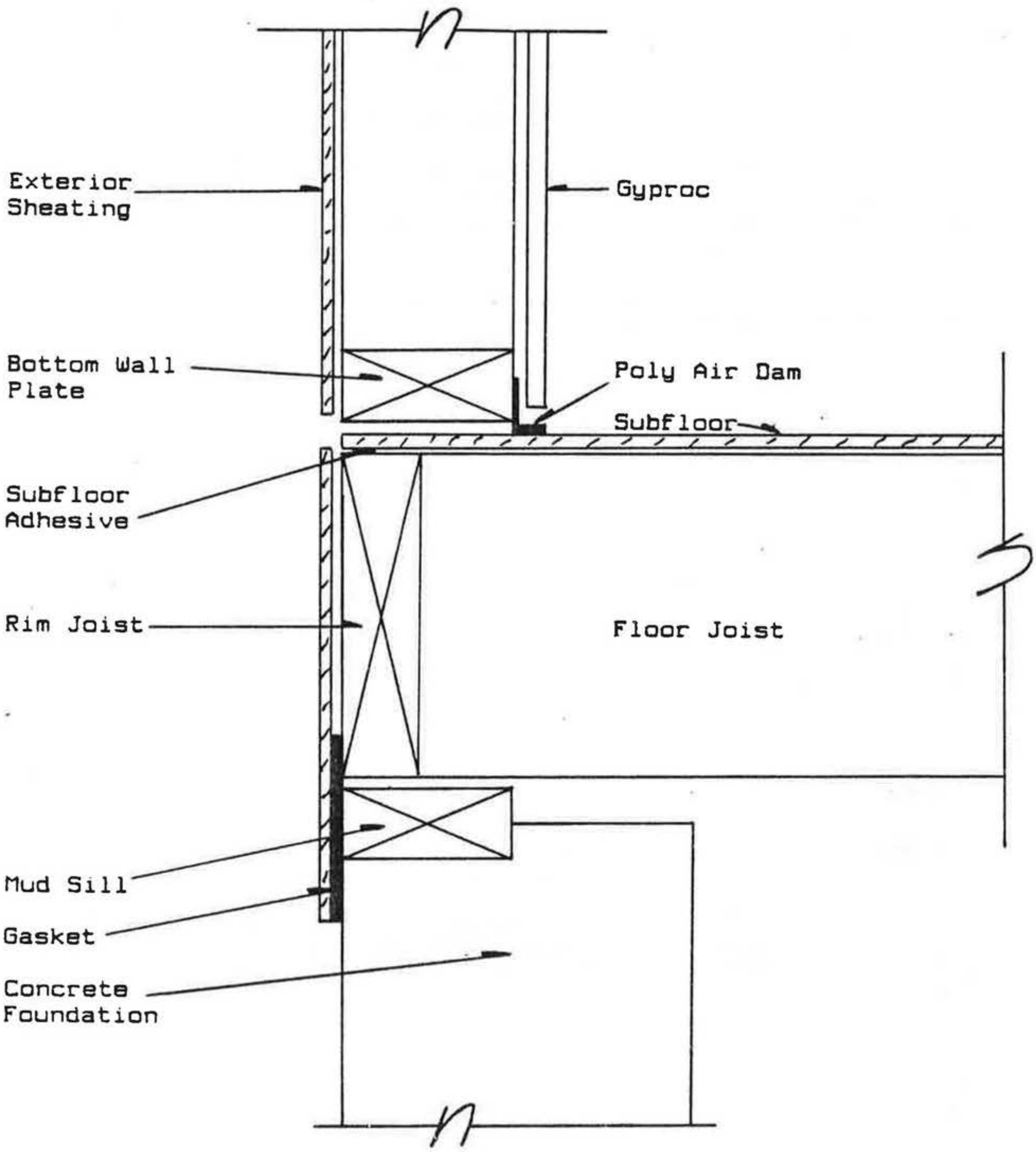


FIGURE 25: Poly Air Dam and sill plate gasket used as a system to stop air leakage at the rim joist.

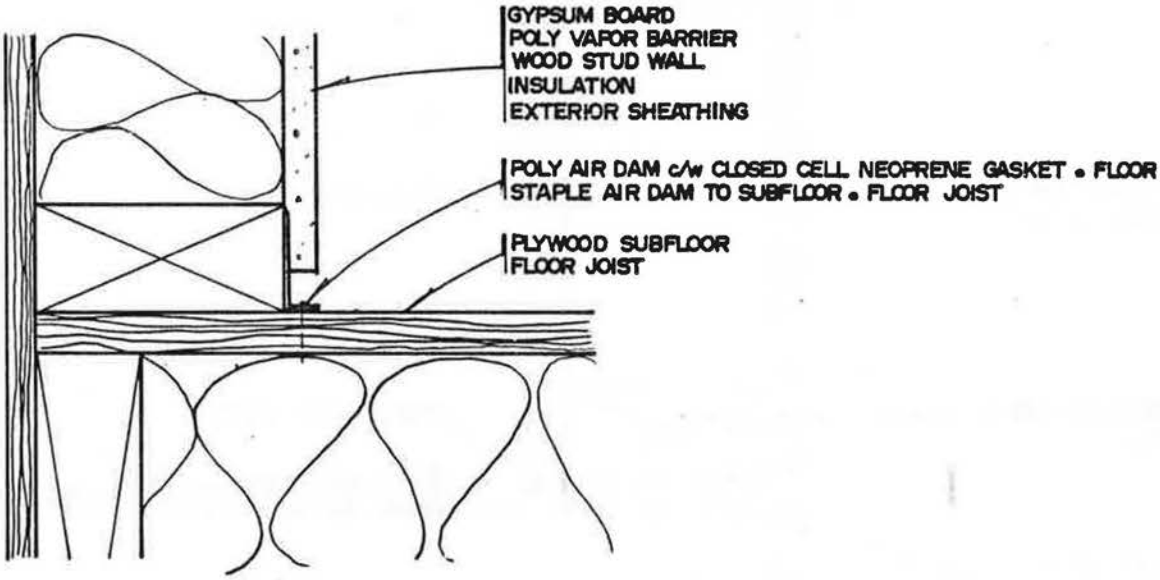


FIGURE 26: Poly Air Dam installed at sill plate on wooden subfloor.

