RESEARCH REPORT

# CMHC Research Project Testing of Air Barrier Construction Details II

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REPORT

# CMHC Research Project Testing of Air Barrier Construction Details II

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# EXECUTIVE SUMMARY


Air leakage control through the building envelope of wood framed houses is more important than ever. This is because owners expect better temperature control, higher indoor humidity in winter, low energy consumption and building durability.

The leakage of air is controlled by the air barrier system. There are several new technologies to construct an air barrier system for the building envelope. These are the Poly Approach, the Air Drywall Approach and the EASE system.

The development of these systems was undertaken primarily by the building community without significant research and development. While it is believed that these methods improve airtightness it is not known if the improvement is marginal or significant. The purpose of the study was to determine the actual performance of several different types of construction details for each of the different approaches. Each of these details was designed and constructed using one of the air barrier methods and tested in the laboratory.

The test details included the sill plate, the partition wall, the stair stringer, the electrical outlets, the bathtub detail, the plumbing stack detail, the metal chimney detail, the bathroom fan detail and the EASE wall system.

The test results have revealed that the Poly, ADA and EASE approaches reduce air leakage by a factor of six, if applied with a modest degree of workmanship. Further, certain Poly details are to be reconsidered because they lack adequate support against design wind load pressures.

The test results and test panel descriptions will be found in the appendices.

## TABLE OF CONTENTS

| | | Page |
|---|---|---|
| EXECUTIVE SUMMARY | | 2 |
| 1. | INTRODUCTION | 1 |
| 2. | OBJECTIVES AND SCOPE | 3 |
| | 2.1 Objectives | 3 |
| | 2.2 Scope | 3 |
| 3. | METHODOLOGY | 5 |
| | 3.1 Apparatus | 5 |
| | 3.2 Equipment and Instrumentation | 6 |
| | 3.3 Test Procedure | 6 |
| 4. | DESCRIPTION OF PANELS AND TEST RESULTS | 9 |
| | 4.1 Sill Detail | 9 |
| | 4.2 Partition Exterior Wall Detail | 10 |
| | 4.3 Stair Stringer Exterior Wall Detail | 11 |
| | 4.4 Electrical Outlet Details | 12 |
| | 4.5 EASE (New Tyvek) Wall System | 14 |
| | 4.6 Bathtub Enclosure Detail | 14 |
| | 4.7 Plumbing Stack Detail | 15 |
| | 4.8 Bathroom Fan Detail | 16 |
| | 4.9 Metal Chimney Detail | 17 |
| 5. | ANALYSIS AND DISCUSSION | 19 |
| | 5.1 Analysis of Results | 19 |
| | 5.2 Discussion | 20 |

## TABLE OF CONTENTS (Cont'd.)


| | | Page |
|---|---|---|
| **6.** | **CONCLUSIONS AND RECOMMENDATIONS** | **23** |
| | 6.1 Conclusions | 23 |
| | 6.2 Recommendations | 24 |

**APPENDIX A:** Wood Frame Construction Methods

**APPENDIX B:** Test Panel Assembly Drawings

**APPENDIX C:** Air Leakage Test Result Graphs

# 1. INTRODUCTION

The leakage of air through the ceilings, exterior walls and windows, and the below grade components of a typical house is considered one of the more serious performance and durability problems. The uncontrolled leakage of air through various components of the building envelope can entrain moisture into cavities, with subsequent moisture damage, cause high energy costs to the homeowner, as well as affect control of the indoor temperature and relative humidity.

The control of air leakage through the envelope is performed by the air barrier system. The performance requirements of the air barrier system were developed quite recently and are distinctly separate from the requirements of the vapour retarder. Since then construction practice has developed methods to incorporate an air barrier system into the design and construction of new buildings. It is also understood that to design and construct an adequate air barrier system, it must be continuous, air impermeable and structurally supported to transmit wind loads to the primary structure of the building envelope.

The structural requirements of air barriers are somewhat of a surprise to most builders, but it was understood as early as 1960 that to prevent air from flowing through materials, the air barrier had to be not only air impermeable but had to be supported against the air pressures of wind that tried to push or pull air at the barrier. What appears as most surprising is the magnitude of the loads that must be resisted. While wind pressures are generally quite small most of the time, they may exceed 1000 Pa from time to time and it is these pressures that must be supported for the air barrier system to be effective for the life of the building. A more complete explanation will be found in the CMHC report "Structural Loads for Air Barriers".

Four types of construction are currently available to the designer/builder of wood frame houses and these are, the Traditional approach (no special measures to control air leakage), the Poly approach, an air/vapour barrier approach that uses folding, stapling, taping and caulking of the polyethylene to air seal ceilings and exterior walls, the air drywall approach also known as ADA, which uses the interior gypsum board to air seal ceiling and walls and paint to provide the vapour retarder. The fourth type of construction is relatively new. It consists of an exterior air barrier system of fiberboard sheathing, polyolefin paper

(TYVEK) and fiberboard sheathing in a sandwich assembly fastened to the exterior side of the exterior frame wall. It is known as the External Air System Elements or EASE system. A more complete description of each type of construction will be found in Appendix A.

The Canada Mortgage and Housing Corporation has commissioned Morrison Hershfield Limited (MHL) to undertake a study of the air leakage performance characteristics of various air barrier system details for wood frame construction. These details include the sill plate, the partition wall to exterior wall joint detail, the stair stringer detail, electrical outlet boxes and covers, the bathtub detail, the EASE wall (new Tyvek), the plumbing stack vent detail, the metal chimney detail and the bathroom fan detail.

For each construction detail, a test assembly was designed and constructed to similar practice standards for each of the four types of construction methods. These assemblies were tested for air leakage characteristics as well as their ability to withstand high air pressure loads. The study is divided into six parts, Part 1, the introduction, Part 2, discussion of the objectives and scope, Part 3, the methodology used to test each detail, Part 4, describes the construction methods, the sample details and results, Part 5, an analysis and discussion and Part 6, conclusion and recommendations.

# 2. OBJECTIVES AND SCOPE

## 2.1 Objectives

The objectives of the test program were to evaluate the ability of the air barrier details of four construction approaches to provide air leakage control and structural wind load resistance. Performance of the air barrier system was evaluated for both air infiltration and air exfiltration. The air pressure loads applied simulated design wind load conditions.

## 2.2 Scope

Testing was carried out on nine typical air leakage control details incorporating three construction methods and one test on an EASE system incorporating the new Tyvek. The construction details were:

1. the sill plate detail;
2. the partition wall detail;
3. the stair stringer detail;
4. the electrical outlet detail with various electrical box cover equipment;
5. the EASE (new TYVEK) wall system;
6. the bathtub detail;
7. the plumbing stack detail;
8. the bathroom fan detail; and
9. the metal chimney detail.

Each detail was incorporated into three test panel assemblies, each using one of the four air barrier approaches. While these details represent only a limited sample of the total number of details in a building envelope, they were considered among the most significant.

The test pressure differences at which air leakage was measured ranged from 50 Pa to a maximum of 1000 Pa (or the pressure difference at which the air flow through the test section was limited by the capacity of the air pump - about 25 L/s). The 1000 Pa limit was selected as the upper limit for validating structural performance against wind loads in low rise, wood framed buildings. It is higher than the hourly wind pressure figures published in the National Building Code of Canada but it includes the effects of the negative pressures induced in the house volume and it is considerably less than the test pressures required by windows - about 2500 Pa.

While the 1990 building code requires that all buildings be provided with a continuous air barrier, no air leakage performance criteria are given to use as an accepted standard. However, Building Science insight 86, "An Air Barrier for the Building Envelope" recommended that the average building envelope air leakage should not exceed 0.1 L/s·m$^2$ at a pressure difference of 75 Pa.

The results of this testing were analyzed and applied to a typical two storey house for an overall rating. Further, these ratings were compared to the suggested maximum average air leakage of 0.1 L/(s·m$^2$) to determine the difference in performance of built construction details from the design objectives.

# 3. METHODOLOGY

The methodology consisted of installing a sample wall or sample ceiling panel, incorporating one of the selected details, into the open face of a pressure chamber. The sample wall or ceiling panel was oriented so that the exterior side of the construction detail faced the inner volume of the pressure chamber. The perimeter of the sample panel was sealed to the pressure chamber and the sample assembly was tested for air leakage rate and structural performance.

The air leakage rate was determined by measuring the overall air leakage of the sample and chamber at 75 Pa. The sample was then masked and sealed to obtain the chamber leakage only. By subtracting the chamber leakage from the overall leakage, the air leakage characteristics of the sample detail was obtained.

To determine the structural performance of the air barrier detail, the chamber pressure was set to 75 Pa and the air leakage rate determined. The chamber pressure was then raised to a higher pressure until the flow stabilized and then lowered again to 75 Pa. The process was repeated several times until a maximum of 1000 Pa was attained. The air leakage rate was determined at various pressures and plotted to determine if the leakage area had increased, that is, if structural damage had occurred.

A description for each test panel assembly and test results will be found in Part 4 that follows.

## 3.1 Apparatus

To facilitate the test sequencing, a chamber was designed to allow easy removal and installation of the sample wall panels described in Section 4. The chamber consisted of an exterior perimeter frame of 38 mm x 286 mm (2" x 12") wood members, and an interior perimeter frame (screwed to the exterior frame) of 38 mm x 190 mm (2" x 8") wood members. Three, uniformly spaced, horizontal members were fixed to the vertical members of the interior perimeter frame to provide additional structural support for the 1200 mm x 2400 mm x 20 mm plywood sheet covering one face of the frame to form a box. Closed cell foam gaskets were used as a seal between the chamber framing and the plywood sheet and each joint and screw hole was sealed with sealant. The resulting chamber was essentially a back-up wall for the test panels. Figures 3.1A and 3.1B are a schematic representation of the test apparatus.

All test panels were held in place and compressed against the perimeter seal of the chamber opening with five "C" clamps, two on each vertical edge of the panel and one at the midpoint of the upper horizontal edge; and by hydraulic jack at the bottom of the panel or the inside edge of the horizontal test panels.

## 3.2 Equipment and Instrumentation

Pressure differentials were created with a 12 amp vacuum cleaner blower. Reinforced corrugated vinyl hoses were used to connect the chamber, flow meters and the air blower. The hoses connected to the suction and discharge openings of the blower were both fitted with valves that controlled the air flow rates. The hose from either the discharge or suction side of the blower could be clamped to a pipe connection fitted to the plywood face of the chamber. The blower was then activated to increase or decrease the pressure in the chamber relative to the laboratory, inducing either infiltration or exfiltration through the test panel.

The flow of air through the chamber was measured with rotometer-type flow meters specifically DWYER type rotometers. The high flow rate meter in this set had a range of 1 and 30 cfm while the low flow rate meter had a range of 1 to 10 cfm. In all cases the calibrations provided by the manufacturer of the flow meters were used to establish the flow rates.

A pressure tap was installed through the plywood backing of the test chamber, and pressure differentials were measured with a Air Instrument Resources Ltd. micro manometer used on the 0-1999 Pa range.

## 3.3 Test Procedure

A series of air flow measurements were made with each test panel, first in the infiltration mode and then in the exfiltration mode. In each case the pressure difference across the panel was increased from 50 to 1000 Pa, with air flow measurements at pressure differences of 50 Pa, 75 Pa, 100 Pa, 150 Pa, 200 Pa, 300

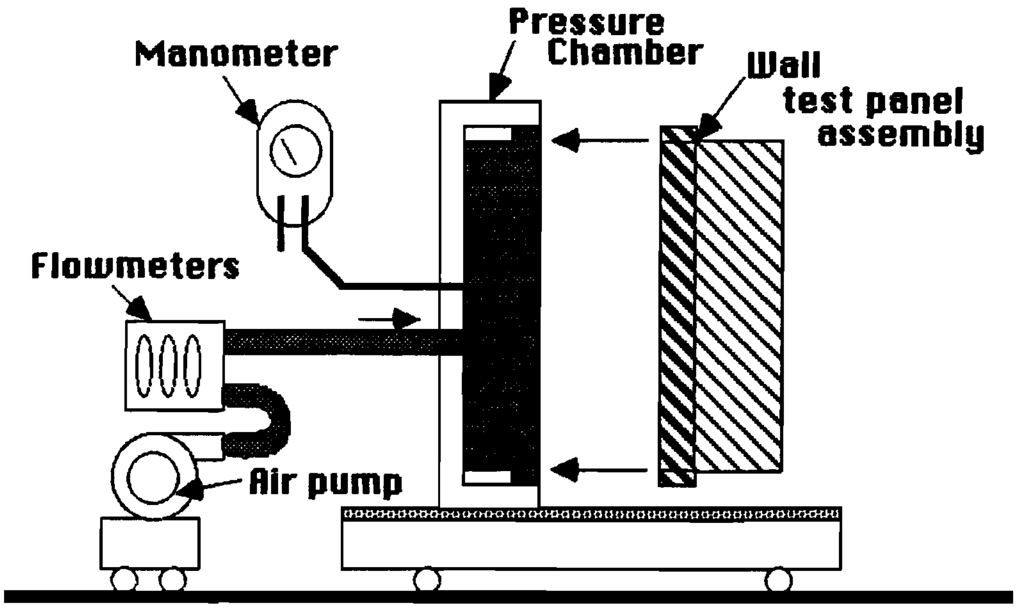


FIG. 3.1A TESTING WALL DETAILS

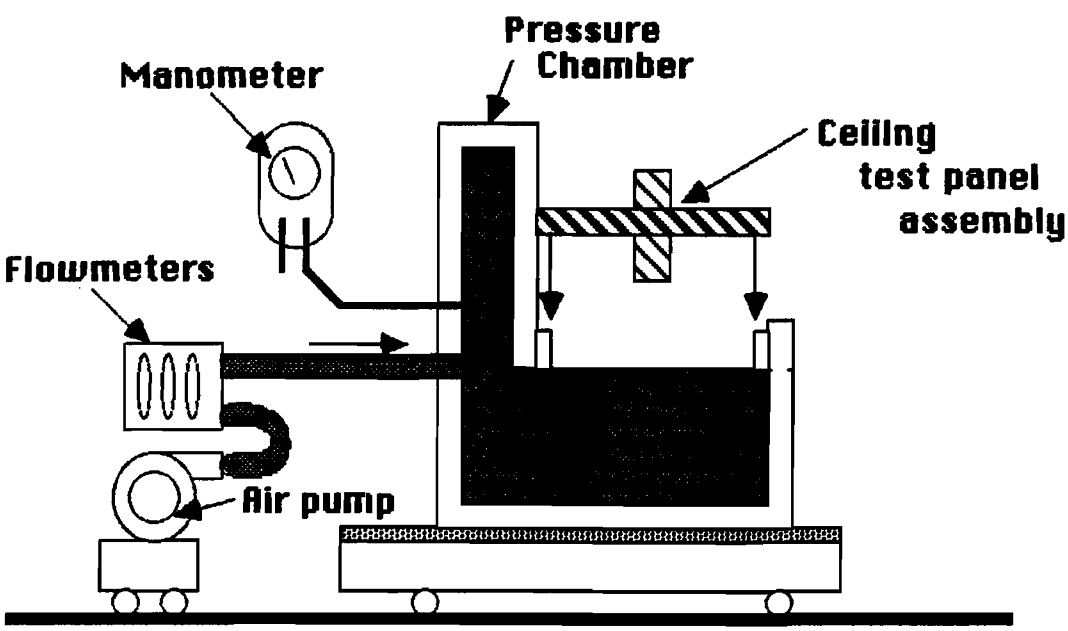


FIG. 3.1B TESTING CEILING DETAILS

Pa, 400 Pa, 500 Pa, 600 Pa, 800 Pa and 1000 Pa. The pressure difference was then decreased, with air flow measurements taken again at 600 Pa, 200 Pa and 75 Pa, to verify earlier readings and to find out if the air barrier had been damaged at higher pressures. The pressure difference was maintained at each setting until air flow readings had stabilized.

During testing, wall sections were observed for signs of failure. In particular, an unexpected drop in the air pressure difference, or a significantly higher flow rate at a particular pressure difference. Either change were noted as a possible indication of rupture of some component of the test panel. In general the following procedure was used for each of the sample construction details:

1. The test panel was constructed.
2. The test panel was then mounted in the test chamber opening and clamped in place. The test panel was then masked with a sheet of polyethylene. The air leakage rate was determined with the wall masked and the results recorded as extraneous chamber leakage.
3. The mask was then removed and the air leakage test series was repeated. The results, less the extraneous leakage, were recorded as leakage through the test panel.
4. The sequence was then repeated for exfiltration rates.
5. After each test sequence, the wall materials were reviewed for signs of damage and any damage found was documented.
6. The results were plotted on log-log graph paper and will be found in Appendix “B”.

# 4. DESCRIPTION OF PANELS AND TEST RESULTS

The sample detail panels were tested as two groups. The first group consisted of those air barrier details that were essentially part of the exterior wall. These included the foundation sill detail, the partition to exterior wall detail, the stair stringer to exterior wall detail, the electrical outlet detail, the electrical outlet cover detail, the EASE exterior air barrier system, and the bathtub exterior wall detail. The second group included those air barrier details that were essentially part of the ceiling and included the plumbing stack detail, the bathroom fan detail and the metal chimney detail.

Each of these details was constructed using the three construction approaches. These were the Traditional Approach, the Poly Approach, and the Air Drywall Approach (ADA). Only one EASE assembly was constructed. The following assemblies describes each of the sample details constructed and the results that were obtained from the air leakage and structural testing.

It should be noted that all gypsum board joints were taped using an aluminum foil tape rather than the traditional tape and plaster approach, it is assumed that the two approaches were equally impermeable to air flow.

## 4.1 Sill Detail

To obtain as many lineal metres of sill plate joints, two simulated foundation joints were stacked one on top of the other to fill the opening of the pressure chamber. This resulted in approximately 5 metres of sill joint. See Figures 1A, 1B, and 1C in Appendix C.

Test panel assembly, 1A, represents the traditional approach. The foundation sill is shimmed level, approximately $^1/_2$ inch above the foundation concrete and then packed using a sand/cement grout between the sill and the top of the foundation. This assembly was then mounted in the chamber and the joint tested.

The second sill plate test panel assembly, 1B, is the poly approach and consisted of wrapping the header joist with Tyvek construction paper, and sealing the Tyvek to the foundation with acoustical sealant.

The third sill plate test panel assembly, 1C, the ADA approach, consisted of constructing the sill plate over 4 layers of 1/4" ethafoam strips, approximately 4 inches wide and compressing the gasket system to about 50% of it's nominal thickness.

Each of these sill details was tested for infiltration and exfiltration, the results of these tests were plotted and illustrated on graph I1 and E1 of Appendix "B". The I in front of the 1 represents infiltration and the E represents exfiltration.

At a reference pressure of 75 Pa, the air leakage rates for infiltration and exfiltration for the three types of details were as follows:

| **Type of Construction** | **Infiltration L/(s·m)** | **Exfiltration L/(s·m)** | **Structural** |
|---|---|---|---|
| Traditional | 0.12 | 0.07 | Pass |
| Polyethylene | negligible | negligible | Pass |
| ADA | 0.03 | 0.03 | Pass |

## 4.2 Partition Exterior Wall Detail

An exterior wall was constructed with three partition walls, each approximately 1.22 m high spaced at a 0.61 m on centre. A separate wall test panel was constructed for the Traditional, the Poly and the ADA approaches. These assemblies are shown in Figures 2A, 2B, and 2C of Appendix C.

In the traditional partition wall construction polyethylene is stapled over the exterior wall studs and cut to fit at the partition wall. The interior of the exterior wall and the partition frame were sheathed in gypsum board and the joints taped as required.

The Poly Approach consisted of wrapping a strip of polyethylene over the end of the partition wall and lapping and joining the main wall polyethylene along the face of each of the partition wall connection studs. The lap joints of poly were also sealed using acoustical sealant and stapled to the partition stud. The wall was sheathed with gypsum board.

The ADA Approach to air sealing the partition wall consisted of installing a 3 mm thick by 12 mm wide glazing tape along the face of the partition wall stud. The gypsum board of the partition wall and the exterior wall were taped at the corner.

Each of these test panel assemblies was installed in the pressure chamber and tested. At a reference pressure of 75 Pa, the air leakage rates for infiltration and exfiltration of the three types of partitions used were as follows:

| Type of Construction | Infiltration L/(s·m) | Exfiltration L/(s·m) | Structural |
|---|---|---|---|
| Traditional | 0.25 | 0.27 | Pass |
| Polyethylene | 0.12 | 0.14 | Pass |
| ADA | 0.16 | 0.15 | Pass |

### 4.3 Stair Stringer Exterior Wall Detail

In this assembly, a stair stringer was attached over wood studs and header joist of a sample exterior wall. The exterior wall air barrier system at this location was constructed in three different ways. These assemblies are shown in Figures 3A, 3B and 3C of Appendix C.

Traditionally, the polyethylene was cut and stapled over the stud face and header joists and trimmed at the stair stringer without air sealing. The interior surface was finished in gypsum board and a quarter round trim was nailed over the stringer.

In the Poly Approach, the interior polyethylene film is joined to another film of polyethylene around the stringer and sealed with acoustical sealant and stapled to the edge of the stringer just underneath the gypsum board edge and quarter round finish.

The ADA approach is slightly different. A 12 mm plywood backer strip, slightly wider than the stringer, is attached to the stringer. The plywood backer extends 50-100 mm past the edges of the stringer on both top and bottom surfaces. The stair assembly is then fastened to the wood stud wall. The interior gypsum board finishes at the 12 mm plywood and is then taped and sealed at the joint.

The test panel assemblies were then installed in the pressure chamber and tested. At a reference pressure of 75 Pa, the air leakage rates for infiltration and exfiltration of the three types of stair stringer details were as follows:

| Type of Construction | Infiltration L/(s·m) | Exfiltration L/(s·m) | Structural |
|---|---|---|---|
| Traditional | 0.30 | 0.28 | Pass |
| Polyethylene | negligible | negligible | Pass |
| ADA | 0.02 | 0.02 | Pass |

## 4.4 Electrical Outlet Details

A 1.2 m x 2.4 m exterior wood frame wall was constructed using 2 x 4's at 400 mm on centre. In each cavity space between studs an electrical outlet box and wire was fastened to the side of the stud at about 400 mm above the floor plate. The stud wall was insulated, sheathed and completed for the Traditional approach, the Poly approach and the ADA approach. See Figures 4B and 4C of Appendix C.

In the Traditional approach, the polyethylene sheet is cut at the electrical box opening. No effort was made to seal the poly to the electrical box. The interior gypsum board and covers were then installed.

In the Poly Approach, an (Enviroseal) molded rubber insert is pushed into the electrical box and the feed wires are passed through it by drilling holes through the rubber insert.

The ADA approach recommend the use of a new (Enviroseal) airtight electrical outlet box that has flanges around the perimeter of the box to which a gasket or tape is installed prior to the installation of the gypsum board.

The test panel assemblies were than installed in the pressure chamber and tested. At a reference pressure of 75 Pa, the air leakage rates for infiltration and exfiltration of the three types of stair stringer details were as follows:

| Type of Construction | Infiltration L/s | Exfiltration L/s | Structural |
|---|---|---|---|
| Traditional | 1.30 | 1.30 | Pass |
| Polyethylene | 0.35 | 0.35 | Pass |
| ADA | 0.20 | 0.21 | Pass |

Further to the type of electrical boxes tested above, the air leakage resistance of different types of electrical outlet covers was determined for a traditional installation. The traditional construction was simulated by using standard electrical outlet covers.

This includes testing the standard electrical outlet cover plus safety plug (plastic) inserted in prong outlets, a Leviton safety cover and gasket, product number 89000/842 Ivory, with vertical sliding half covers and a Stewca safety cover that has horizontal sliding covers over the prongs of the outlet.

The test panel assembly and its various covers were tested for air infiltration and exfiltration rates. The results are plotted on graph I5 and E5 in Appendix B and tabulated below.

| Type of Construction | Infiltration L/s | Exfiltration L/s | Structural |
|---|---|---|---|
| Traditional Covers | 1.80 | 1.80 | Pass |
| Traditional w/plugs | 1.39 | 1.43 | Pass |
| Leviton Safety Plate | 0.40 | 0.50 | Pass |
| Stewca Safety Plate | 0.23 | 0.24 | Pass |

### 4.5 EASE (New Tyvek) Wall System

The EASE test wall assembly consisted of a 1.2 m x 2.4 m exterior wall test panel simulating a full height wall from a sill plate through to a double plate at the top of the wall. The perimeter of the EASE system was sealed to the framing using glazing tape gasket under a starter strip of Tyvek. See Figure 6 in Appendix C. The exterior sheathing, first layer of 7/16" fiberboard is installed over this perimeter seal and starter strip, and fastened to the header joist and exterior stud face using common roofing nails. A layer of Tyvek is then installed over the starter strips, held in place by stapling and the joints are taped. A second layer of 7/16 fiberboard is then installed over the Tyvek to create the EASE assembly. The wall assembly and the EASE system were then installed in the chamber and tested.

