BASF
The Chemical Company

Wall Energy Rating
Impact of Air Leakage on Energy Performance

From 2005 to 2010 BASF Canada participated in a research consortium comprised of stakeholders from the spray polyurethane foam (SPF) industry and the NRC Institute for Research in Construction. The objective of the project was to develop a procedure to quantify the combined effect of heat loss due to conduction and air leakage through a wall assembly. This innovative approach is referred to as a wall energy rating (WER) and is used to assess the thermal performance of an insulated wall assembly.

This information bulletin presents a brief summary of the project findings, the assembly descriptions and some results.

A total of 16 wall assemblies were evaluated under this research. Construction varied as to type of thermal insulation (glass fibre, open cell spray polyurethane foam or closed-cell spray polyurethane foam), partial or complete fill of the wall cavities with thermal insulation, and walls with or without penetrations (electrical boxes, ducts, pipes, window). Details for each wall assembly are provided below in Table 3.

The wall assemblies consisted of 2x6 wood frame construction with exterior weather resistive membrane (spunbonded polyethylene), 11 mm (7/16") exterior OSB sheathing, wall cavity insulation (glass fibre, open cell spray polyurethane foam or closed-cell spray polyurethane foam), 6 mil polyethylene sheet (air/vapour barrier material, in glass fibre insulated walls), 12.7 mm (½") interior gypsum board.

Full scale wall specimens (8ft x 8ft) were constructed and then submitted to the task sequence outlined below.

1) Measurement of the initial thermal resistance of the wall assembly in a guarded hot box apparatus (without air pressure, prior to exposure of the wall assembly to air pressures);
2) Determination of the initial air leakage rate for the wall assembly (prior to exposure of the wall assembly to air pressures);
3) Exposure of the wall assembly to a sequence of positive and negative air pressures – sustained, cyclic and gust pressures;
4) Determination of the air leakage rate for the wall assembly after subjecting the wall assembly to air pressures;
5) Measurement of the thermal resistance of the wall assembly in a guarded hot box apparatus following exposure of the wall assembly to air pressures.

Findings

- Air leakage reduces the thermal resistance and performance of thermal insulation and of wall assemblies.
- The higher the air leakage rate through a wall assembly, the greater the reduction in the thermal resistance and performance of the same wall assembly.
- Air-tightness improves the overall thermal performance of a wall.
- The tighter the assembly, i.e. the greater is the assembly's resistance to air leakage, the less is the reduction in the wall's thermal resistance and performance.
- The practice of overlapping and clamping polyethylene sheet, such as between framing members, furring, blocking and rigid panels (as permitted in the 2005 and 2010 National Building Code of Canada under paragraph 9.25.3.3.(2)(b)), is insufficient to achieve airtightness and to ensure continuity of the air barrier system.
- Closed-cell medium density spray polyurethane foam insulation is an air barrier material and can be used to achieve very low rates of air leakage in wall assemblies.
- Open-cell low density spray polyurethane foam insulation is also effective in achieving very low air leakage rates in wall assemblies.

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Polyurethane Solutions

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Results

Figure 1 provides a summary of the air leakage rates for walls WER-1 to WER-5 while Figure 2 provides a summary of the air leakage rates for walls WER-11 and 12 and WER-AA to DD, after the wall assemblies had been subjected to the air pressure program of sustained, cyclic and gust pressures. Wall assemblies WER-1, 5, 11 and 12 rely on polyethylene sheet to fulfill the function of air barrier material and system.

Assessed against the Canadian Centre for Materials and Construction (CCMC) target of 0.05 l/(s·m^2), the results highlight the ability of spray polyurethane foam insulation to achieve very low rates of air leakage and the failure of polyethylene sheets to accomplish the function of air sealing when the sheets are only overlapped or not adequately sealed for continuity of the air barrier system.

