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AIR LEAKAGE TESTS ON POLYETHYLENE MEMBRANE INSTALLED IN A WOOD FRAME WALL

by

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ABSTRACT

This report presents the results of air leakage tests on polyethylene membranes installed in a frame wall. The results would be useful in evaluating the methods commonly used for installing such a component.

INTRODUCTION

A polyethylene membrane has been used extensively for improving airtightness and reducing problems of condensation in houses. There are no standards for the installation of such a component. The common practice is to install the polyethylene membrane in such a way that it envelops the house except for window and door openings. At a joint, the two sheets of polyethylene are overlapped, with the joint located over a solid wood backing, usually a stud. Staples are used to hold the polyethylene sheets together and in place. At windows and doors, a rough opening is made in the polyethylene and the edges are stapled to the surrounding wood frame.

Since the installer usually makes no attempt to seal the joints, a gap exists between the staples, especially when the polyethylene sheet is wrinkled. To reduce air leakage through the gaps, in some installations accoustic sealants and duct tape have been used to hold the sheets together. Also a 'spline system' is being investigated by CMHC for this purpose.

The Canada Mortgage and Housing Corporation asked the Division of Building Research to conduct air leakage tests on polyethylene membranes installed by these methods. The objective of the tests was to obtain the strength and air leakage characteristics of the joint between two sheets of polyethylene, as would occur in a wood frame wall, and between the polyethylene and the wood frame, as would occur around a window. The results would be useful in developing a standard test method for evaluating polyethylene membranes installed in a wood frame wall.

TEST APPARATUS

The test chamber was constructed with standard 38 by 89 mm wood studs. The test wall was 2.9 m wide by 2.3 m high. Pressure taps were installed at the interfaces of various wall components for measuring the pressure differences across the drywall, the polyethylene membrane and the wall assembly (Fig. 1). The pressures were measured using an electronic micromanometer with a resolution of 1 Pa and an accuracy within 1% of the measured value. The air flow rates were measured using a laminar flow element with an accuracy within 1% of the measured flow rate. The test chamber and the experimental set-up are shown in Fig. 1.

To measure the air leakage rate of the test chamber, the test wall was covered with a gypsum board sandwiched between two full sheets of polyethylene. Both the gypsum board and the polyethylene sheets were taped separately to the wood frame enclosing the test wall. The air leakage rate of the test chamber was measured several times before and during the experiment under both pressurization and depressurization conditions. The mean value of these measurements was used as the air leakage rate of the test chamber (Fig. 2). The net air leakage rate through the polyethylene membrane is

$$Q_{poly} = Q_m - Q_{ch} \tag{1}$$

where:

Q_{poly} = air leakage rate through polyethylene membrane, L/s,
Q_m = measured overall air leakage rate, L/s,
Q_{ch} = air leakage rate of test chamber, L/s.

RESULTS

The tests, conducted as shown in Table 1, were similar to those suggested by CMHC. For all tests, the polyethylene sheet was stapled to the studs at 305 mm centres. An accelerated weathering test was also conducted by the Building Materials Section of DBR on the sample of polyethylene used, to ensure that the material was in good condition.

Each air leakage test was conducted under both depressurization and pressurization conditions. A brief summary of the test results is also given in Table 1. The net air leakage rates through the polyethylene membrane were expressed as litres per second per unit length of crack (L/(s.m)). For the joint between two sheets of polyethylene, the length of crack was the length of the joint (2.3 m). For the window, it was the perimeter of the window frame (5.2 m). These air leakage rates were then plotted against the pressure difference across both the polyethylene sheet and the wall. These pressure differences are defined by the equation:

$$\Delta P_{wall} = \Delta P_{poly} + \Delta P_{sdg} \tag{2}$$

where:

ΔP_{wall} = pressure difference across wall, Pa,
ΔP_{poly} = pressure difference across polyethylene sheet, Pa,
ΔP_{sdg} = pressure difference across sheathing and siding, Pa.

<u>One full sheet of polyethylene, stapled to studs at 305 mm centres</u>

Test 1a: 4 mil, stapled, depressurization

The objective of the test was to measure the air leakage rate through a polyethylene membrane with no joint. The air leakage rate was too small to measure, even though numerous holes were punched in the polyethylene sheet by the staples. As shown in Fig. 3, depressurization helped to seal the holes by pressing the polyethylene sheet tightly against the wood frame. No permanent tear in the polyethylene sheet around the holes was observed at a pressure difference across the polyethylene of 781 Pa, the maximum pressure differential that could be obtained for this test.

Test 1b: as Test 1a, pressurization

Unlike conditions in the previous test, pressurization helped to expose the holes by pushing the polyethylene sheet away from the wood frame (Fig. 4a). Figure 4b shows the measured air leakage rates through the holes. Permanent tearing at the staples was observed when the pressure difference across the polyethylene reached 55 Pa, but the change in the leakage opening was too small to affect the air leakage characteristic.

Two sheets of polyethylene, overlapped and stapled

Test 2a: 4 mil, 40 mm overlap, depressurization

The air leakage rate increased with the pressure difference across the polyethylene (Fig. 5). After the pressure difference reached 140 Pa, it started to decrease as the air leakage rate continued to increase. The change occurred when the polyethylene was ripped at the staples. The maximum pressure difference that could be applied to the polyethylene membrane without tearing it was about 140 Pa.

Test 2b: as Test 2a, pressurization

Figure 6 shows that the air leakage rate increased continuously with the pressure differential. The maximum pressure difference across the polyethylene reached under pressurization conditions was about 14 Pa, because the gap between the staples was fully open when the polyethylene was pushed away from the wood frame under pressurization

Test 3: 6 mil, 40 mm overlap

Tests 2a and 2b were repeated with 6 mil polyethylene sheets. Figure 7 shows the air leakage characteristic of the 6 mil polyethylene under depressurization conditions. A comparison of the results between Test 3 (6 mil) and Test 2 (4 mil), indicates that the air leakage characteristic of the two polyethylene sheets was similar. The maximum pressure differential the 6 mil polyethylene could resist was about 160 Pa. The pressurization test led to a similar conclusion. All subsequent tests were conducted on 4 mil polyethylene sheets only.

Test 4: as Test 2a, gypsum board, depressurization

The objective of the test was to determine the effect of gypsum board on the air leakage characteristic of the polyethylene membrane. The air leakage through the polyethylene-gypsum board combination was too small to measure for pressure differences across the polyethylene up to 865 Pa. As Fig. 8 shows, the polyethylene sheet was under stress but was held firmly on the stud. This suggests that the gypsum board helped to hold the polyethylene sheets together and in place. A pressurization test was not conducted.

Test 5: as Test 2a, reinforced at staples, depressurization

Test 2a indicated that the weakest point of the polyethylene was at the staples. To overcome this problem, a piece of duct tape was placed on the polyethylene before it was stapled to the wood frame. The measured air leakage rates (Fig. 9a) increased continuously with the pressure differential for a pressure difference as high as 700 Pa. This kind of treatment for improving the strength of polyethylene locally works well to prevent it from tearing around the holes (Fig.9b).

A pressurization test was also conducted. The pressure difference across the polyethylene was too small to measure because pressurization helped to open the gaps between the staples.

Test 6a: 4 mil, 400 mm overlap, depressurization

This configuration was similar to that of Test 2a except that the two sheets of polyethylene were overlapped by 400 mm. The wider overlap permitted the joint to be stapled to two studs, instead of one as in the case of Test 2a. Figure 10a shows the measured air leakage rates. The air leakage characteristics were similar to those in Test 2a, but the air leakage rate through the 400 mm joint was smaller than that through the 40 mm one. Permanent tearing appeared at the holes, but the polyethylene sheets were held together and in place firmly by the two columns of staples (Fig. 10b).

Test 6b: as Test 6a, pressurization

The air leakage characteristic, as shown in Fig. 11, was different from that for a 40 mm joint (Fig. 6), because the flow resistance in the 400 mm joint was greater than that in the 40 mm one. Consequently, the air leakage rate through the wider joint was smaller than that through the narrower one.

Test 7a: 4 mil, spline method, depressurization

The spline method was developed to eliminate the air leakage through the joint between two sheets of polyethylene. Figure 12a shows that the measured air leakage rates were much greater than that for a full sheet of polyethylene with no joints (Test 1a). There was no air leakage through the joint, but some air leakage was found at locations where two joints met (e.g., corners, see Fig. 12b).

Test 7b: as Test 7a, pressurization

Figure 13 shows the measured air leakage rates. Again, the air leakage of this installation was greater than that of a full sheet of polyethylene for the same pressure differential (Test 1b).