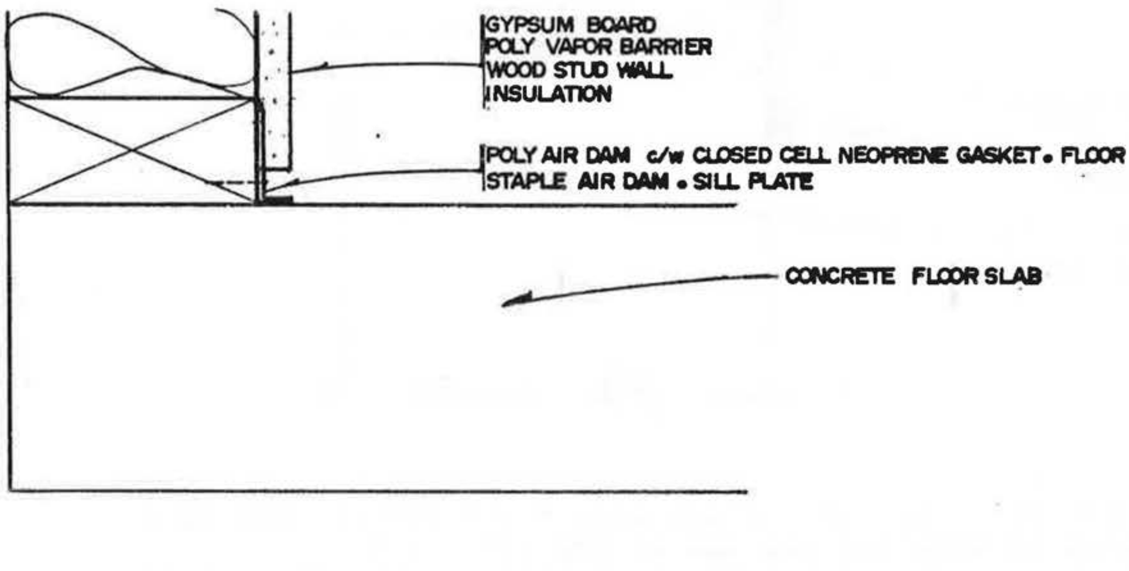


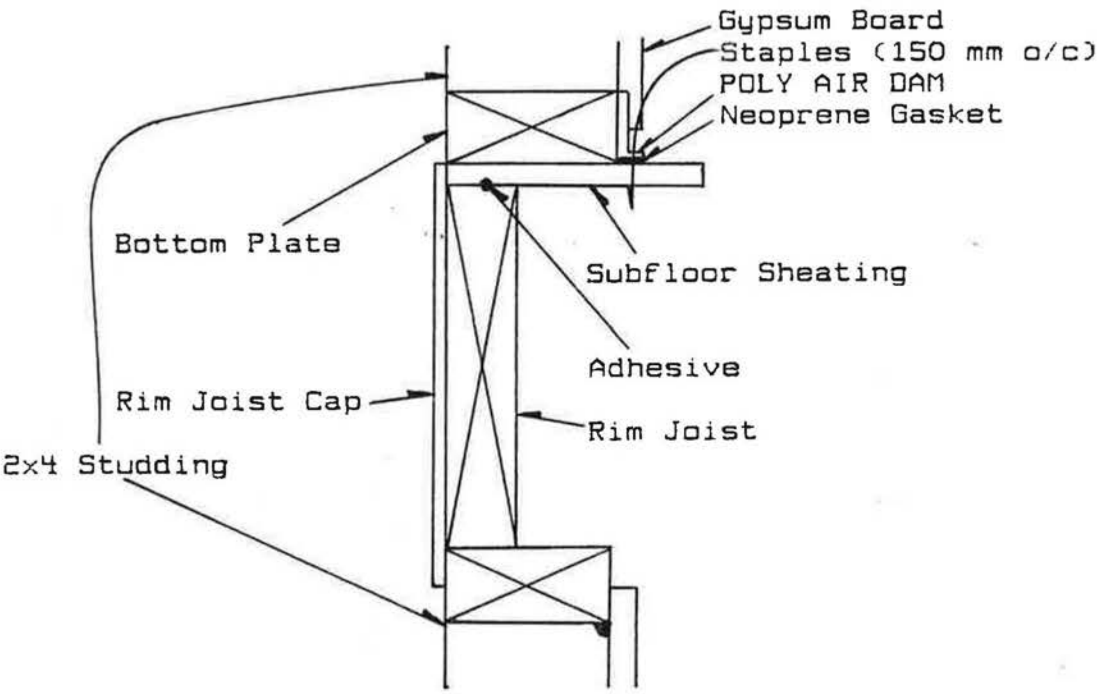
FIGURE 27: Poly Air Dam installed at sill plate on concrete subfloor.

to insure that the stapler does not drive the staples entirely through the PAD material.

5.4 LABORATORY TESTING OF RIM JOIST SEALING TECHNIQUES

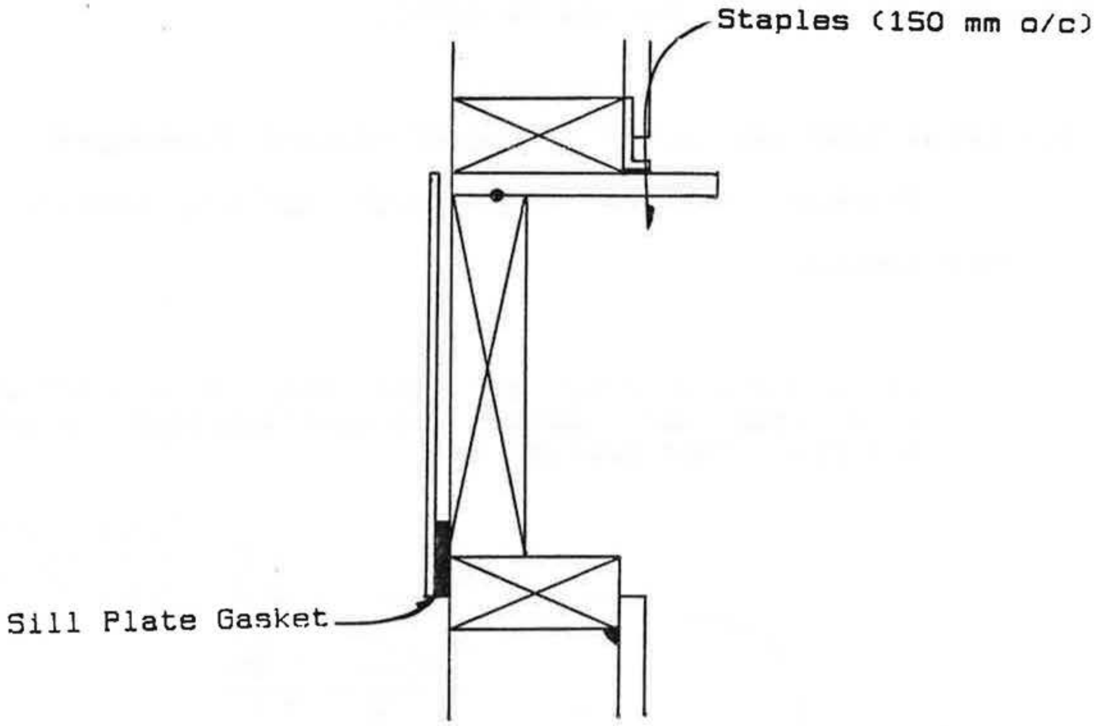
Thirteen subfloor rim joist sealing configurations were tested:

1) Gasketted Poly Air Dam stapled to subfloor at 6 inch (150 mm) centers to seal subfloor/bottom plate junction (Test Section #1).

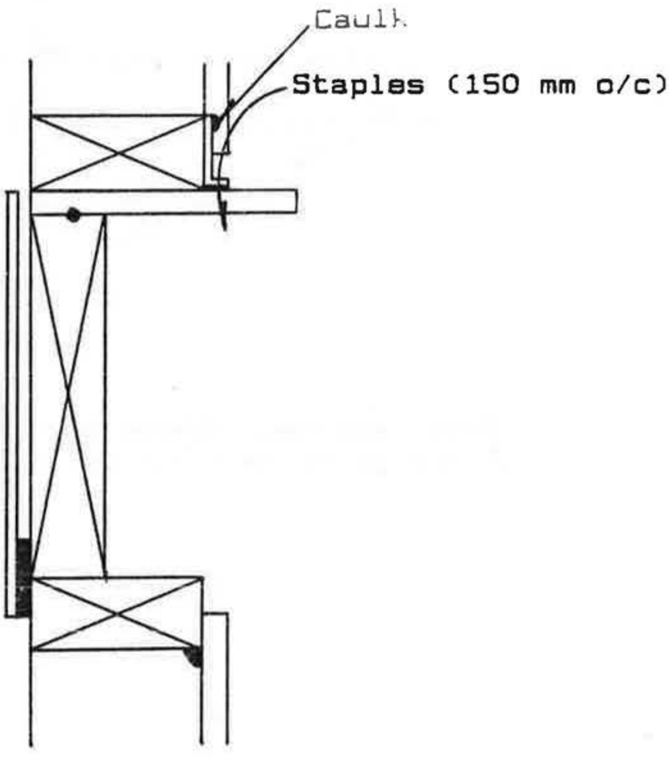


This typical cross section of the test panel shows no floor joist as none was included.

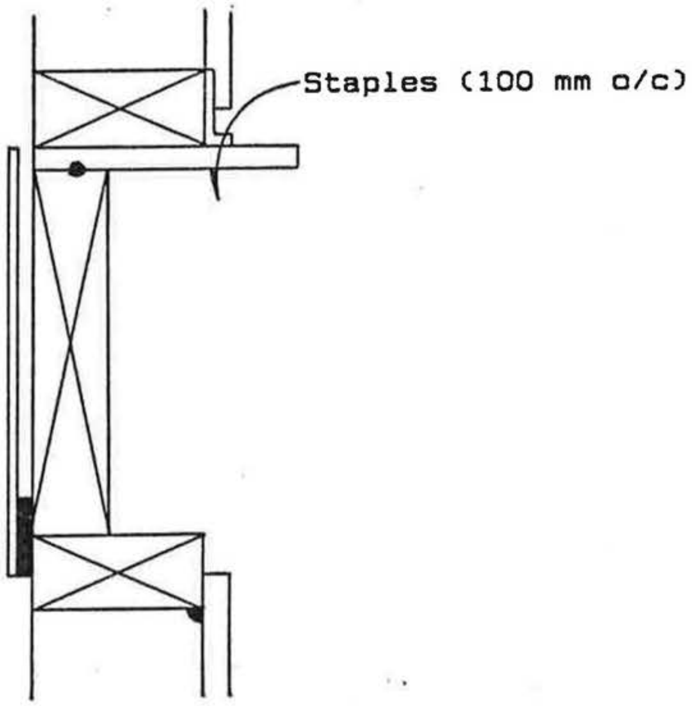
2) Poly Air Dam as in #1, with sill plate gasket installed (Test Section #2).



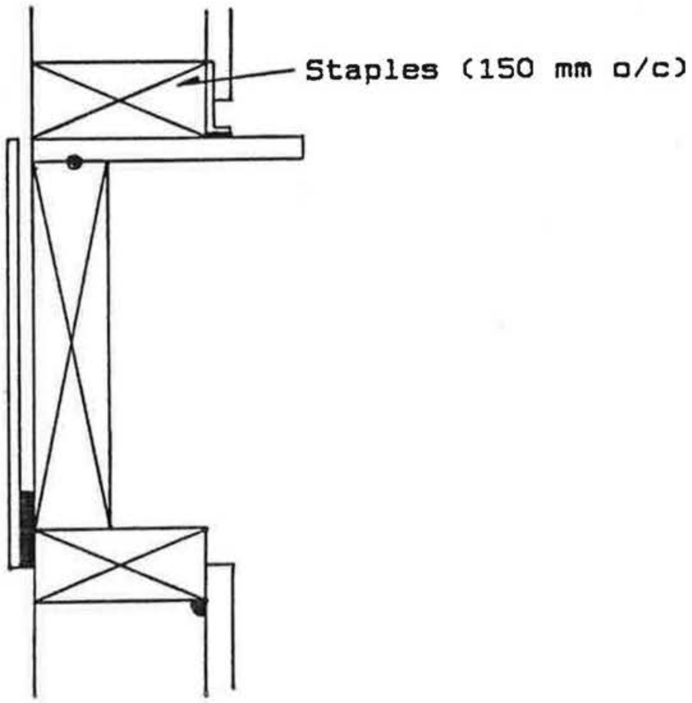
3) As in #2 with PAD caulked to air barrier (Test Section #3).