At the reference pressure of 75 Pa the EASE system exhibited the following leakage characteristics.

| Type of Construction | Infiltration $L/(s \cdot m^2)$ | Exfiltration $L/(s \cdot m^2)$ | Structural |
|---|---|---|---|
| EASE System | 0.09 | 0.09 | Pass |

### 4.6 Bathtub Enclosure Detail

A 1.2 m x 2.4 m sample exterior wall was constructed with two partition walls, spaced about 5 ft. The construction of the exterior wall between these two partitions was prepared to receive a bathtub. The exterior wall and partitions were constructed in the Traditional approach, the Poly approach and the ADA approach. See Figures 6A, 6B and 6C in Appendix C.

In the Traditional approach, the lower part of the wall below the bathtub is insulated but not sealed or protected with a vapour retarder.

In the Poly approach, the polyethylene is passed behind the furring strip of the wall that supports the edge of the bathtub and sealed to the bottom plate using acoustical sealant and stapled.

In the ADA approach, the inside dimensions for the interior partitions are increased by one inch so that a backer of 1/2 plywood can be installed over the area of the wall behind the bathtub. Then two layers of gypsum are used to air seal the exterior wall and partition walls.

The test panel walls and bathtub supports were installed in the pressure chamber and tested. At a referenced pressure of 75 Pa, the bathtub wall construction detail performed as follows:

| **Type of Construction** | **Infiltration L/(s·m²)** | **Exfiltration L/s·m²)** | **Structural** |
|---|---|---|---|
| Traditional | 3.96 | 3.81 | Pass |
| Polyethylene | 0.84 | 0.61 | ***(Fail)** |
| ADA | 0.61 | 0.76 | Pass |

* See graph #I7 and E7 of Appendix B.

## 4.7 Plumbing Stack Detail

A 0.75 m x 2.4 m ceiling test panel assembly representing the lower chords of trusses was constructed with 2 x 4's over a 2 x 6 plumbing wall. Four square holes were cut through the top plates between each chord segment with a chainsaw. A 75 mm diameter plumbing stack was installed through each opening and sealed to the ceiling air barrier in three ways. See Figures 7A, 7B, and 7C in Appendix C.

In the Traditional approach the opening around the plumbing stack is packed with glass fibre insulation.

In the Poly approach a strip of polyethylene is glued with acoustical sealant to the ceiling polyethylene and held in place using a plywood collar. The other end of the polyethylene strip is wrapped around the stack pipe and taped in place.

In the ADA approach a thin sheet of flat rubber was cut slightly larger (25 mm) than the opening for the stack vents. It was fastened to the underside of the opening over a gasket (glazing tape) and a 50 mm hole was cut in the center to pass the stack pipe and to obtain a tight fit.

Each of the sealing methods was tested in turn. The results are shown in Graph I8 and E8 of Appendix B. At the reference pressure of 75 Pa, the following air leakage results were obtained.

| Type of Construction | Infiltration L/s | Exfiltration L/s | Structural |
|---|---|---|---|
| Traditional | 1.90 | 1.89 | Pass |
| Polyethylene | 0.79 | 1.17 | Pass |
| ADA | 0.55 | 0.57 | Pass |

## 4.8 Bathroom Fan Detail

A 0.75 m x 2.4 m ceiling test panel assembly representing the lower chord of trusses was constructed with 2 x 4's at 400 mm on centre. Three, 200 mm x 200 mm, bathroom fan housings were attached to the side of the 2 x 4 chords. The housing and ceiling air barrier were then joined using the method appropriate to Traditional, Poly and ADA approaches. See Figures 8A, 8B and 8C in Appendix C.

In the Traditional approach the polyethylene and gypsum board of the ceiling are cut to fit around the fan housing. The interior trim cover is then installed to hide the openings and fan housing. The Fan duct was sealed to prevent thru flow during all air leakage measurements.

In the Poly approach, a polyethylene sheet is installed over the fan housing and taped (and sealed with acoustic sealant) to the ceiling vapour retarder. The poly is further wrapped around the duct piping and sealed using duct tape.

In the ADA approach, the fan housing is air sealed by encapsulating the housing with blocking between the chords, and with plywood over the chord faces. These elements are sealed to the gypsum board and to themselves using a glazing tape. The fan duct was routed and sealed at an opening in the plywood cover.

Each of the sealing methods was tested in turn. The results are shown in Graph I10 and E10 of Appendix B. At the reference pressure of 75 Pa, the following air leakage results were obtained.

| **Type of Construction** | **Infiltration L/s** | **Exfiltration L/s** | **Structural** |
|---|---|---|---|
| Traditional | 7.85 | 6.5* | Pass |
| Polyethylene | 0.42 | 0.44 | **(Fail)** |
| ADA | 1.26 | 1.27 | Pass |

* This measure was obtained at 50 Pa.

## 4.9 Metal Chimney Detail

A 0.75 m x 2.4 m ceiling test panel assembly, representing the lower chords of trusses was constructed with 2 x 4's at 400 mm on centre. Two metal chimneys, 300 mm diameter, were installed through a firestop metal liner between two chords of the test panels. The chimney fire stops were sealed to the ceiling and at the chimney opening in three different ways. See Figures 9A, 9B and 9C of Appendix C.

In the Traditional approach, the fire stop fits snug over the liner but is not sealed.

In the Poly approach, the fire stop is sealed at the ceiling polyethylene with acoustical sealant and with silicone sealant at the collar opening between the metal chimney and the fire stop.

In the ADA approach, the fire stop is sealed to the ceiling gypsum board using a gasket (glazing tape) between the edges of the fire stop and the gypsum board finish and with silicone at the collar openings as described above.

Each of these sealing methods was tested in turn. The results are shown in Graph I9 and E9 of Appendix B. At the reference pressure of 75 Pa, the following air leakage results were obtained.

| **Type of Construction** | **Infiltration L/s** | **Exfiltration L/s** | **Structural** |
|---|---|---|---|
| Traditional | >25 | >25 | ---- |
| Polyethylene | 0.45 | 0.45 | Pass |
| ADA | 0.38 | 0.40 | Pass |

# 5. ANALYSIS AND DISCUSSION

## 5.1 Analysis of Results

In general there are significant differences in the leakage rates of the Traditional approach, the Polyethylene approach and the ADA approach. These differences were sometimes as large as one hundred times as with the chimney air sealing detail of the Poly or ADA approaches.

The Poly approach proved to be quite airtight compared to the ADA approach and the Traditional approach at 75 Pa for many of the details. However, some of the polyethylene details were found to be structurally unsatisfactory as was the case with the bathtub enclosure detail where the unsupported polyethylene caused a sealant failure between the insulation and the bathtub at about 200 Pa.

Similar results occurred with the Poly bathroom fans detail.

In the sill detail it was found that the Traditional approach provided air leakage control of 0.12 L/(s·m) without air sealing effort. The ADA and Poly approaches reduced the leakage by 10 times. The Poly approach appeared the tightest with use of sealant. It is recommended, however, that the acoustical caulking be replaced by other sealants because acoustical sealant will flow out of joints under sustained air pressure differences such as stack effect or fan pressurization.

The performance of the electric outlet covers was interesting. As it turned out the performance of the molded rubber insert (Poly approach) was about the same as using the horizontal slider cover plate (STEWCA) with a standard electrical box.

The bathtub details were expected to be leaky but not as leaky as indicated by test measurement. These tests were repeated and found to be consistent.

It is to be noted that all ceiling penetration details including the vent stacks, the bathroom fans and the metal chimney exhibited substantial improvement with the Poly and ADA approaches over the Traditional.

## 5.2 Discussion

There are not yet standards that define the acceptable levels of air leakage through the construction details of wall systems evaluated in this study. There are, however, some bench-mark numbers to which our results can be compared.

- Lux and Brown of NRC suggested in a paper presented at the Building Insight of 1986, that wall air leakage be restricted to 0.05, 0.1 or 0.15 L/s $m^2$ @ 75 Pa for buildings that have an RH value above 55% (Type 3), between 25% and 55% (Type 2) or below 27% (Type 1) respectively. Residential buildings would fall into the type 2 category or the 0.1 l/s·$m^2$ rate at 75 Pa.

- The Architectural Aluminum Manufacturers Association (AAMA) allows a total airflow of 0.3 l/s·$m^2$ at 75 Pa for glass and aluminum curtain walls.

- The R-2000 Program requires that the equivalent leakage area of the envelope assembly, including intentional openings, penetrations, etc., not exceed .7 $cm^2/m^2$ (in addition there is a limit on the air change per hour @ 50 Pa due to envelope leakage). This equivalent leakage area can be converted to a flow rate per $m^2$ at 10 Pa pressure difference with the equation:

  $Q_{10}(l/s) = 788\ ELA\ (m^2)\ (10)^{1/2}$

  The flow rate $m^2$ at 75 Pa is then:

  $Q_{75}(l/s) = Q_{10}(7.5)^n$

  Using a value for n of 0.65 gives a flow of about 0.64 l/s·$m^2$ at 75 Pa.

- Recent airtightness testing in current tract built construction has shown average leakage characteristics of more than double this value (e.g. 1.4 l/s·$m^2$ at 75 Pa).

The above numbers define leakage rates based on the overall envelope area. Our test panel assemblies had very high ratio of joint to wall or ceiling area. Another way of looking at the results is to consider the contribution these construction details could provide to overall house leakage. Table 5.1 provides the leakage values for each test panel assembly in terms of unit length, unit area or unit item.

**Table 5.1**

**Air Leakage Rates @ 75 Pa**

| Description | Graph # | Traditional | Poly | ADA | EASE |
|---|---|---|---|---|---|
| Sill - Infil. | I1 | 0.12 L/s·m | 0.00 L/s·m | 0.03 L/s·m | |
| Sill - Exfil. | E1 | 0.07 L/s·m | 0.00 L/s·m | 0.03 L/s·m | |
| Partition - Infil. | I2 | 0.25 L/s·m | 0.12 L/s·m | 0.16 L/s·m | |
| Partition - Exfil. | E2 | 0.27 L/s·m | 0.14 L/s·m | 0.15 L/s·m | |
| Stair - Infil. | I3 | 0.30 L/s·m | 0.00 L/s·m | 0.02 L/s·m | |
| Stair - Exfil. | E3 | 0.28 L/s·m | 0.00 L/s·m | 0.02 L/s·m | |
| Electric - Infil. | I4 | 1.32 L/s | 0.35 L/s | 0.20 L/s | |
| Electric - Exfil. | E4 | 1.30 L/s | 0.35 L/s | 0.21 L/s | |
| EASE - Infil. | I6 | | | | 0.09 L/s·m² |
| EASE - Exfil. | E6 | | | | 0.09 L/s·m² |
| Bathtub - Infil. | I7 | 3.96 L/s·m² | 0.84 L/s·m² | 0.61 L/s·m² | |
| Bathtub - Exfil. | E7 | 3.81 L/s·m² | 0.61 L/s·m² | 0.76 L/s·m² | |
| Plumbing Stacks - Infil. | I8 | 1.90 L/s | 0.79 L/s | 0.55 L/s | |
| Plumbing Stacks - Exfil. | E8 | 1.89 L/s | 1.17 L/s | 0.57 L/s | |
| Chimney - Infil. | I9 | >25 | 0.45 L/s | 0.38 L/s | |
| Chimney - Exfil. | E9 | > 25 | 0.45 L/s | 0.40 L/s | |
| Fans - Infil. | I10 | 7.58 L/s | 0.42 L/s | 1.26 L/s | |
| Fans - Exfil | E10 | >25 | 0.44 L/s | 1.27 L/s | |
| | | **Traditional** | **Leviton** | **Stewca** | |
| Cover Plates - Infiltration | I5 | 1.32 L/s | 1.61 L/s | 0.32 L/s | |
| Cover Plates - Exfiltration | E5 | 1.30 L/s | 1.60 L/s | 0.33 L/s | |

The values given in Table 5.1 provide the air leakage through each type of detail by area, joint length or by type. By using the numbers in Table 5.1, an estimate of how much the details contribute to the overall leakage of a house can be obtained.

Consider a 150 $m^2$ (1,600 $ft^2$) 2 storey house with a basement and outside plan dimension of 7.5 m x 10 m. It would have a volume of 560 $m^3$, approximately 70 m of header joist, 15 electrical outlets in the exterior walls and about 40 m of window perimeter. Further assume, 164 $m^2$ of exterior wall with out windows and a total envelope area above the foundation of 239 $m^2$.

**TABLE 5.2**

**Contribution to Overall Tightness**

| Description | Joint Length, Area or Quantity | Traditional (L/s) | Poly (L/s) | ADA (L/s) |
|---|---|---|---|---|
| Sill Plate | 35 m | 4.2 | 0.0 | 1.1 |
| Partition Wall | 19.2 m | 5.0 | 2.5 | 2.9 |
| Stair Stringer | 3.4 m | 1.0 | 0.0 | 0.1 |
| Bathtub Wall | 0.6 m2 | 2.3 | 0.4* | 0.4 |
| Electrical Outlets | 15 | 19.7 | 5.3 | 3.2 |
| Header Joist ① | 70 m | 15.4 | 3.5 | 1.5 |
| Bathroom Fan | 1 | 7.6 | 0.4* | 1.3 |
| Plumbing Stack | 1 | 1.9 | 1.2 | 0.6 |
| Chimney | 1 | 25 | 0.5 | 0.4 |
| Total Leakage | | 82.1 | 13.8 | 11.5 |

* Indicates rupture at higher pressure.

① From CMHC report on Details I

It is noted from the results that the overall contribution to air leakage for the Traditional, the Poly and the ADA approaches are 82.1, 13.8 and 11.5 l/s respectively. Both the Poly and ADA approaches reduce the air leakage rate by a factor of six. While both approaches were found to be quite similar in controled flow rates, the Poly approach was found structurally weak in two applications, the bathtub detail and the bathroom fan detail.

It was not possible to compare these rates with the EASE system, because the overall wall area leakage for the other three methods are unknown. Nevertheless, the EASE system using the new Tyvek was found to be less than 0.1 $l/s{\cdot}m^2$.

# 6. CONCLUSIONS AND RECOMMENDATIONS

## 6.1 Conclusions

1. The sill pate detail for Poly and ADA reduce the air leakage by a factor of ten over the Traditional detail.

2. The EASE wall systems using the new TYVEK provides air leakage resistance better than the IRC recommendation of 0.1 $l/s{\cdot}m^2$ at 75 Pa.

3. Several of the Poly joint details failed structurally, specifically the bathtub detail and the bathroom fan detail.

4. It appears that the air leakage rate of electrical outlets can be greatly reduced through the use of the Stewca cover plate in combination with a gypsum board air barrier system.

5. The ceiling air barrier details for the vent stack, the bathroom fan and the metal chimney were substantially improved through the Poly and ADA approaches, however, the Poly approach was found to be structurally inadequate for the bathroom fan detail.

6. The use of the roof jack for sealing the plumbing stack was unsuitable due to its rigid and tilted form.

7. The overall results of the analysis in Part 5 indicate that the Poly, and ADA approaches provide air leakage control that is better than traditional details by a factor of six.

## 6.2 Recommendations

1. While most typical details of wood frame construction were addressed by the first and second study there remains a few details for future consideration. These are exterior wall corners, 2nd floor overhangs, fireplace construction, dryer and kitchen exhaust ducts, and exterior wall plumbing penetrations.

2. The information obtained from Detail I and Detail II studies would be suitable for the design and commissioning of the air barrier system of wood frame buildings.

3. While the study was limited to wood frame construction, it would be practical to extend the study approach to multi and high-rise construction detail, and in particular, steel stud/brick veneer, stucco and EIFS system.

**MORRISON HERSHFIELD LIMITED**

R Quirouette
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Alain Chevrier, C.E.T.

Richard L. Quirouette, B.Arch.

# APPENDIX A
# WOOD FRAME CONSTRUCTION METHODS

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# WOOD FRAME CONSTRUCTION METHODS

With the general recognition of the importance of controlling air leakage through the building envelope, three basic construction approaches to achieving airtightness have evolved around modification of the traditional method of construction. Two are based on using a sealed, flexible membrane and the third uses the rigid interior cladding materials and framing components as the plane of airtightness.

## TRADITIONAL Approach

Traditionally, the airtightness of houses was achieved through the inherent resistance to air flow of sheathing materials and vapour barrier membranes, the tightness in fit between components, the airtightness of material used to fill the space between the rough openings and frames of windows and doors, and the effect of exterior caulkings used to provide weather tightness.

## POLY Approach (Polyethylene Membrane and Acoustical Sealant)

The POLY Approach uses the polyethylene vapour retarder and acoustical sealant to form the airtightness plane. Polyethylene, as a material, is essentially airtight and has a low water vapour permeability. However, it requires structural support to resist damage by wind load pressures, and it requires overlapping joints with mechanical clamping between rigid members for durable sealing. These limitations can be overcome by proper design and construction of envelope assemblies but it is obvious that polyethylene should not remain exposed to the elements for long periods. Prolonged exposure to sunlight does not usually occur during construction (walls are typically sheathed from the outside in), but there are periods during construction when the air barrier is susceptible to damage if exposed to high wind pressures without the support of interior drywall. Minor tears or rips in the polyethylene may not be noticed prior to installing the gypsum board finish and may therefore never be repaired.

There has also been some concern expressed that movement of the membrane under wind loads can cause tearing at staples and displacement of non-rigid insulation.

**ADA Approach (Airtight Drywall Assembly)**

The ADA or "airtight drywall assembly" approach relies on rigid interior cladding materials, such as gypsum board, and gaskets to resist air flow. While not effective as a vapour retarder, gypsum board is highly resistant to the passage of air. Being a rigid material, it is also not likely to be damaged by high air pressure differentials. Also, great care is typically given to its installation as it is the finished surface. Therefore any screw holes will be covered with dry-wall joint compound. The vapour barrier properties of the wall can be provided by using foil backed gypsum board, polyethylene or vapour resistant paints.

**EASE Approach (Exterior Air System Element)**

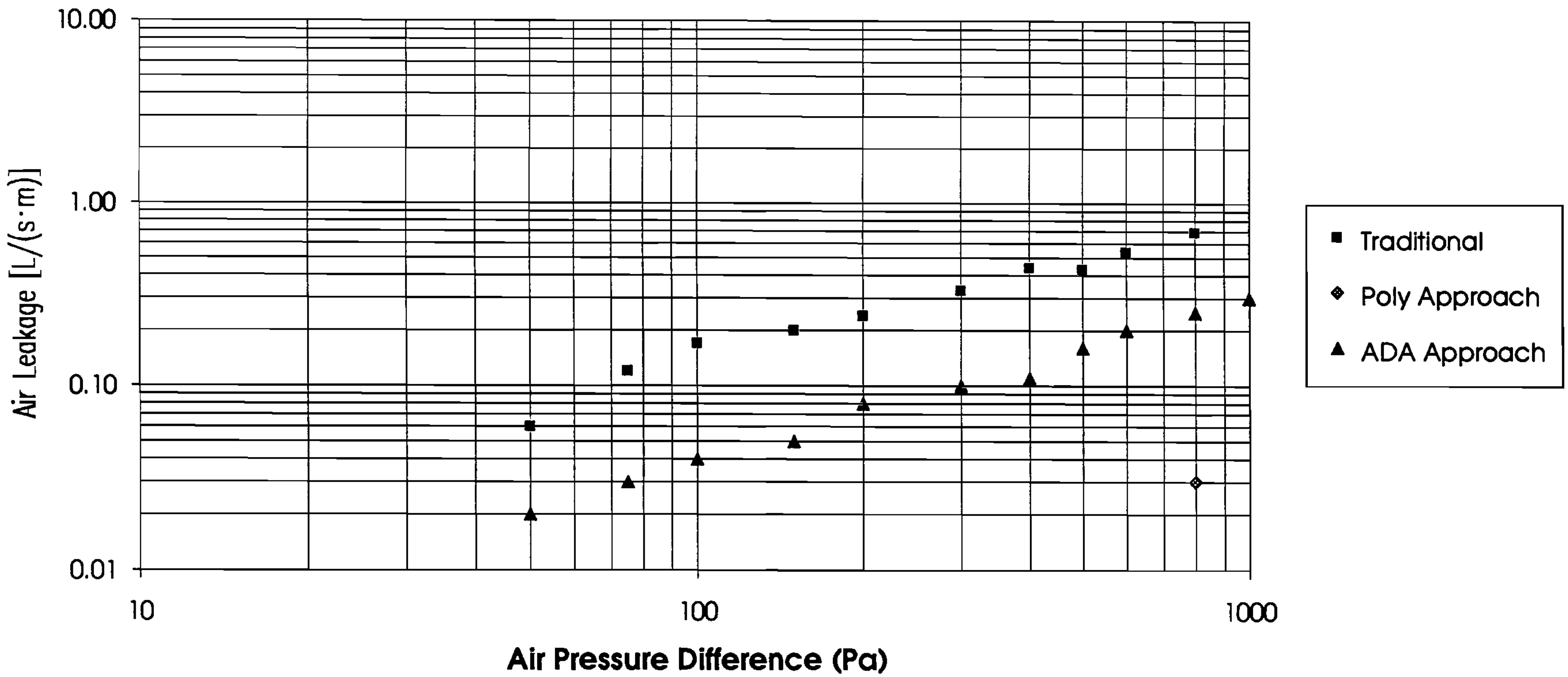
The more recently developed EASE approach also uses a membrane to provide the airtightness plane but it is located on the cold side of the insulation. In this location in the building envelope the membrane must be relatively permeable to water vapour in order to facilitate the escape of any accumulated moisture, so a spun bonded olefin membrane is used. Structural support is provided by sandwiching the membrane between two layers of fiberboard (or other rigid sheathing material). Vapour diffusion control on the warm side of the insulation is provided by an adequate vapour retarder which need not be air sealed. Because the EASE barrier is relatively permeable to water vapour, it does allow drying by diffusion to the outside.

While this method of construction is relatively new, advocates point out that this air barrier system is the first element of the wall to be erected. This provides some protection to the other elements of the wall and reduces the risk of damaging the air seal since it is always supported by rigid materials that are intended for use in exposed conditions.

