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IN-SITU LONG-TERM THERMAL PERFORMANCE OF IMPERMEABLY FACED POLYISO FOAM BOARDS

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ABSTRACT

During 2001-2003, researchers at the National Research Council (NRC) Canada – Institute for Research in Construction (IRC) in association with the Canadian Polyisocyanurate Council conducted collaborative research activities on the long-term thermal resistance (LTTR) of polyisocyanurate (polyiso) foam insulation with impermeable facers. The primary objective of that research project was to contribute towards the development of a comprehensive test procedure that could be used to predict the LTTR of polyiso foam insulation products with impermeable facers. As a part of that initiative, in order to investigate the field performance, three types of rigid polyiso foam boards with impermeable facers were installed in a purpose-built test-hut at the NRC-IRC's Ottawa, Ontario campus in 2001.

This paper presents the thermal characteristics of the rigid polyiso foam boards with impermeable facers after more than six years of field exposure (up to seven years from the manufacturing date) and it is hoped that these firsthand observations about the field performance will help the construction professionals and researchers to develop a better understanding on the LTTR of impermeably faced polyiso foam insulation boards.

1. INTRODUCTION

Closed-cell polyisocyanurate (*polyiso*) foam insulation products are extensively used in building envelope constructions as they have one of the highest R-values per unit thickness among the insulations used in the construction industry (Figure 1). This is primarily due to the replacement of air in the cellular structure of the foam (Figure 2) with a gas that has thermal conductivity less than that of air. However, aging of closed-cell foam insulation can occur due to inward diffusion of external air and outward diffusion of the blowing agent gas (Figure 3). *Polyiso* insulation products are made with facers in the form of a rigid board. Facers can be permeable or impermeable. The introduction of impermeable facers on the surface of *polyiso* rigid board is aimed at enhancing the long-term thermal resistance (LTTR) properties of the foam insulation.

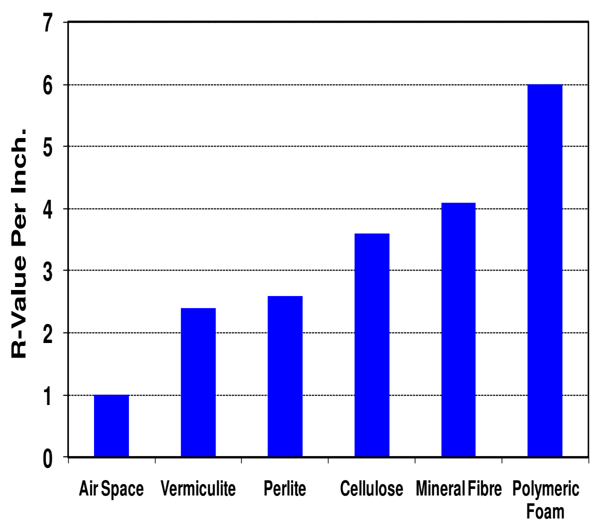


Figure 1 – Typical thermal properties of various insulations used in the building envelope construction