Test 8: 4 mil, 40 mm overlap, taped

Figure 14a shows the measured air leakage rates under the depressurization condition. The tape worked well under depressurization, but did not reduce the air leakage to zero as expected. Under pressurization, however, the tape failed to hold the polyethylene sheets together (Fig. 14b).

Test 9: 4 mil, 40 mm overlap, caulked and covered with gypsum board

The test could only be conducted when the joint was covered by gypsum board because the non-drying caulking component failed to hold the two sheets of polyethylene together under pressure. Figures 15 and 16a show the measured air leakage rates under depressurization and pressurization conditions, respectively. Surprisingly, the air leakage rate through the caulked joint was greater than that through the uncaulked one (Test 4). The contacting surface between the polyethylene and the caulking component was not smooth (Fig. 16b). This suggests that instead of sealing the joint, in some cases the use of caulking component can produce the opposite result by preventing the gypsum board from pressing the polyethylene sheets tightly against the wood frame.

Window frame

Test 10: 4 mil, stapled

Figure 17a shows the air leakage characteristic for the window frame under depressurization conditions. The pressure difference across the polyethylene was not detectable at low air leakage rates. When the air leakage rate reached about 0.42 L/(s.m), there was an abrupt change in the air leakage characteristic. As shown in Fig. 17b, the polyethylene was stapled to both the window frame and the wall frame around it. At low air leakage rates, the polyethylene sheet was loosely covering the frames. This permitted the air to move freely through the gap between the polyethylene and the frames. When the leakage rate reached 0.42 L/(s.m), the polyethylene was pulled tightly against the wall frame. As a result, the flow resistance in the gaps was significantly increased which, in turn, caused a decrease in the air leakage rate.

A pressurization test was also conducted on the window. The pressure difference across the polyethylene was not detectable because the gap between the staples was fully open under pressurization.

Test 11: as Test 10, gypsum board

In this test, the polyethylene sheet stapled to the wall frame was covered by gypsum board, but that stapled to the window frame remained uncovered (Fig. 18a). Figure 18b shows the air leakage characteristic for the window under depressurization conditions. Unlike results from the previous test, the pressure difference across the polyethylene at low air leakage rates was measurable, because the gaps between the polyethylene and the wall frame were closed when the polyethylene sheet was covered with gypsum board. Similar to the previous test, an abrupt change in the air leakage characteristic was observed, when the edges of the polyethylene sheet were pulled towards the wall.

The results of a pressurization test (Fig. 19) however, did not indicate a similar change in the air leakage characteristic. This is because the amount of pressurization imposed was too small to cause such a change.

SUMMARY

The results could be summarized as follows:

1. A 6 mil polyethylene membrane was stiffer than a 4 mil membrane and had a greater air leakage rate through the joint.
2. The best method for installing a wall joint was to have the two sheets of polyethylene overlapped by about 400 mm, with the edges stapled to two vertical studs.
3. The spline system was too difficult to apply, especially at the corners.
4. Taping and caulking the joint did not produce an air-tight joint.
5. New technique is needed to fasten the edges of the polyethylene sheet to the window frame and hold the edges in place.

ACKNOWLEDGMENTS

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TABLE 1 Test Conditions and Results

Test No.	Test Conditions		Air Leakage Rates, L/(s.m) ΔP_{poly} = 50 Pa	ΔP_{poly}[2] = 100 Pa	Remarks
1a	One full sheet, 4 mil, stapled	S[1]	0.0	0.0	Air leakage too small to measure
1b	as Test 1[3]	P[1]	0.2	2.5[4]	Fig. 4b
2a	Two sheets, 4 mil, 40 mm overlap	S	0.15	0.3	Fig. 5
2b	as Test 2a	P	1.8[4]	2.4[4]	Fig. 6
3	Two sheets, 6 mil, 40 mm overlap	S	0.44	0.47	Fig. 7
4	as Test 2a, gypsum board	S	0.0	0.0	Air leakage too small to measure
5	as Test 2a, reinforced at staples	S	0.2	0.21	Fig. 9a
6a	Two sheets, 4 mil, 400 mm overlap	S	0.014	0.02	Fig. 10a
6b	as Test 6a	P	1.1	–	Fig. 11
7a	Two sheets, 4 mil, spline method	S	0.13	0.2	Fig. 12a
7b	as Test 7a	P	0.32	4.0	Fig. 13
8	Two sheets, 4 mil, 40 mm overlap, taped	S	0.05	0.07	Fig. 14a
9a	Two sheets, 4 mil, 40 mm overlap, caulked, gypsum board	S	0.04	0.06	Fig. 15
9b	as Test 9a	P	0.07	–	Fig. 16a
10	Window test, 4 mil, stapled	S	Fig. 17a		ΔP_{poly} too small to measure
11a	as Test 10, gypsum board	S	Fig. 18b		Air leakage characteristic changed
11b	as Test 11a	P	Fig. 19		

[1] S, depressurization (suction) test; P, pressurization test.
[2] ΔP_{poly}, pressure difference across polyethylene sheet.
[3] To facilitate comparison, value listed is net air leakage rate through polyethylene membrane divided by height of test wall.
[4] Extrapolated.