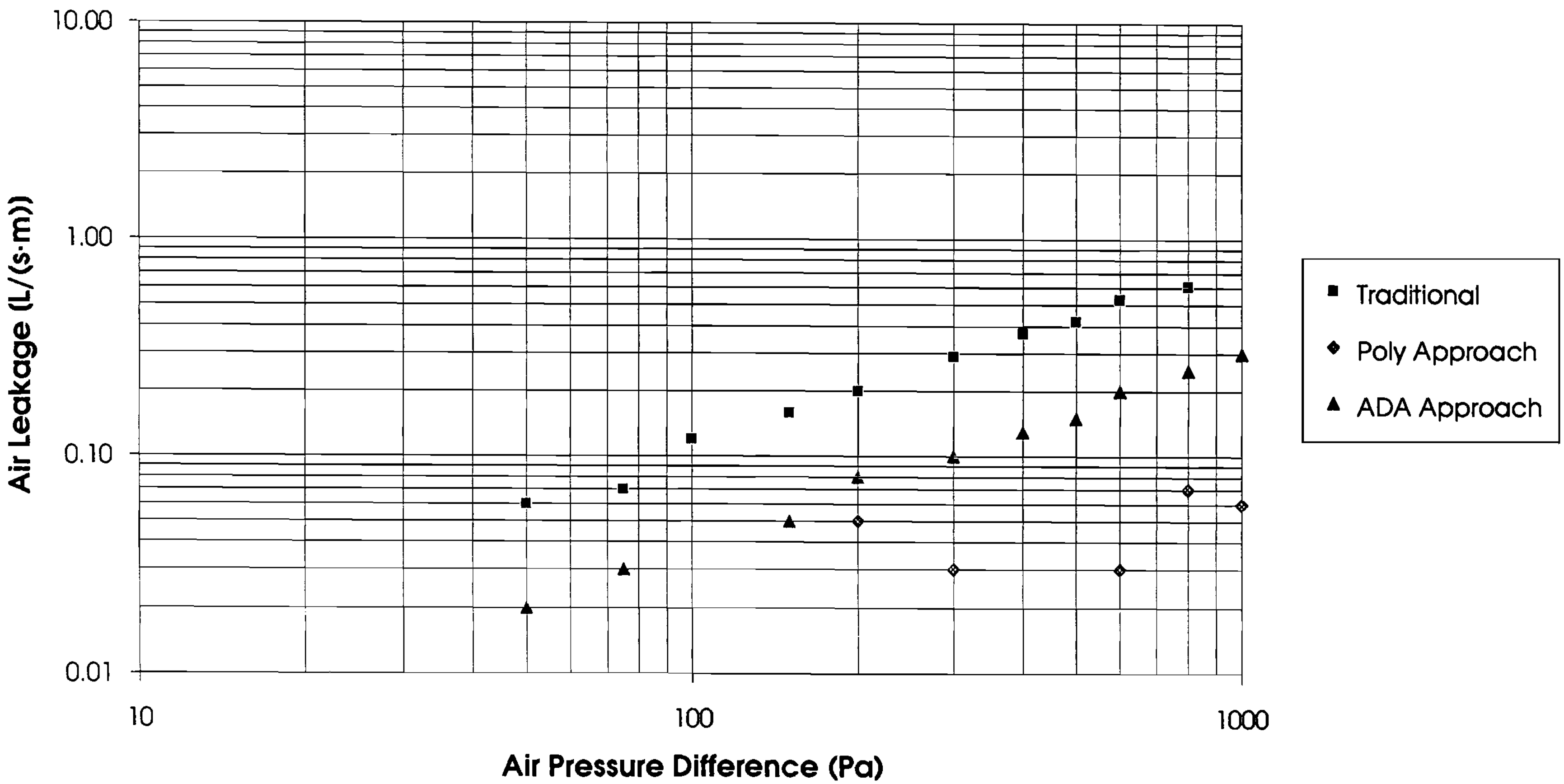
**APPENDIX B**

AIR LEAKAGE TEST RESULT GRAPHS

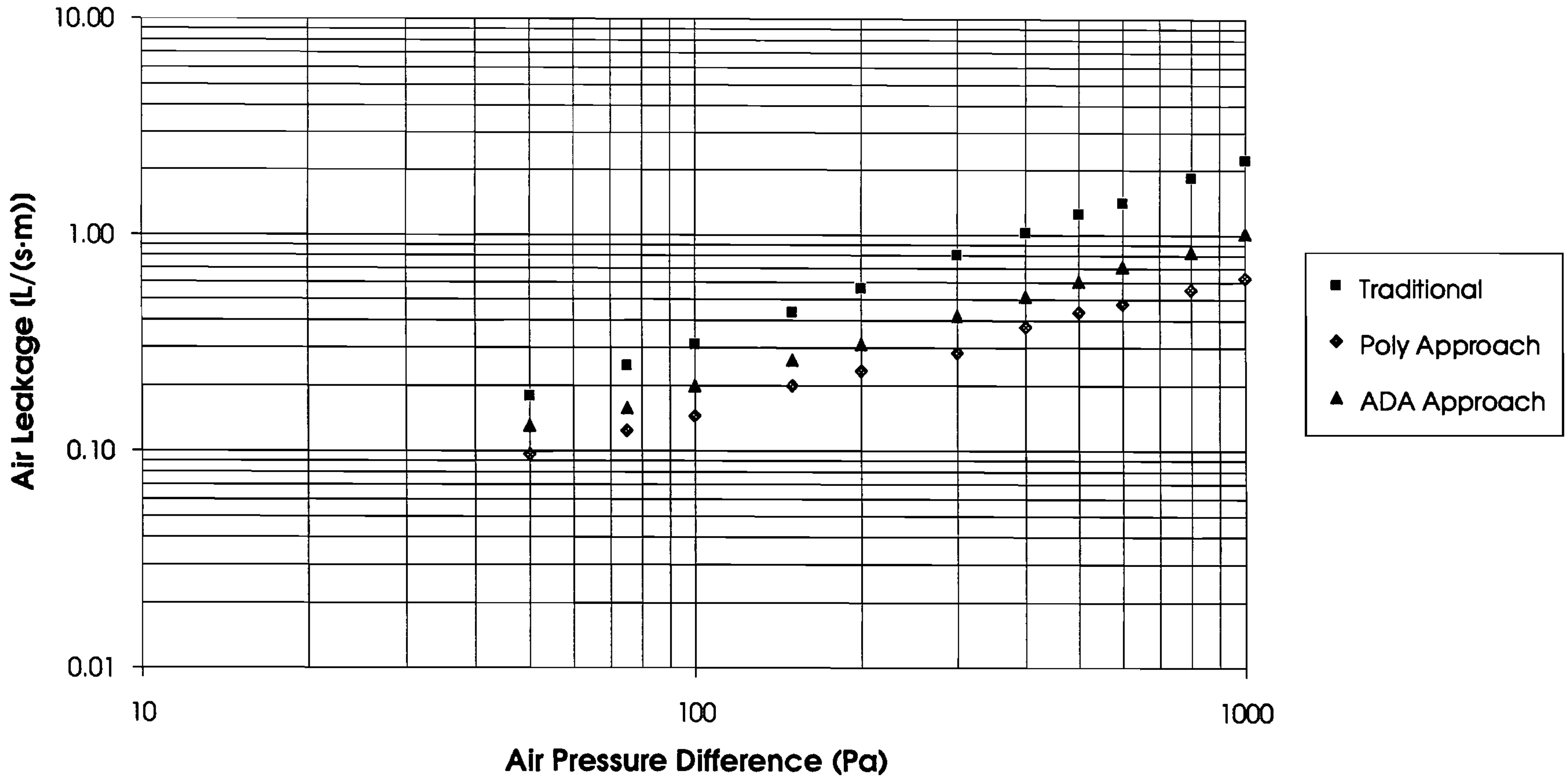
## Graph I1 - Foundation Sill Detail - Infiltration



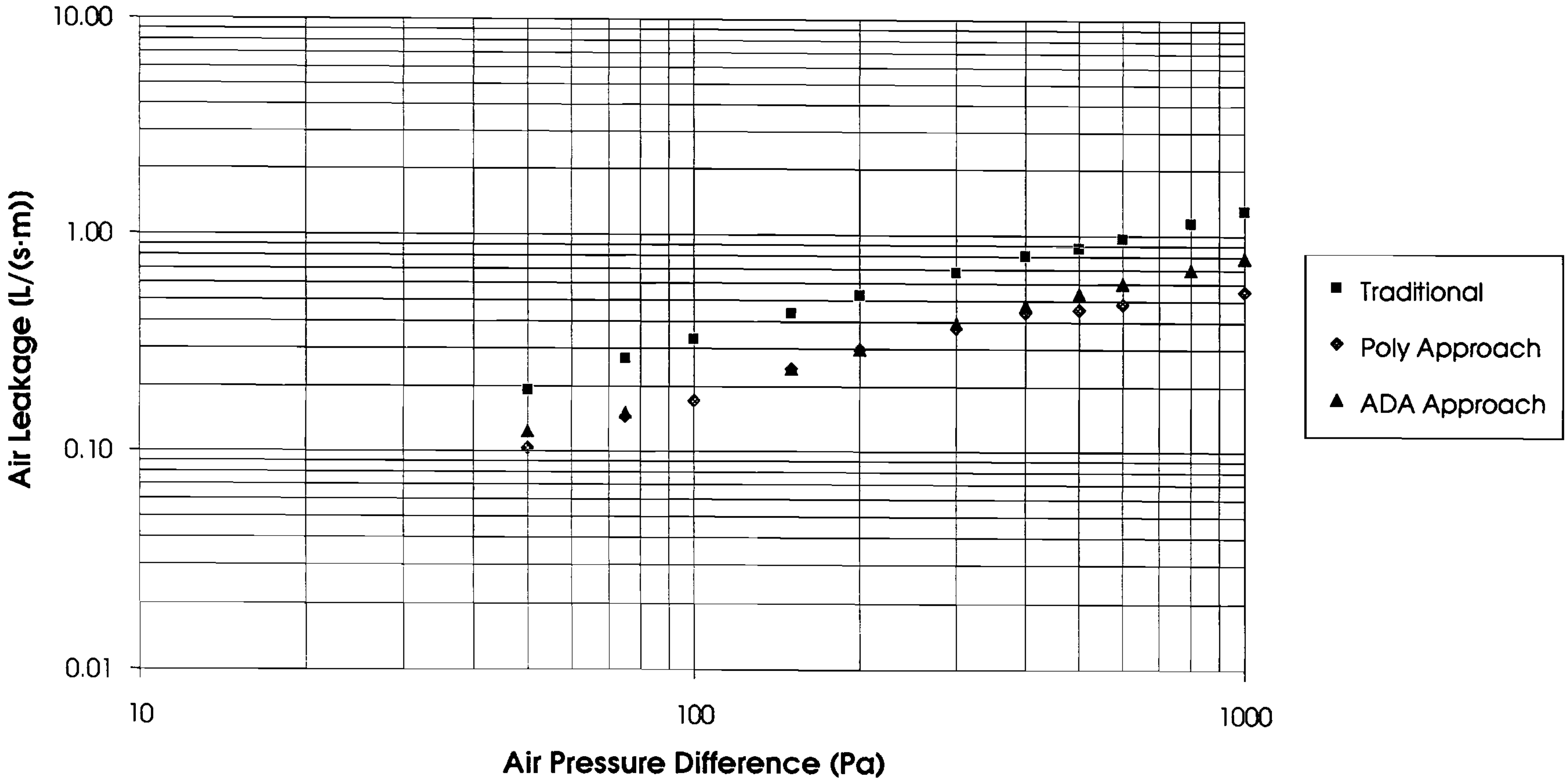
## Graph E1 - Foundation Sill Detail - Exfiltration



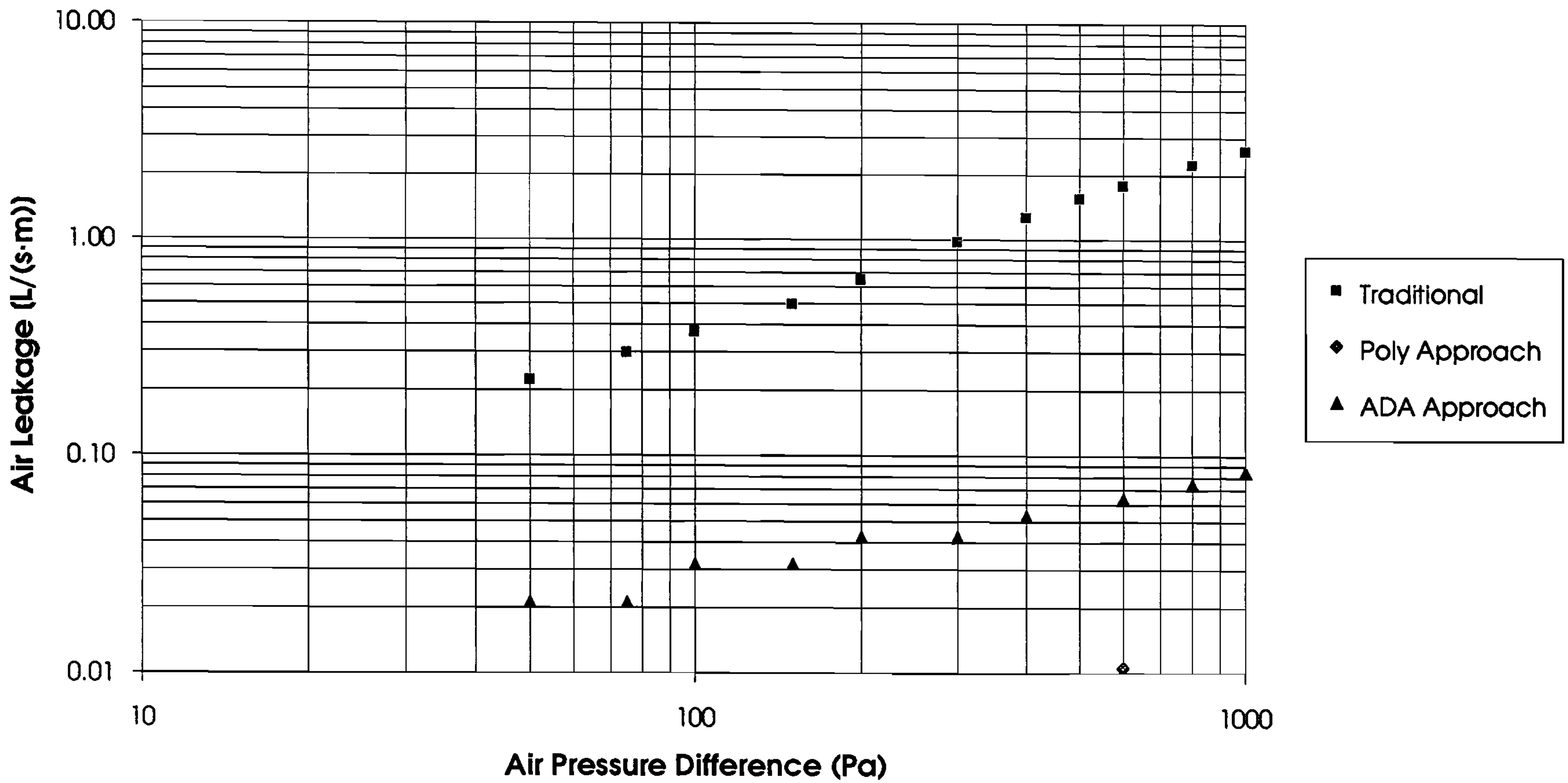
## Graph I2 - Partition Exterior Wall Detail - Infiltration



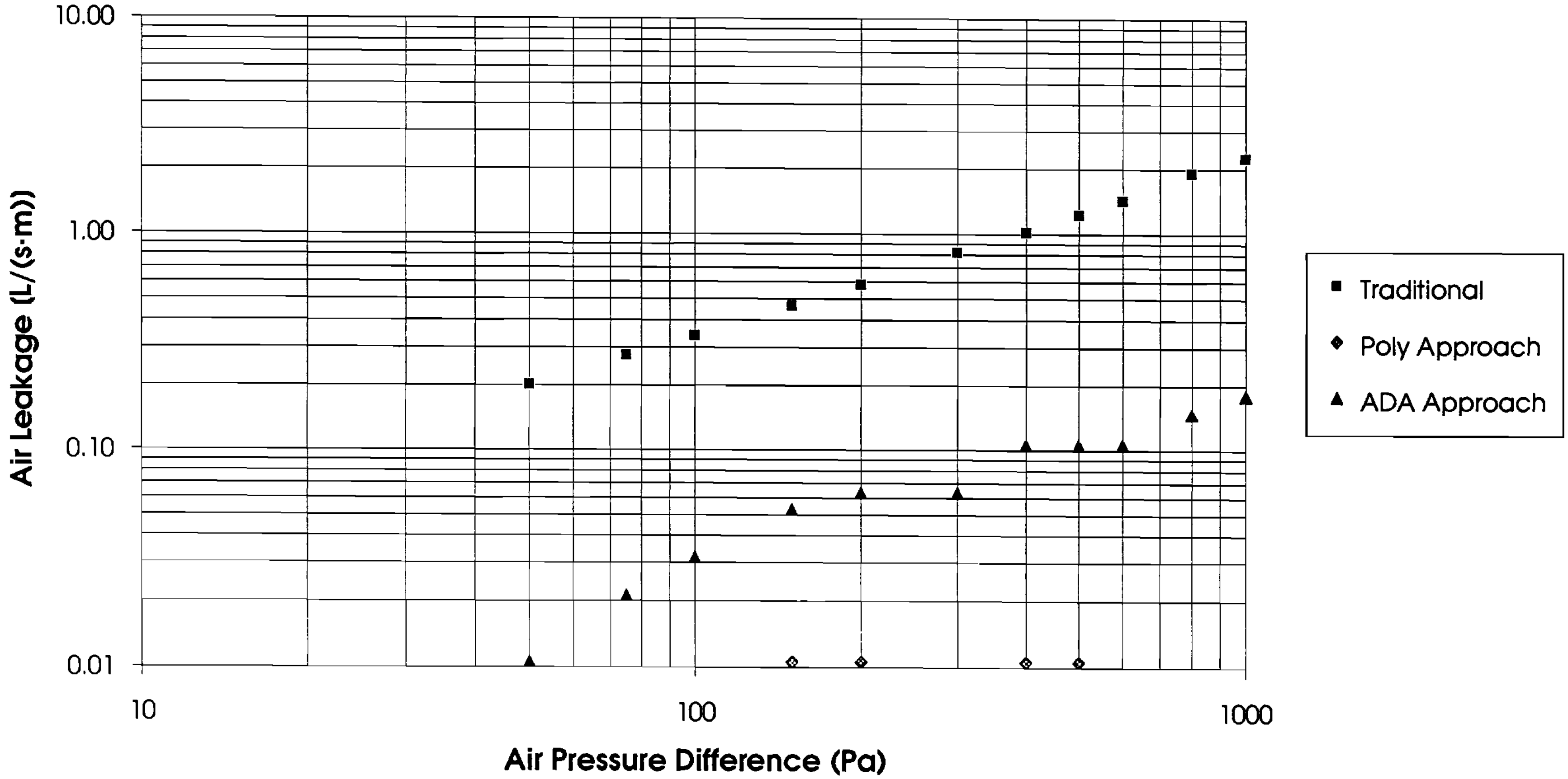
## Graph E2 - Partition Exterior Wall Detail - Exfiltration



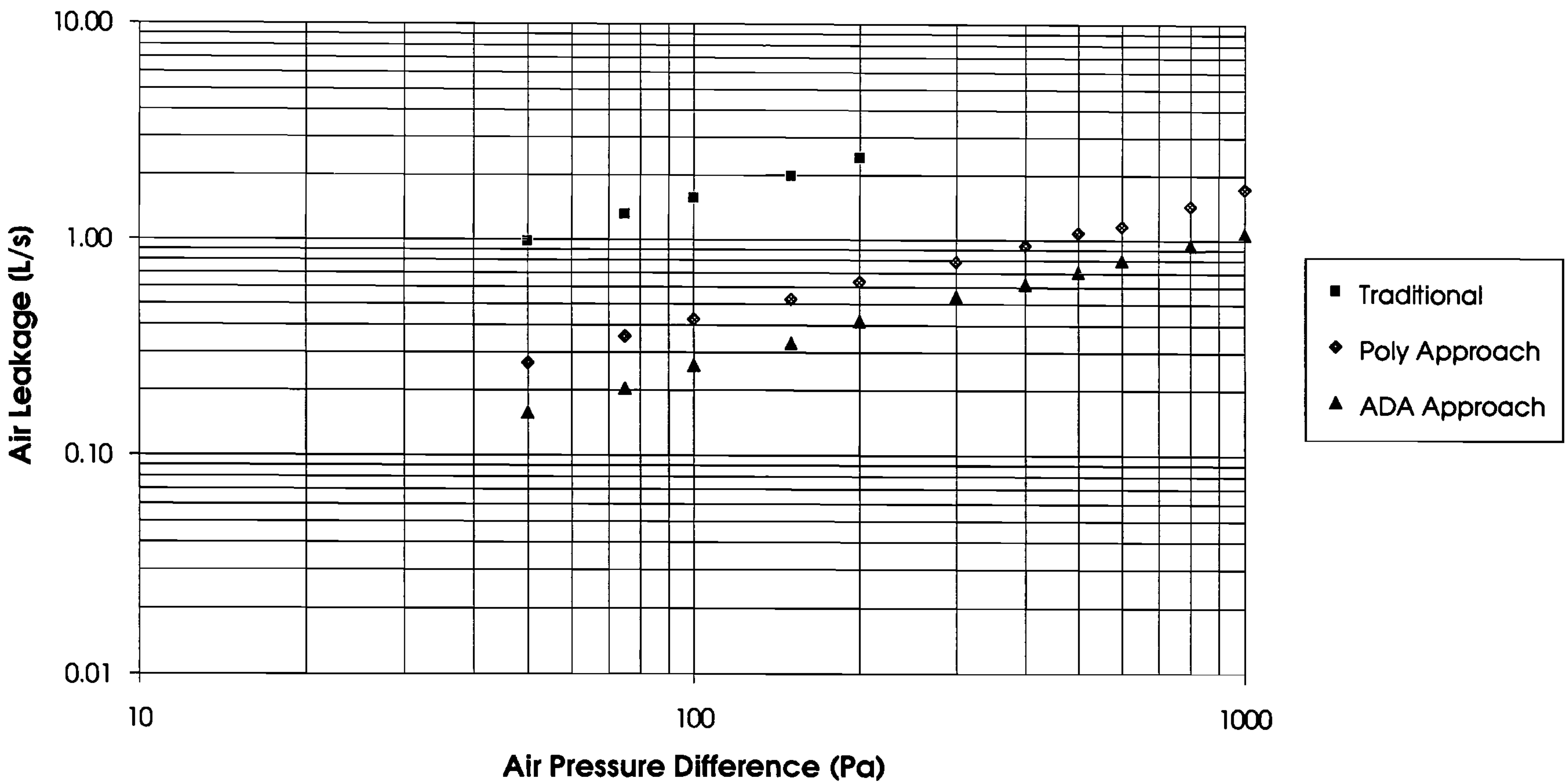
## Graph I3 - Stair Stringer/Exterior Wall Detail - Infiltration



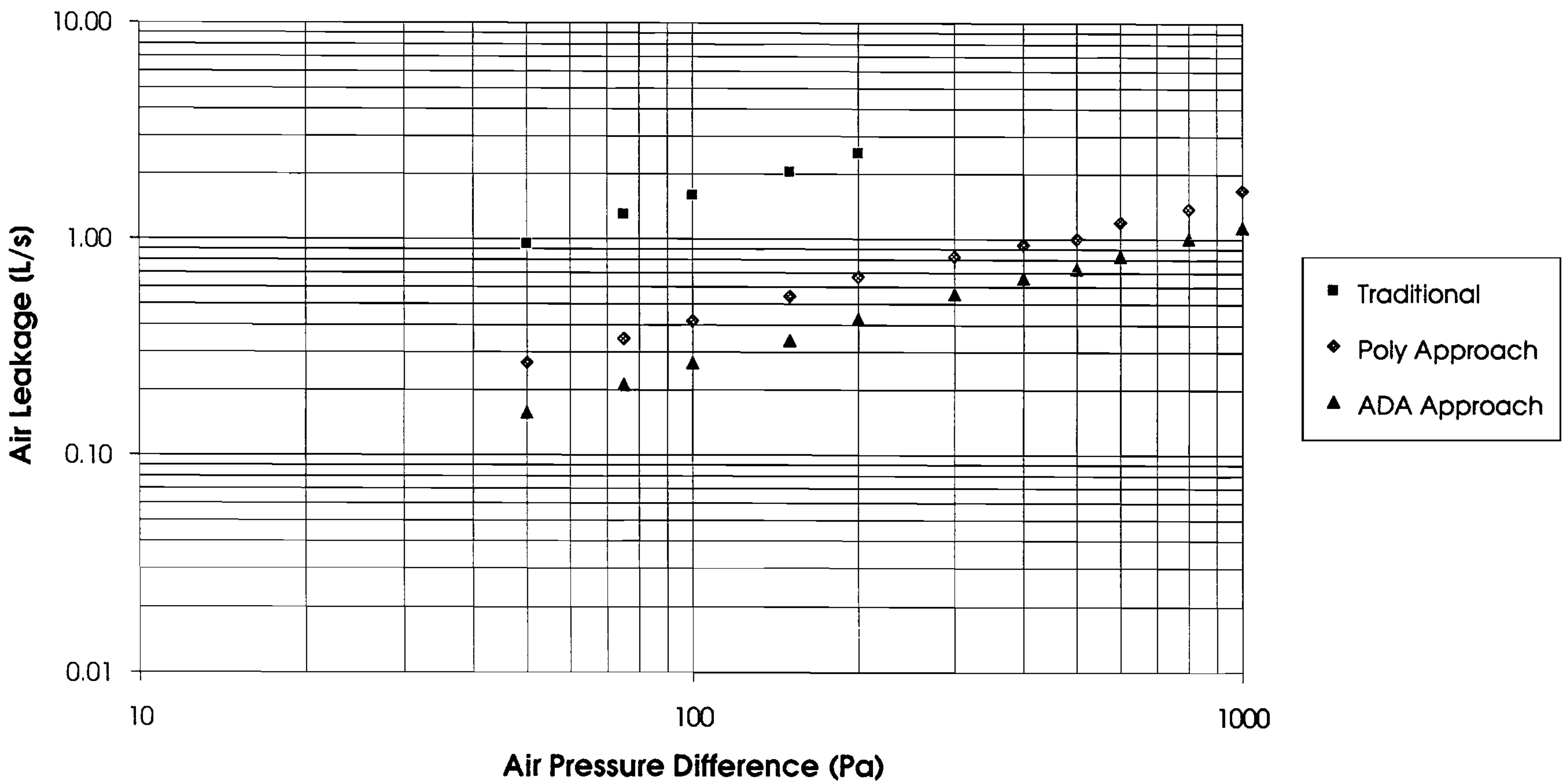
## Graph E3 - Stair Stringer/Exterior Wall Detail - Exfiltration