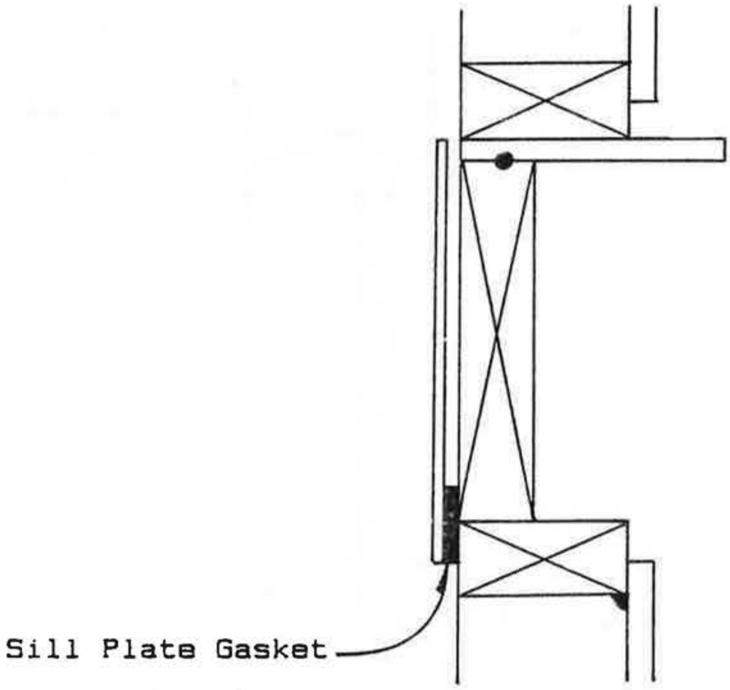
4) As in #2 without PAD gasket, stapled to subfloor at 4 inch (100 mm) centers (Test Section #4).



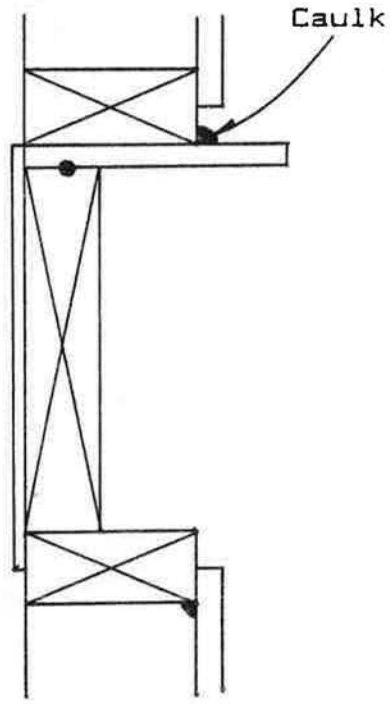
5) As in #2, deleting staples to subfloor and stapling PAD at 6 inch (150 mm) on center to bottom plate (Test Section #5).



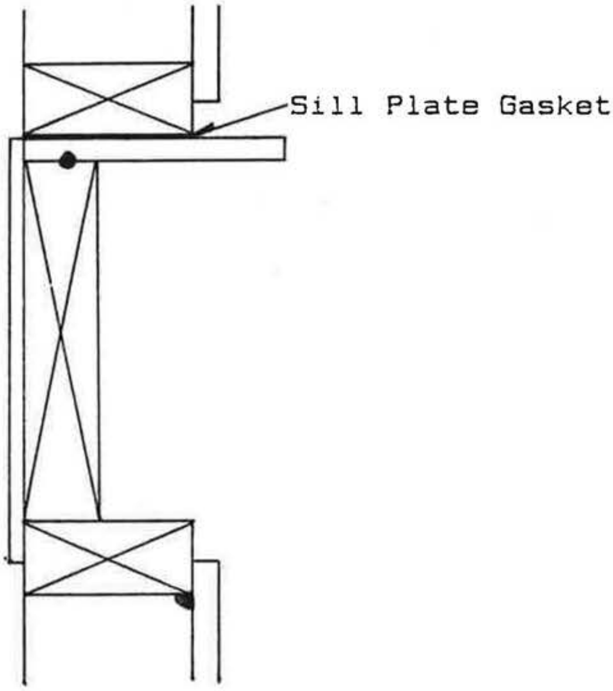
6) Sill plate gasket applied vertically to top of foundation wall/rim joist junction (Test Section #6).



7) Subfloor/bottom plate junction only caulked (Test Section #7).



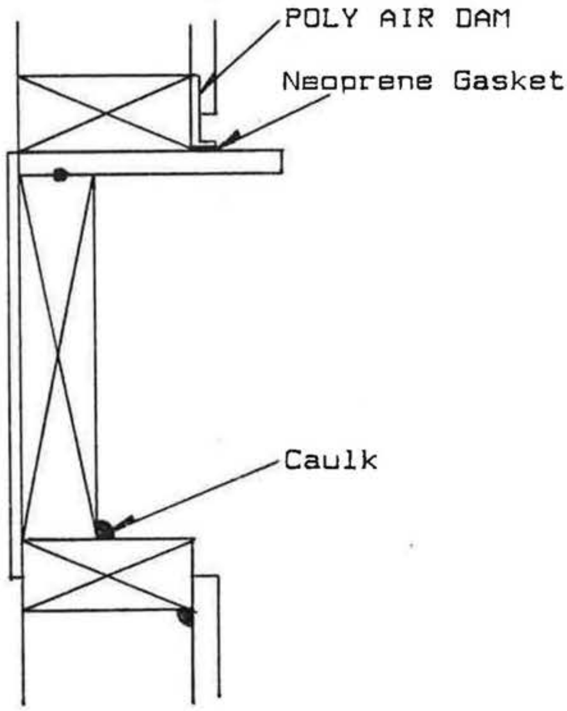
8) Subfloor/bottom plate junction sealed with the use of a sill plate gasket (Test Section #8).



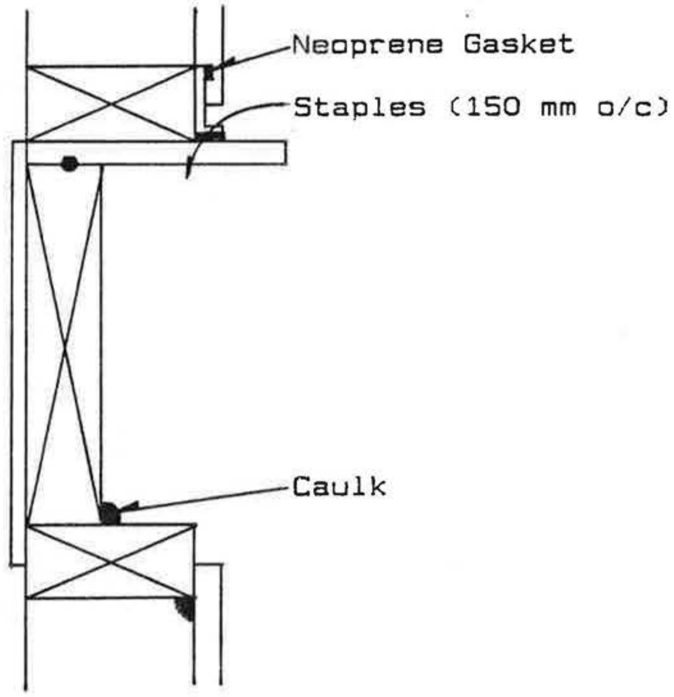
9) Poly wrapped rim joist as used in R-2000 houses (Figure 22, Page 41) (Test Section #9).

10) Repeat of test #1 (Test Sections #10A and #10B).

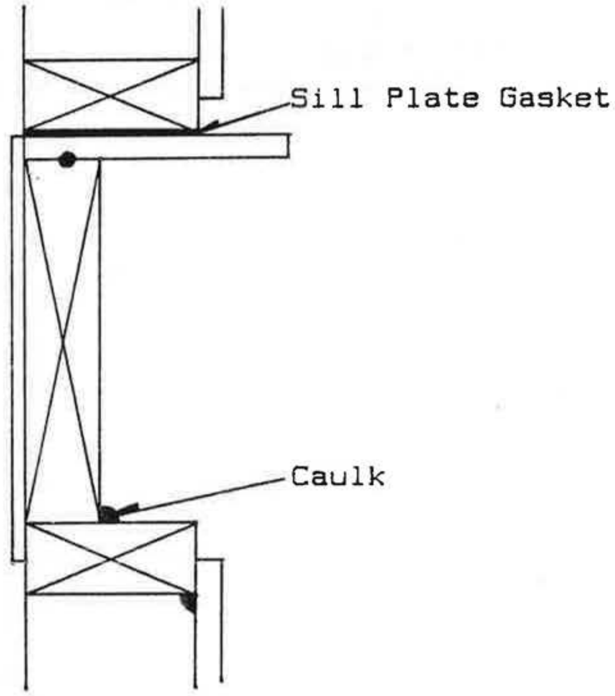
11) Repeat Test Section #1, caulk bottom of rim joist (Test Sections #11A and #11B).