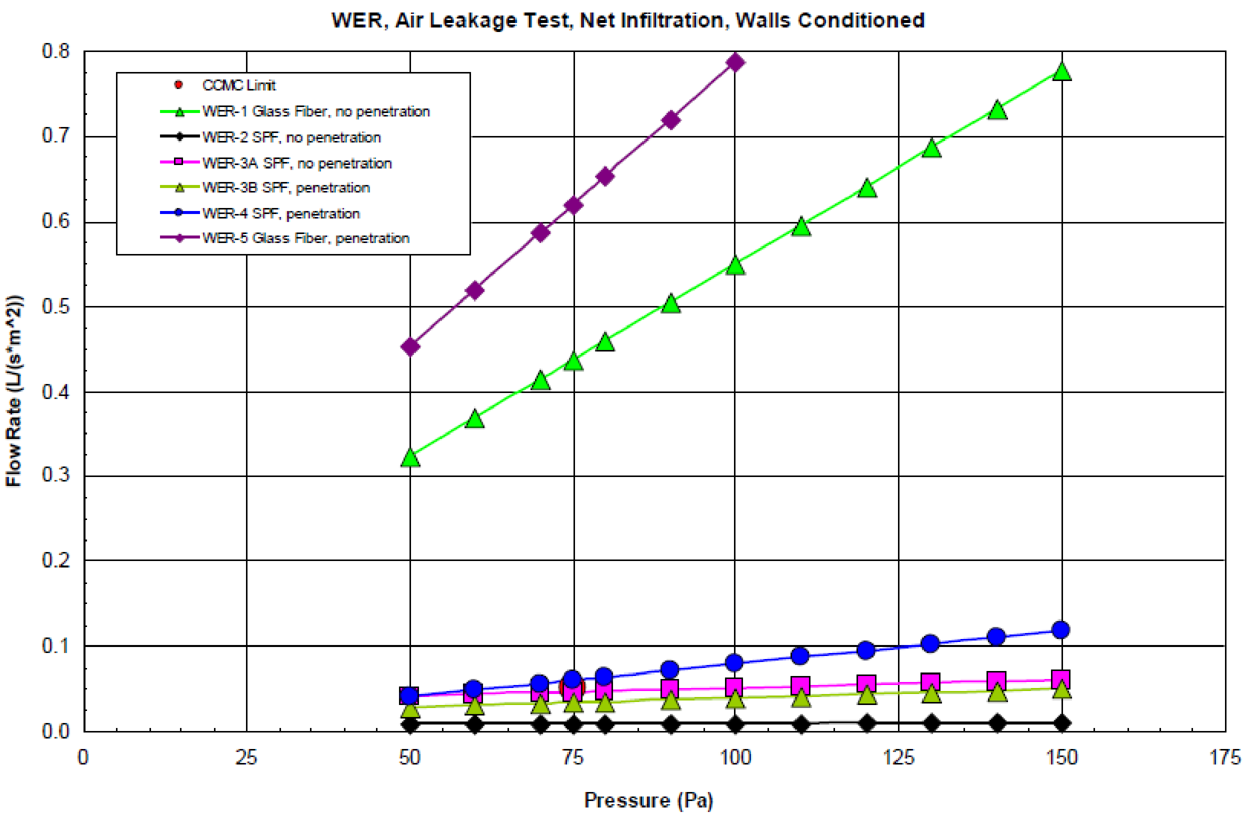

Figure 1 - Air leakage rates for walls WER-1 to WER-5 after these had been subjected to the air pressure program of sustained, cyclic and gust pressures

Note to Figure 1: WER-1 and WER-5 read as “Glass Fiber”, however the component of interest is the combination of glass fibre insulation and polyethylene sheeting that provide the primary energy function of these assemblies: thermal insulation and resistance to air leakage.

Source: Maref, W., Elmahdy, A.H., Swinton, M.C., Tariku, F. (2009, October). *Assessment of Energy Rating of Polyurethane Spray Foam Walls: Procedure and Interim Results*. NRCC-50847. National Research Council of Canada.