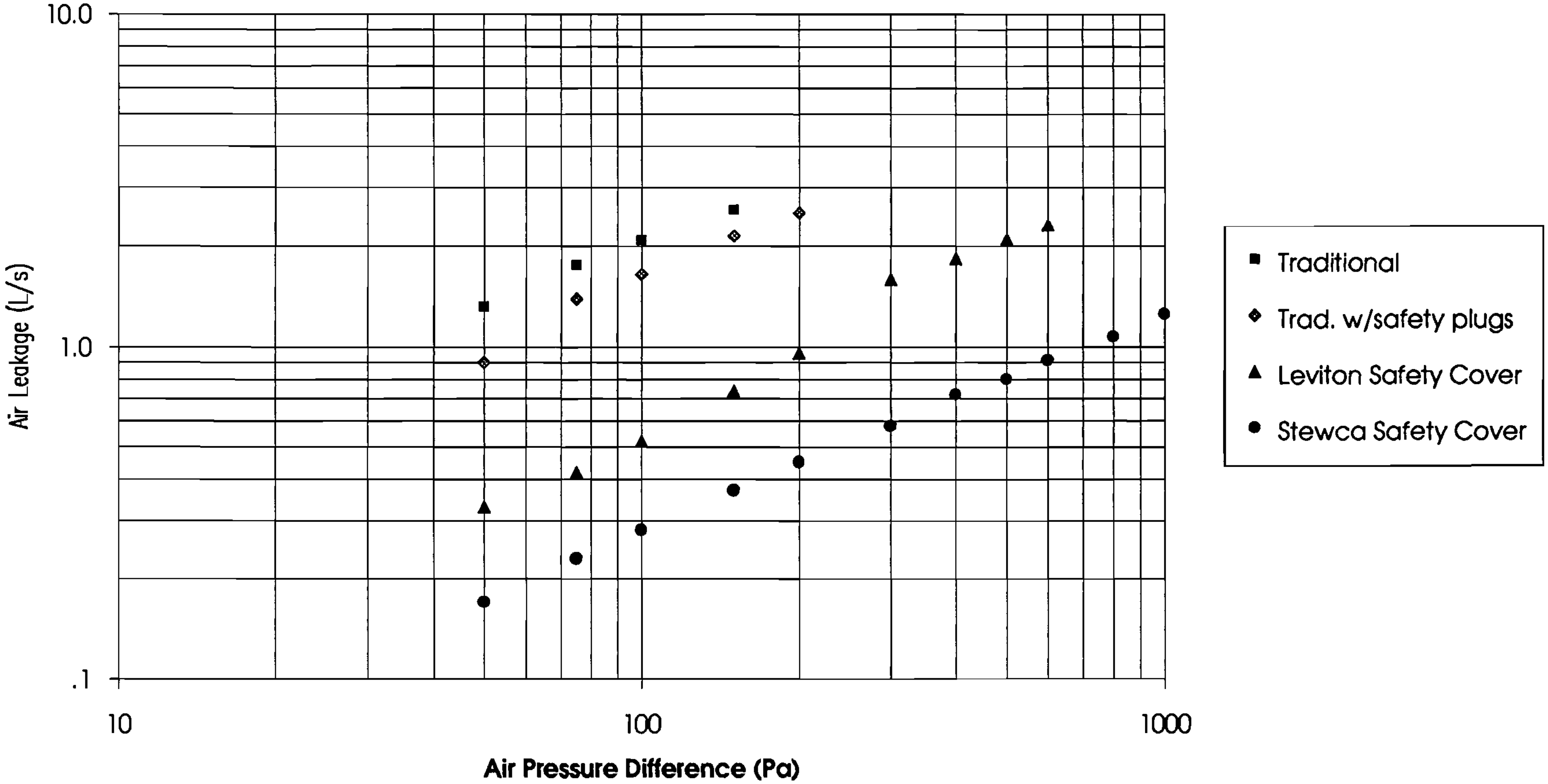
## Graph I4 - Electrical Outlet Detail - Infiltration



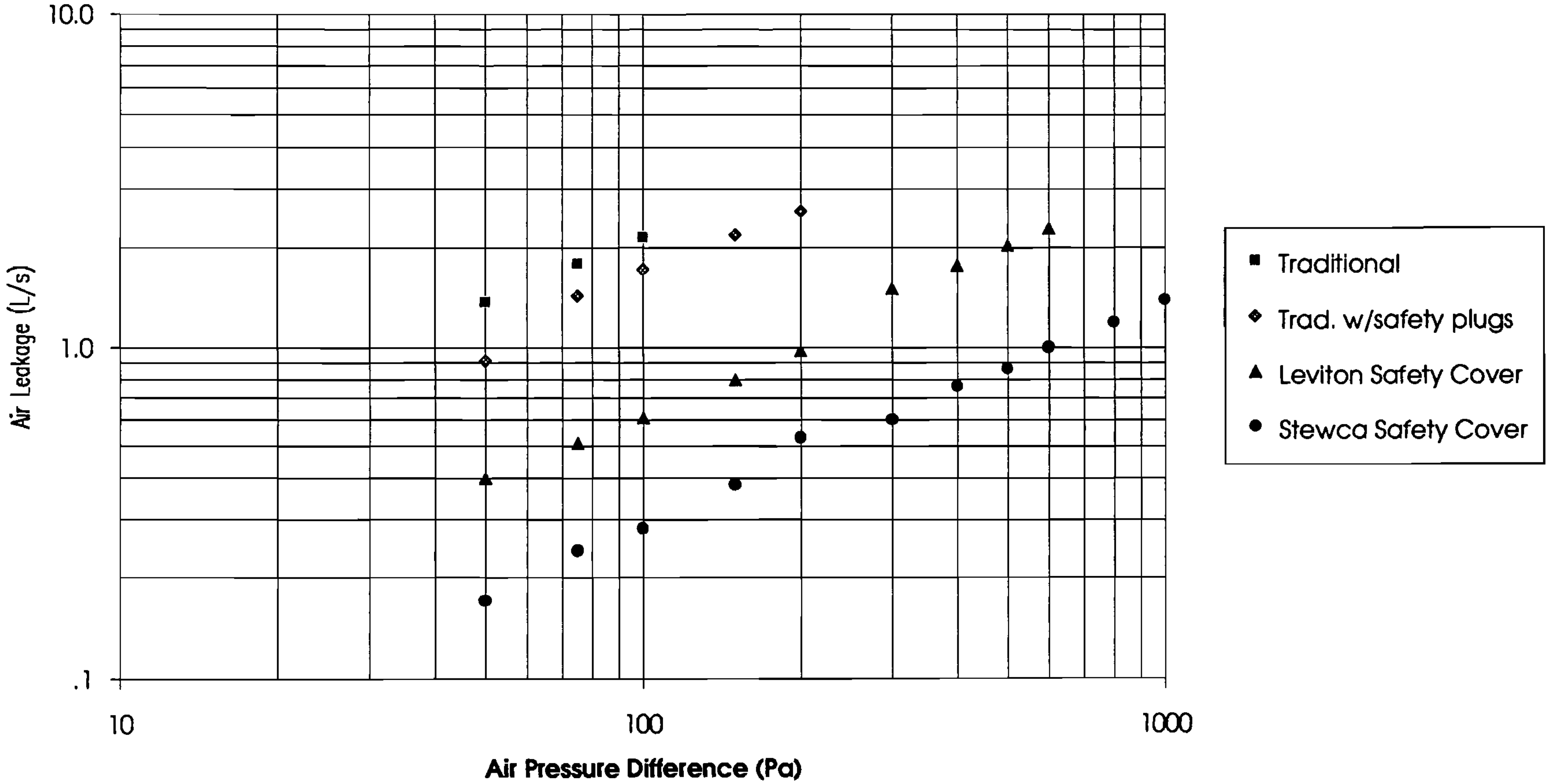
## Graph E4 - Electric Outlet Detail - Exfiltration



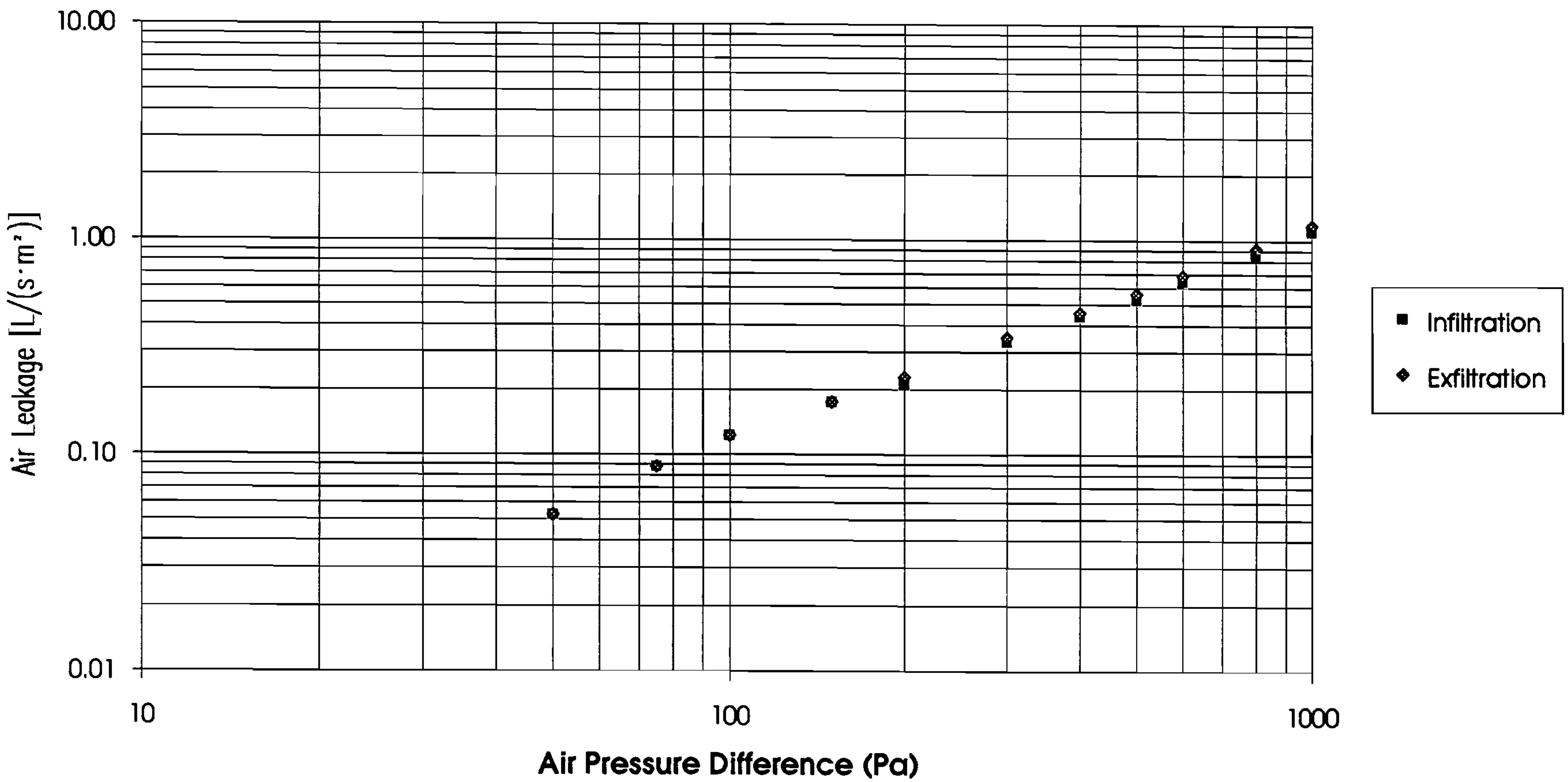
## Graph I5 - Electrical Outlet Cover Plate Detail - Infiltration



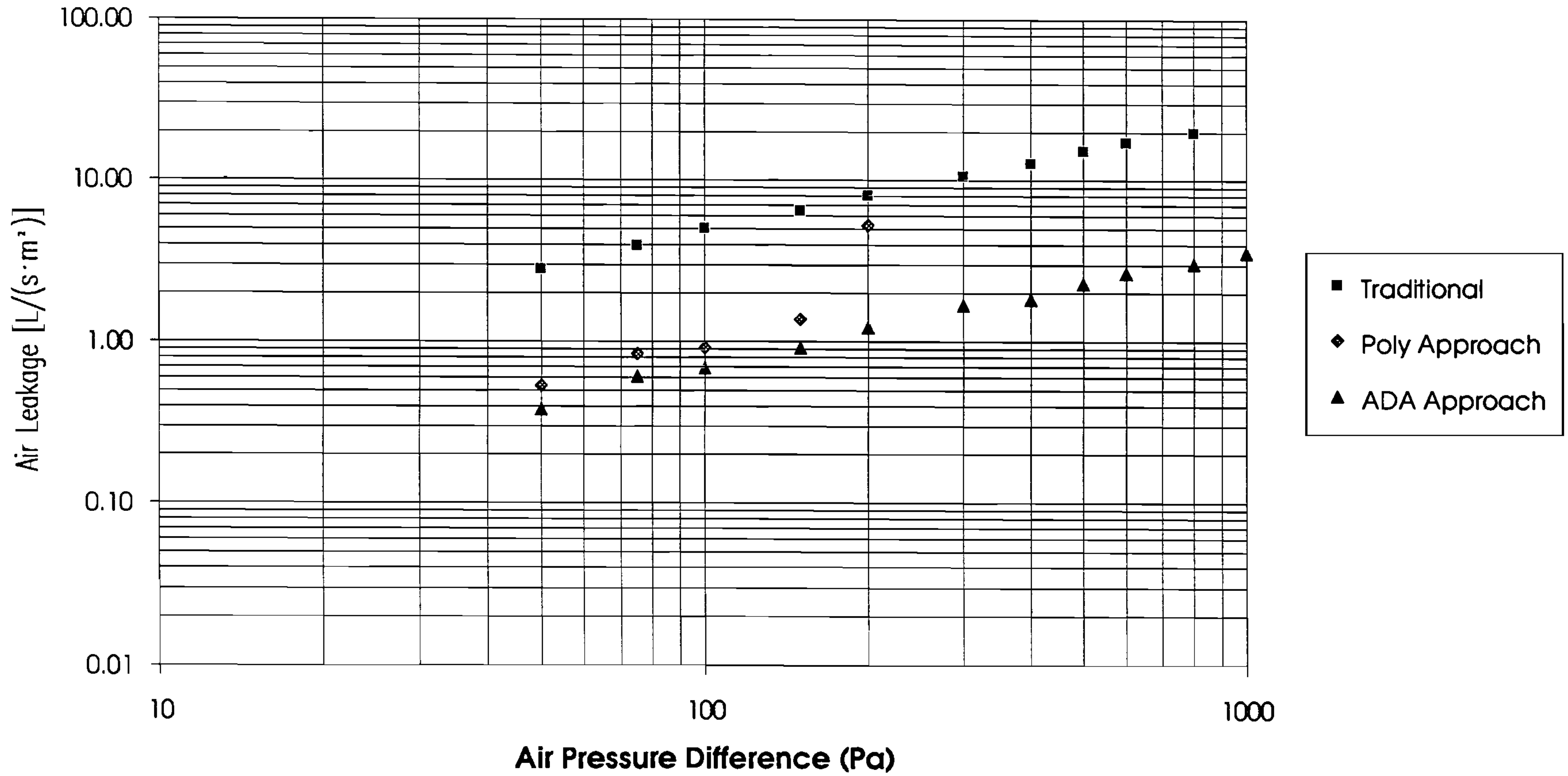
## Graph E5 - Electrical Outlet Cover Plate Detail - Exfiltration



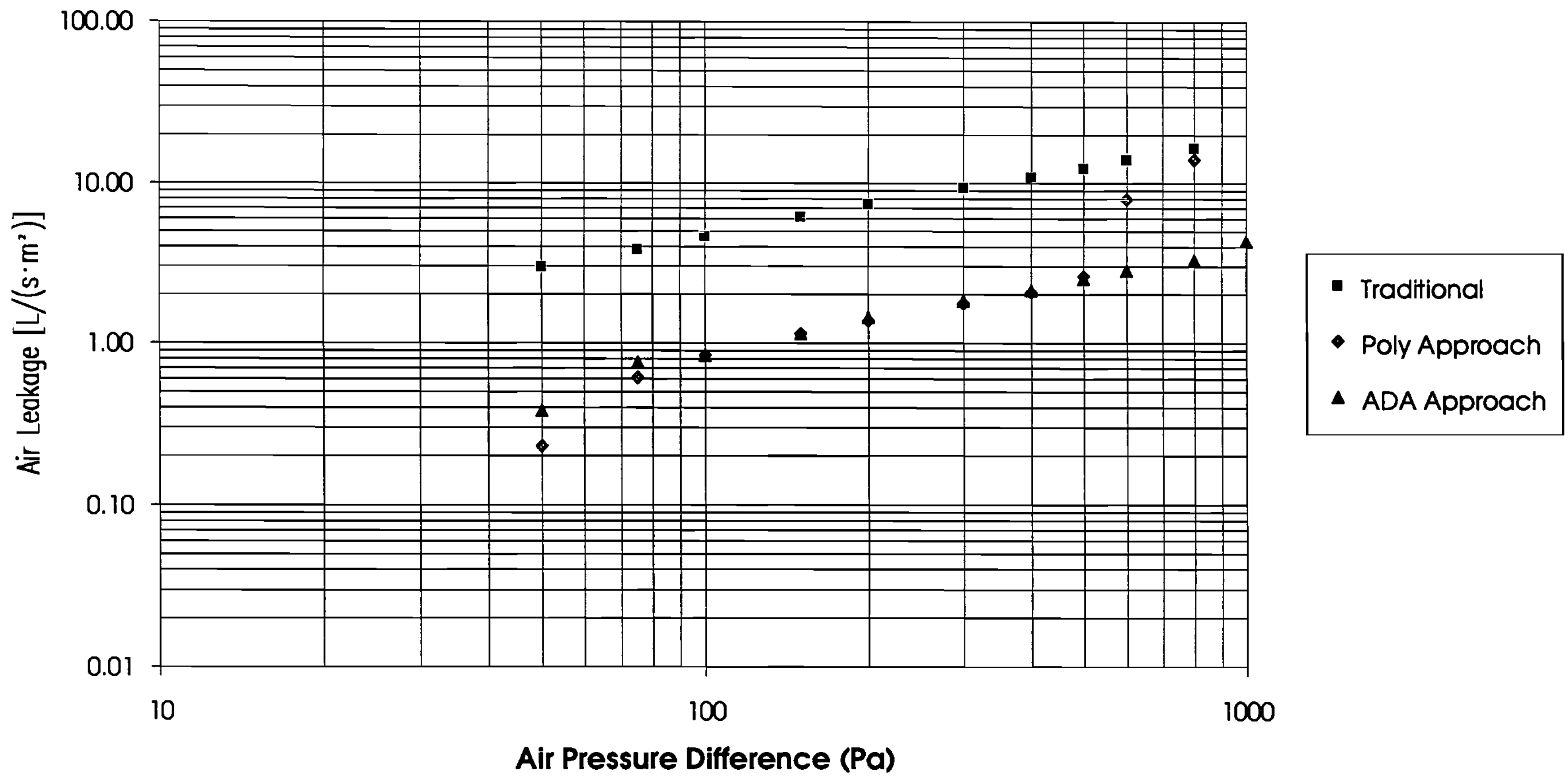
## Graph 6 - EASE (New Tyvek) Exterior Wall



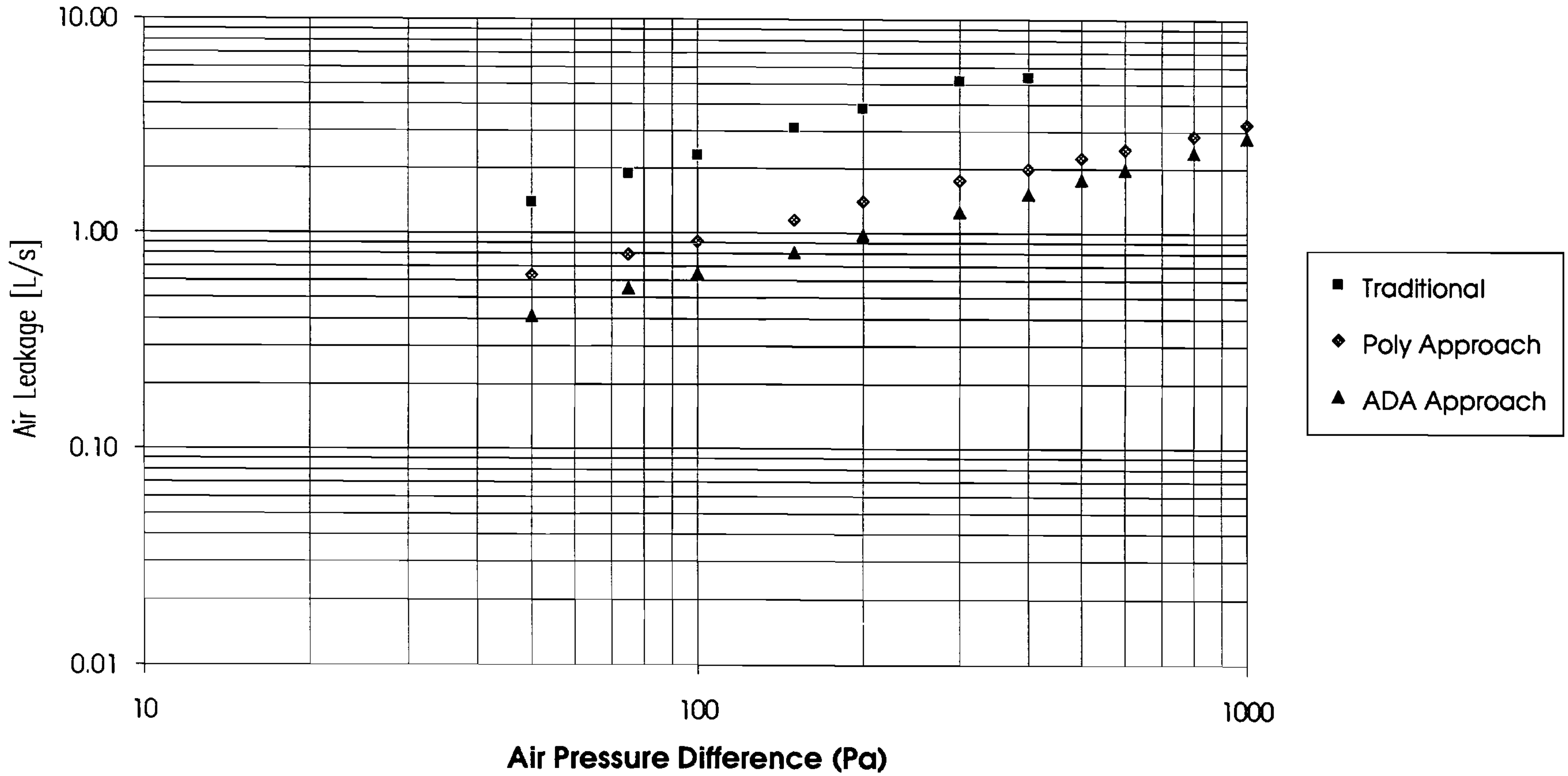
## Graph I7 - Bathtub/Exterior Wall Detail - Infiltration



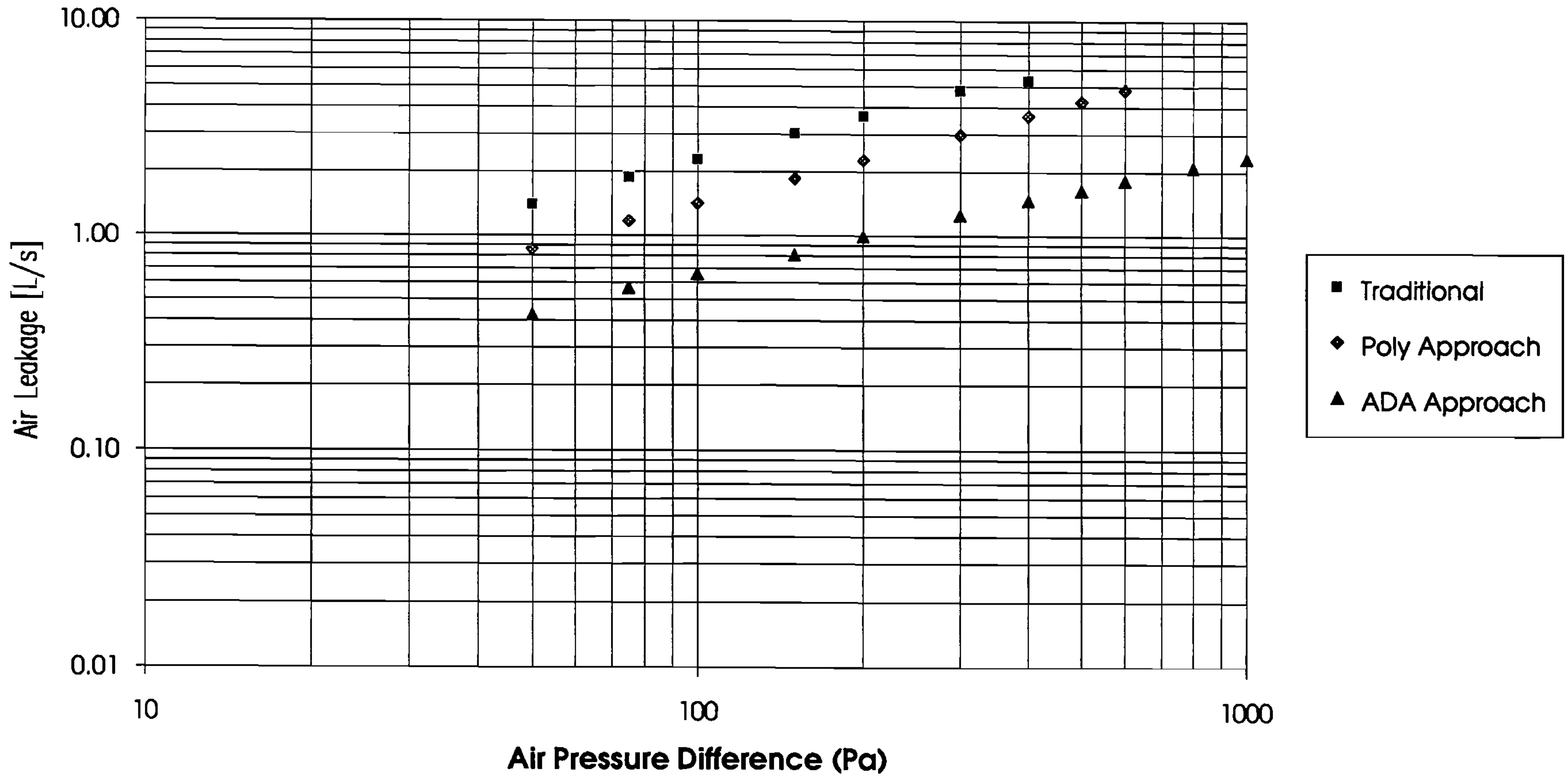
## Graph E7 - Bathtub/Exterior Wall Detail - Exfiltration