12) As in #11B, add gasket to top edge of Poly Air Dam (Test Section #12).



13) Repeat test #8, caulk bottom of rim joist (Test Section #13).



Tests #1 to #9, and #10 to #13 were run as sets on different days. During test #8, extreme tightness was noted while installing the rim joist with the sill plate gasket in place. Test #9 was run and the results assessed. Because of the tightness of the installation in test #8, it was felt that the joint at the bottom of the rim joist had been closed. Tests #10 to #13 were run.

Test #10 was run to establish a baseline for comparison to test #1. The effect of the gap at the bottom of the rim joist was measured in test #11. High levels of leakage were noted on tests #10A and #11A; dried caulk on the backside of the component simulating the gyproc was determined to be the cause. Tests #10B and #11B involved cleaning and re-testing. Test #12 was added to determine the effect of a gasket on the top edge of the air dam.

To compensate for the 1/4 inch thickness of the sill plate gasket, during test #13, 3/16 inch of material was cut from the bottom edge of the rim joist. After installation, the rim joist was shimmed upward 1/8 inch. The plate above the gasket was blocked, to straighten it and achieve consistent contact with the gasket throughout its length. To eliminate the bottom joint in test #13, it was caulked as in tests #11 and #12.

5.5 TEST RESULTS: RIM JOIST

Exfiltration test results are illustrated in Figure 28 (Page 55), and Table 2 (Page 56). Each line number on the graph relates to the appropriate test section number (eg:

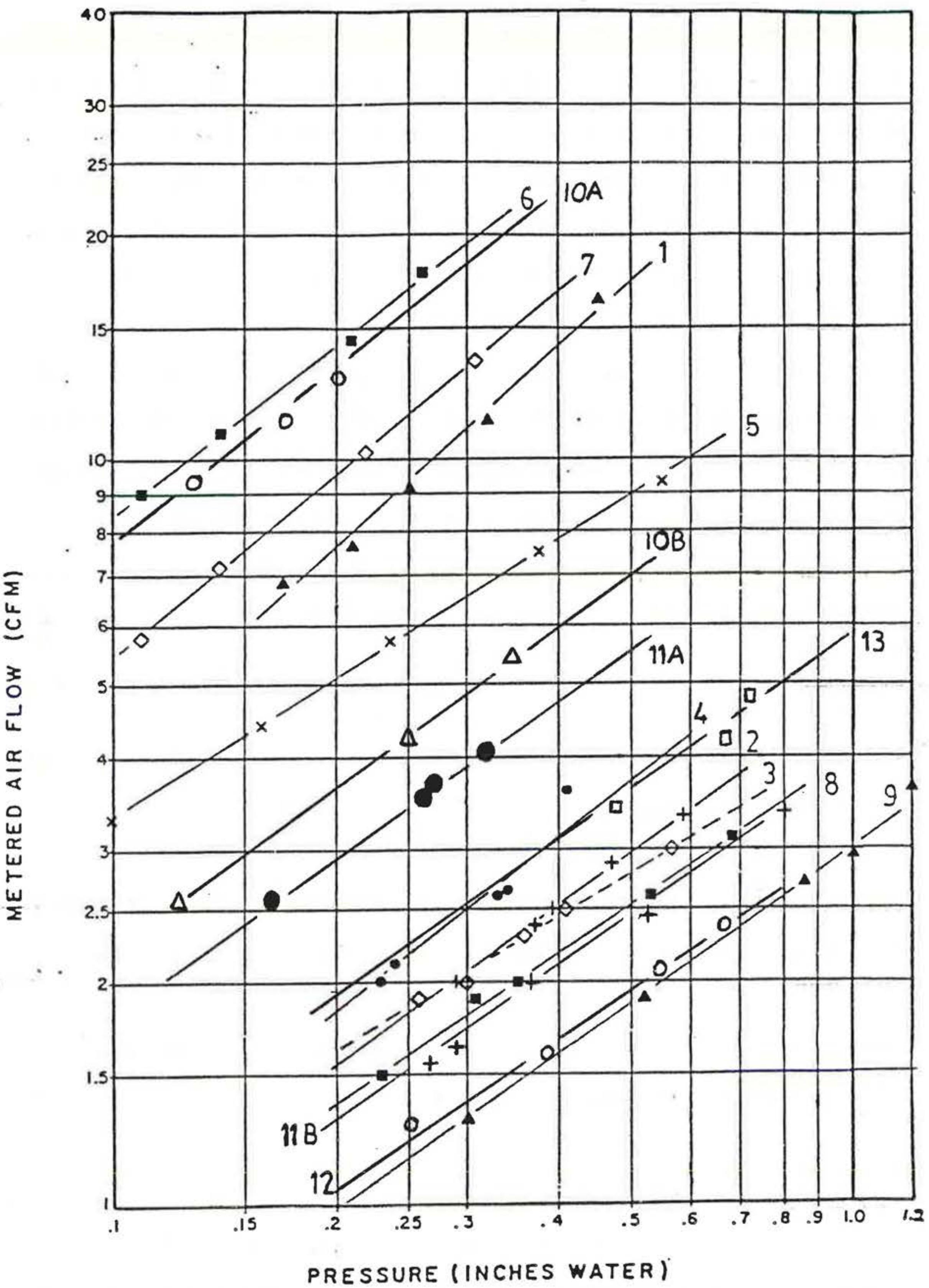


FIGURE 28: Exfiltration test results: rim joist.
(0.2 inches of water column = 50 Pa)

TEST SECTION NUMBER	DESCRIPTION	AIR LEAKAGE (CUBIC M/HR/M CRACK LENGTH)	AIR LEAKAGE REDUCTION AS COMPARED TO CONVENTIONAL PRACTISE:TEST SECTION #7 (PER CENT)
1	GASKETTED PAD STAPLED TO SUBFLOOR 150MM O/C	5.54	17.4
2	PAD AS #1 WITH SILL PLATE GASKET AS #6	1.08	83.9
3	AS #2 WITH TOP EDGE OF PAD CAUKED	1.13	83.2
4	AS #2, DELETE PAD GASKET, STAPLED 100MM O/C	1.30	80.6
5	AS #2, PAD STAPLED TO BOTTOM PLATE 100MM O/C SUBFLOOR STAPLES DELETED	3.62	46.1
6	SILL PLATE GASKET INSTALLED VERTICALLY AT BOTTOM OF RIM JOIST	10.00	-
7	CONVENTIONAL PRACTICE: CAULK SUBFLOOR/BOTTOM PLATE JUNCTION ONLY	6.71	-
8 *	CONVENTIONAL PRACTICE: SILL PLATE GASKET USED TO SEAL SUBFLOOR/BOTTOM PLATE JUNCTION	1.00	*
9	POLY WRAPPED RIM JOISTS AS PER R-2000 LITERATURE	0.71	89.4
10A	REPEAT TEST #1	9.34	-
10B	REPEAT TEST #10A, CLEAN HARDENED CAULK FROM BACK OF GYPROC	2.53	-
11A	REPEAT TEST #1, CAULK BOTTOM OF RIM JOIST	2.07	-
11B	REPEAT TEST #11A, CLEAN HARDENED CAULK FROM BACK OF GYPROC	0.93	86.1
12	AS #11B, ADD GASKET TO TOP EDGE OF POLY AIR DAM	0.76	88.7
13	REPEAT TEST #8, CAULK BOTTOM OF RIM JOIST	1.34	80.0

* TEST 8: RIM JOIST COMPONENTS WERE TIGHT FITTING BEFORE THE INCLUSION OF THE SILL PLATE GASKET. AFTER ITS INSTALLATION, JOINT TIGHTNESS WAS EXTREME. TEST WAS RERUN. FOR FURTHER DISCUSSION, SEE TEXT ON PAGE 54.

TABLE 2: Air leakage test results of test sections at 50 Pa as compared to conventional practice: rim joist.

Line 9 - Test Section #9, poly wrapped rim joist). Percentages of leakage reduction were calculated at 50 Pa, as this is the R-2000 standard testing pressure.

Laboratory test results were as follows:

1) Leakage through the bottom plate/subfloor junction is indicated in Test Section #6. This junction was caulked, as in conventional construction (Test Section #7), and used as the baseline for comparison of test results.

2) With no attempt being made to seal the bottom of the rim joist, the gasketted PAD reduced leakage 17.4% (Line #1). Caulk, which forms an excellant seal initially, can deteriorate rapidly over time. The PAD will not. The difference in air tightness is probably due to the PAD's ability to seal the drywall to whatever is used as an air barrier.

3) The importance of the seal between the air barrier and its support is demonstrated in comparing tests #10A and #10B, and #11A and #11B (see respective Line numbers). Both "A" tests had dramatically worse leakage than the succeeding "B" test. This difference was due to dried caulk on the backside of the panel which simulated the gyproc interior wall cladding. For the "B" tests, these panels were cleaned.