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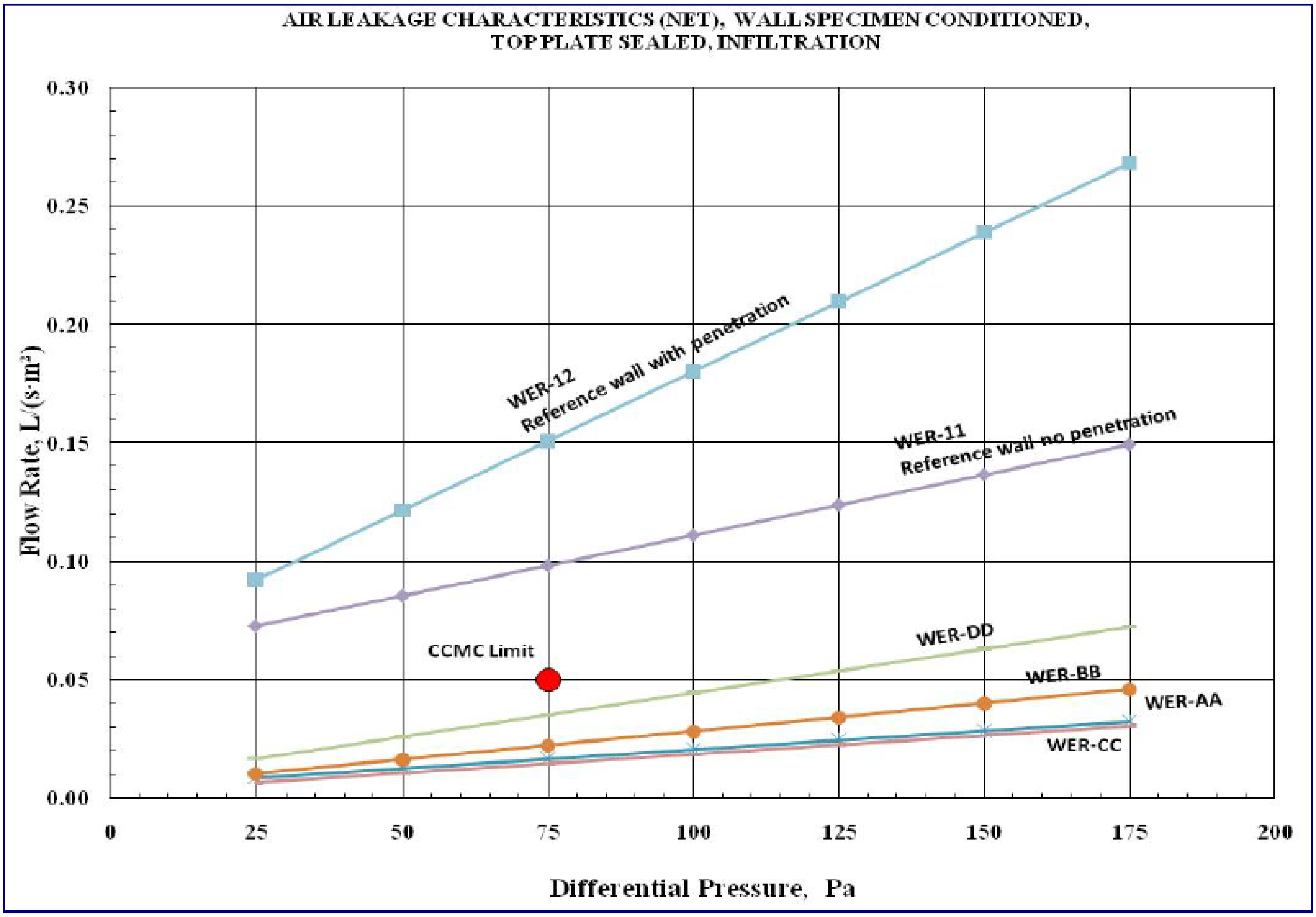

Figure 2 - Air leakage rates for walls WER-11 and 12, and WER-AA to WER-DD after these had been subjected to the air pressure program of sustained, cyclic and gust pressures

Source: Elmahdy, A.H., Maref, W., Swinton, M.C., Saber, H.H., Glazer, R. (2009, October). *Development of Energy Ratings for Insulated Wall Assemblies*. NRCC-51419. National Research Council of Canada.

The data presented in Table 1 compiles measured air leakage rates and thermal performance for the wall assemblies, as well as the WER numbers based on these measurements. The measurements were obtained after the walls were exposed to the sequence of sustained, cyclic and gust air pressures.

The WER value without air leakage represents the maximum WER number the wall could achieve if there is no air leakage. The difference between the two WER numbers captures the effect of air leakage in reducing the thermal performance of an assembly.

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Table 1 – Air Leakage, Thermal Resistance and WER of Wall Assemblies

Wall	Measured Air Leakage Rate at 75 Pa (L/(s·m^2))	Measured Initial Thermal Resistance		Wall Energy Rating worse 0 ← WER → 100 better	
		RSI$_o$ (m^{2}K/W)	R$_o$ (ft^2·hr·°F/Btu)	Without Air Leakage	With Air Leakage at 75 Pa
WER-1	0.367	3.25	18.45	87.7	76.9
WER-2	0.013	3.53	20.04	88.7	88.3
WER-3a	0.046	3.85	21.86	89.6	88.5
WER-3b	0.034	2.86	16.24	86.0	84.9
WER-4	0.052	3.30	18.74	87.9	86.5
WER-5	0.620	2.78	15.78	85.6	60.6
WER-AA	0.017	3.59	20.38	88.9	88.4
WER-BB	0.023	3.30	18.74	87.9	87.2
WER-CC	0.015	3.36	19.08	88.1	87.7
WER-DD	0.036	3.00	17.03	86.7	85.6
WER-11	0.105	3.25	18.45	87.7	84.9
WER-11a	0.027	3.25	18.45	87.7	86.9
WER-12	0.160	2.78	15.78	85.6	80.5
WER-13	0.048	1.85	10.50	78.4	76.0
WER-14	0.016	2.66	15.10	85.0	84.4
WER-15	0.009	4.55	25.83	91.2	91.0

Table 2 gives a summary of the averaged results by type of air barrier material and air sealing approach. The information highlights the efficacy and efficiency of spray polyurethane foam insulation in achieving high levels of airtightness with relative ease. The low air leakage rates for walls insulated with spray polyurethane foam mean that, as a thermal insulation material, the spray polyurethane insulation is also delivering higher thermal performance efficiency.