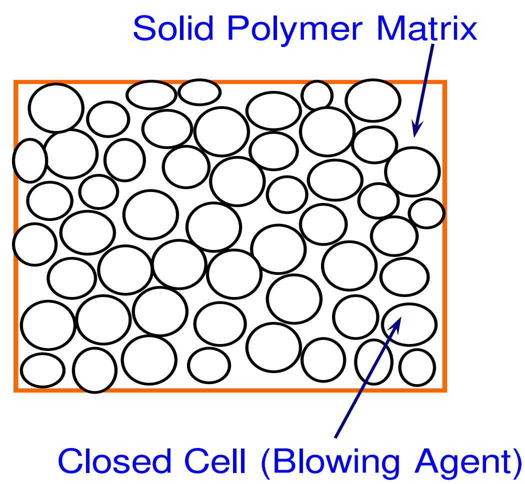


Figure 2 – Schematic cellular structure of polyiso foam

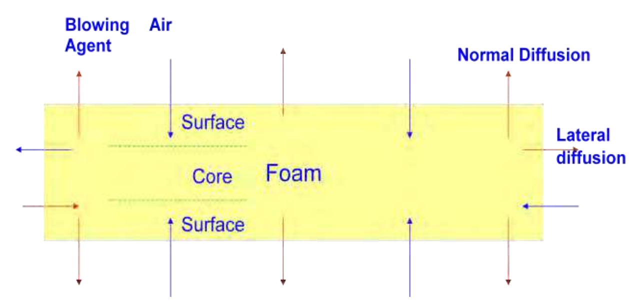


Figure 3 – Aging mechanisms in polyiso foam board

2. RESEARCH BACKGROUND

Researchers at the National Research Council (NRC) Canada – Institute for Research in Construction (IRC) have been collaborating with the Canadian Polyisocyanurate Council and Polyisocyanurate Insulation Manufacturers Association (PIMA) for many years now to study the long-term thermal resistance (LTTR) of closed-cell foam insulation. Under this initiative, in 2001, four (4) impermeably faced polyiso boards were installed in a test hut, located at the Ottawa campus of the NRC-IRC. Detailed experimental, numerical modelling and field performance monitoring studies were carried out at that time to predict the LTTR of impermeably faced polyiso boards. Full details of that study can be found in the relevant publications (*Mukhopadhyaya et al. 2002; 2003; 2004*). This paper presents results from a subsequent follow-up initiative that evaluates the thermal performance of impermeably faced polyiso boards after more than six years of field exposure (up to seven years from the manufacturing date). It is expected that these field performance data can be used to refine the laboratory test procedure and modelling tool used to predict the LTTR of impermeably faced closed-cell foam insulation boards.

3. POLYISO BOARDS

Three different types of rigid polyiso foam insulation boards with aluminum foil facer were under consideration in this study. These boards were obtained from three different North American sources and each one differs from the others in terms of the blowing agent or the manufacturing process. The physical and initial thermal properties of these boards are shown in Table 1. The boards are identified as *Product A*, *Product B* and *Product C* in this study. *Product A* is a restrained rise polyiso manufactured with hydrochlorofluorocarbon (HCFC) blowing agent. *Product B* is a restrained rise polyiso manufactured with a zero-ozone depletion potential blowing agent (i.e. pentane). *Product C* is a free rise polyiso product manufactured with HCFC.

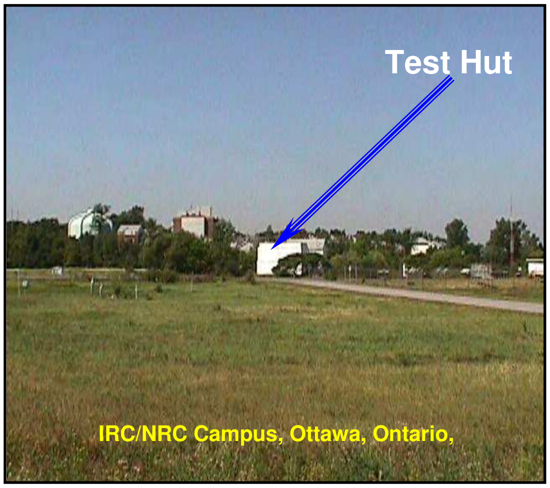
4. FIELD INSTALLATION AND MONITORING

The boards were installed and instrumented at NRC-IRC's field test facility, during the period from November 2001 to January 2002. Figures 4 and 5 illustrate the test site, the specimen placement inside the test hut and the cross-section of the test hut wall as described in the report.

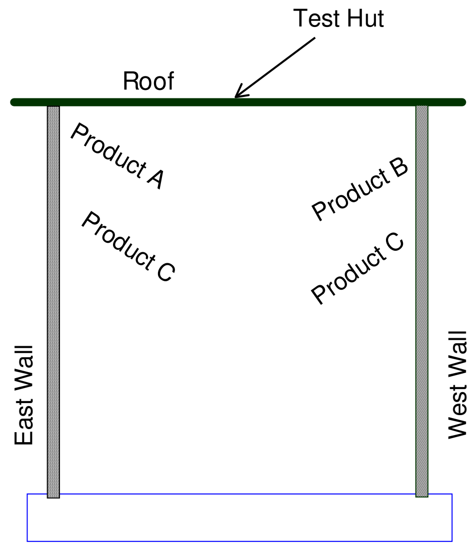
Field monitoring was done on a regular basis for 6 years of exposure. Measurements were recorded until January 5, 2008. However, actual calculations of resistivity were conducted during the winter months only when there was larger temperature difference or gradient across the insulation board and the wall mounted heat flow sensor.