4) A second conventional technique, the sill plate gasket, was found to be less effective than the PAD (Line #11B vs. Line #13). Much work was required to get the sill plate gasket to perform at this level (See discussion of test #8 in Section 5.4 on Page 54).

5) The poly wrapped rim joist, as used in SEEH housing, produced the greatest leakage reduction (89.4%, Line #9), but was only 5.5% less than the PAD system (83.9%, Line #2). It was noted by Larry Clarke of LJ Rida Construction in Calgary, an experienced R-2000 builder, that this result would not hold true outside of the laboratory. His feeling was that, because of the difficulty of installing the poly wrapped joist on site, it would exhibit more leakage than the PAD system.

6) Caulking the top edge of the PAD to the air barrier marginally increased leakage (0.7%) over the uncaulked configuration (83.2%, Line #3).

7) When a gasket was used, instead of caulk, performance increased only marginally over the

uncaulked version (Line #11B vs. Line #12).

8) The ungasketted version of the PAD exhibited excellent performance in reducing leakage 80.6% (Line #4). These results were obtained by spacing the staples 4 inches on center, as compared to 6 inches on center for the gasketted version. Using the gasketted version would cut down on site installation time and allow a greater margin for variations in workmanship and material roughness.

9) Stapling the gasketted PAD to the bottom plate is about half as effective as stapling to the subfloor (46.1% reduction, Line #5), and could only be recommended where stapling to the subfloor is impossible (eg: concrete subfloor). This result was corroborated during window jamb testing.

5.6 CONCLUSIONS

The poly wrap technique effectivly seals the rim joist against air leakage. This is a time consuming, expensive job that must be started before the floor framing is installed and completed after the exterior walls are framed. Extensive caulking is required. Sealing this area using the PAD system gives comparable performance at a much lower incremental cost of $147.00 (as compared to $354.00). This use is most suited to the gasketed version, for both wooden and concrete subfloors.

6.0 CONSTRUCTION TRIAL

6.1 JOBSITE TEST

6.1.1 JOBSITE TEST: WINDOW/DOOR JAMB

Field trials were conducted to compare the attributes and costs of four window/door rough opening sealing configurations:

1) filling the cavity using fibreglass insulation, with no attempt being made to seal the air/vapour barrier to the extension jamb,

2) gasketted PAD with acoustical sealant,

3) PAD deleting all acoustical sealant,

4) poly collar as used in SEEH houses. .

Each PAD system was installed in two residences, then compared to the other two techniques, depending on that builder's construction practice and experience. Extrapolation was necessary, as low inventories required using existing housing stock and dissimilar house styles.

Field trials included SEEH, R-2000, and conventional houses. The air/vapour barrier and PAD installations on the conventional homes were done by the drywall subtrades; while, on SEEH and R-2000 houses, it was done by the general contractors.

6.1.2 JOBSITE TEST: RIM JOIST

Field trials were conducted to compare the attributes and costs of four rim joist sealing configurations:

1) caulking the subfloor/bottom plate junction,

2) sill plate gasket sealing the subfloor/bottom plate junction,

3) PAD with sill plate gasket used to seal bottom of rim joist (no acoustical sealant) and,

4) poly wrapped rim joist as used in SEEH houses.

Costs for the sill plate gasket were estimated, as that system was not used by any of the builders contacted, though they were all familiar with it. The PAD system was installed in three residences, then compared to the other sealing techniques. Extrapolation is necessary, as low inventories necessitated using existing houses and dissimilar house styles. Builders registered with the R-2000 program were chosen for their familiarity with the techniques used in that program.

Field trials included sealing the window and door extension jambs and the rim joists, using the PAD system. Air leakage tests were performed on one of these houses, using a fan door (Figures 29 and 30, Pages 61 and 62 respectively). Another test was run on a similar, conventionally built house, and was intended to be a baseline for comparison (Figures 31 and 32, Pages 63 and 64 respectively). Both houses had these characteristics in common:

-two storey,

-approximately 1650 square feet,

-location,

-same builder and,

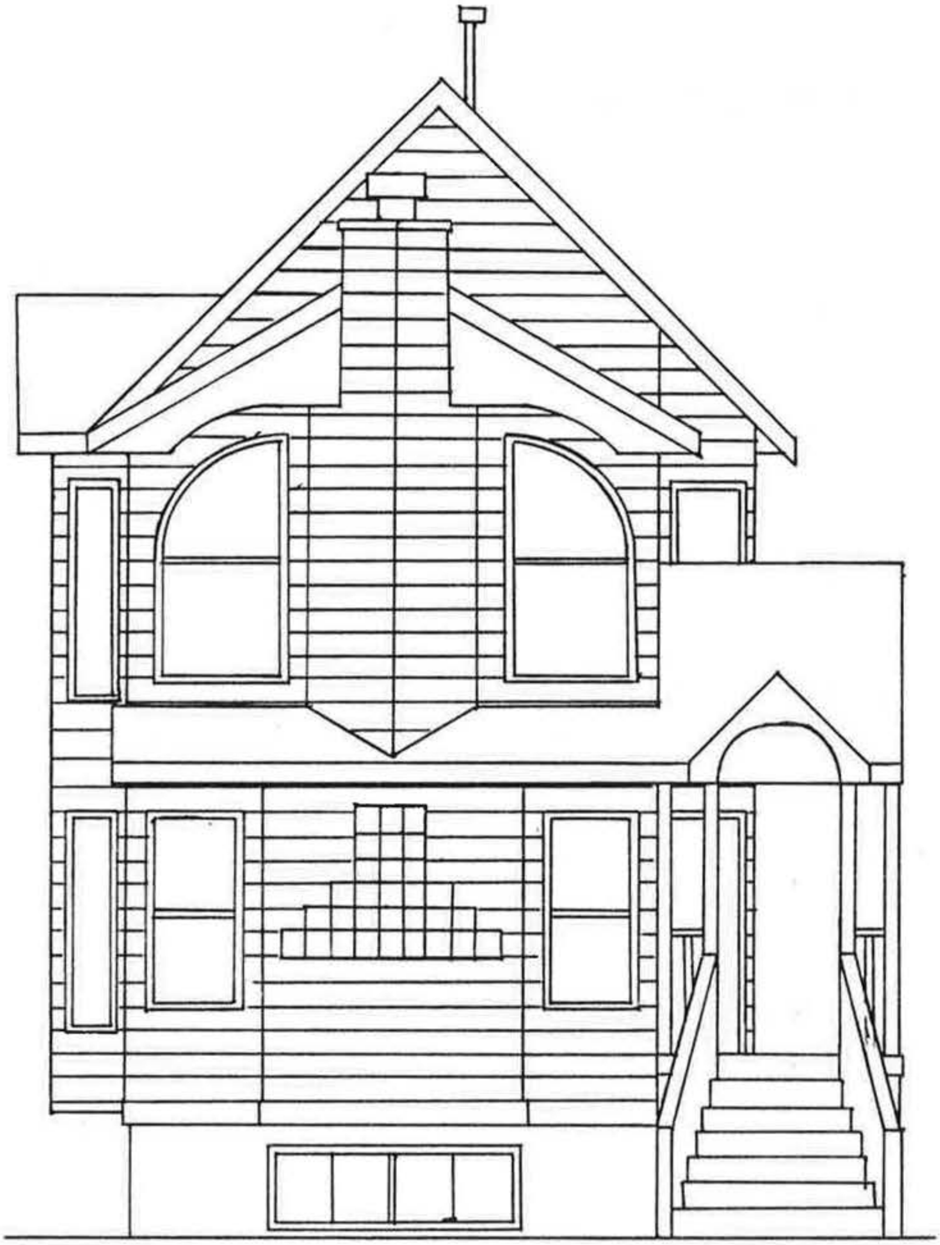


FIGURE 29: Front elevation of test house.

