REQUEST FOR PROPOSAL
FOR
WIND PRESSURE TESTING OF WALL ASSEMBLIES
WITH FOAM SHEATHING AND VINYL SIDING PRODUCTS

1. SCOPE

The proposed work includes the following scope:

- Positive and negative wind pressure resistance testing of 4'x8' wall assemblies (ASTM Standards E330-02 and D5206-06a as modified herein) with variations of foam sheathing and vinyl siding materials.
- Construction of wall test specimens for purpose of conducting the prescribed tests.
- Sampling foam sheathing and vinyl siding materials from manufacturer stock and purchasing of all other materials required for construction of wall test specimens.
- Frequent progress updates during the course of testing to allow for revisions to the test plan or test specimen construction, as needed, to meet the objectives of this project.
- Reporting of final test results including:
    - documentation of test method, test rigging, and specimen preparation
    - photographs of test specimens before and after testing demonstrating construction details and failure modes,
    - description of failure mode(s) for each specimen (including initial localized failures prior peak load),
    - peak pressure resistance, and
    - mid-span deflection of interior framing members (stud) and, separately, foam sheathing mid-span deflection between studs (measured relative to stud deflection) for load increments up to a minimum of 67% of peak pressure resistance.

Testing shall be conducted by a laboratory with appropriate accreditations for model building code acceptance of the results and appropriate means of ensuring the credibility and accuracy of the data produced.

Any report and data associated with this project shall remain the exclusive property of the Foam Sheathing Coalition (FSC) and shall not be released without written permission by an authorized representative of the FSC. All results shall be reported on the basis of foam sheathing types without associating specific foam sheathing manufacturers to specific test results or specimens in the final report. A separate key relating specific manufacturers to specific test specimens shall be provided to only the FSC Technical Representative assigned to manage this test program (see contact information in Section 7). The FSC Technical Representative or an alternate appointed by the FSC Technical Representative shall have the exclusive right to witness the tests.

2. OBJECTIVE

The objective of this test program is to provide data for the purpose of verifying a design methodology for application of vinyl siding with foam sheathing. The design methodology is described in Section 8 of this RFP and makes use of vinyl siding design pressure data available in ICC-ES evaluation reports for various vinyl siding products. Evaluation and application of the test data shall be the responsibility of the FSC and is addressed in Section 8 of this RFP. Section 8 is included for the purpose of communicating the intended use of results to the selected test laboratory personnel and other interested parties at the discretion of the FSC.

Depending on test results obtained during the course of this test program, modifications of the test plan or testing of enhanced applications may be considered, but are not included in this RFP and will be treated as an add-cost change should additional tests be required. Thus, responses to this RFP should include a lump sum for the entire test program as specified herein plus a unit cost for any additional tests conducted in continuity with the proposed test program. Also, the respondent shall include a unit cost for potential elimination of tests (less any cost for pre-purchased materials).

3. TEST PROGRAM

A. Materials and Specimen Fabrication

Wall test specimens, 4'x8' in size, shall be assembled using materials and installation requirements specified in this section.

<u>Foam Sheathing Materials (3 types)</u>

The following foam sheathing materials shall be sampled from manufacturer production stock by the test laboratory (or sampling representative) and used in constructing the required test specimens[1]:

- *½" Foil-Faced, Preformed, Rigid Cellular Polyisocyanurate* (ISO) complying with ASTM C1289-06 – minimum of eight samples of standard residential wall sheathing product from each of three FSC member manufacturers as follows:
    - Atlas – ½" Energy Shield with foil facers
    - Rmax – ½" R-Matte Plus-3 with foil facers
    - Dow – ½" Tuff-R with foil facers

- *3/8" Expanded Polystyrene* (EPS) complying with ASTM C578-07 (Type II, 1.35 pcf density) – minimum of nine samples of standard residential wall sheathing product from each of two FSC member manufacturers as follows:
    - Premier – 3/8" R-Tech insulating sheathing with nominal 1.2mil polymeric facers
    - Atlas/Falcon Foam – 3/8" Falcon insulating sheathing with nominal 1.2mil polymeric facers

- 1/2*" Extruded Polystyrene* (XPS) complying with ASTM C578-07 (Type IV, 1.6 pcf density) – minimum of eight samples of standard residential wall sheathing product from each of three FSC member manufacturers as follows:
    - Pactiv – ½" GreenGuard® Insulative Sheathing (nominal 1.2mil polymeric facers)

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[1] Sample counts include exact amount required for wind pressure and small specimen bending tests required in Section 3.C. They do not include extra samples for re-tests, additional tests, or replacement of damaged material. The listed products are intended to represent the minimum product for use in the IRC with respect to wind pressure resistance.

- o Owens Corning – ½” FOAMULAR® Insulating Sheathing (IS) (nominal 1.2mil polymeric facers)
- o Dow – ½” Styrofoam® Residential Sheathing (nominal 1.2mil polymeric facers)

The type of facer material and any variation in type of facer material shall be verified and reported for each product type.