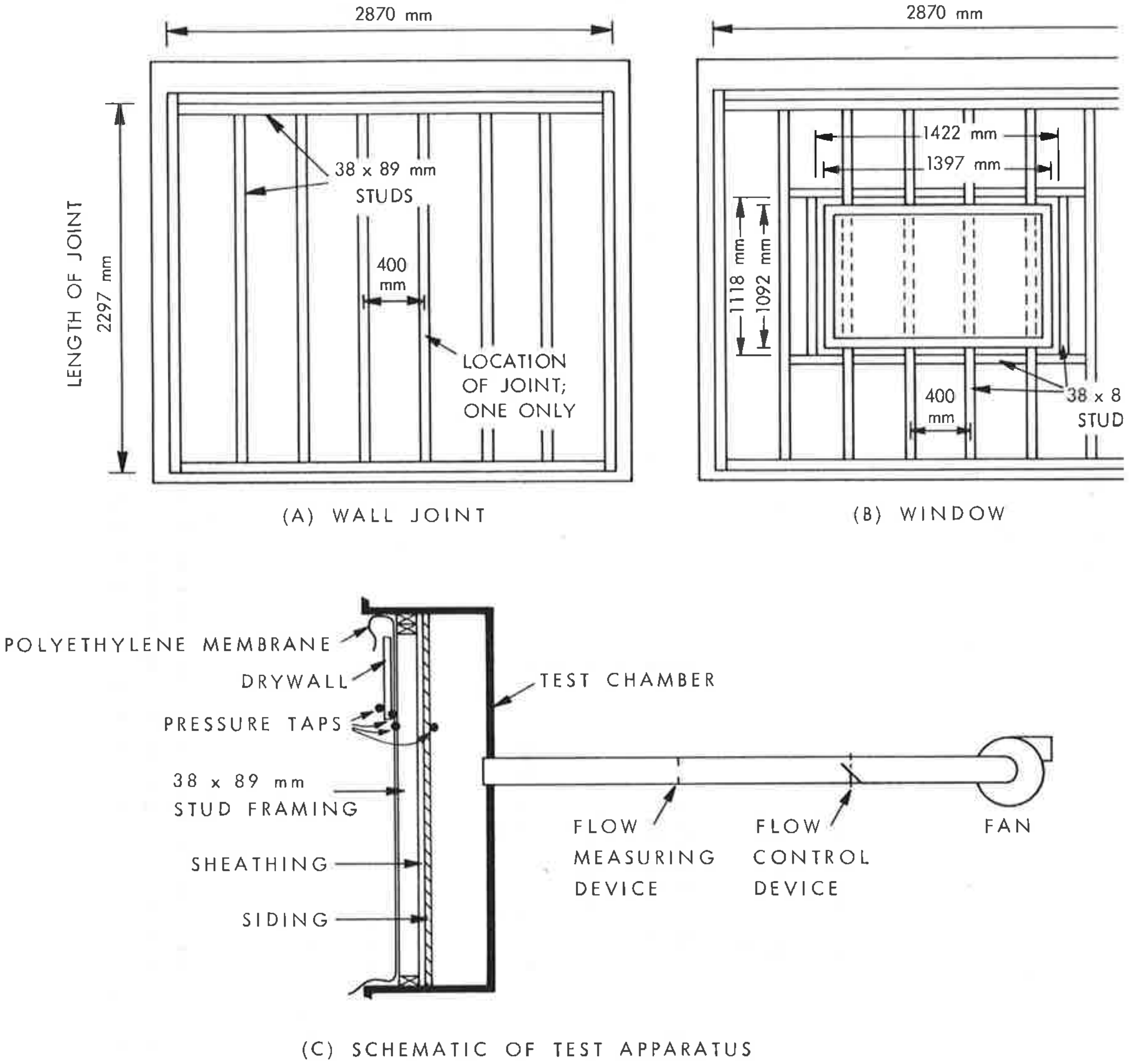

FIGURE 1

TEST CHAMBER AND EXPERIMENTAL SET-UP

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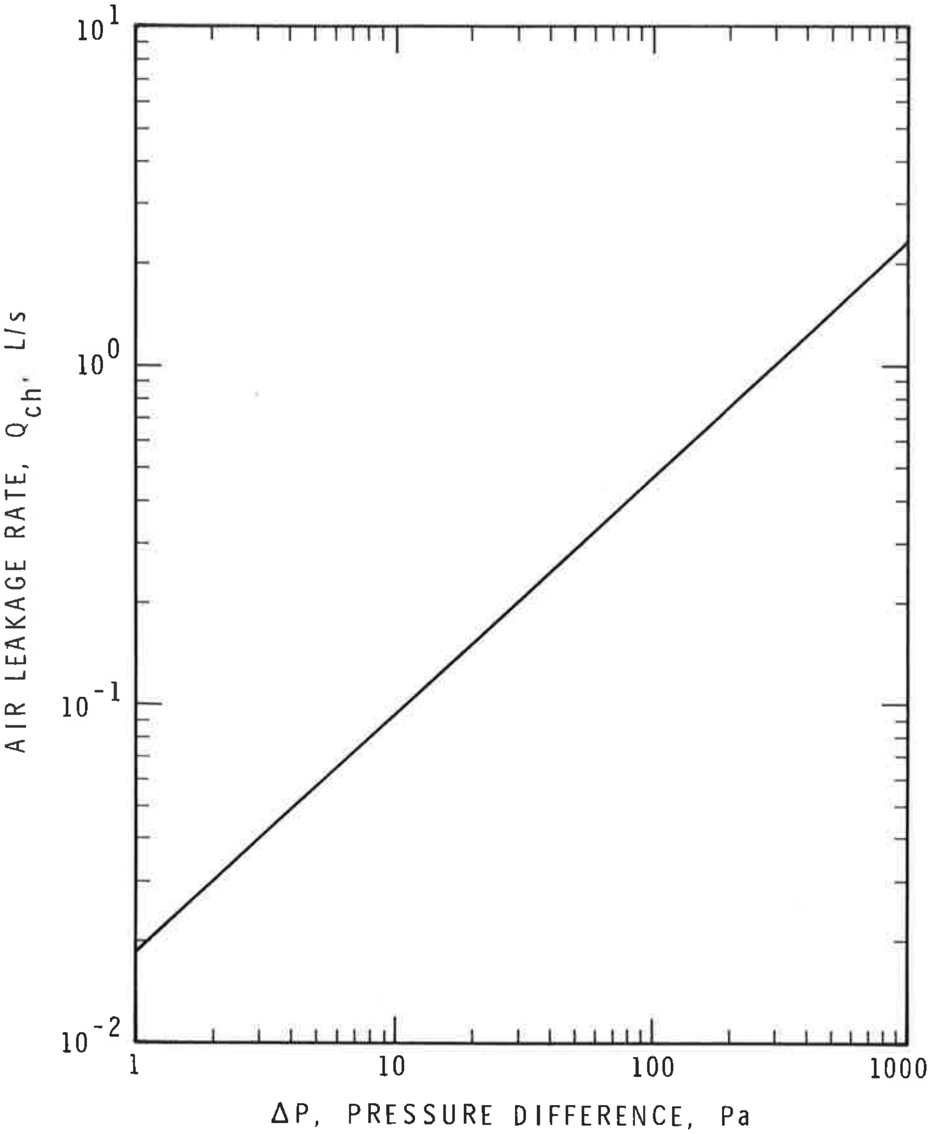