Table 1 – Physical and thermal properties of polyiso boards

Product ID	Average thickness (mm)	Density (kg/m^3)	Full board size (mm × mm)	Initial thermal resistivity (m.K/W)	Production date
A	24.8	35.9	1220 × 2440	53.5	Last week of January 2001
B	25.6	36.9	1220 × 2440	48.1	3rd week of March 2001
C	24.8	34.3	1220 × 2440	55.2	Last week of June 2001



Test site



Specimen placement inside the test hut (cross-section)

Figure 4 - Field test facilities

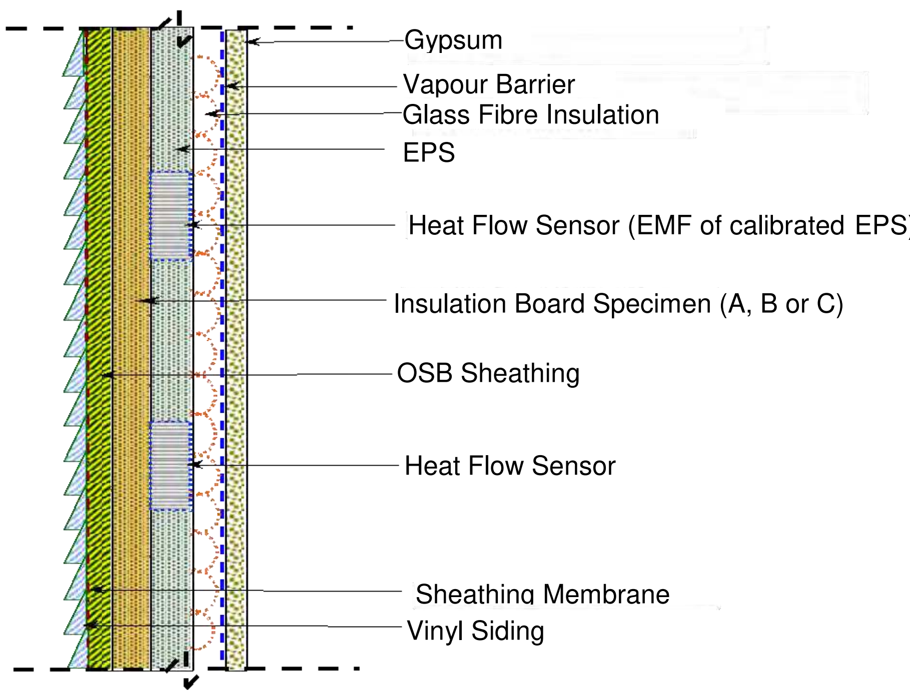


Figure 5 - Schematic cross-section of the test hut wall

5. LABORATORY TESTING

Nine (9) specimens (30 cm × 30 cm) were cut from each of the four boards removed from the test hut to evaluate their thermal characteristics. Locations of the two (2) heat flux transducers are also indicated on the schematic diagram (Figure 6) and represent the areas of field measurements. Edges along the entire perimeter of each board (approx. 75 mm wide) were discarded. The thermal characteristics were determined using the heat flow meter apparatus, according to the ASTM C518-04, *Standard Test Method for Steady-State Thermal*

Transmission Properties by Means of the Heat Flow Meter Apparatus. The tests were at first done with a mean temperature of 24°C and a temperature difference across the specimen of 22°C.The accuracy of this measurement is considered to be about 2%. In order to develop a better understanding of the results obtained from the laboratory and field observations, and identify any influence of temperature on the thermal resistivity, another series of tests were performed with a mean temperature of 0°C and a temperature difference of 5°C.

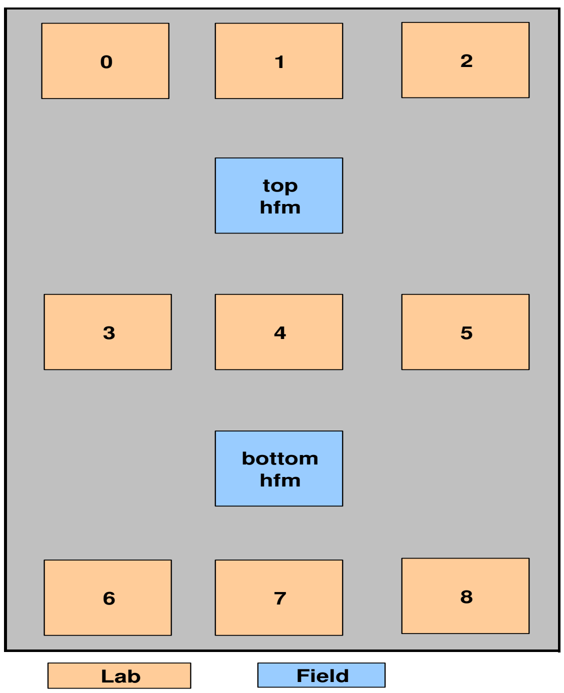


Figure 6 - Full board (4 ft. x 8 ft. x 1 in.)