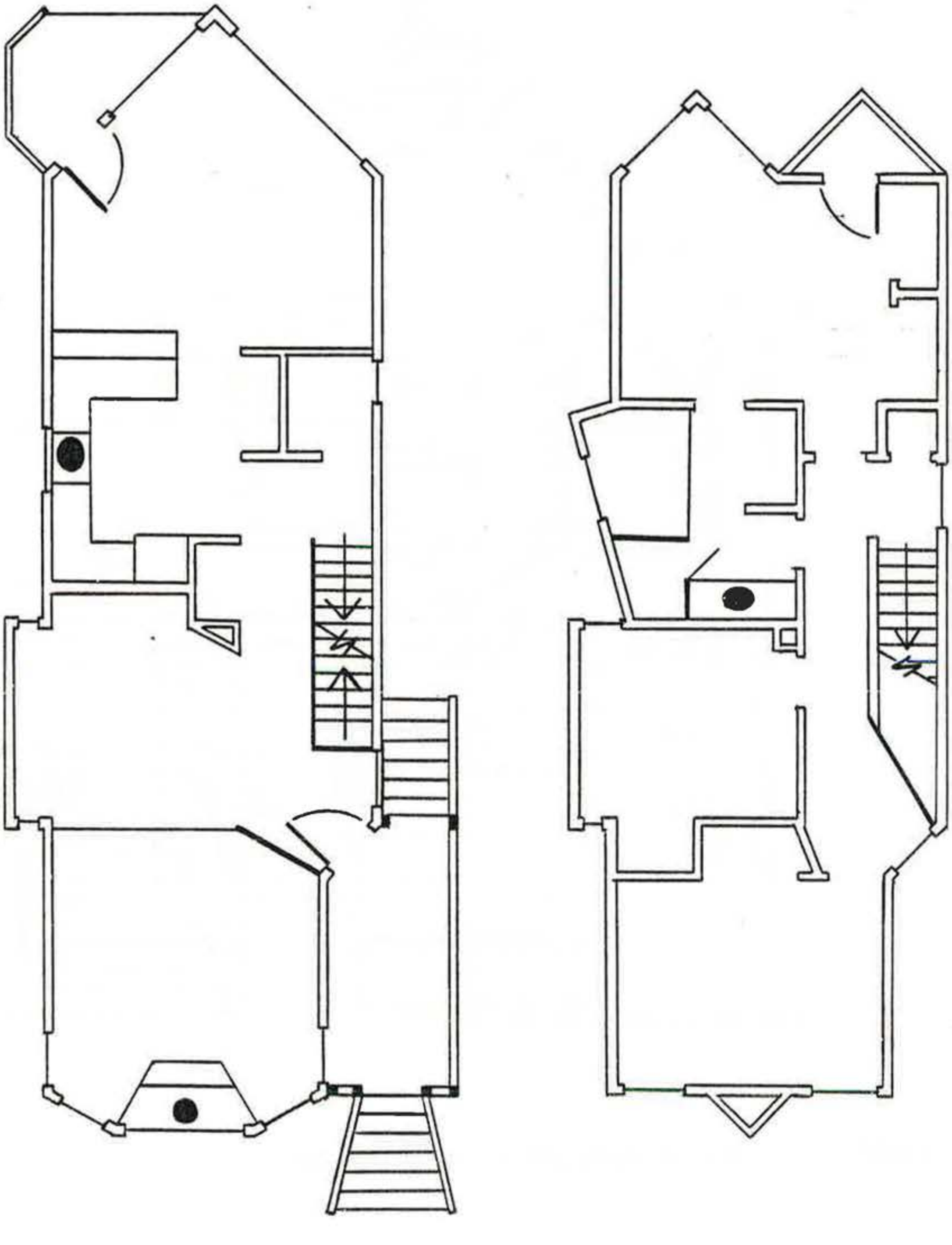


FIGURE 30: Floor plan of test house.

FIGURE 31: Front elevation of control house.

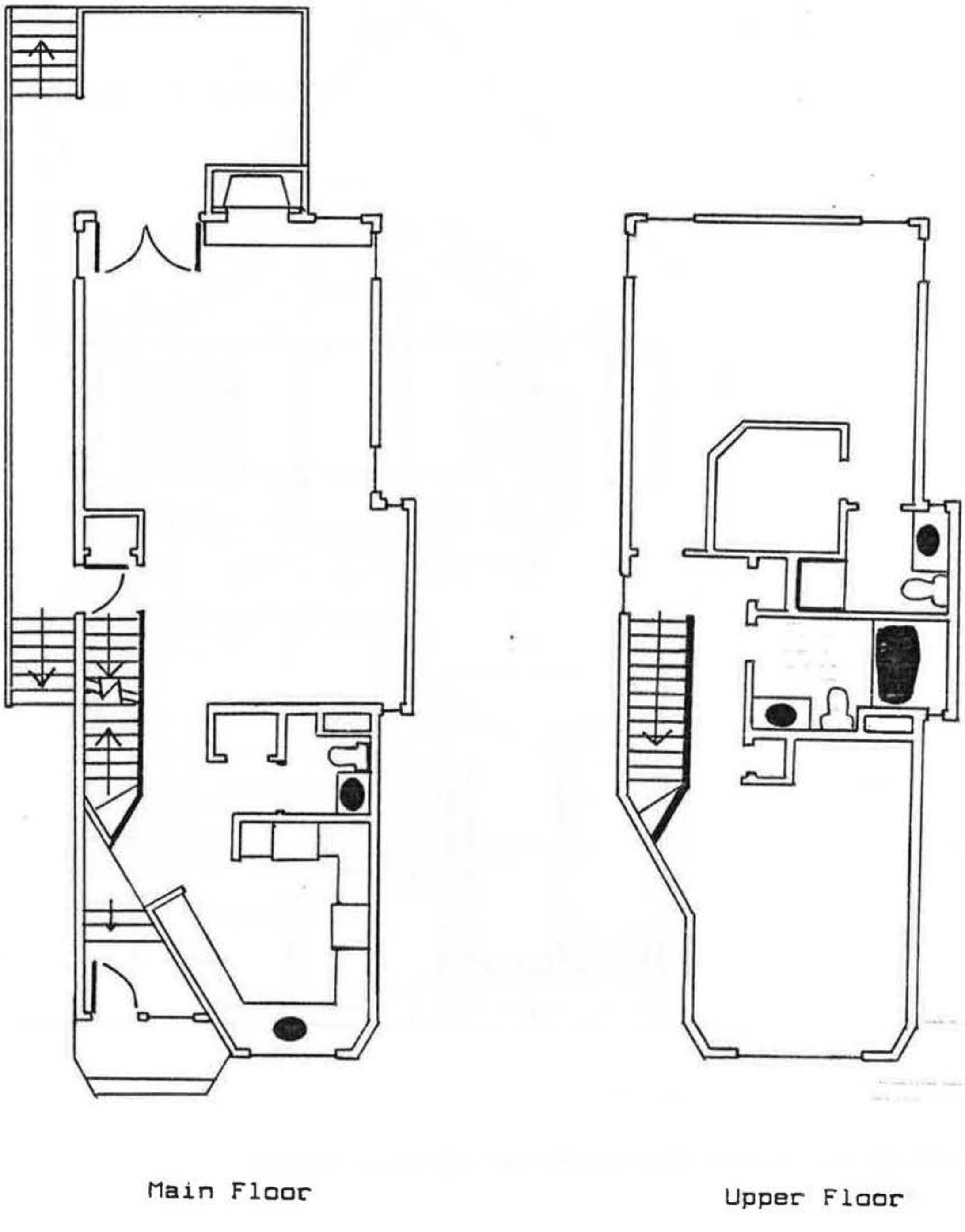


FIGURE 32: Floor plan of control house.

-PWF foundation, floor trusses, 2X6 exterior walls, siding.

The baseline house was one year old and had basement development, whereas the test house was new and had more windows.

Measurements were taken and leakage calculated in air changes per hour (Ach) at 50 Pa. The baseline house exhibited leakage (3.0 Ach) well below averages reported by Sulatisky (13) for Alberta (5.3 Ach) and Canada (4.8 Ach). The test house produced readings of 5.25 Ach. A large cut had been made in the basement portion of the air/vapour barrier by the heating sub-contractor. It was not repairable, and would have made a significant contribution to infiltration. During the test, PADs on the basement windows were observed to be allowing little infiltration. An R-2000 house, which was part of the field trial, had PADs installed on the windows and passed the airtightness requirement of less than 1.5 Ach.

The many uncontrollable variables present in a field test make it necessary to test a relatively large number of houses. Bob Passmore of RTM Engineering suggested that at least ten control and ten test houses would be necessary to produce meaningful results (14). This does not diminiish the validity of the laboratory tests, as variable factors can be isolated and studied in detail.

6.2 CONTRACTOR AND SUBTRADE INPUT

Feedback was sought from those directly involved in the field trials. The individuals included company managers/owners, site superintendents, vapour barrier (and air dam) installers, and drywallers. Input was obtained through an interview which was based on a questionnaire prepared by the researcher. Interviews were conducted in an informal, conversational rather than structured, context, often on-site. Attitudes, experience, and possible inter-trade problems were identified and summarized. Sample questions are included in Appendix "A".

Respondents fell into three categories as characterized by their construction practice:

1) conventional builders and trades,

2) SEEH and R-2000 builders and,

3) conventional builders with R-2000 experience.

Conventional builders have increased insulation levels in their homes in recent years, as well as improving airtightness levels. These improvements, however, meet or only slightly exceed required levels. SEEH builders have gone further in both cases, with particular attention being paid to airtightness. Conventional builders registered with the R-2000 program have built at least one R-2000 house, after completing the required training. Most concentrate their efforts on conventional housing (it is the largest market segment), but some have a sizable R-2000 mix. They understand the importance and implementation of SEEH techniques, and apply them to conventional housing, where feasible.

Four technical concerns arose, the first two of which were experienced by both conventional and SEEH builders during the first set of field trials (PADs installed on the window and door extension jamb only). The PVC used in the first PAD prototypes was very temperature sensitive. Left in the sun, it became soft and would wrinkle when cooled, but at +5 degrees Celcius it became brittle, and exhibited splitting and cracking during installation. Storage and handling difficulties would also arise from these characteristics. This was remedied by changing to PVC of a different composition (costs were the same). It functioned at -18 degrees Celcius, and retained its shape when heated. Polyethylene or a different composition PVC may further enhance performance.