FIGURE 2

AIR LEAKAGE RATE OF TEST CHAMBER

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FIGURE 3

DEPRESSURIZATION TEST

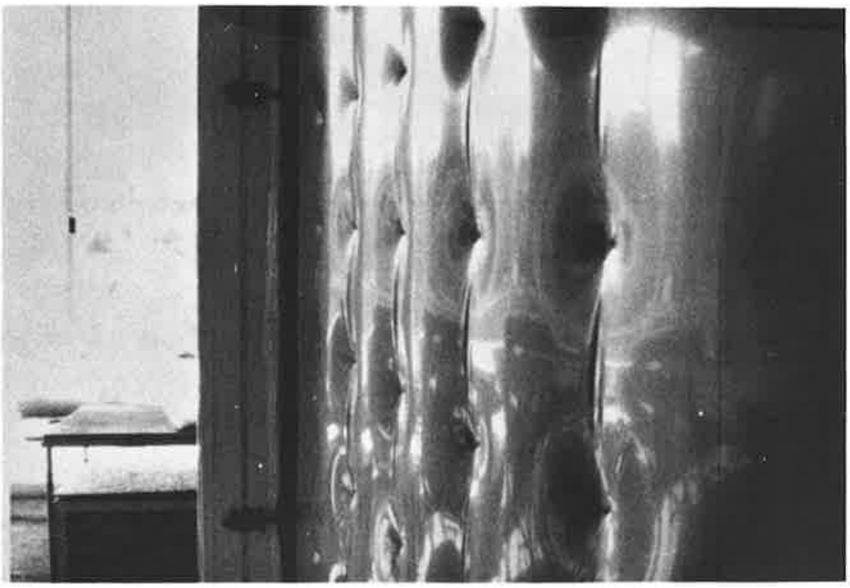

FIGURE 4a

PRESSURIZATION TEST

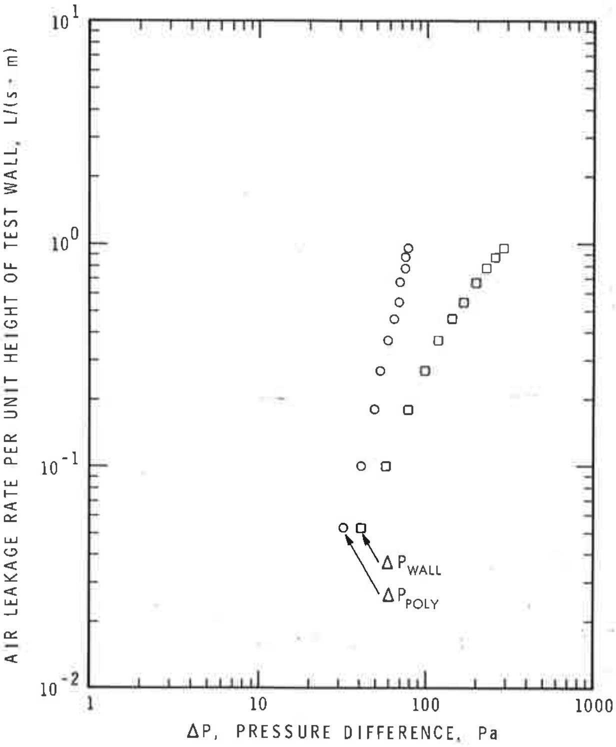

FIGURE 4b

AIR LEAKAGE RATE VS PRESSURE DIFFERENCE. TEST 1b, PRESSURIZATION, 4 mil, FULL SHEET STAPLED

BR 6621-3

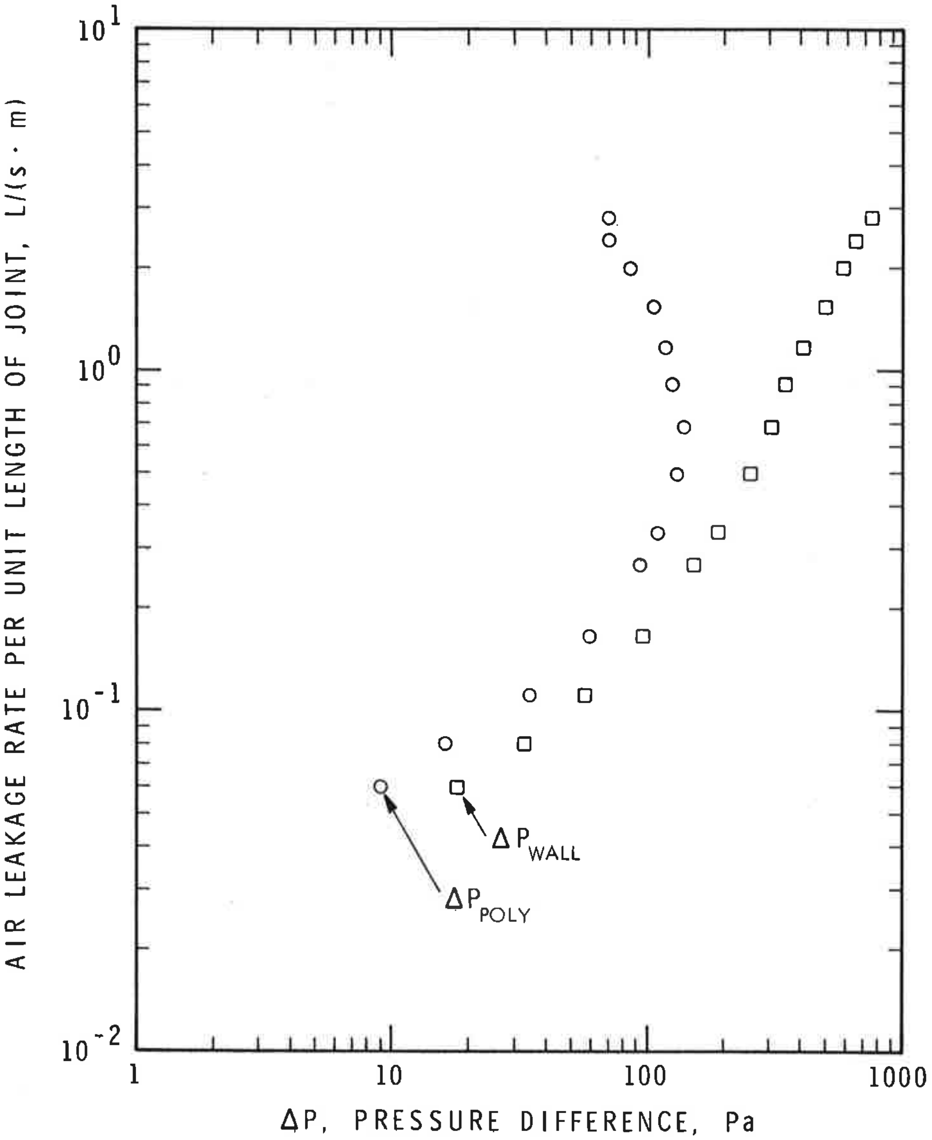

FIGURE 5

AIR LEAKAGE RATE VS PRESSURE DIFFERENCE. TEST 2a, DEPRESSURIZATION, 4 mil, 40 mm OVERLAP

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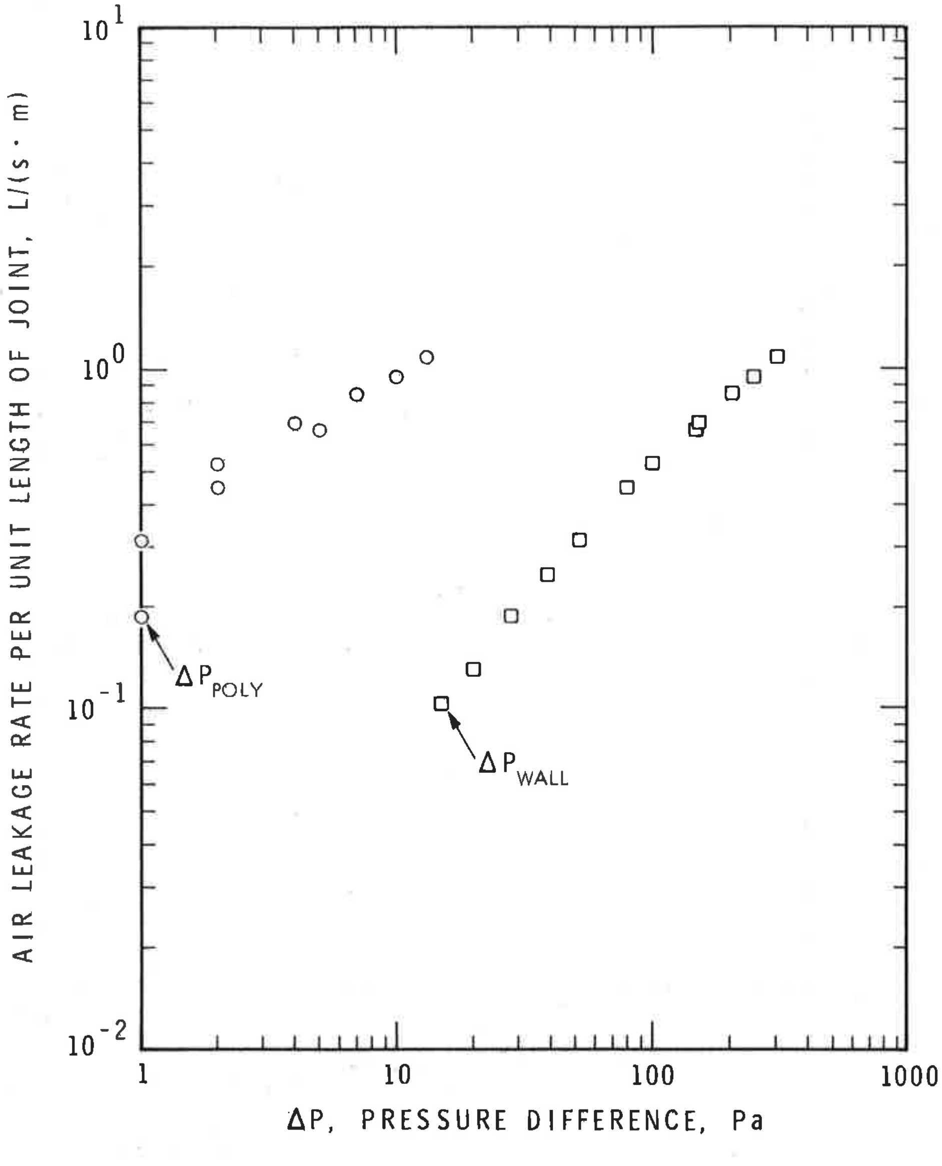

FIGURE 6

AIR LEAKAGE RATE VS PRESSURE DIFFERENCE.
TEST 2b, PRESSURIZATION, 4 mil, 40 mm OVERLAP

BR 6621-5

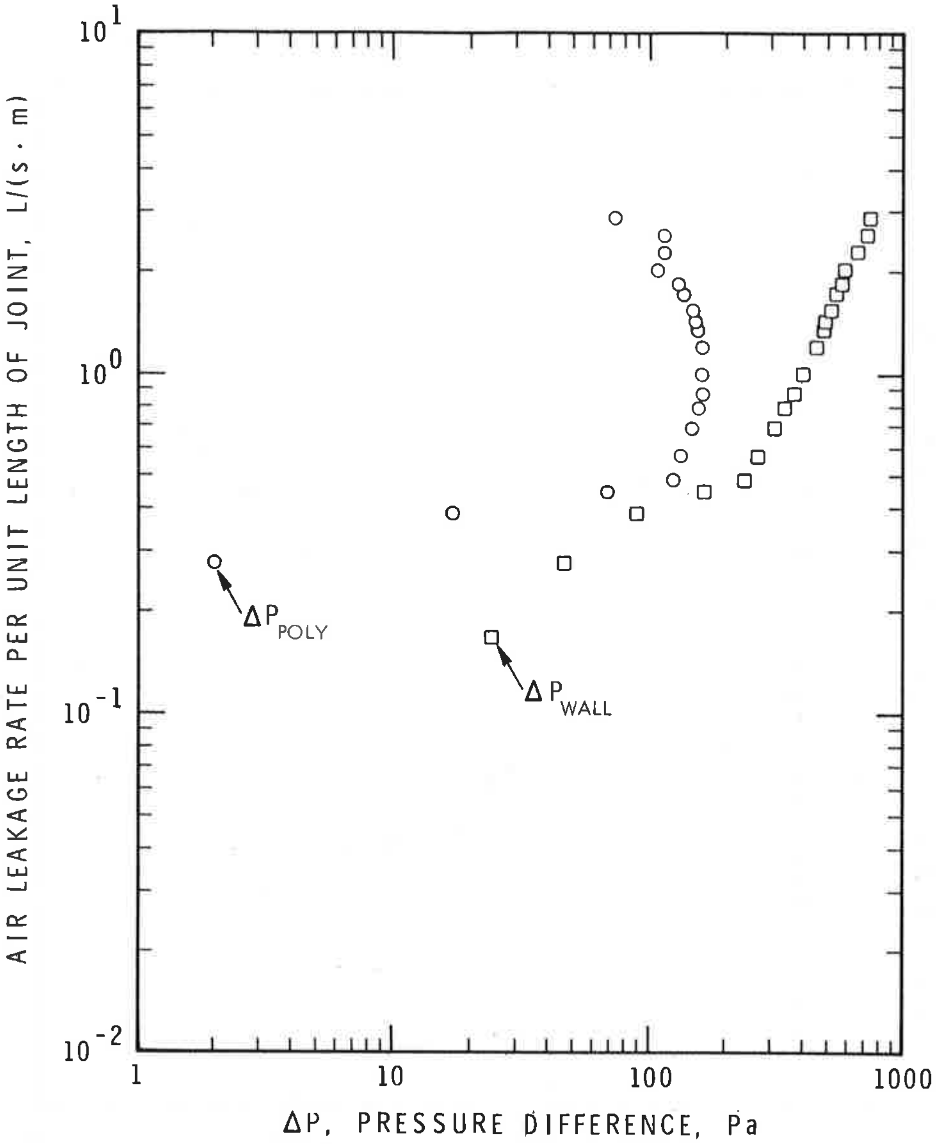

FIGURE 7

AIR LEAKAGE RATE VS PRESSURE DIFFERENCE.
TEST 3, DEPRESSURIZATION, 6 mil, 40 mm OVERLAP

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FIGURE 8

CONDITION OF POLYETHYLENE AFTER GYPSUM BOARDS REMOVED (ΔP_{POLY} = 865 Pa)