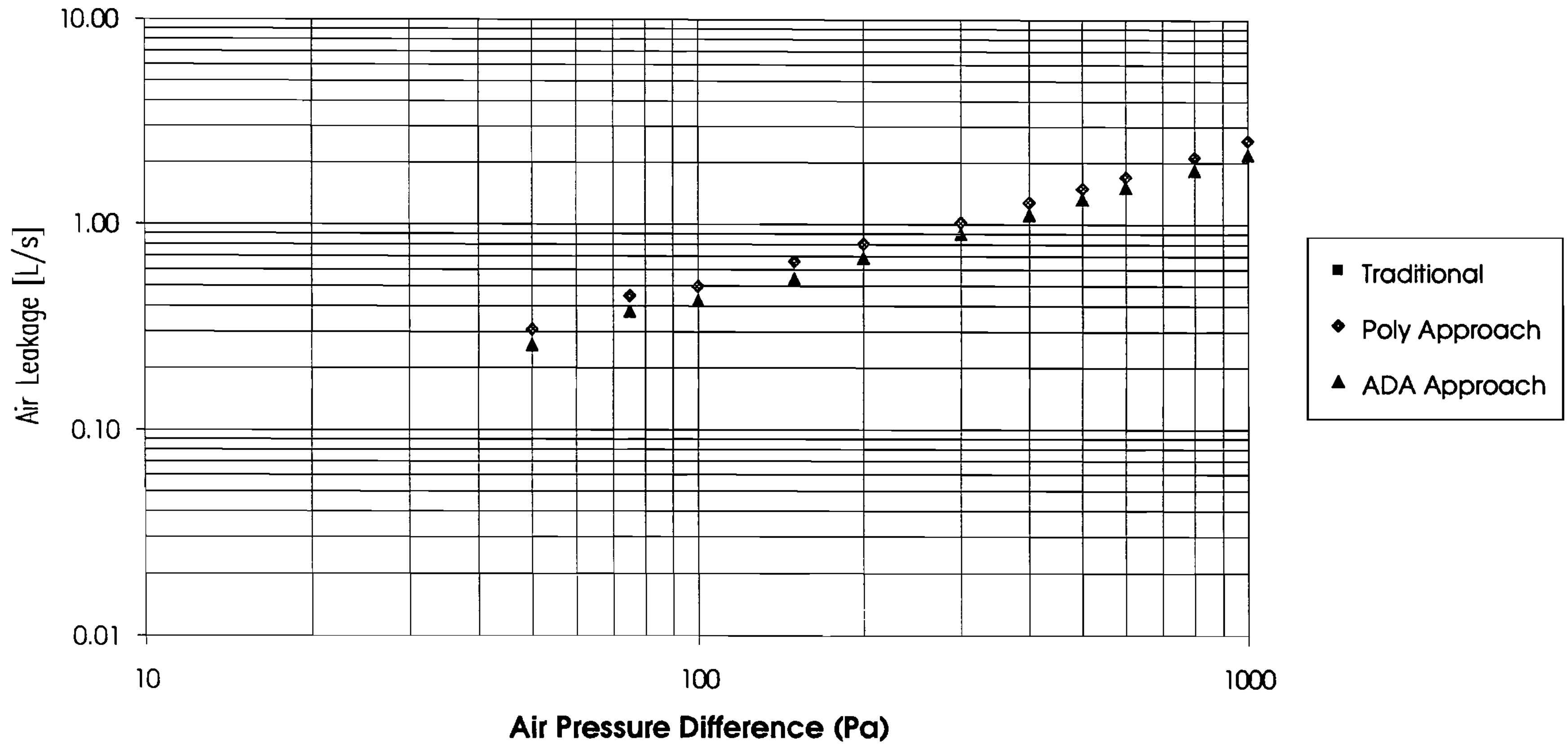
## Graph I8 - 75mm Plumbing Stack Detail - Infiltration



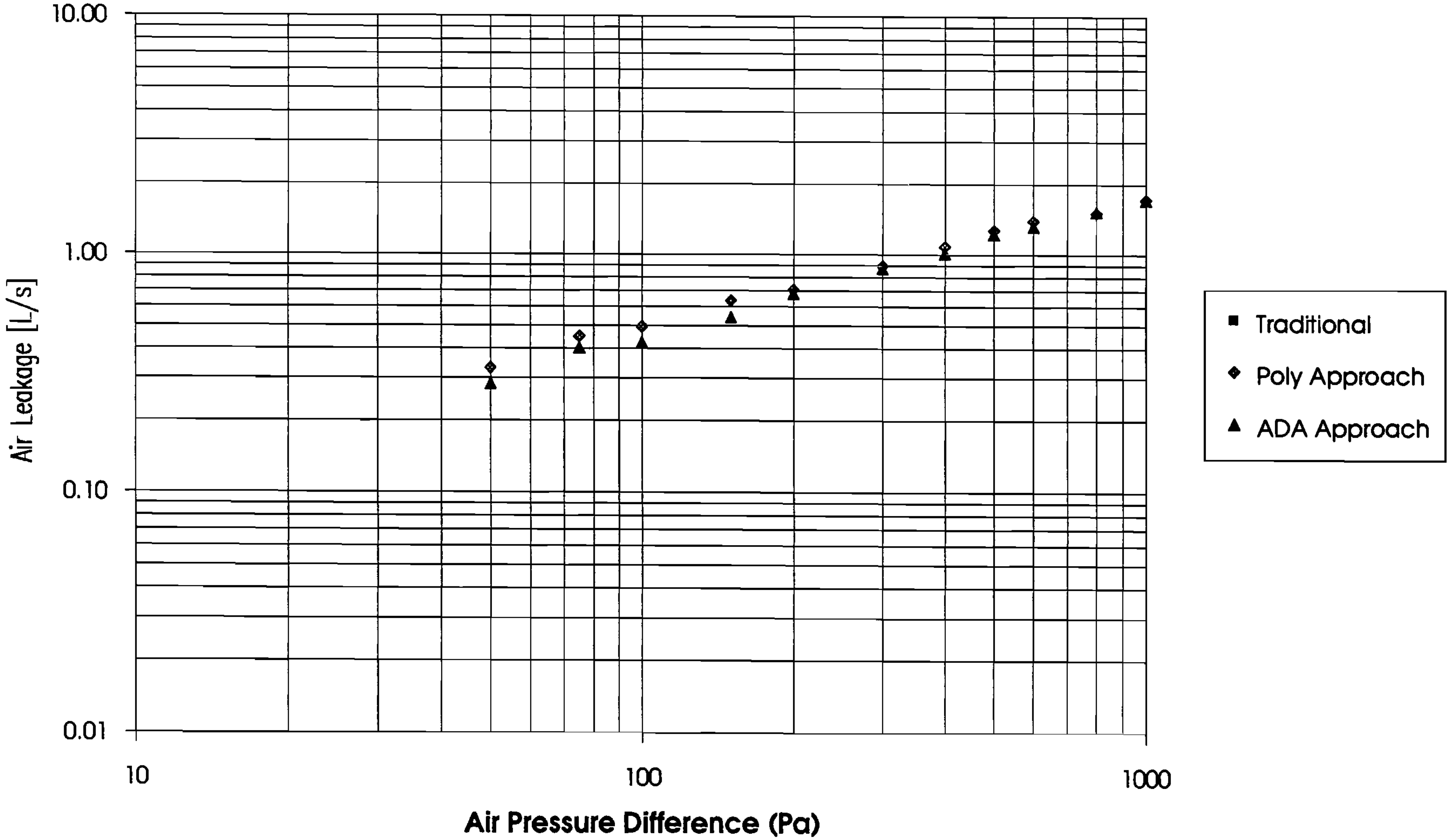
## Graph E8 - 75mm Plumbing Stack Detail - Exfiltration



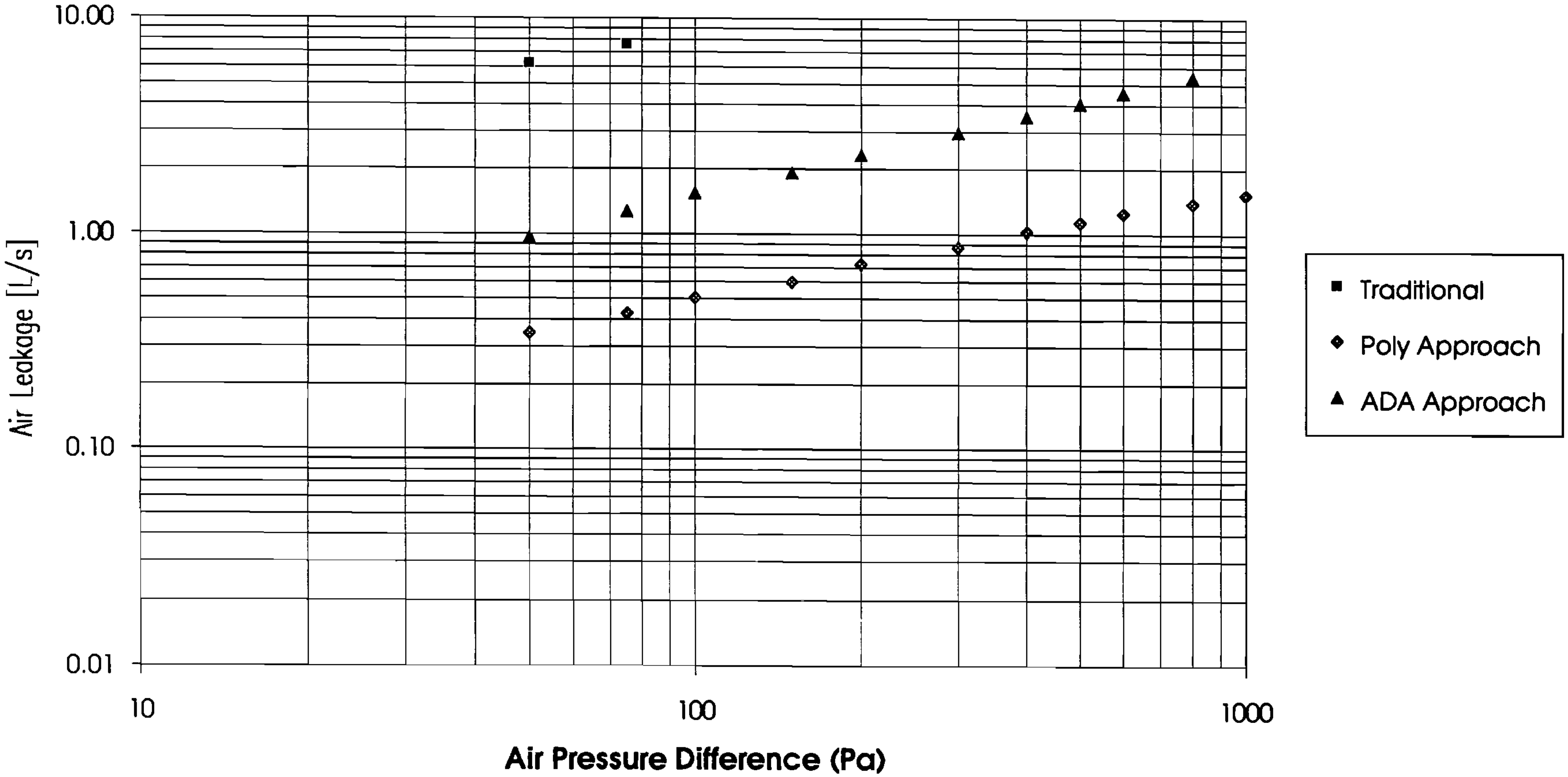
## Graph I9 - 300mm Metal Chimney/Ceiling Detail - Infiltration



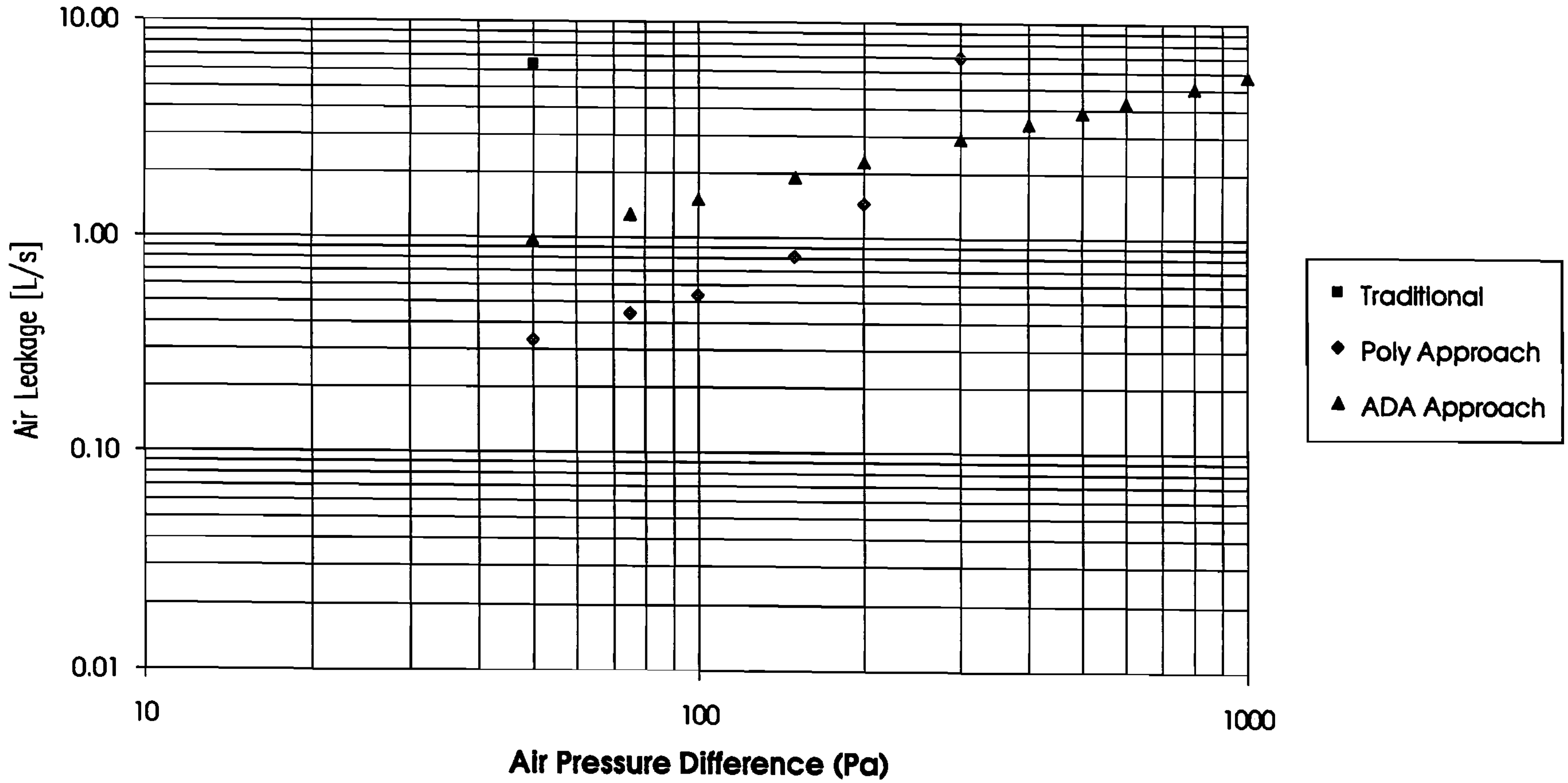
## Graph E9 - 300mm Metal Chimney/Ceiling Detail - Exfiltration



## Graph I10 - Bathroom Fan/Ceiling Detail - Infiltration



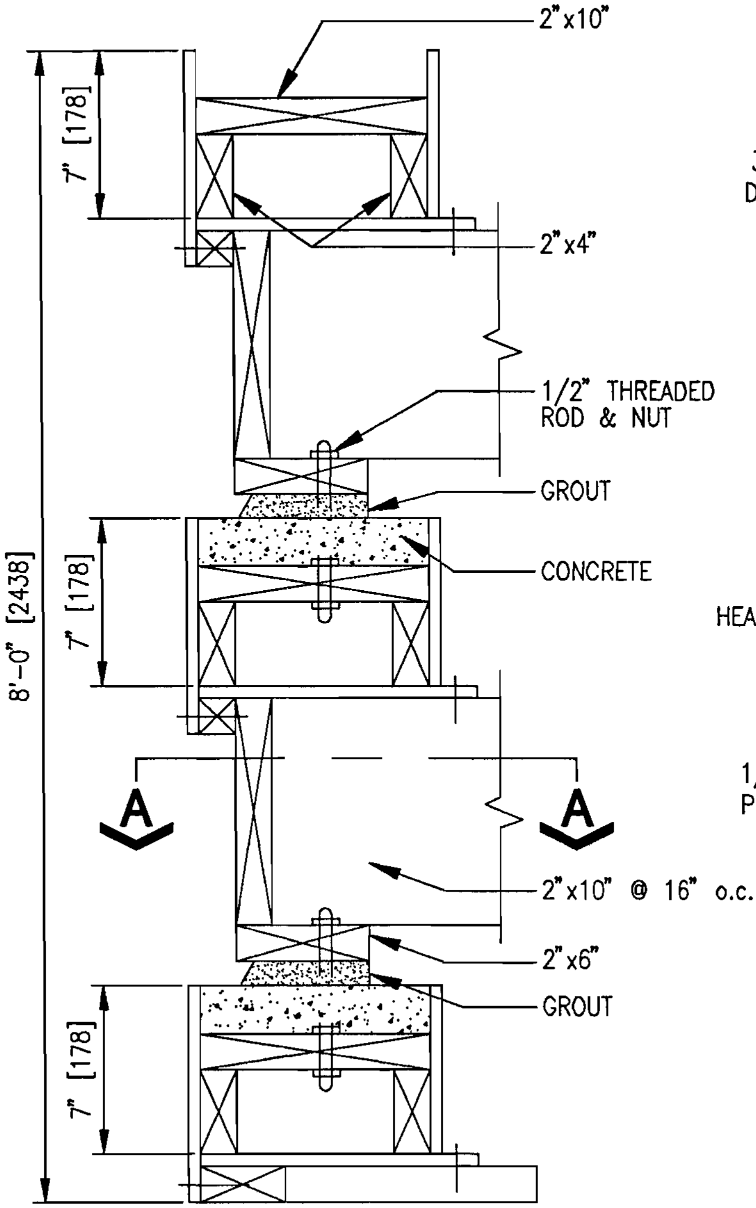
## Graph E10 - Bathroom Fan Ceiling Detail - Exfiltration