6. EXPERIMENTAL RESULTS

Table 2 lists seven-day averages of the thermal resistivity values of four polyiso boards over the six-year period. Each resistivity was calculated over a seven-day period. The resistivity values are given for each "top" and "bottom" wall mounted heat flow sensor location. It is to be noted that the products were received between 5 and 12 months before they were installed in the field.

The thermal resistivities determined from the laboratory tests are presented in Tables 3 and 4. They list the thermal resistivity for each of the nine (9) specimens per board with their respective locations (Figure 6) on the walls. Table 3 shows the results from the first tests conducted with a mean temperature of 24°C and Table 4 shows the results from the tests conducted with a mean temperature of 0°C.

7. DISCUSSION

Results presented in Table 2 show a gradual decline in the resistivity for each of the four polyiso boards installed in the test hut. This phenomenon indicates that the polyiso boards have been aging in the field. The variations between top and bottom heat flow meter readings for all four polyiso boards in the field do not follow systematic patterns and are probably due to the nature of experimental setup (i.e. imperfect contact surface) or presence of moisture/air flow through the wall system.

It is also very significant to note that the thermal characteristics of the polyiso foam at various locations on the same board appear to vary significantly for one type of polyiso (Product C, see Tables 3 and 4) no longer in production in North America. However, there appears to be no systematic pattern to relate these variations with the location of the foam on the polyiso board.
Product C was exposed to both East and West walls. From the overall results and observations, it is difficult to identify any effect of the wall exposure orientation (East versus West) on the long-term thermal aging of polyiso boards.

Table 2 – Seven-day average thermal resistivity of polyiso boards during field exposure

Date	Product B (West)		Product C (West)		Product C (East)		Product A (East)	
	Thermal Resistivity (m.K/W)							
	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom
23-Nov-01	43.4	48.9						
13-Jan-02	42.4	46.6	59.5	52.0	56.2	61.6	45.3	45.7
15-Feb-02	42.0	46.3	59.7	50.0	57.0	60.2	45.0	44.4
15-Dec-02	40.5	44.4	57.4	48.1	54.8	55.8	42.4	42.4
15-Feb-03	39.8	43.2	57.3	47.6	54.3	56.1	42.4	42.9
15-Dec-03	39.5	43.6	53.5	46.5	52.8	55.6	41.4	42.1
15-Feb-04	39.5	43.7	52.6	46.8	52.7	55.6	41.4	42.8
09-Jan-06	37.9	42.4	48.2	45.1	49.5	53.1	40.0	41.3
15-Feb-06	38.0	42.5	49.0	45.1	50.2	53.4	40.7	42.0
02-Jan-08	35.1	41.4	45.6	45.0	46.8	52.8	39.7	42.8

Table 3 - Thermal resistivity (mean temperature 24°C) of polyiso boards retrieved from field

Location	Product B West	Product C West	Product C East	Product A East
	Thermal Resistivity (m.K)/W			
0	44.3	40.9	46.3	36.7
1	45.3	38.8	49.9	35.9
2	45.5	39.9	51.3	35.8
3	44.9	41.9	40.4	36.5
4	44.7	40.1	39.0	35.8
5	44.2	43.6	41.6	35.7
6	44.9	49.2	45.7	36.1
7	43.8	51.4	43.3	36.4
8	45.9	49.5	40.4	36.1
Average	44.8	43.9	44.2	36.1

Table 4 - Thermal resistivity (mean temperature 0°C) of polyiso boards retrieved from field.