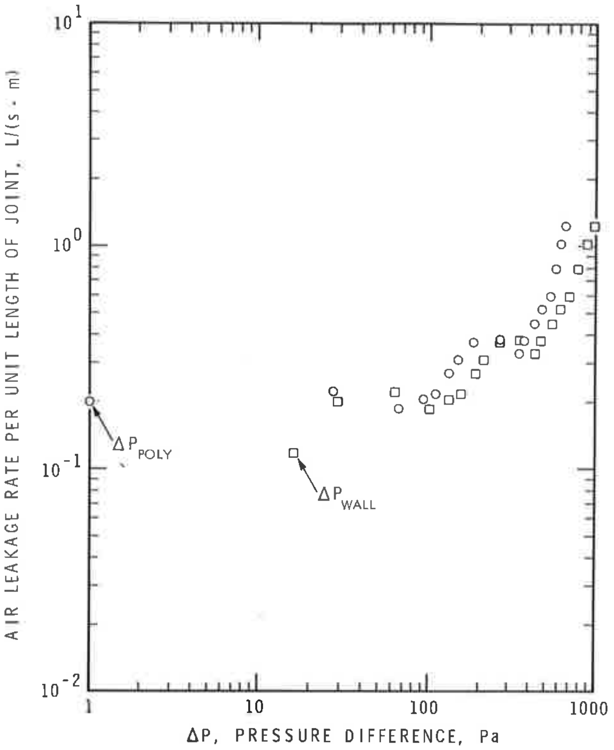

FIGURE 9a

AIR LEAKAGE RATE VS PRESSURE DIFFERENCE.
TEST 5, DEPRESSURIZATION, 4 mil, 40 mm OVERLAP,
REINFORCED AT STAPLES (JOINT ONLY)

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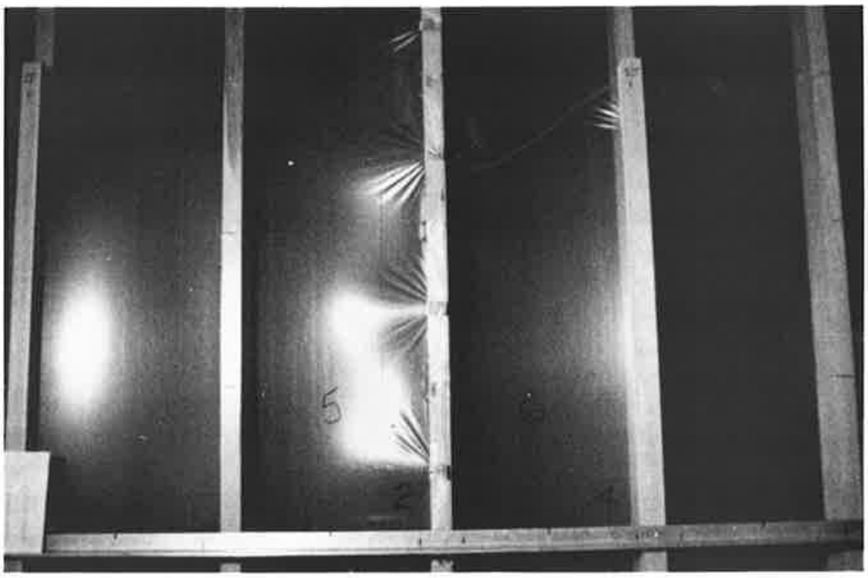

FIGURE 9b

REINFORCED POLYETHYLENE UNDER DEPRESSURIZATION

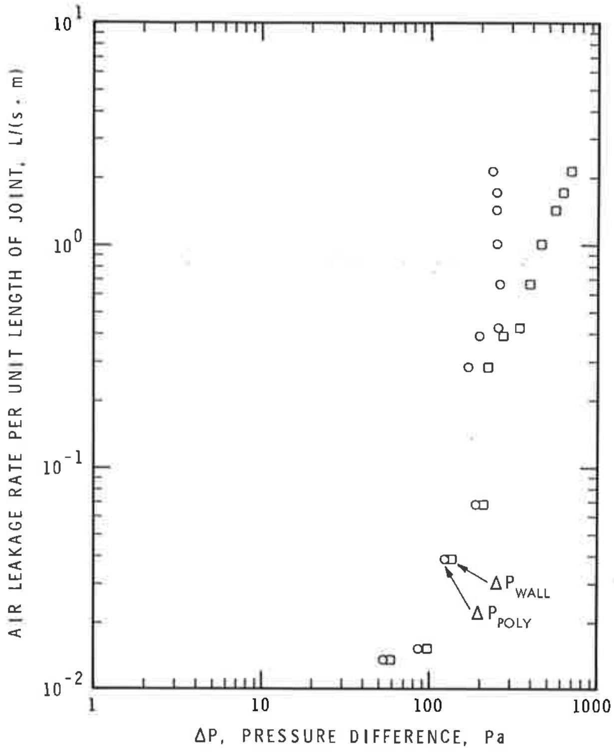

FIGURE 10 a

AIR LEAKAGE RATE VS PRESSURE DIFFERENCE. TEST 6a, DEPRESSURIZATION, 4 mil, 400 mm OVERLAP

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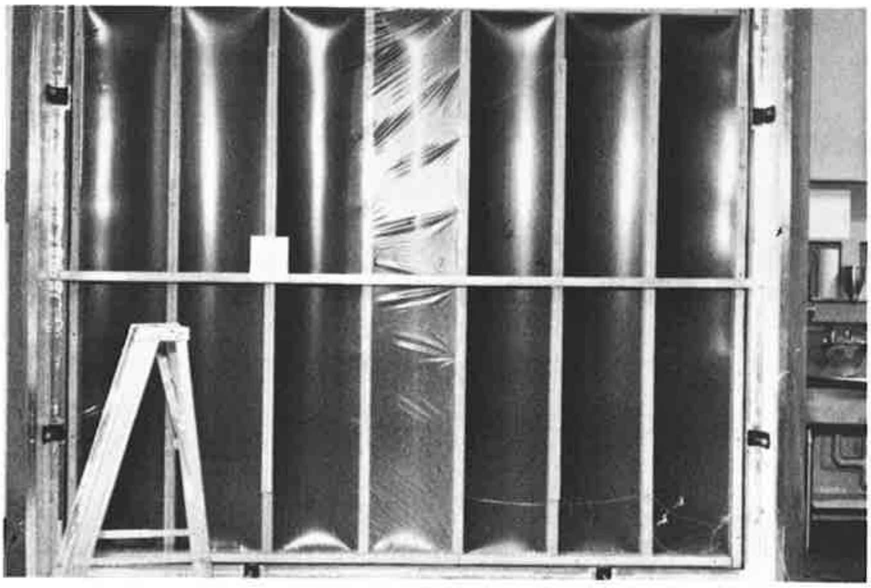