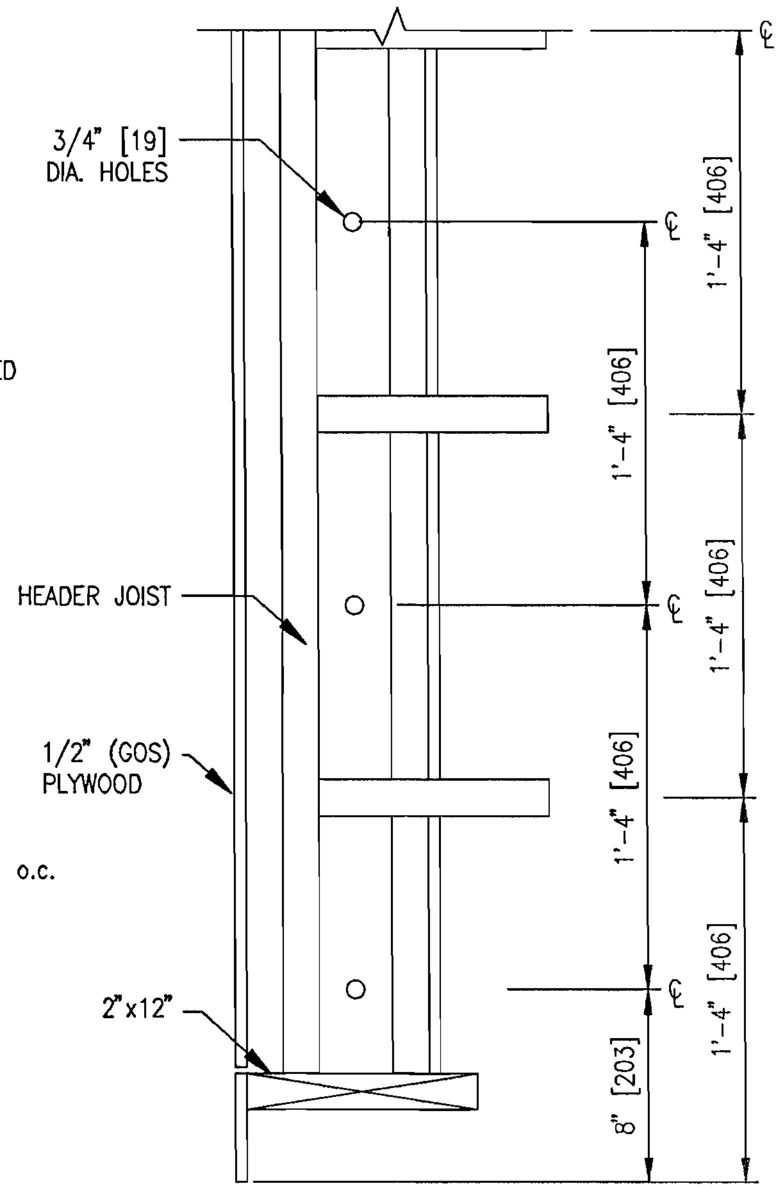
## APPENDIX C

TEST PANEL ASSEMBLY DRAWINGS

# SILL PLATE - TRADITIONAL DETAIL

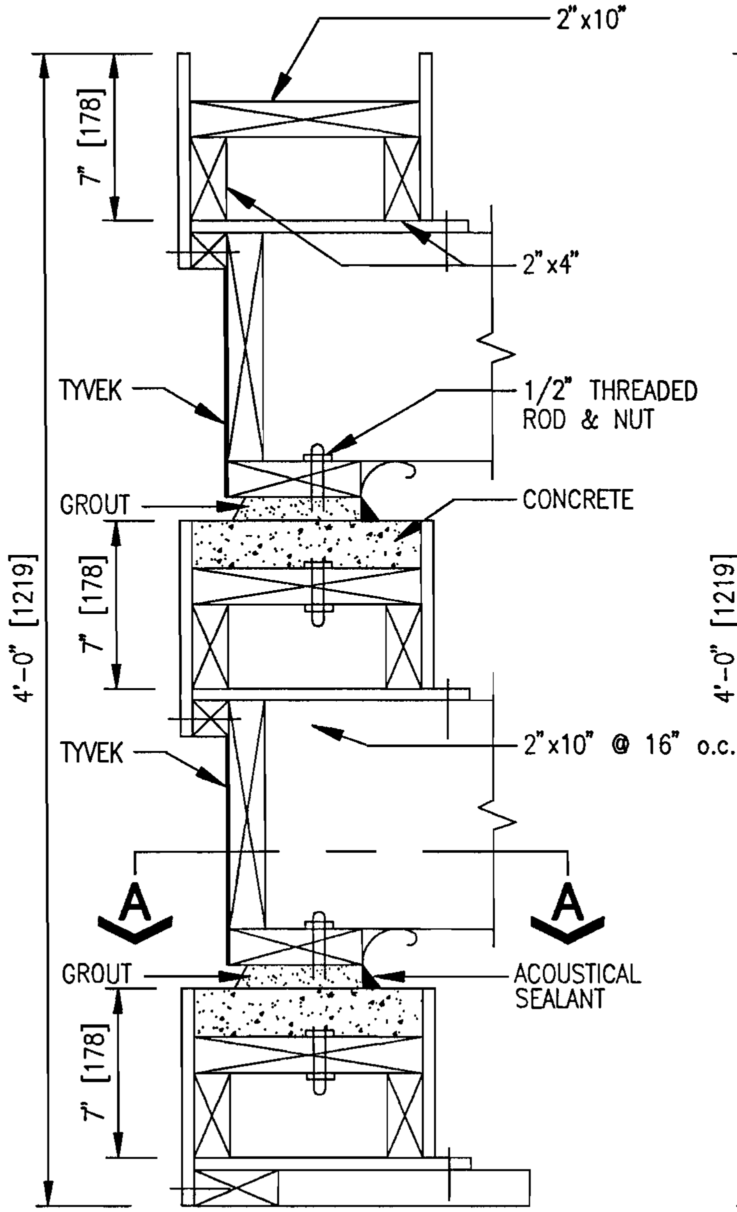



SILL PLATE DETAIL

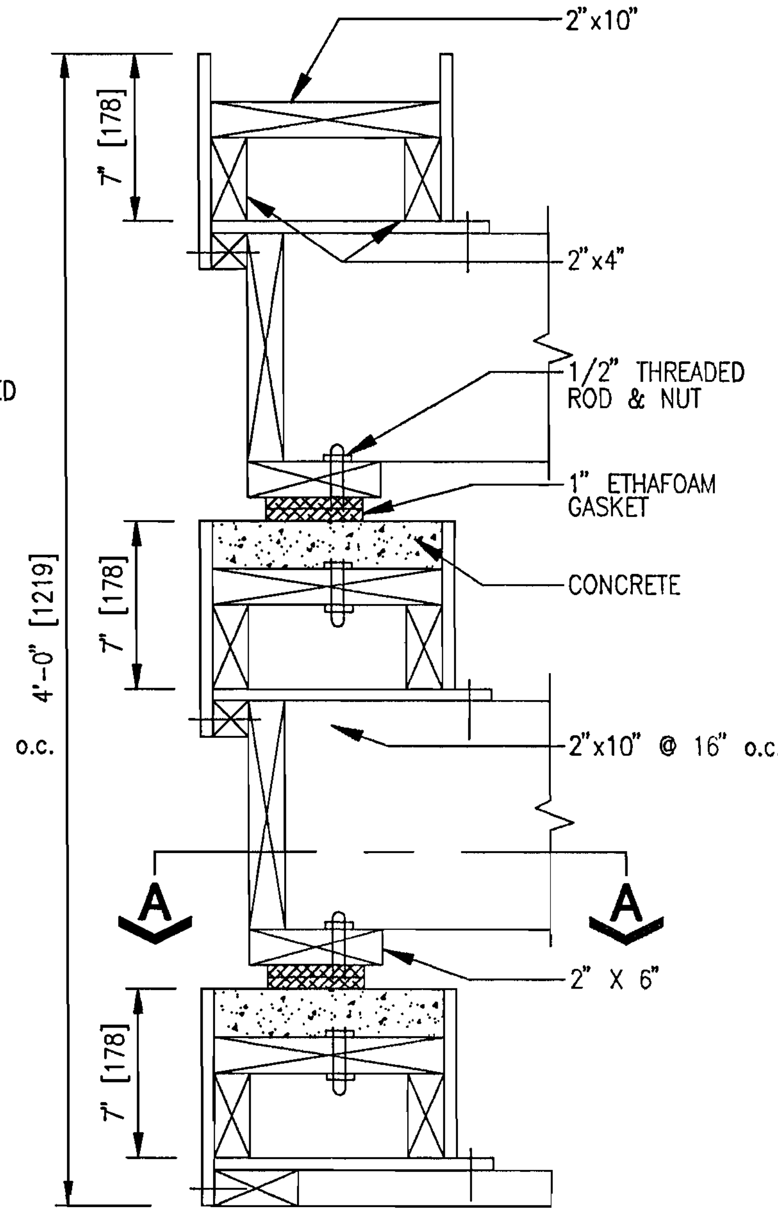



SECTION - A

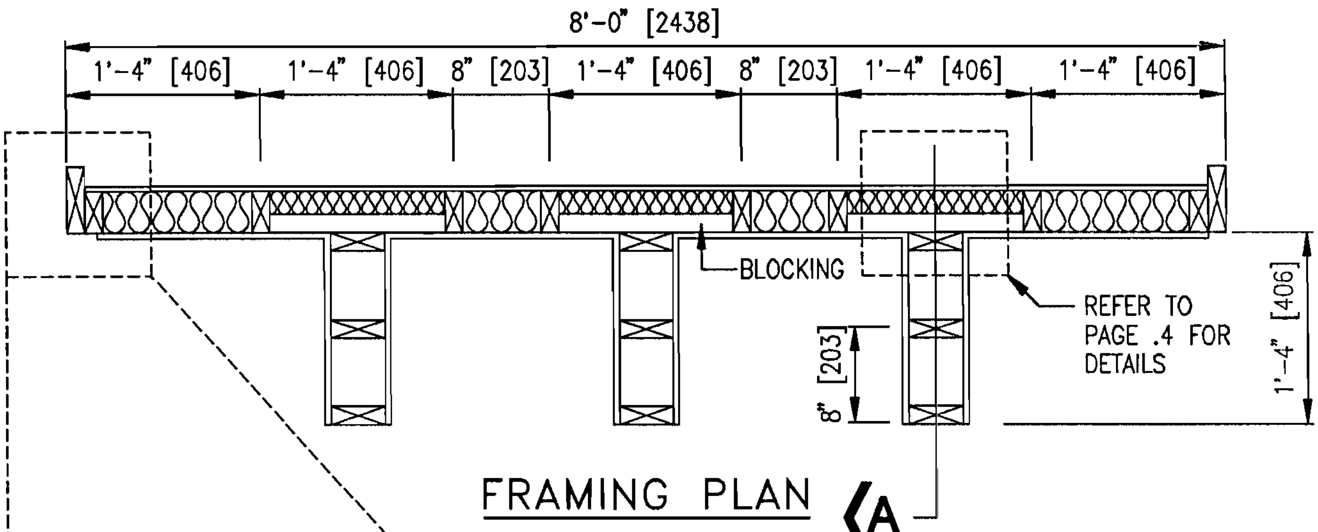
# ASSEMBLIES No. 1b, 1c: SILL PLATE - POLY and ADA DETAILS