A second concern is related to the short leg (Edge "A", Figure 5, Page 7) overhanging past the extension jamb. This occurs when the extension jamb does not come 1/2 inch past the framing, as it is designed to do. This is a structural problem, and not related to the PAD itself.

Bumps left at the corners when drywall was installed created finishing problems. This occured on only one trial, was minor in nature, and resulted from the installer NOT trimming the overlaps at the corners, as recommended.

Jim Marke of Stuckey Construction recommended changing from 12 foot lengths of PAD to 8 foot lengths. He felt this would eliminate handling problems on site. The 12 foot lengths experienced considerable end breakage during shipping. This recommendation has been implemented.

Both conventional and SEEH trades involved saw the PAD as a simple product and process, even when the trades people were comparing it to filling the rough opening space with insulation, which is still done when the PAD is used. The PAD was installed by stapling it to the framing around a window or door, mostly because of the hammer stapler commonly used by those trades. Changing to an electric or air stapler would facilitate stapling to the jamb, and speed up the installation.

Management for conventional housing (without R-2000 experience) viewed the PAD as difficult to install because of the additional time and costs. There was a recognition of the importance of airtightness, but the opinion remained that there was no benefit to be derived from increased levels. Those with R-2000 experience had the opposite view. Gary Moore of Burnwood Homes, Calgary, felt the two leakage pathways of concern to the current study, are largely ignored by the industry. He further suggested that a product aimed at this area, had its "finger on the pulse of the marketplace".

Builders with a SEEH background see the PAD and similar technologies as beneficial, requiring only attention to detail and a reasonable amount of care. Those specializing in SEEH housing, emphasize high levels of energy conservation, airtightness, and air quality. A system or technology, such as the PAD, which enhances these characteristics and improves cost effectiveness is given a positive response.

6.3 AIR BARRIER COST COMPARISONS

Data, from the field and laboratory trials, facilitated establishing lineal foot costs for the various materials and activities involved in the reduction of air leakage at window and door openings (Table 3, Page 70, and Table 4, Page 71) and the rim joist (Table 5, Page 72, and Table 6, Page 73). These unit costs were then compared to three configurations of PAD and the window poly collar, or the poly wrapped rim joist. As the conventional practice of filling the rough opening gap with insulation is used with each technique, no cost was attributed to it. The unit costs were applied to a conventional house which had been included in the field trials which had 320 lineal feet of rough opening and 180 lineal feet of rim joist.

When incremental costs for the PAD and other window and door jamb sealing techniques were compared, the findings were:

1) The poly collar had an installed cost in the range of $234.00 per house, while the PAD reached the same levels of performance with costs of only $77.00 to $135.00 (depending on whether or not a gasket is used) assuming in-house labor at $12.00 per hour.

2) Using subtrade labor rates at 2.5 times the in-house labor rate, the incremental cost to achieve R-2000 level performance with the PAD ranges from $110.00 to $168.00. Since the poly collar is a labor intensive technique, its comparable incremental cost is a minimum of $488.00.

When subfloor and rim joist sealing techniques were compared, the findings were:

SEALING METHOD - WINDOW AND DOOR OPENINGS			COST PER LINEAL FT (DOLLARS)
POLY AIR DAM (NO ACOUSTICAL SEALANT)			
	GASKETED PAD		0.34
	STAPLES	2/LF	0.01
	MATERIALS		0.35
	LABOR	2 LF/MIN	0.07
	TOTAL		0.42
POLY AIR DAM (WITH ACOUSTICAL SEALANT)			
	PAD MATERIAL AND INSTALLATION		0.42
	CAULK		0.10
	LABOR	8 LF/MIN	0.03
	TOTAL		0.55
POLY COLLAR (AS PER R-2000 LITERATURE)			
	GLASS FILAMENT TAPE		0.03
	POLY	6 MIL 18 IN. BY 12 IN./LF	0.05
	CAULK	30 OZ. TUBE/80 LF AT $7.95 EACH	0.10
	STAPLES	6/LF	0.02
	MATERIALS		0.20
	LABOR	INSTALL POLY COLLAR, HANDLE WINDOW, CAULK AND CONNECT TO AIR/VAPOUR BARRIER 40 MIN.	0.53
	TOTAL		0.73

A DISCUSSION OF COSTING PROCEDURE IS IN SECTION 4.2.1, PAGE 12.

TABLE 3: Installed cost for material and labor of gasketed Poly Air Dam without caulking as compared to the window poly collar.

SEALING METHOD - RIM JOIST		COST PER LINEAL FT (DOLLARS)
POLY AIR DAM (NO ACOUSTICAL SEALANT)		
GASKETED PAD		0.34
STAPLES	3/LF	0.01
MATERIALS		0.35
LABOR	7 LF/MIN	0.03
TOTAL		0.38
SILL PLATE GASKET (INSTALLED VERTICALLY TO SEAL BOTTOM OF RIM JOIST)		
SILL PLATE GASKET MATERIAL/LF		0.10
STAPLES		0.01
LABOR	6 LF/MIN	0.04
TOTAL		0.15
PAD SYSTEM USED TO SEAL RIM JOIST		
GASKETED PAD		0.38
SILL PLATE GASKET AND LABOR		0.15
PLYWOOD TO CAP RIM JOIST		0.31
LABOR TO INSTALL PLYWOOD		0.17
TOTAL		1.01
POLY WRAPPED RIM JOIST (AS PER R-2000 LITERATURE)		
POLY	6 MIL 36 IN. BY 12IN./LF	0.10
CAULK	30 OZ. TUBE/40 LF AT $7.95 (DOUBLE BEAD REQUIRED)	0.20
STAPLES	12/LF	0.04
MATERIALS		0.34
LABOR	INSTALL POLY WRAP, PROTECT WRAP, CAULK AND CONNECT TO AIR/VAPOR BARRIER 7.5 MIN/LF	1.48
TOTAL		1.82

A DISCUSSION OF COSTING PROCEDURE IS IN SECTION 4.2.1, PAGE 12.

TABLE 4: Installed cost for material and labor of gasketed Poly Air Dam with and without caulking as compared to the poly wrapped rim joist.

TEST SECTION NUMBER	DESCRIPTION	AIR LEAKAGE REDUCTION AS % OF CONVENTIONAL	COST PER LINEAL FOOT (DOLLARS)	COST PER HOUSE AT 320 LINEAL FEET (DOLLARS)
1	CONVENTIONAL: R/O SPACE FILLED WITH INSULATION	-	-	-
6	PAD: STAPLED TO JAMB 100 MM O/C, NO CAULK	73.3	0.24	76.80
7	PAD WITH GASKET: STAPLED TO JAMB 150 MM O/C, NO CAULK	82.2	0.42	134.40
10	PAD: STAPLED TO JAMB 150 MM O/C, JAMB CONTACT SURFACE, CORNER CUTS, AND OUTER EDGE OF PAD CAULKED	87.9	0.47	150.40
11	POLY COLLAR AS PER R-2000 LITERATURE	80.0	0.73	233.60

TABLE 5: Effectiveness and incremental costs of 3 Poly Air Dam configurations and the window poly collar as compared to conventional practice.

TEST SECTION NUMBER	DESCRIPTION	AIR LEAKAGE REDUCTION AS COMPARED TO CONVENTIONAL PRACTISE:TEST SECTION #7 (PER CENT)	PRICE PER LINEAL FOOT (DOLLARS)	COST PER HOUSE AT 180 LINEAL FEET (DOLLARS)
1	GASKETTED PAD STAPLED TO SUBFLOOR 150MM O/C	17.4	0.38	68.40
2	PAD AS #1 WITH SILL PLATE GASKET AS #6	83.9	1.01	181.80
4	AS #2, DELETE PAD GASKET, STAPLED 100MM O/C	80.6	0.90	162.00
7	CONVENTIONAL PRACTICE: CAULK SUBFLOOR/BOTTOM PLATE JUNCTION ONLY	-	0.24	43.20
9 *	POLY WRAPPED RIM JOISTS AS PER R-2000 LITERATURE	89.4	1.82	327.60
9	INCLUDING STYROFOAM INSULATION JOIST CAP	**	2.44	439.20

* - ADD $0.62/LF FOR STYROFOAM INSULATION

** - ASSUME SAME TEST RESULTS

TABLE 6: Effectiveness and incremental costs of 3 Poly Air Dam configurations and the poly wrapped rim joist as compared to conventional practice.

1) The poly wrapped rim joist had an installed cost in the $330.00 range, but once the necessary rigid insulation is added, the cost becomes $439.00. The PAD reached similar levels of performance with costs ranging $162.00 to $182.00 (depending on whether or not the PAD gasket was used).

2) Using subtrade labor rates, performance at the R-2000 level can be achieved in the $227.00 to $247.00 range with the PAD system. Since wrapping the rim joist is a labor intensive technique, its incremental cost increases markedly, to $837.00 (including rigid insulation).

3) At the junction of the subfloor and the bottom plate of the exterior wall, the PAD produces a reduction in leakage of 17.4% over caulk. This is probably due to the PAD's ability to provide a connection to the air barrier. The incremental cost of the PAD is $68.00 as compared to $43.00 for caulk.

4) The costs in #3 assume in-house labor at $12.00 per hour, but if subtrade labor rates are used the incremental cost of the PAD increases to only $77.00 as compared to $62.00 for caulk.