FIGURE 10 b

CONDITION OF 400 mm WIDE JOINT UNDER DEPRESSURIZATION

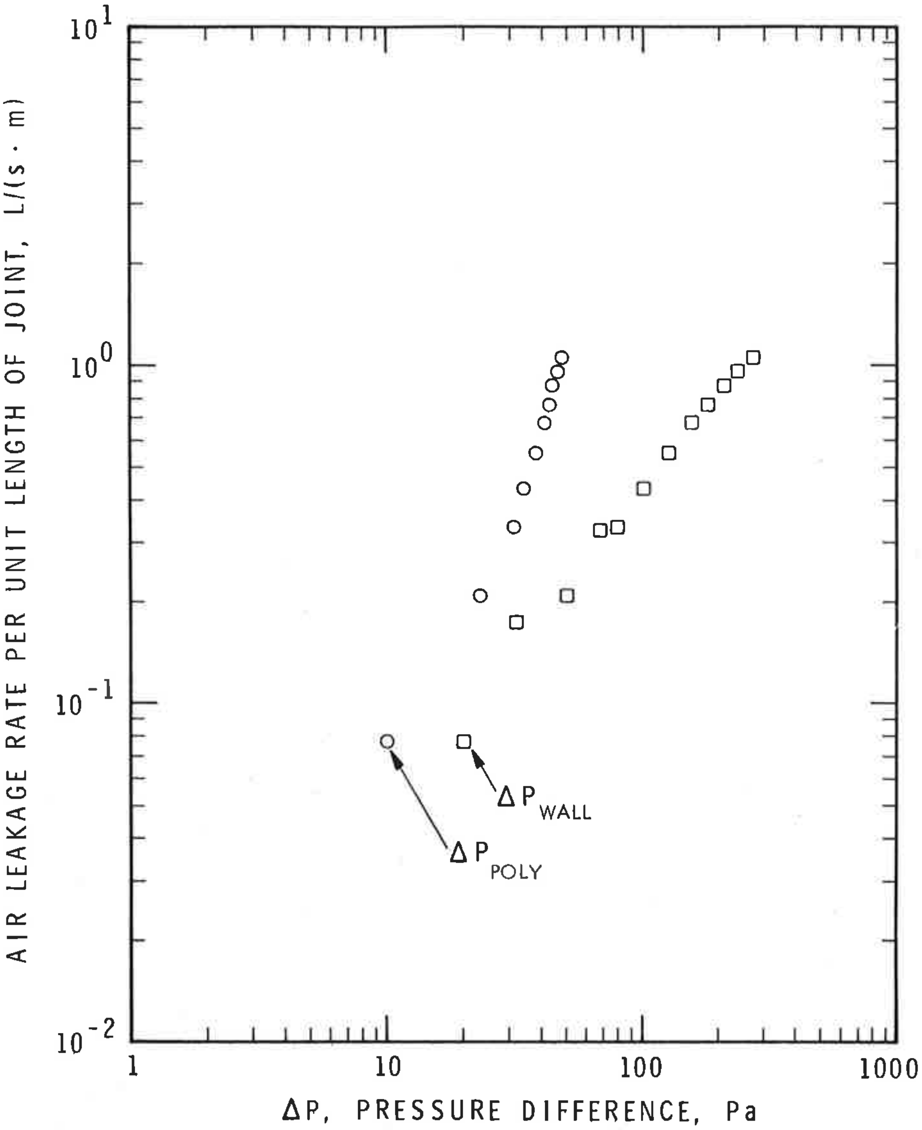

FIGURE 11

AIR LEAKAGE RATE VS PRESSURE DIFFERENCE.
TEST 6b, PRESSURIZATION, 4 mil, 400 mm OVERLAP

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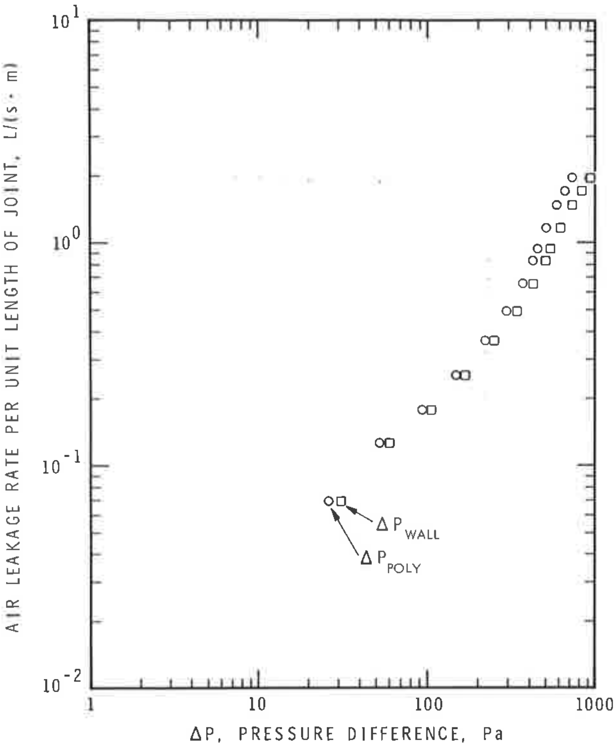

FIGURE 12a

AIR LEAKAGE RATE VS PRESSURE DIFFERENCE.
TEST 7a, DEPRESSURIZATION, 4 mil, SPLINE METHOD

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FIGURE 12b

SOAP BUBBLE TEST SHOWING THE AIR LEAKAGE SOURCE, SPLINE METHOD

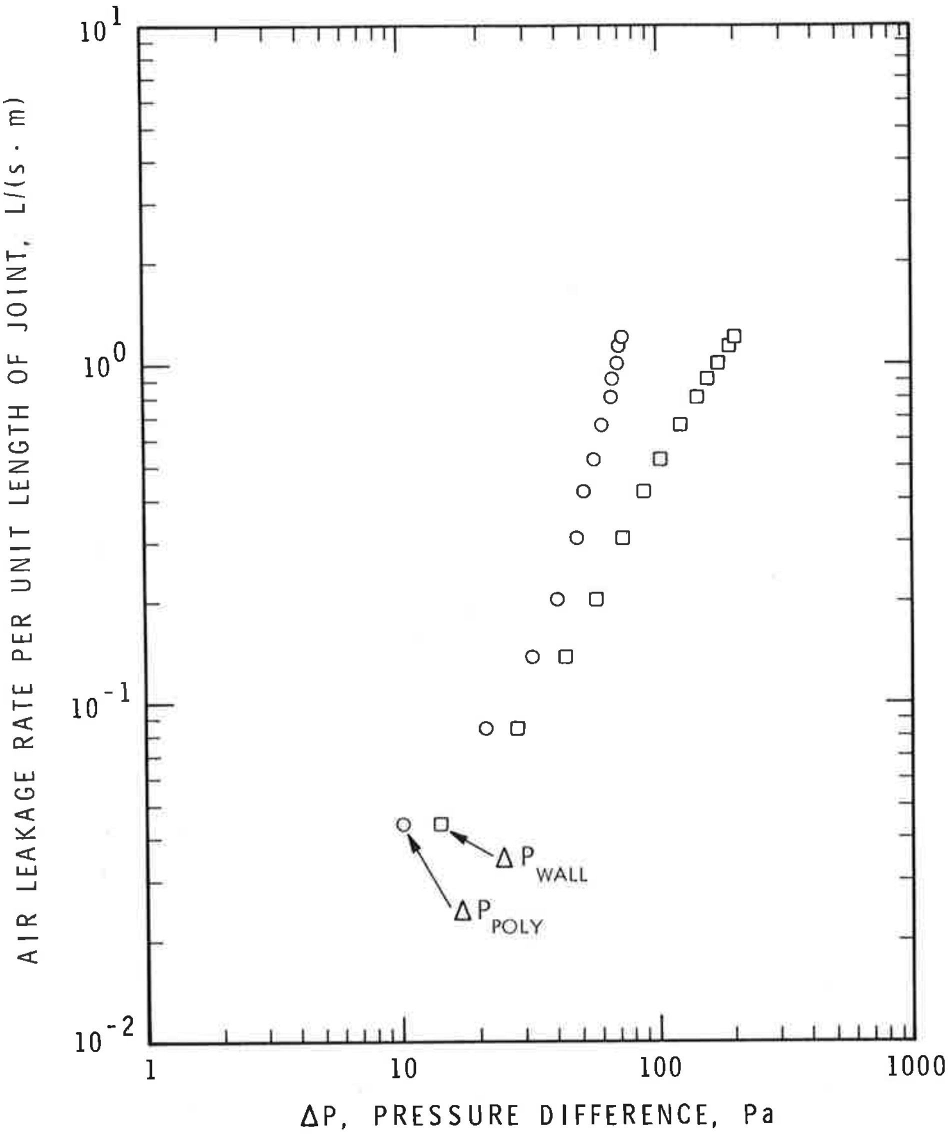

FIGURE 13

AIR LEAKAGE RATE VS PRESSURE DIFFERENCE.
TEST 7b, PRESSURIZATION, 4 mil, SPLINE METHOD

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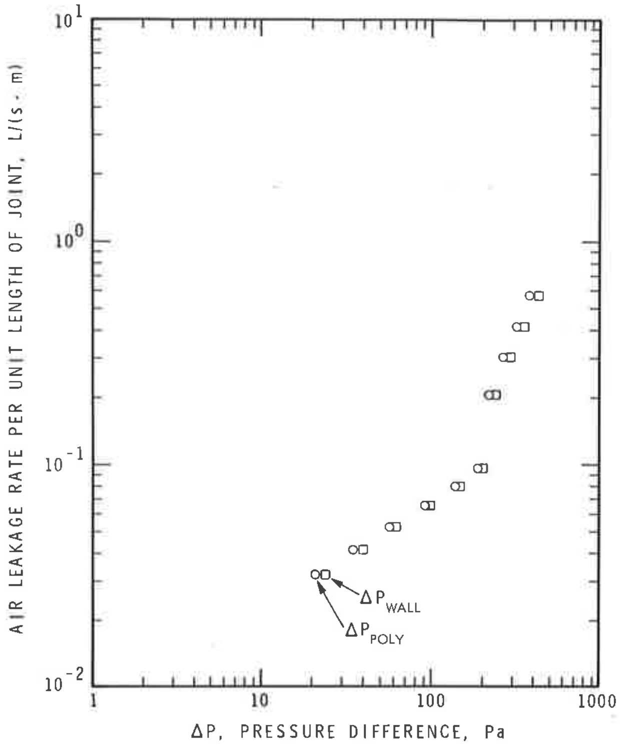