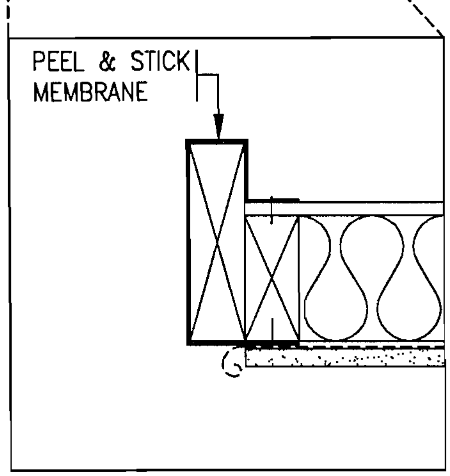

1b – POLY DETAIL

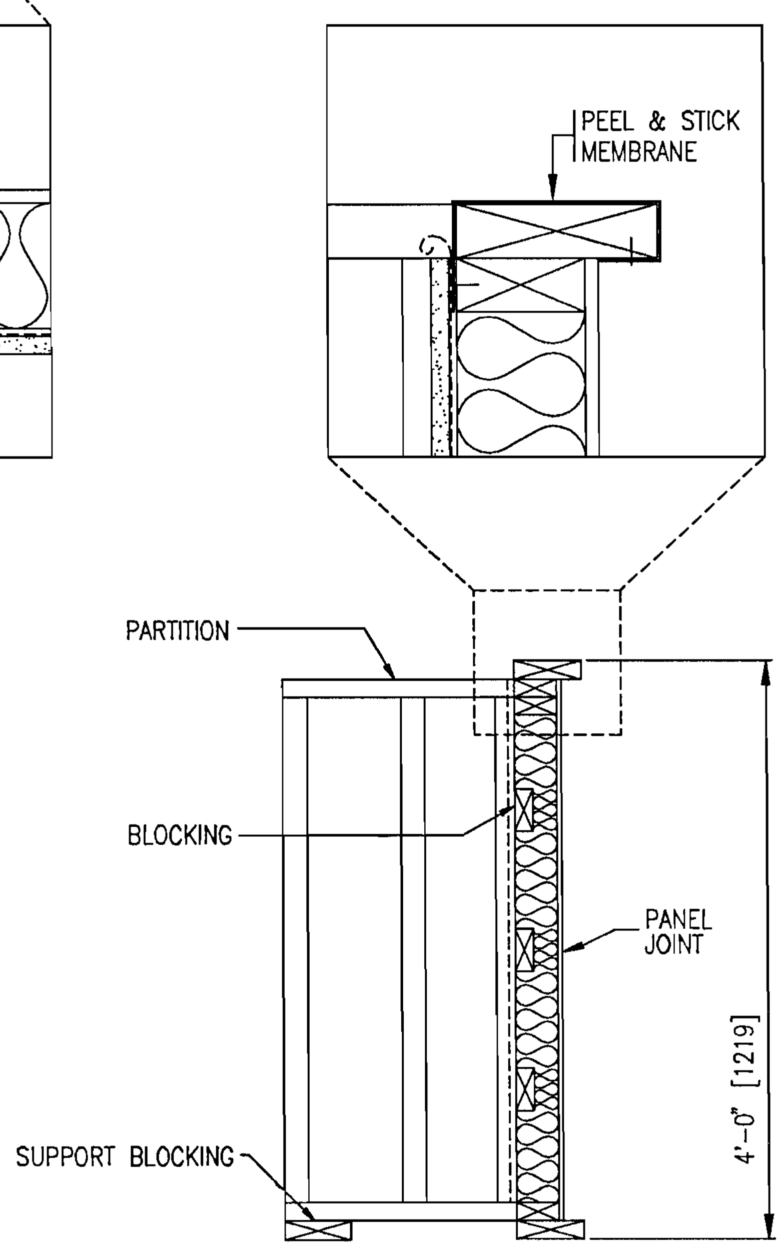



1c – ADA DETAIL

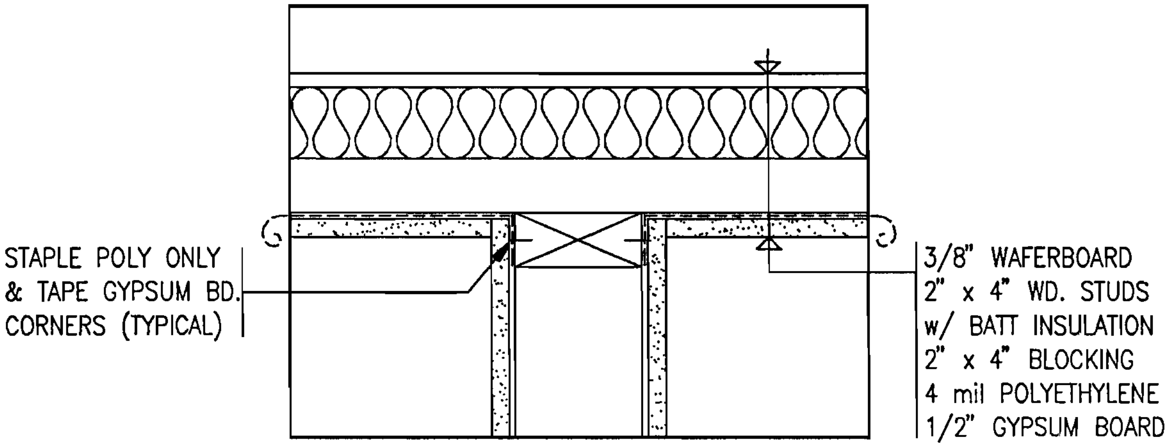



FRAMING PLAN

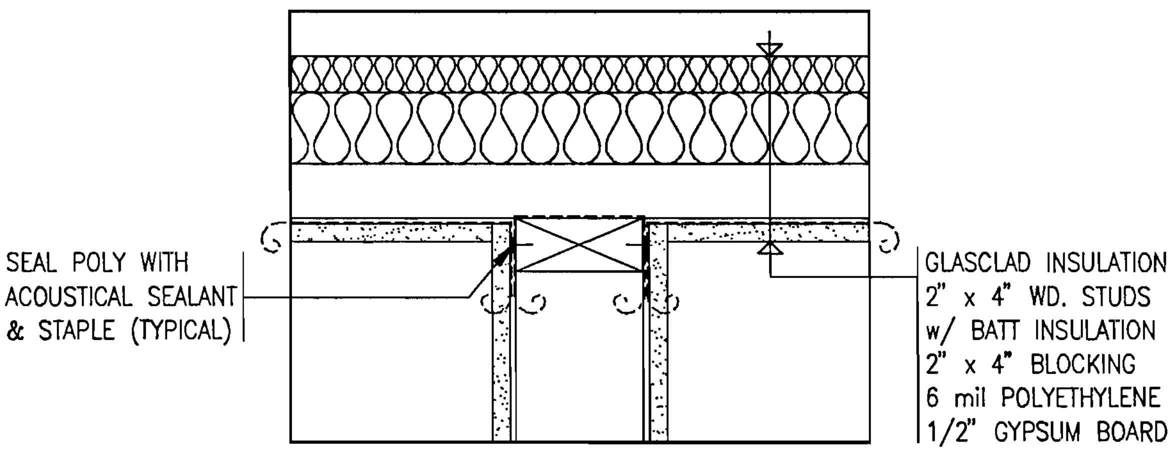


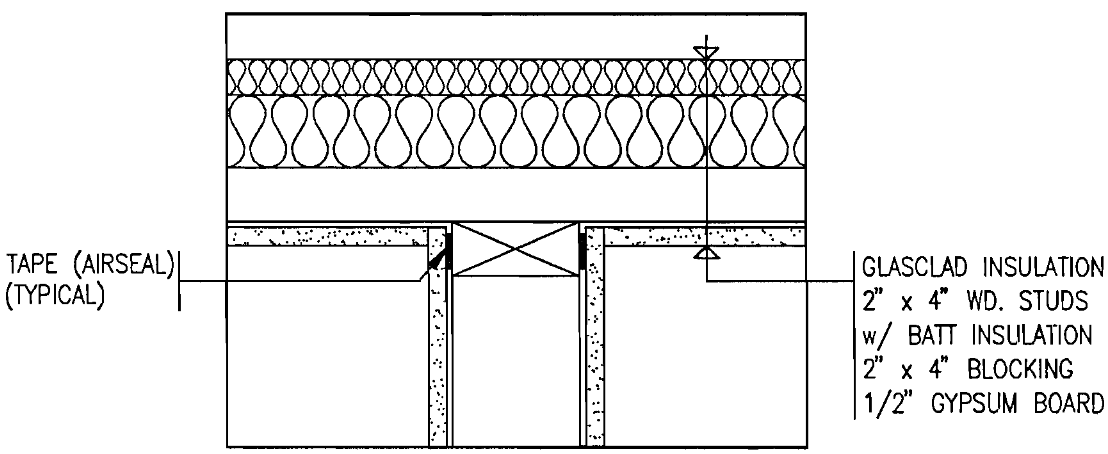

SECTION – A



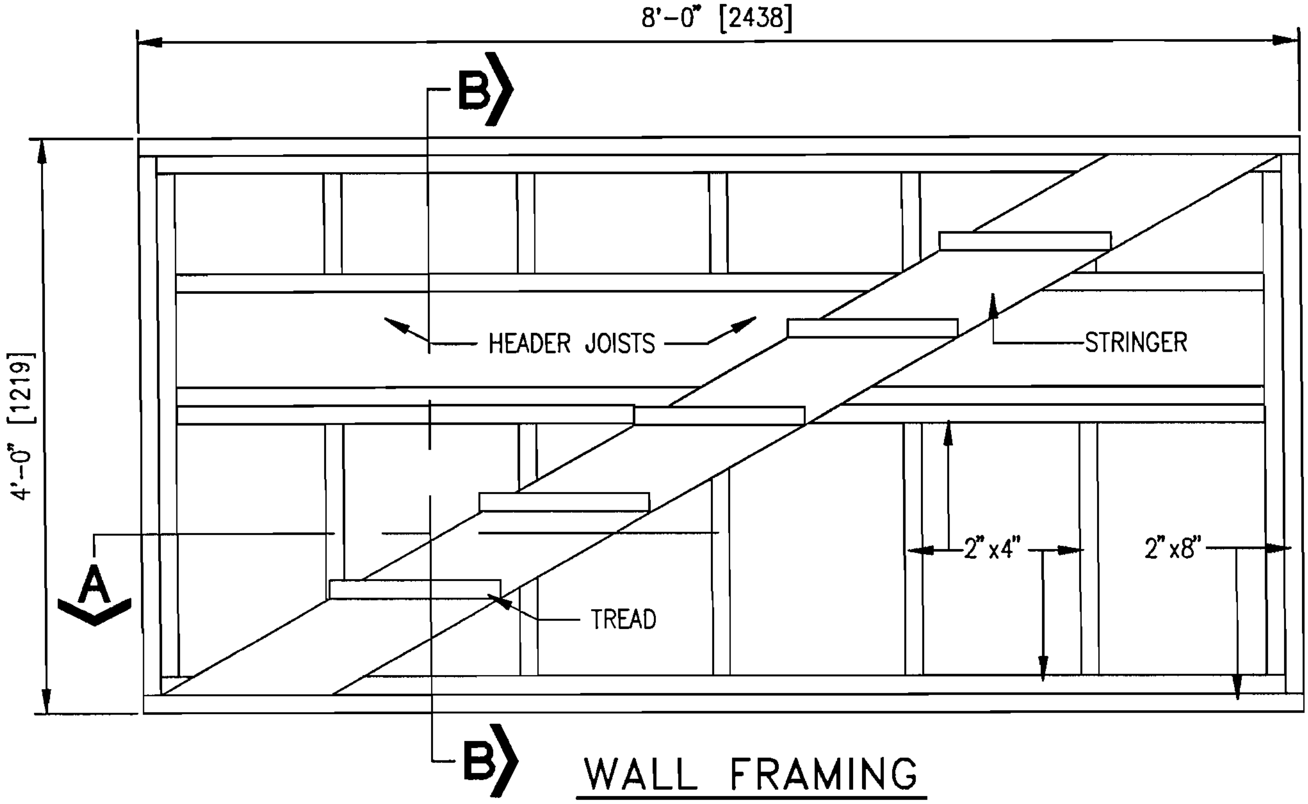

2a – TRADITIONAL DETAIL



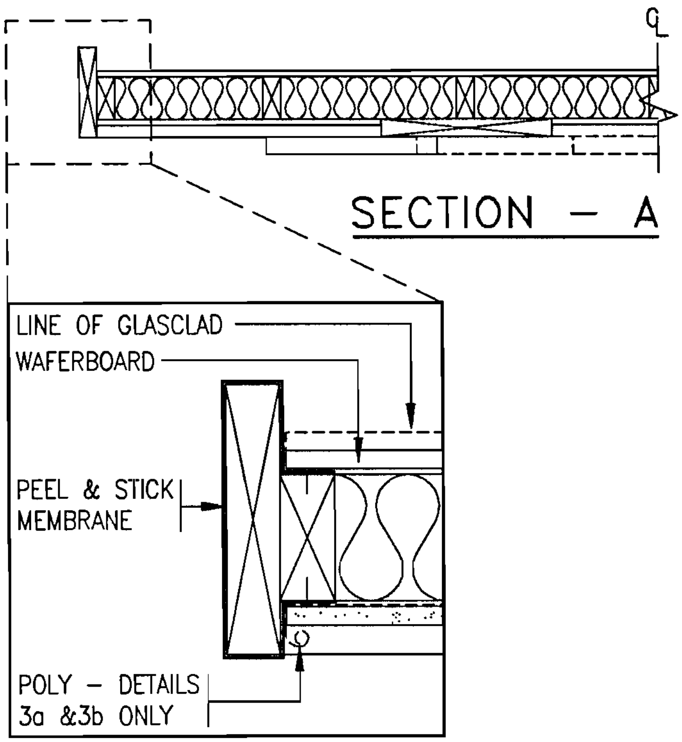

2b – POLY DETAIL



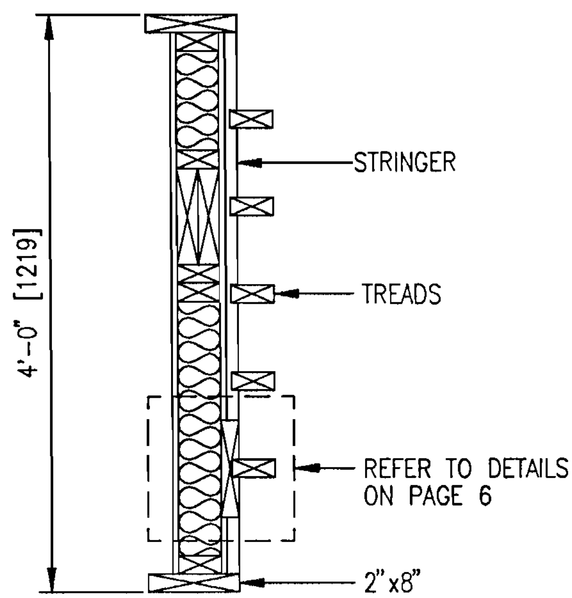

2c – ADA DETAIL



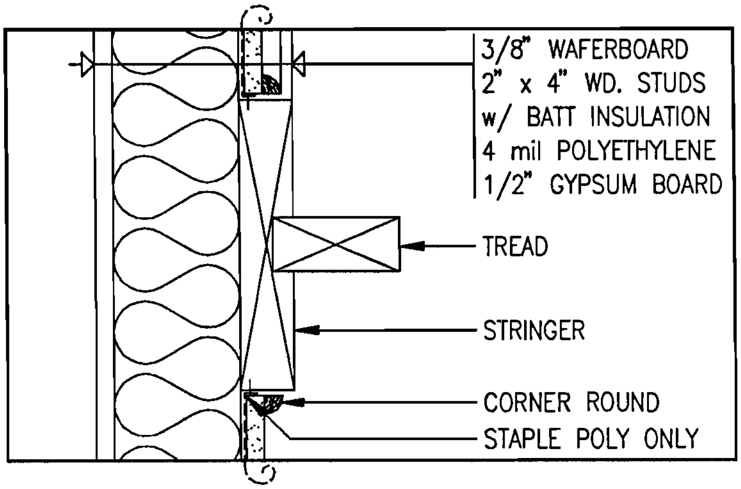

WALL FRAMING



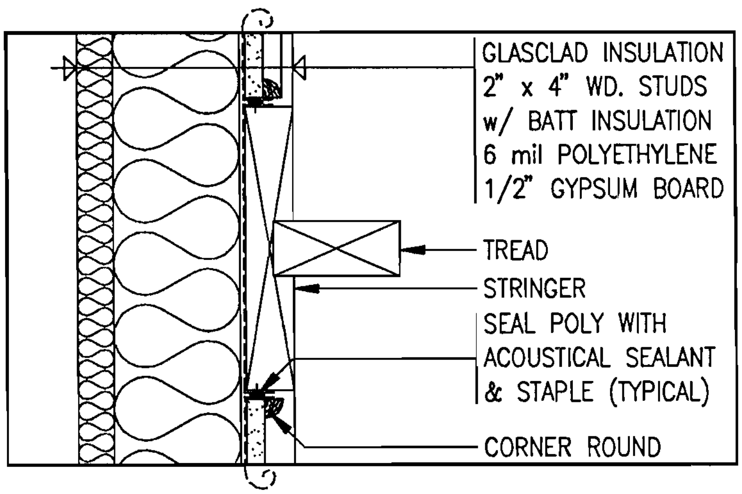

SECTION - A



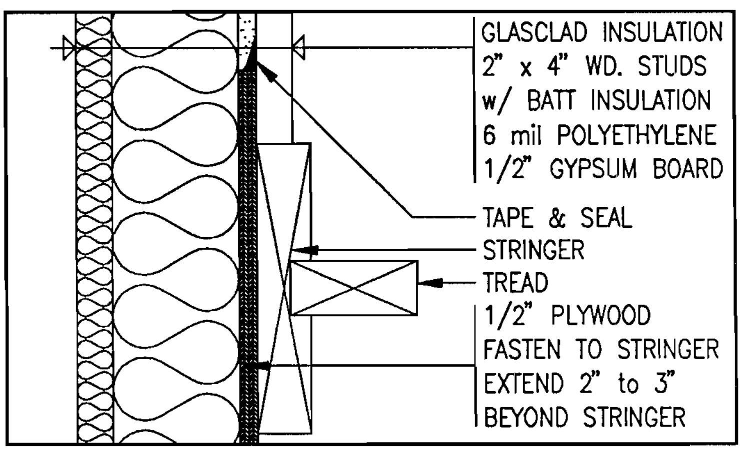

SECTION - B



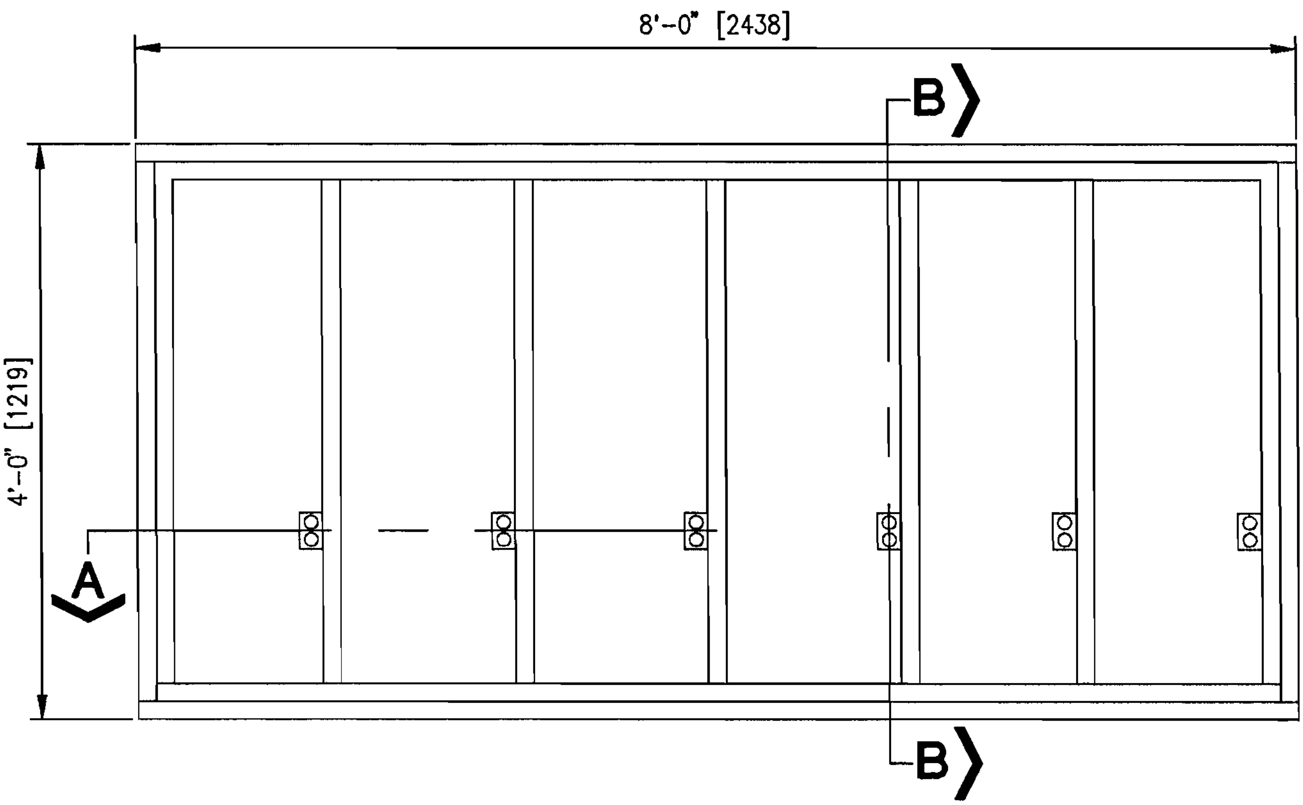

3a – TRADITIONAL DETAIL



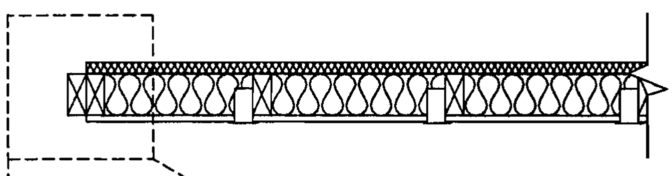

3b – POLY DETAIL



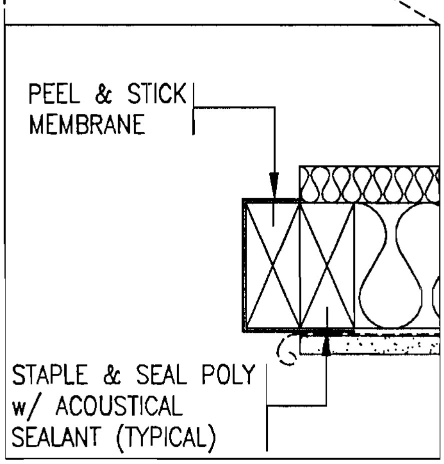

3c – ADA DETAIL

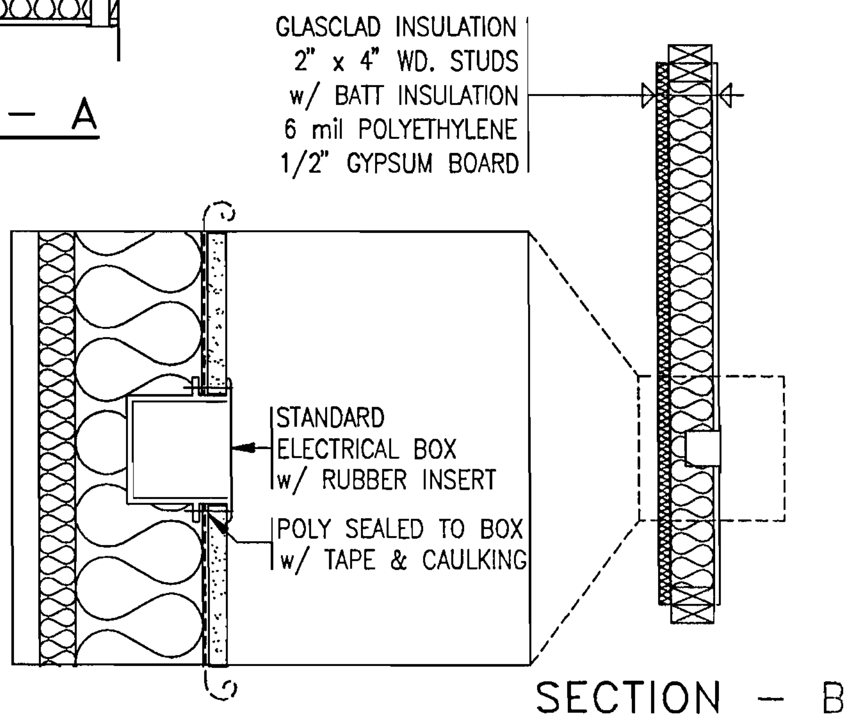



FRAMING ELEVATION



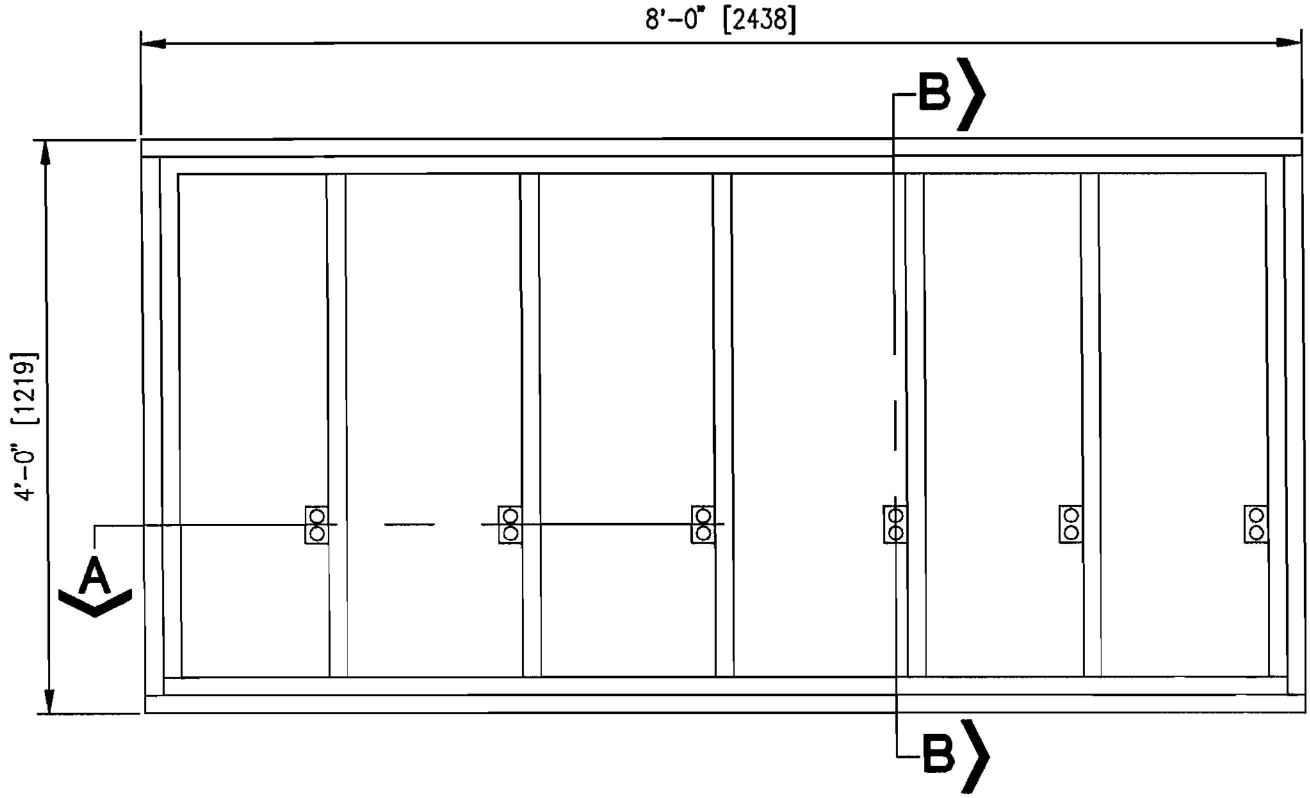
SECTION – A



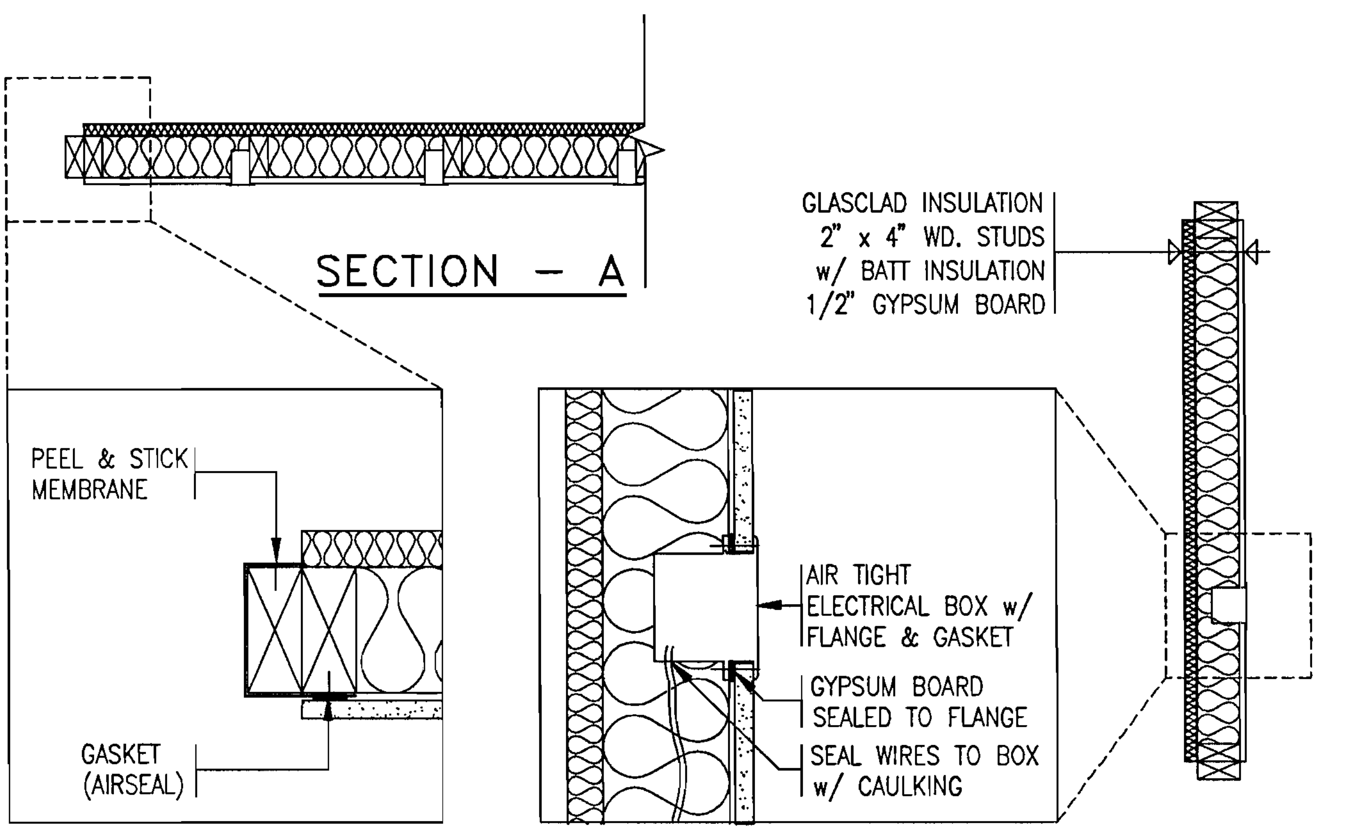




SECTION – B

# ASSEMBLY No. 4c ELECTRICAL OUTLET - ADA DETAIL



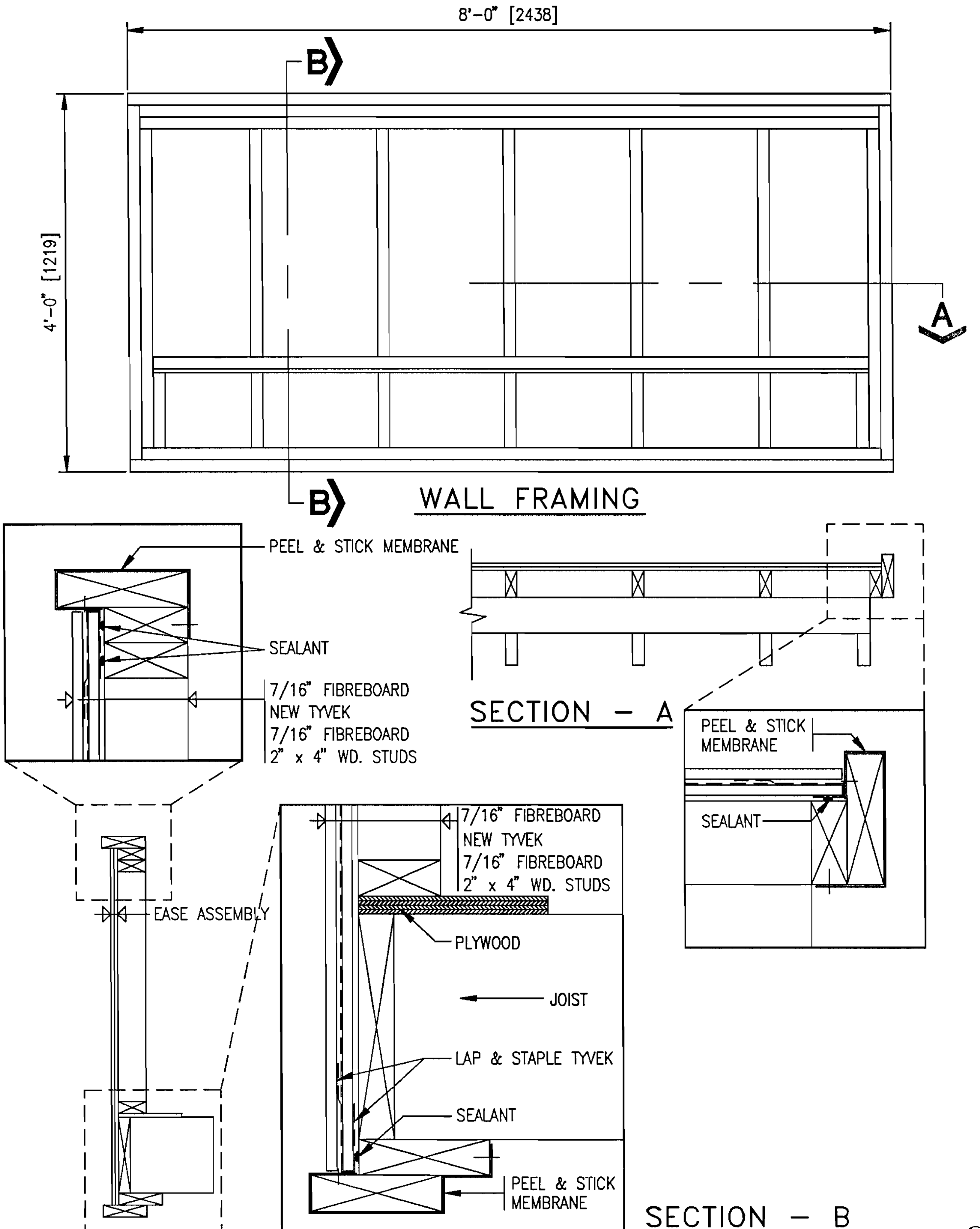

FRAMING ELEVATION

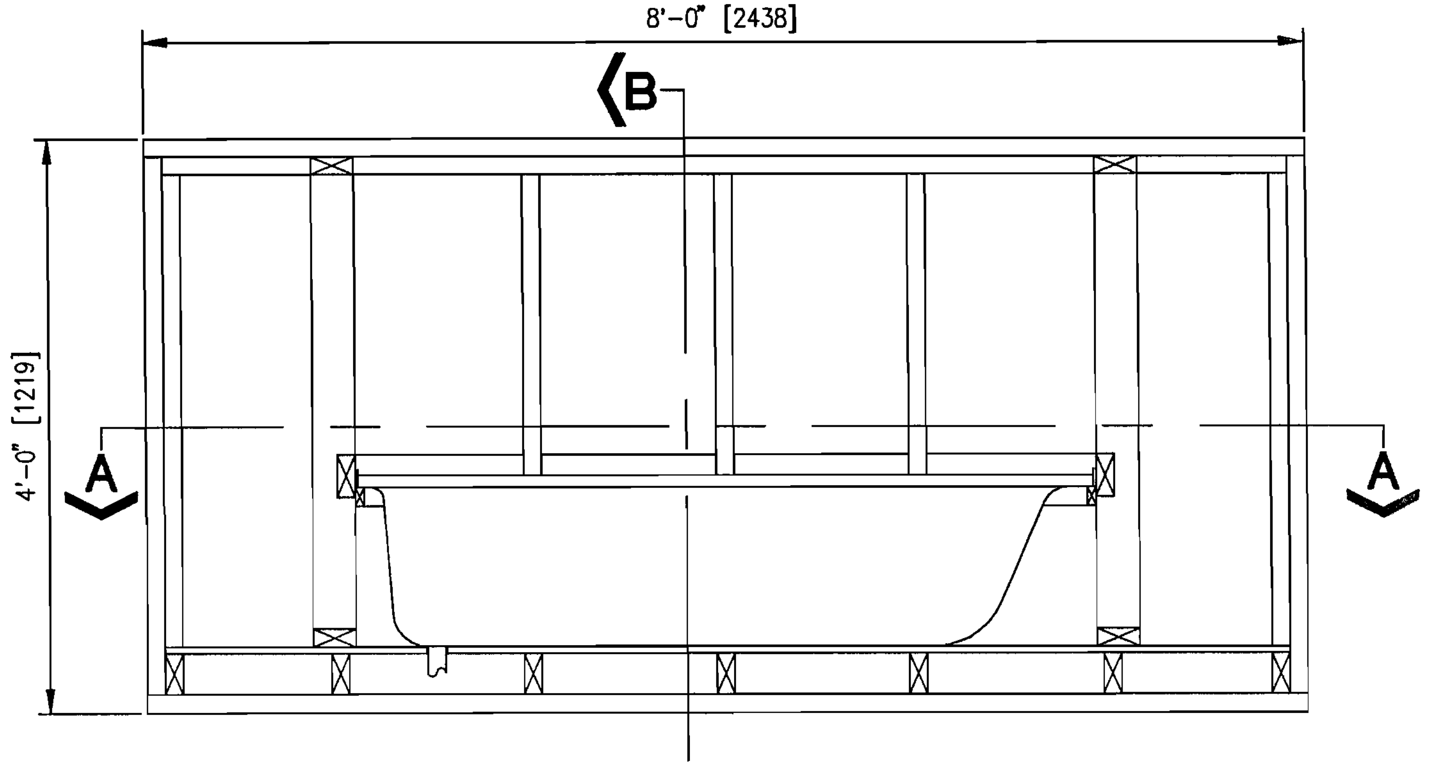



SECTION – A

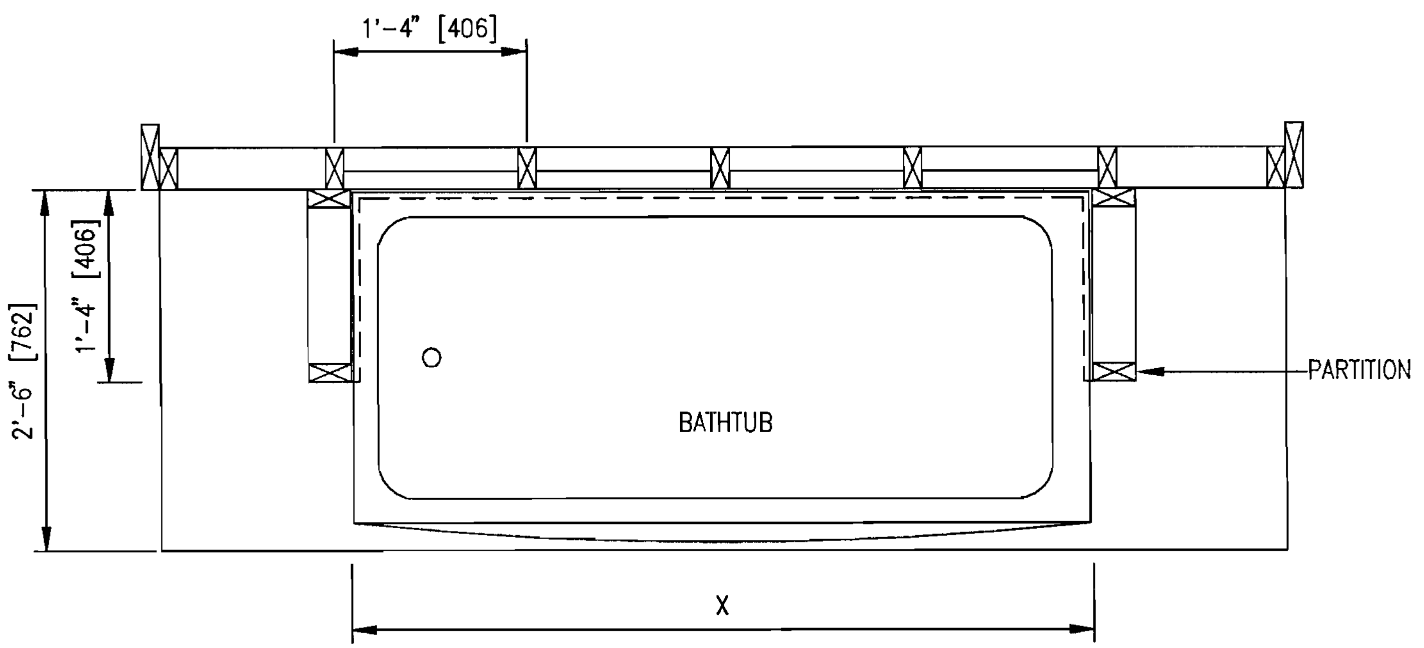
SECTION – B

# ASSEMBLY No. 5 : EASE WALL SYSTEM [NEW TYVEK]



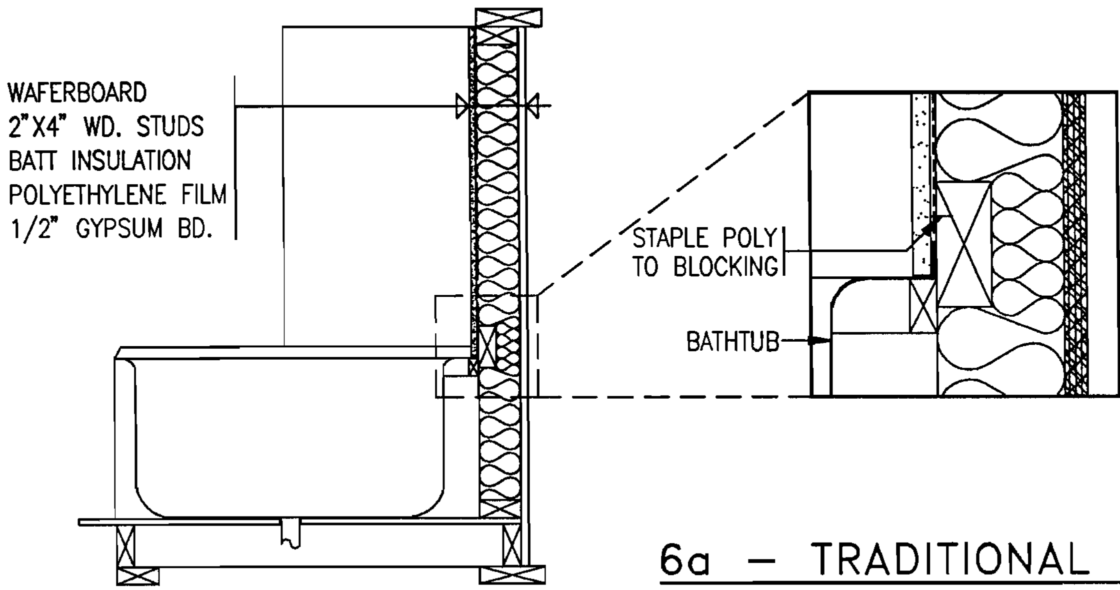



FRAMING ELEVATION

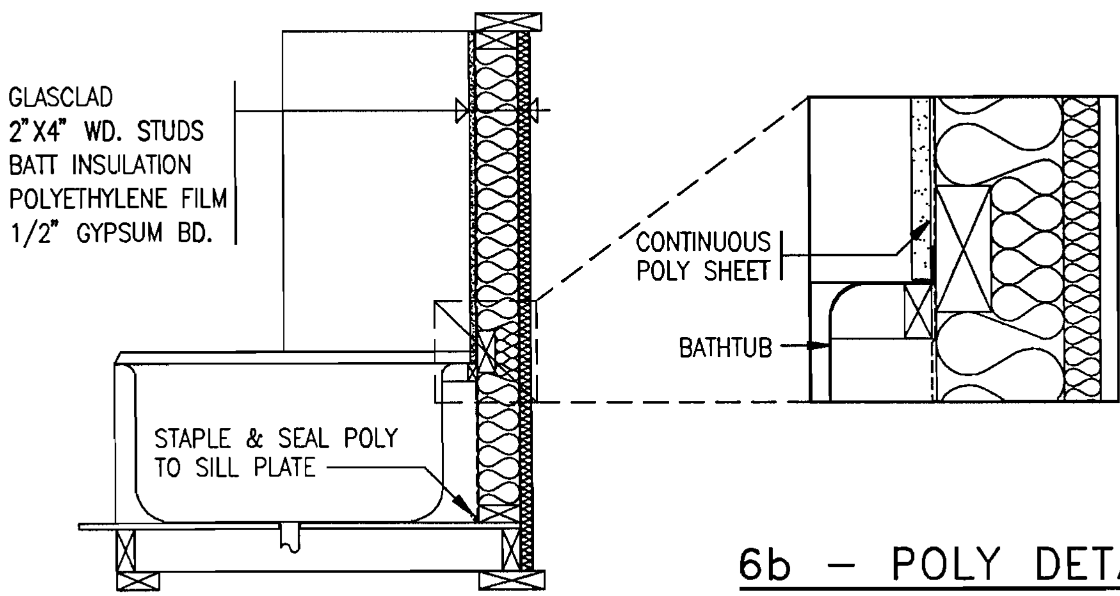



FRAMING PLAN – SECTION A