	Thermal Resistivity (m.K)/W			
Location	Product B West	Product C West	Product C East	Product A East
0	41.4	45.4	52.6	41.2
1	43.6	41.7	56.8	39.5
2	43.7	43.9	59.3	40.1
3	41.4	46.2	44.4	40.3
4	43.1	44.7	43.3	40.2
5	41.8	47.4	45.4	39.6
6	42.2	56.5	51.6	40.7
7	41.4	59.0	46.4	39.9
8	43.6	55.7	44.6	39.3
Average	42.5	48.9	49.4	40.1

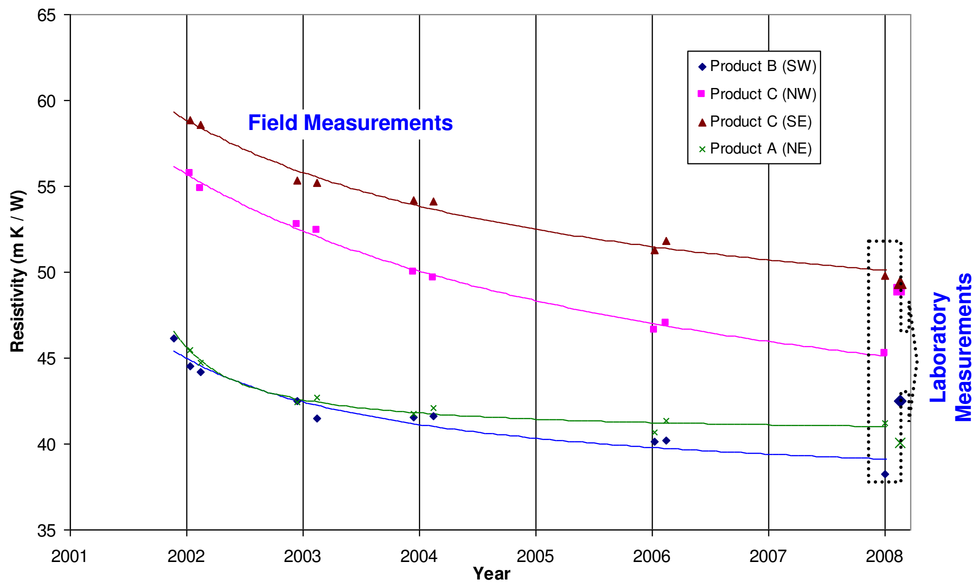


Figure 7 - Average thermal resistivity of each product (Field and Laboratory)

Figure 7 shows the average thermal resistivity of each polyiso board over the six-year period in the field. The lines on the graph show a curve fit of the field resistivity measurements. The final point, on the right hand side of the graph shows the average resistivity measured in the laboratory at 0°C. This graph indicates that the resistivity, particularly in Product C, has continued to decline, although at a slow rate, after six years of field exposure. Product A and Product B have been decreasing at a slower rate and are closer to reaching their final long-term thermal resistivity.

It is to be noted that some thermal resistivity values presented in this paper are lower than the published LTTR values available in the literatures and technical documents for permeably faced polyiso foam boards (Graham 2006). However, for Product B, the thermal resistivity, as measured in the laboratory after field exposure, is slightly higher than the published LTTR value for permeably faced products (*http://www.pima.org/UploadedFiles/bro_polyperflttr.pdf*).

8. CONCLUSIONS

Field measurements at NRC-IRC's field test facility make it possible to assess the real life long-term thermal performance of impermeably faced polyisocyanurate (i.e. polyiso) foam insulation boards. In this investigation following conclusions can be made based on the field performance observations.

1. Based on the recorded field data, the impermeably faced polyiso foam insulation boards used in this study aged significantly.
2. Thermal characteristics of the foam at various locations on the same board for one type of product, no longer in production in North America, vary significantly. However, there appears to be no systematic pattern to relate these variations with the location of the foam on the polyiso board.
3. Some thermal resistivity values, but not all, presented in this paper are lower than the published LTTR values available in the literatures and technical documents for permeably faced polyiso foam boards. For Product B, the only one of the three products currently in production in North America, the average thermal resistivity value, measured in the laboratory after field exposure, meets or exceeds published LTTR values available in the literature and technical documents for permeably faced polyiso foam boards.
4. Further investigation and critical evaluation of the available field and laboratory test data need to be done to address relevant issues concerning the LTTR of impermeably faced polyiso boards. In addition, testing of more impermeably faced polyiso boards needs to be done to corroborate the apparent benefit of impermeable facers to long-term thermal values seen in this test program.

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