FIGURE 14 a

AIR LEAKAGE RATE VS PRESSURE DIFFERENCE.
TEST 8, DEPRESSURIZATION, 4 mil, 40 mm OVERLAP
(TAPED JOINT)

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FIGURE 14b

CONDITION OF TAPED JOINT UNDER PRESSURIZATION

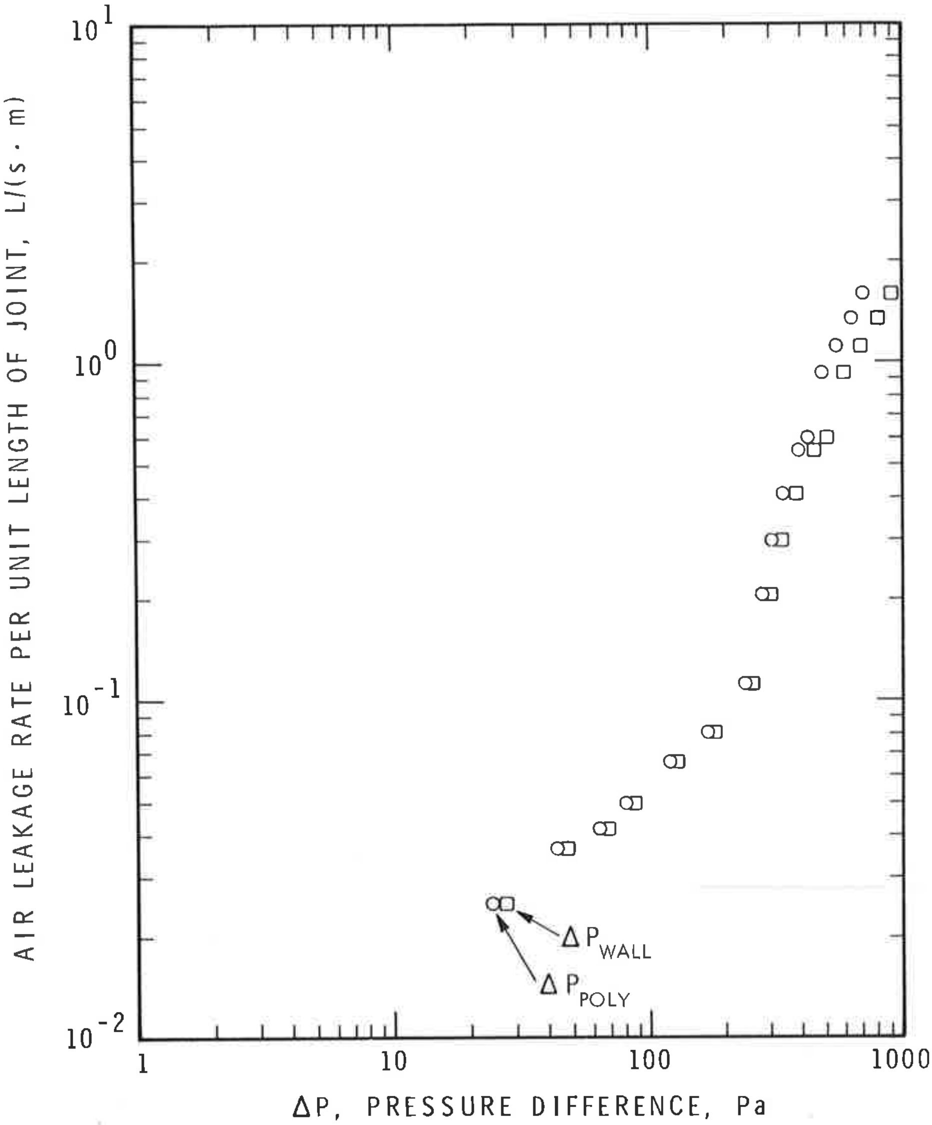

FIGURE 15

AIR LEAKAGE RATE VS PRESSURE DIFFERENCE. TEST 9a, DEPRESSURIZATION, 4 mil, 40 mm OVERLAP (CAULKED JOINT), COVERED WITH GYPSUM BOARD

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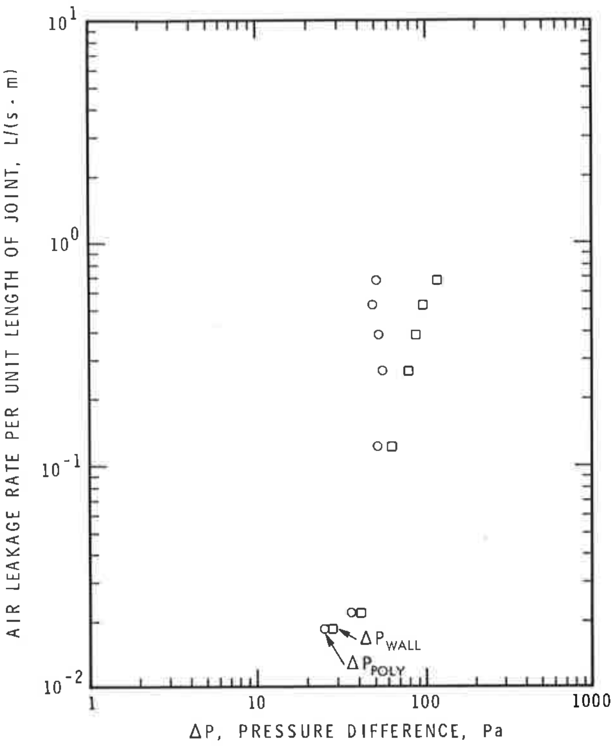

FIGURE 16 a

AIR LEAKAGE RATE VS PRESSURE DIFFERENCE.
TEST 9b, PRESSURIZATION, 4 mil, 40 mm OVERLAP
(CAULKED JOINT), COVERED WITH GYPSUM BOARD