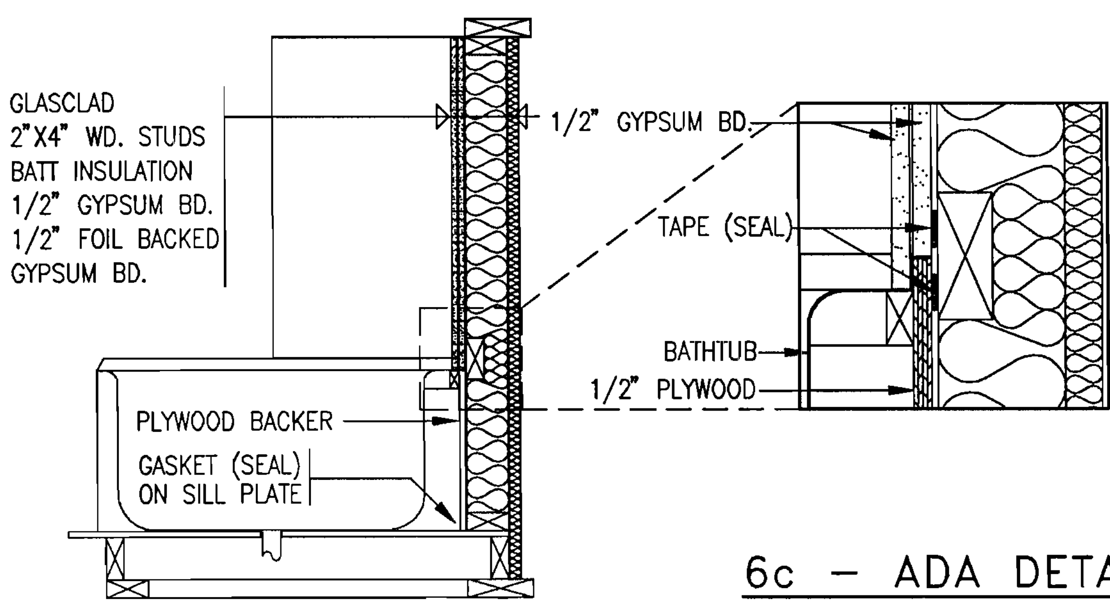
| | |
|---|---|
| TRADITIONAL | : X = 5'-0" |
| POLY | : X = 5'-0" |
| ADA | : X = 5'-1" |



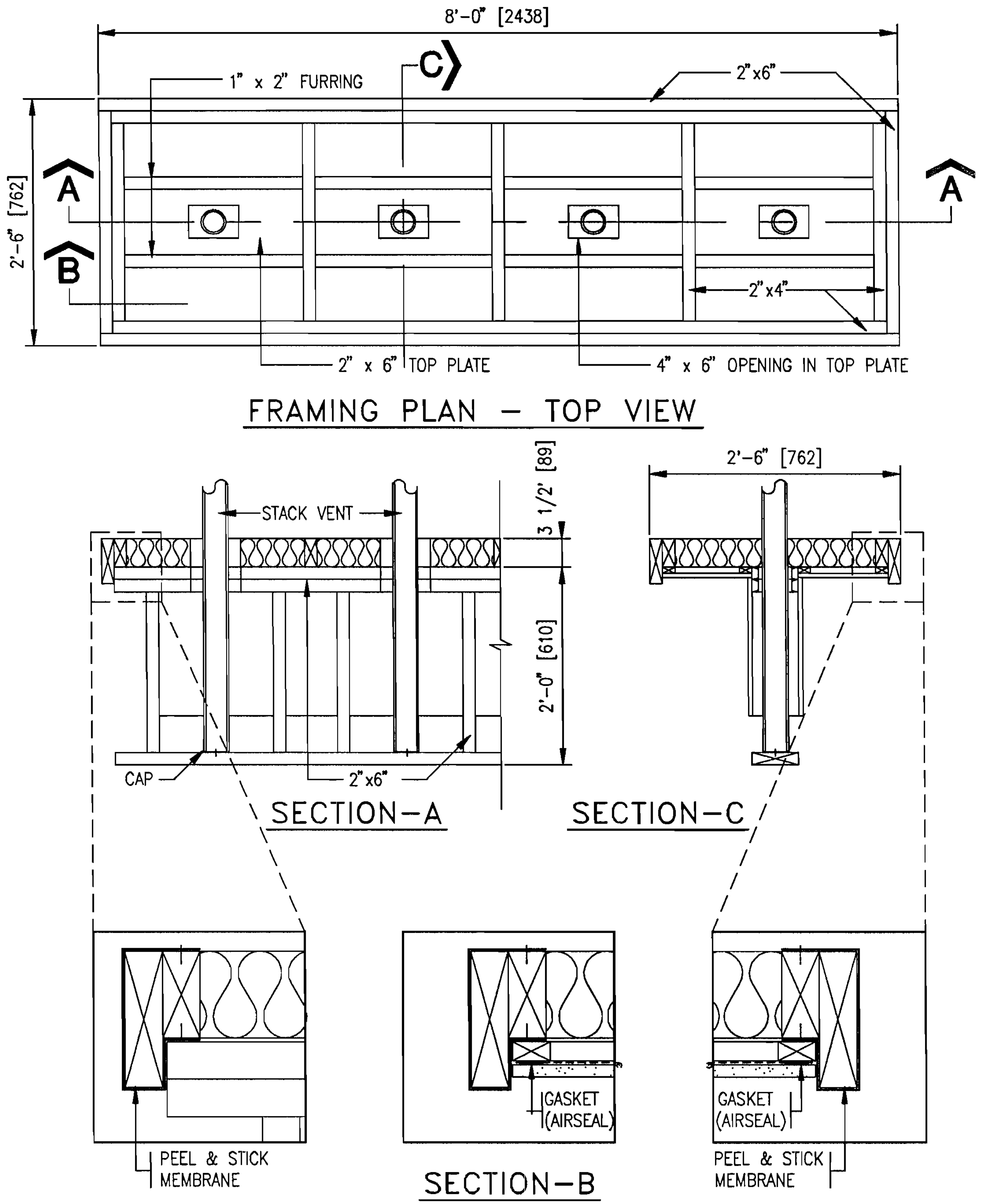

6a – TRADITIONAL DETAIL

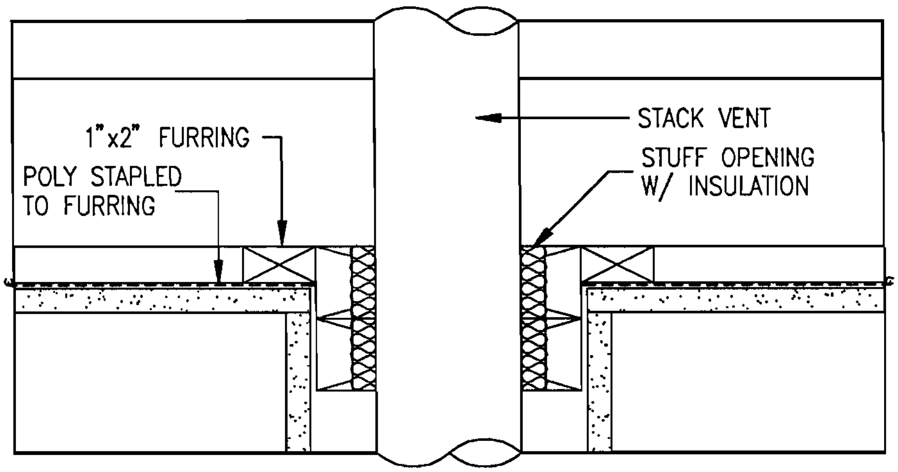



6b – POLY DETAIL

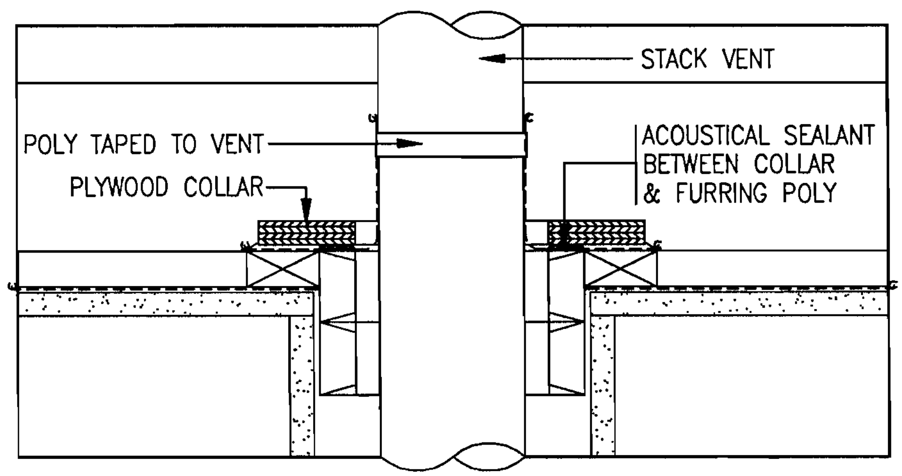



6c – ADA DETAIL

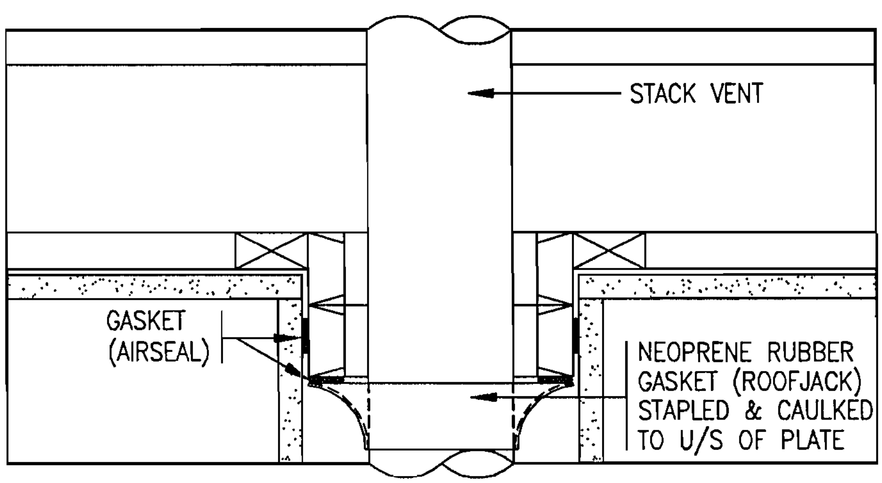

8'-0" [2438]
1" x 2" FURRING
C
2"x6"
2'-6" [762]
A
B
2"x4"
2" x 6" TOP PLATE
4" x 6" OPENING IN TOP PLATE
FRAMING PLAN – TOP VIEW
3 1/2' [89]
STACK VENT
2'-0" [610]
CAP
2"x6"
SECTION–A
2'-6" [762]
SECTION–C
PEEL & STICK MEMBRANE
GASKET (AIRSEAL)
GASKET (AIRSEAL)
PEEL & STICK MEMBRANE
SECTION–B




7a – TRADITIONAL DETAIL

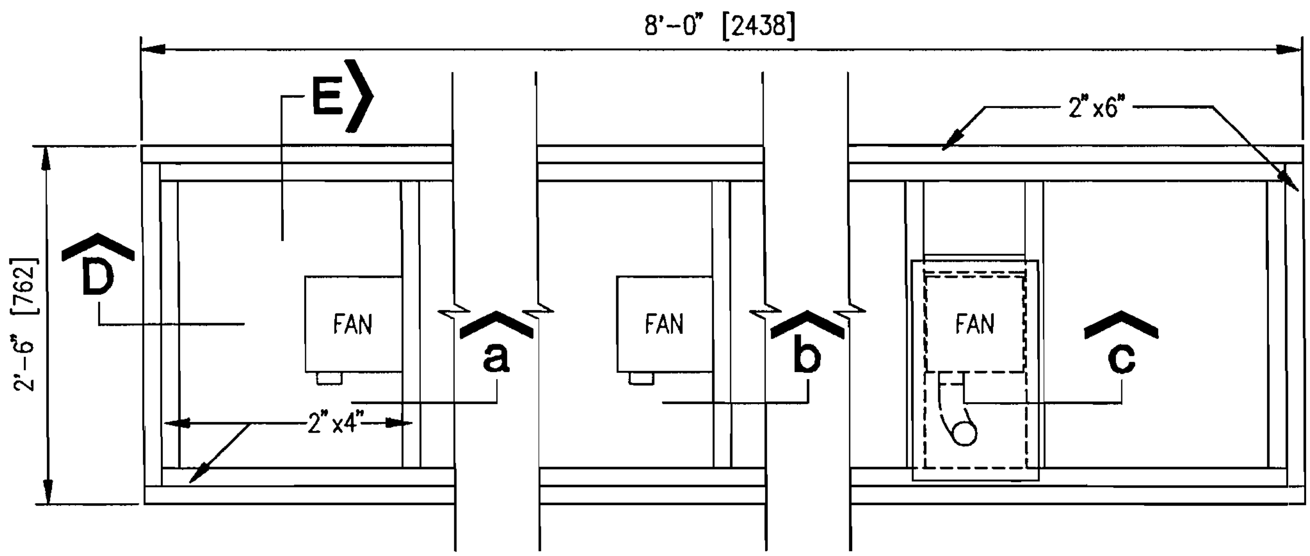



7b – POLY-SOCK DETAIL

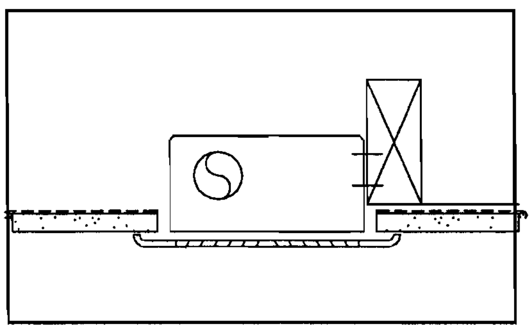



7c – ADA DETAIL

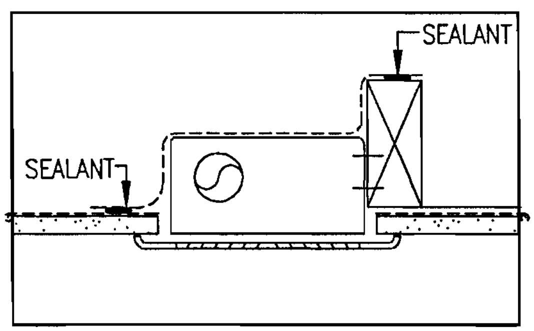
# ASSEMBLIES No. 8a, 8b, 8c: BATHROOM FAN DETAILS



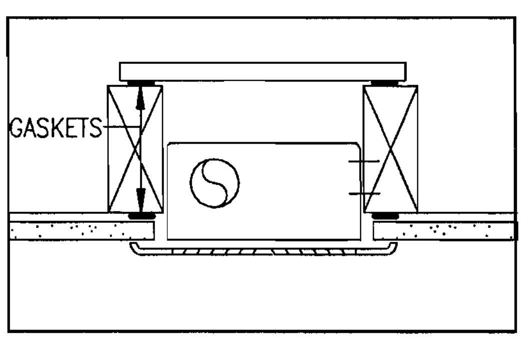

FRAMING PLAN - TOP VIEW



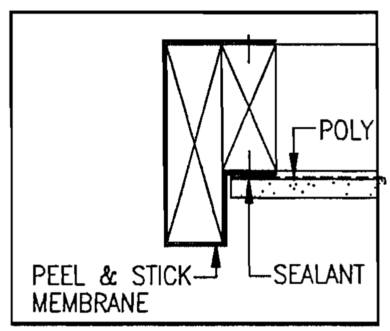
8a - TRADITIONAL DETAIL



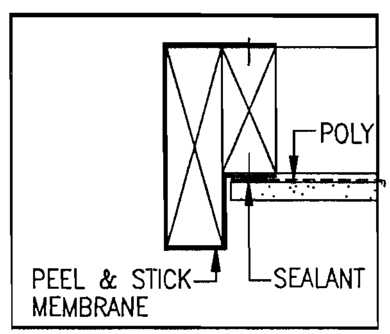

8b - POLY DETAIL




8c - ADA DETAIL

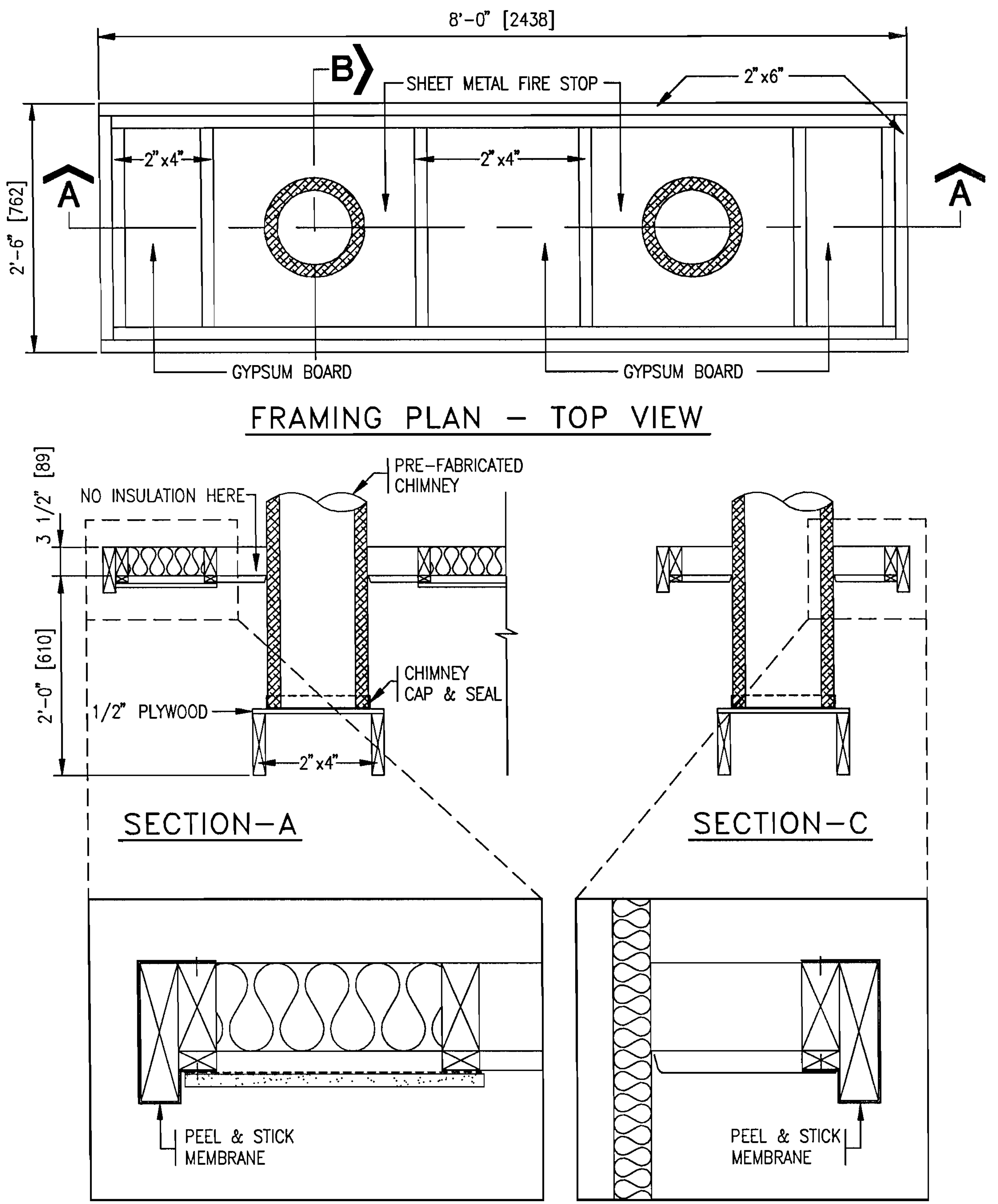


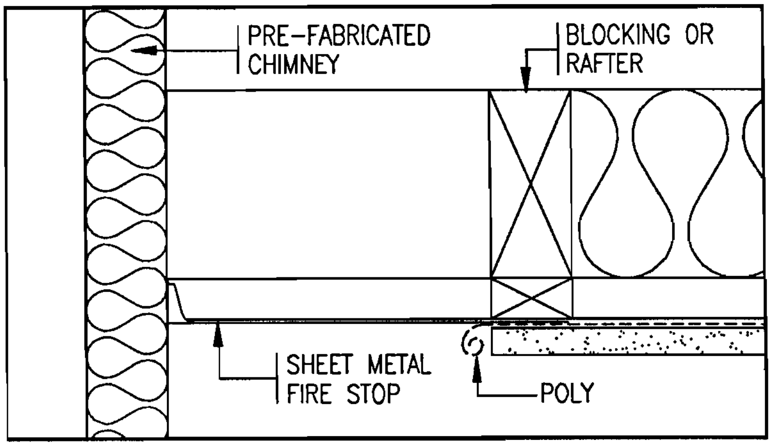

SECTION-D



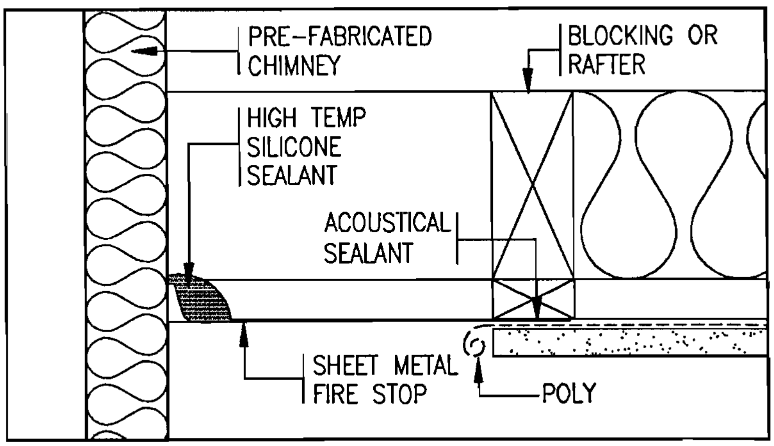

SECTION-E

# ASSEMBLY No. 9: CHIMNEY DETAIL

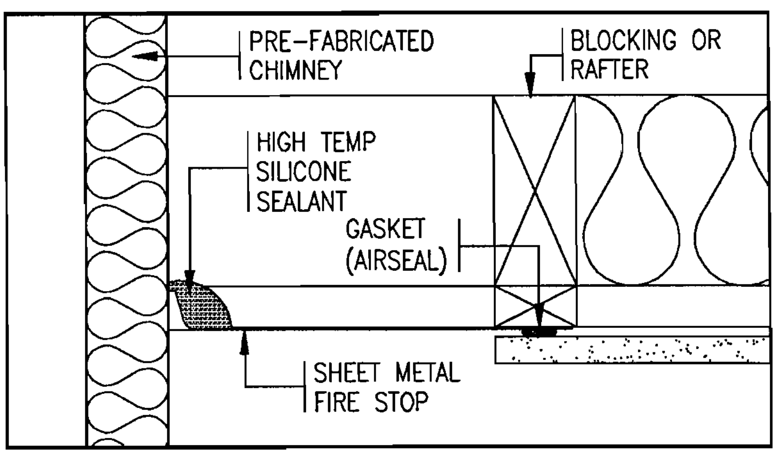





9a – TRADITIONAL DETAIL




9b – POLY DETAIL




9c – ADA DETAIL