Table 2 – Average: Air Leakage, Thermal Resistance and WER of Wall Assemblies by Type of Air Barrier Material and System

Wall Assemblies	Measured Air Leakage Rate at 75 Pa (L/(s·m^2))	Initial Thermal Resistance		Wall Energy Rating (WER)	
		RSI$_o$ (m^{2}K/W)	R$_o$ (ft^2·hr·°F/Btu)	without Air Leakage	with Air Leakage at 75 Pa
Polyethylene – Overlapped, Not Sealed					
WER-1, 5, 11	0.364	3.093	17.56	87	74.1
Polyethylene – Overlapped and Sealed					
WER-11a, 12	0.094	3.015	17.02	86.7	83.7
Closed-cell Medium Density SPF					
WER-2, 3a, 3b, 4, 14, 15(1)	0.032	3.24	18.40	87.4	86.5
Open-cell Light Density SPF					
WER-AA, BB, CC, DD, 13(2)	0.023	3.31	18.81	87.9	87.2

(1) Data for WER-15 not included as this wall has full-cavity fill, while WER-2, 3, 4, 14 are half-cavity installation.
(2) Data for WER-13 not included as this wall has half-cavity fill, while WER-AA, BB, CC, DD are full-cavity installation.

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Table 3 – Details of Wall Assembly Construction

Wall ID	Thermal Insulation Type	Wall Details	Average Thickness of Insulation (mm)
WER-1	glass fibre	Reference wall, no penetrations, interior and exterior electrical outlets, poly vapour barrier stapled and overlapped but not sealed	138 nominal
WER-2*	medium density closed cell SPF	Reference wall, no penetrations, interior and exterior electrical outlets; SPF fills half the cavity	76 nominal
WER-3a*	medium density closed cell SPF	Wall without penetrations; SPF fills half the cavity	93.6 measured
WER-3b*	medium density closed cell SPF	Wall with penetrations; SPF fills half the cavity; window/wall junction sealed with one-component foam	81 measured
WER-4*	medium density closed cell SPF	Wall with penetrations, interior and exterior electrical outlets; SPF fills half the cavity; window/wall junction sealed with one-component foam	76 nominal
WER-5	glass fibre	Reference wall similar to WER-1, with penetrations, interior and exterior electrical outlets; poly vapour barrier stapled and overlapped but not sealed; window/wall junction sealed with backer rod and glass fibre insulation	138 nominal
WER-AA*	low density open cell SPF	Wall without penetrations; SPF fills entire cavity; polyethylene sheet used as vapour barrier but is not the primary air barrier material	138 nominal
WER-BB*	low density open cell SPF	Wall with penetrations; SPF fills entire cavity; window/wall junction sealed with one-component foam; polyethylene sheet used as vapour barrier but is not the primary air barrier material	138 nominal
WER-CC*	low density open cell SPF	Wall without penetrations; SPF fills entire cavity; window/wall junction sealed with one-component foam; polyethylene sheet used as vapour barrier but is not the primary air barrier material	138 nominal
WER-DD*	low density open cell SPF	Wall with penetrations; SPF fills entire cavity; polyethylene sheet used as vapour barrier but is not the primary air barrier material	138 nominal
WER-11	glass fibre	Wall similar to WER-1 but without penetrations; sealing at wall perimeter and electrical outlet; poly vapour barrier overlapped and sealed (primary air barrier material)	138 nominal
WER-11a	glass fibre	Wall without penetrations, similar to WER-1; with sealing at wall perimeter and improved sealing at electrical outlet; poly vapour barrier overlapped and sealed (primary air barrier material)	138 nominal
WER-12	glass fibre	Wall with penetrations, window/wall junction sealed with one-component foam; poly vapour barrier overlapped and sealed to 2005 NBC	138 nominal
WER-13*	low density open cell SPF	Wall without penetrations; SPF fills half the cavity; to study effect of air cavity on wall thermal performance; polyethylene sheet used as vapour barrier but is not the primary air barrier material	64 measured
WER-14*	medium density closed cell SPF	Wall without penetrations; SPF fills half the cavity	55 measured
WER-15*	medium density closed cell SPF	Wall without penetrations; SPF fills entire cavity; to study effect of removing air cavity on overall wall thermal performance	118 measured

* Double top plate sealed with caulking

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