No builder overhead costs were added to the in-house labor rates, so the higher subtrade prices are probably a more accurate reflection of pricing.

All costs relating to the PAD are the real costs incurred for prototype production. Once manufactured on a commercial scale, costs should stay about the same. Production costs will go down, but distribution and resale costs will be added.

7.0 PATENTS, APPROVALS, AND CERTIFICATIONS

7.1 PATENT APPLICATIONS

Patent applications have been submitted to both the Canadian and U.S. patent offices and patents are pending. A computer search of the World Patents Index data base was done by the Alberta Research Council office in Calgary. It showed no similar products patented.

7.2 APPROVALS AND CERTIFICATIONS

Contacts were made with the following licensing and certification organizations regarding the use of the PAD materials and techniques in Canada:

1) Discussions with Energy, Mines, and Resources Canada (EMR) concerning the R-2000 program indicated that some materials, used in their houses need CSA certification; otherwise, a product or procedure is acceptable if - once applied - it functions as required. PAD samples and test results were forwarded to EMR. The product appears to be acceptable, and efforts are underway to have information about PAD technology included in builder training sessions.

2) Canada Mortgage and Housing Corporation (CMHC) acceptance is coordinated by the manager of the Materials Evaluation section in its national office in Ottawa. Testing procedures, results, and product samples were forwarded with a query about certification. To obtain a CMHC number, a product must be in commercial production, and Ottawa advised that application for evaluation be submitted at that time.

3) A discussion with the Edmonton office of CSA indicates that this product may not require their certification. Air infiltration standards would have to exist. To confirm this, test results and product samples are being submitted to their Applications Group, Building Standards Branch in Rexdale, Ontario.

4) Mr. Rob Dumont of the National Research Council has indicated that the National Building Code is a minimum standard, and the Canada Service Bureau has indicated

that only provincial building code regulations will relate to the Poly Air Dam.

5) Alberta Building Standards Branch has a new product listing which goes to all building inspectors to indicate approval of a new product. Acceptance and inclusion on this list is handled by the Alberta Building Standards head office in Edmonton. they have indicated that the PAD would be classified as a "minor component" by the code. Because the PAD is made from a combustible material, it is acceptable for any structure as long as it is installed in the suggested manner (ie- covered by gyproc or another fire barrier). A product description and sample is required for departmental analysis and approval.

6) Canada Consumer and Corporate Affairs, Product Safety Division, have indicated they will have no interest in this product because of its composition and intended use.

7) The Canadian General Standards Board has no standards in this area.

Broad support offered the Poly Air Dam concept underlines a concern about housing air tightness, though little exists by way of standards and no product certification seems to be required. JFJ Mold Processors of Old Castle, Ontario confirmed that this applied to their product (electrical polyhats).

8.0 SUMMARY AND CONCLUSIONS

Large variations in cost and functional effectiveness are evident between the various air sealing sytems. Without considering the Poly Air Dam, it appears that the techniques which best enhance resistance to air leakage on a long term basis are the window and door poly collar and the poly wrapped rim joist used in SEEH and R-2000 houses. These techniques have negligible market penetration. Two concerns arise with relation to all sealing techniques discussed:

1) Effective methods are costly and/or complex.

2) Less expensive methods are simple but not as effective.

The Poly Air Dam was designed to address these problems. It will work with both the poly air/vapour barrier and the ADA technique, and conventional construction techniques can be followed. Simple installation and inexpensive cost, coupled with a high degree of effectiveness, should give the PAD strong market potential. Shaw has stated that a "new technique is needed to fasten the edges of the polyethylene sheet to the window frame and hold the edges in place"(3).

As information was being gathered on systems used to seal air/vapor barriers, it became apparent that caulking was a concern both from an application and a longevity standpoint. A test incorporating the gasketed PAD demonstrated that an effective air seal can be achieved without the use of caulk. This configuration is also appropriate for conventional housing, because of simple installation and low cost.

No matter how effective a product is, to suceed it has to penetrate its intended market. Consumers make their buying decisions from among those alternatives available. Energy efficient houses and housing products will be chosen more often the more widely they are available (15). Energy, economics, and perceptions will influence that choice.

Housing producers and manufacturers are slow to change unless a demand is present for a service or product, and ultimately it is the consumer who creates that demand. Advertising is a key to this process, but percieved value and credibility are its basis. Credibility can be lent by a product having a CMHC acceptance number. A secondary result of this evaluation of the PAD, may be more recognition that better methods exist for sealing the rim joist and the window/door jamb to the air/vapour barrier.

A new product niche can be created. An example of this process is the CMHC requirement for sealing exterior wall electrical outlets to the air/vapour barrier. It is now common practice to install electrical polyhats, and there currently are a number of manufacturers of that product.

Acceptance by the R-2000 program not only lends credibility, but also provides participating builders with training and information in the use of the product.

It has been suggested by Don Muson of Lennox Industries that "a home can go two thirds of the way in energy Efficiency with good cost effectiveness" (16). Fibreglas Canada Inc. has constructed a house meeting the

R-2000 energy budget, but with higher air infiltration levels. An air change rate of 2.0 Ach was used rather than the R-2000 maximum of 1.5 Ach. One of the factors influencing the success of their project is the use of "simple techniques to provide a reasonable level of air sealing". The air/vapour barrier was not caulked and "major air leakage paths" were sealed "using 'builder friendly' techniques" (17, 18).

The PAD was designed to be just such a technique and should simplify controlling infiltration. Test results suggest its effectiveness where air barrier continuity is necessary (as required by CMHC), but a structural member causes termination (eg - partition wall). Further research in this area may reveal a multiplicity of uses for the Poly Air Dam in residential construction.

Several factors suggest the basis of a marketing strategy. To gain a strong market share, a manufacturing facility, a sales and distribution network, and a substantial advertising budget are necessary. Associated products would assist in defraying the costs connected with meeting these prerequisites. An established presence in the marketplace would possess these characteristics.

If, as in the case of polyhats, many manufacturers enter the arena, the resources to enforce proprietory rights may be necessary. An existing strong presence would discourage infringement. These considerations indicate the desirability of some form of joint-venture as a route to marketing the PAD. Marketing assumes aceptability and cost effectiveness of not only the PAD, but energy efficient technology. There must be a mesh with conventional technology.

Five conclusions have been drawn from this project:

1) Most builders are aware of air leakage as a factor in building energy consumption. Those who have had some training, such as the R-2000 program, tend to do more about leakage. They are also more receptive to new ways to control it.

2) There are several ways to seal a window or door jamb and rim joist to an air/vapour barrier, but most are either expensive, ineffective, difficult, or a combination of the three. Simple systems tend to be expensive. Some systems have a problem with longevity.

3) The Poly Air Dam system is as effective as best methods now used to seal the window and door jamb or rim joist. Further, it has the advantages of being simple to install and is less expensive. It requires no special training to install.

4) Changes in conventional building techniques or sequences are often necessary to achieve airtightness with many sytems. The PAD system does not require this.

5) A market appears to exist for the PAD system and for technologies with similar attributes.

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GLOSSARY OF ABBREVIATIONS

Ach
- Air changes per hour
- The number of times the volume of air in a room or building enters or leaves in one hour.

ADA
- Airtight Drywall Approach
- The interior drywall sheeting of a building envelope is sealed to form an effective barrier against air leakage.

ASTM
- American Society for Testing Materials

CHBA
- Canadian Home Builders' Association

CMHC
- Canada Mortgage and Housing Corporation

CSA
- Canadian Standards Association

EMR
- Energy, Mines, and Resources Canada

EPDM
- Ethylene Propylene Dien Monomer
- A plastic resin.

PAD
- Poly Air Dam
- A plastic gasket which is the subject of this document.

PVC
- Poly Vinyl Chloride
- A plastic resin.

R-2000
- The R-2000 Program
- This is a program run by EMR and CHBA to train builders in the construction of energy efficient homes. It also sets standards for, certifies, and monitors these homes.

SEEH
- Super Energy Efficient Home
- A home that has a low energy demand, such as an R-2000 home.

WIRTC
- Western Industrial Research and Training Centre

APPENDIX "A"

QUESTIONNAIRE

1) What is your construction experience?

2) In what way have you been involved with the field trials of the "Poly Air Dam"?

3) How would you rate the ease of installation of the "Poly Air Dam" on a scale of 1 to 10 (1 - difficult, 10 - easy)?

4) Was training in the suggested installation method adequate (yes or no)?

If "no"

What additional training is required?

5) Can you suggest any improvements to the installation method?

6) Can you suggest any changes in shape which would improve the "Poly Air Dam's" performance or ease of installation?

7) Can you offer a comparison of installation time and costs?

8) What is the maximum you would pay for this product per lineal foot or job?

9) Do you anticipate any storage or handling problems?

10) Have you ever been involved in constructing a super energy efficient or R-2000 type house (yes or no)?

If "yes"

What did you think of air/vapour barrier installation in general and particularly at window and door openings and at the rim joist?

11) Were there any problems with trades or trade interface?

12) What sort of comments did you get from the subtrades?

13) Were there comments by others, and what were they?

14) What were your expectations of the product and how did they turn out?

15) Do you have any other comments (benefits or other uses for the product, etc.)?