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FIGURE 16b

CONDITION OF CAULKED JOINT AFTER
GYPSUM BOARDS REMOVED

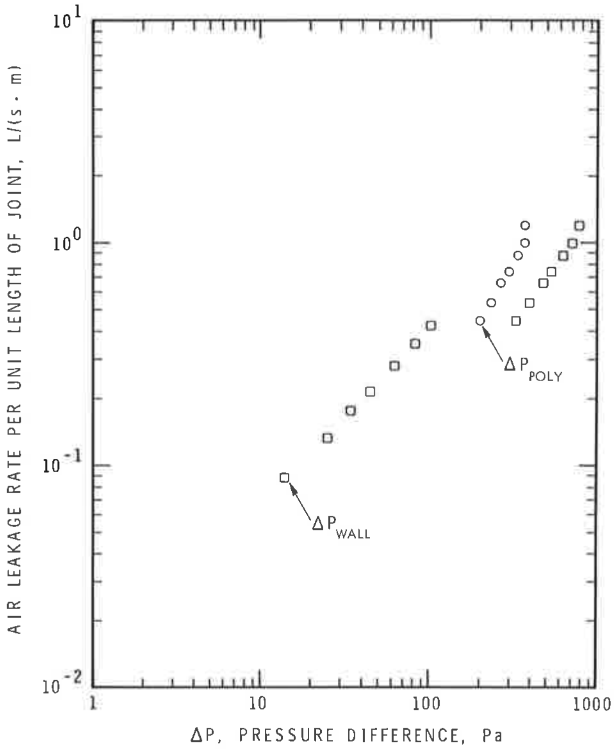

FIGURE 17a

AIR LEAKAGE RATE VS PRESSURE DIFFERENCE, TEST 10, DEPRESSURIZATION, WINDOW TEST, STAPLES ON STUD AND FRAME

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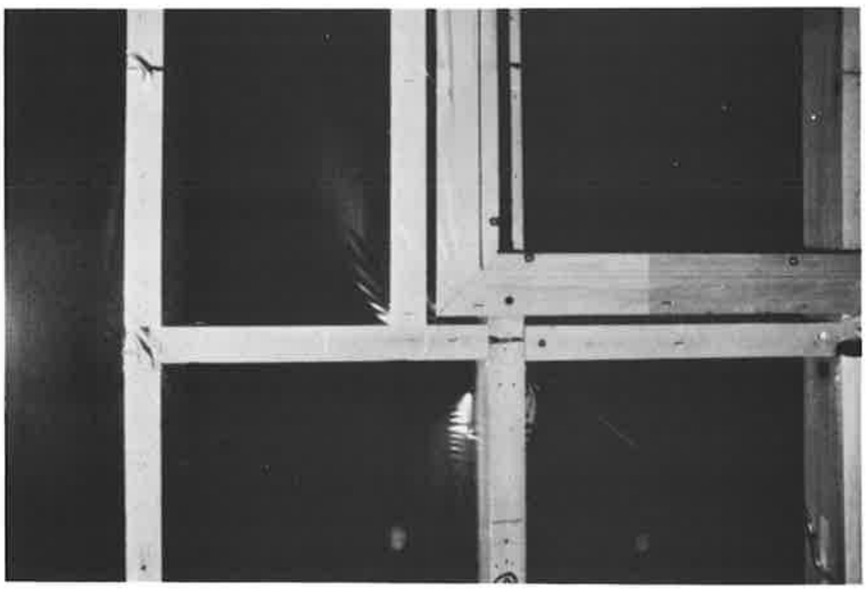

FIGURE 17b

CONDITION OF POLYETHYLENE AROUND WINDOW UNDER DEPRESSURIZATION

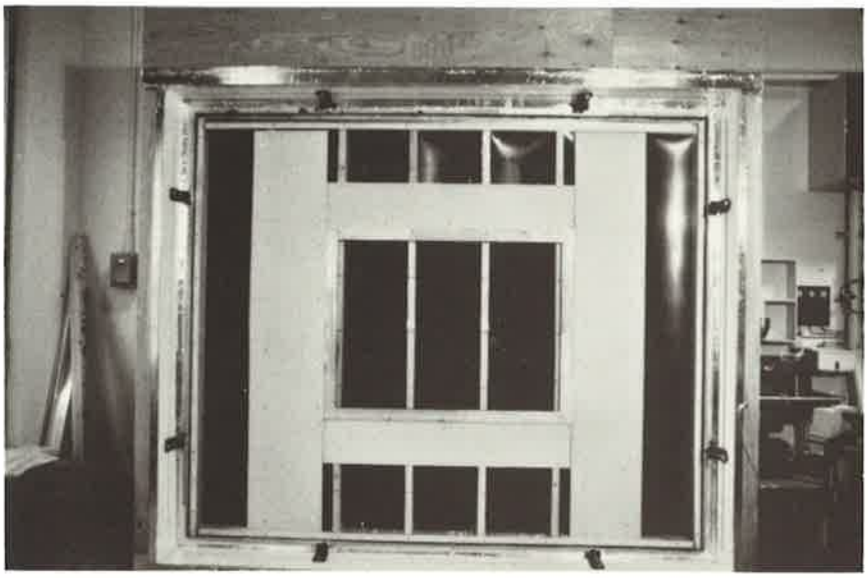

FIGURE 18a

INSTALLATION OF GYPSUM BOARD AROUND WINDOW

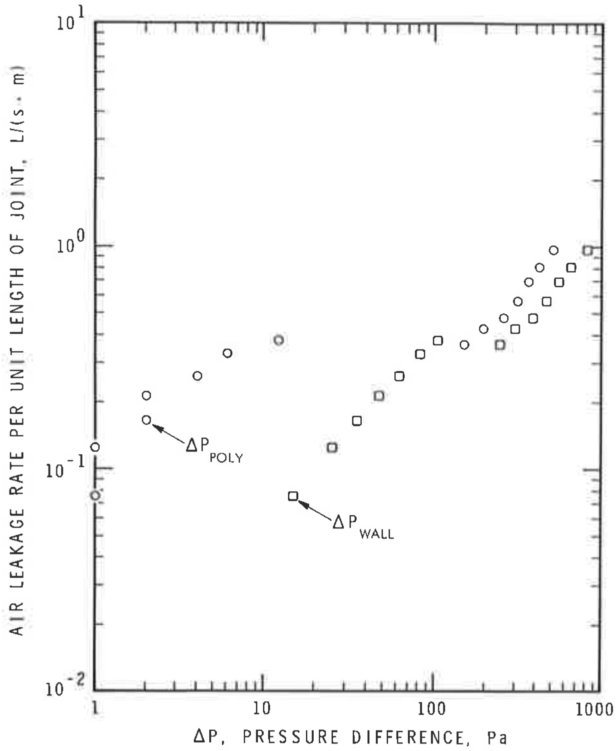

FIGURE 18b

AIR LEAKAGE RATE VS PRESSURE DIFFERENCE.
TEST 11a, DEPRESSURIZATION, WINDOW TEST,
WINDOW PERIMETER COVERED WITH GYPSUM BOARD

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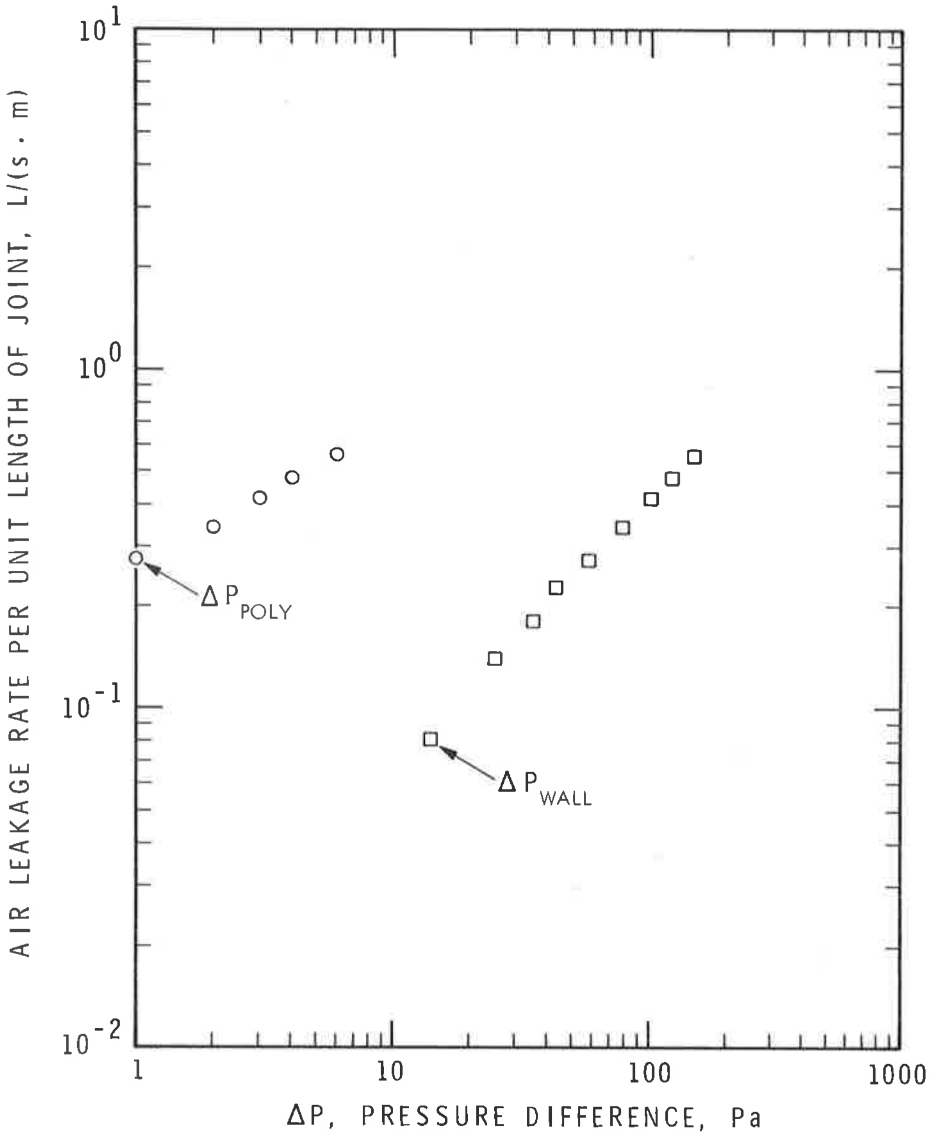

FIGURE 19

AIR LEAKAGE RATE VS PRESSURE DIFFERENCE.
TEST 11b, PRESSURIZATION, WINDOW TEST,
WINDOW PERIMETER COVERED WITH GYPSUM BOARD

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