Foam Sheathing Fastening Requirements:

Manufacturers generally provide installation recommendations for their respective foam sheathing products. The IRC is silent on fastening of foam sheathing, relying primarily on siding fasteners for permanent installation. Therefore, for the purpose of this test program, the following uniform fastening schedule shall be used for attachment of foam sheathing to test frames:

Fastener:	0.106” diameter, smooth-shank, zinc-coated roofing nails with 3/8” (0.375”) head diameter per ASTM F 1667 (see below *)
Spacing:	12”oc (all framing members)
Penetration:	¾” into studs

** Fastener specification per ASTM F 1667:*
For 3/8” thick foam sheathing: F 1167 NL RF S S – 22 Z (L = 1-1/8”, D = 0.106”, H = 0.375”)
For ½” thick foam sheathing: F 1167 NL RF S S – 28 Z (L = 1-1/4”, D = 0.106”, H = 0.375”)

NOTE: This testing program shall use a smooth shank nail without caps for foam sheathing attachment (with the exception of three exploratory tests using ring-shank cap nails – See Table 1). The 0.106” shank diameter roof nail is also available in as ring-shank nail; so using this nail diameter as a minimum would permit use of ring-shank nails commonly used with caps.

Vinyl Siding Materials (representing three products of different design pressure ratings)

- *Horizontal Vinyl Siding* (e.g., Double 5” lap style) complying with ASTM D3679 installed in accordance with manufacturer recommendations and ASTM D5206 (for guidance on vinyl application on 4’x8’ test specimen only). One siding product shall be selected from the manufacturers’ ICC-ES Evaluation Report (ER) corresponding to each of the following design pressure categories for the purposes of this RFP (the “types” have no standardized definition):
    - o Type 1: <40 psf effective design pressure rating (minimum 29.12 psf per ASTM D3679-06a Section 5.11.1; corresponds to an ultimate tested pressure resistance of 15.73 psf depending on vinyl PEF factor used in ER report – see Note 1 below)
    - o Type 2: 60 +/- 10 psf effective design pressure rating (see Note 1 below)
    - o Type 3: 80 +/- 10 psf effective design pressure rating (see Note 1 below)

NOTES:

1. *FSC staff (working with VSI staff) shall identify specific siding materials conforming with the above effective design pressure ranges and confirm with manufacturer the ultimate tested pressure resistance and PEF factor used in each case. The minimum ultimate pressure resistance (average of three tests per ASTM D5206) for the selected Type 1 product shall not be less than 20.5 psf to ensure that the vinyl siding plus foam sheathing system’s effective design pressure is at least -19.5 psf (= 20.5 psf / 1.5 SF / 0.7 PEF) which corresponds to a 90 mph / Exposure B wind condition. Similarly, the Type 2 and Type 3 products’ ultimate pressure resistance shall not be less than 30 psf and 45 psf, respectively. See Section 8.1 for explanation of PEF factors applicable for use with vinyl siding plus foam sheathing combinations.*

2. *The siding for each design pressure category (type) may come from different manufacturers or the same manufacturer. Preferably, the Type 1 siding shall comply with the minimum requirements in Table R703.4 of the 2006 IRC (e.g., minimum 0.035" thickness). However, the primary goal is to verify the design methodology presented in Section 8 of this RFP. So, the design pressure rating from the manufacturer's ER is the key parameter of interest for the purpose of selecting representative vinyl siding products for this testing program.*

Fastening Requirements:

- o Fastening shall be in accordance with the ER report requirements for the specified design pressure rating. Hand-driven roofing nail connections shall be used. The nail head diameter and shank diameter shall be identical to that required in the relevant ER report. The nail length shall be adjusted to give penetration into studs similar to that used to obtain the design pressure rating in the ER report (length will vary depending on use of 3/8"- or ½"-thick foam sheathing).

NOTE: Minimum fastening requirements required by Table R703.4 of the 2007 IRC Supplement are a 0.120" shank diameter zinc-coated roofing nail with minimum 0.313" head diameter and minimum 3/4" penetration into studs. This fastening requirement is preferable (not required) for the Type 1 siding installation and will require selecting a siding product with <40 psf design pressure rating that uses this minimum IRC connection (refer to manufacturer's ER report). None of the selected siding types should use less than this minimum fastener per the IRC..

Framing Materials & Installation

- Studs: 2x4 at 16"oc, Spruce-Pine Fir (Specific Gravity, G=0.42), Stud or No2 Grade
- Plates: same as studs
- Fastening Requirements (per IRC Table R602.3(1)):
  - o Stud-to-Plates: 2-16d (3-1/2" x 0.135") end nail
  - o Top Plate-to-Top Plate[2]: 2-10d (3"x0.182") at 16"oc[3]
  - o Bottom Plate-to-Bottom Plate: 16d (3-1/2"x0.135") at 16"oc[2]

NOTE: All wall specimens shall be assembled with ½" GWB on the interior face of the wall (applied in accordance with IRC Chapter 7). The purpose of including interior finish is to stiffen the overall wall assembly as would occur in actual walls, but plastic sheeting is placed so as not to produce a pressure differential across the GWB. In addition, holes should be added to GWB to allow deflection measurement of mid-span of foam sheathing between studs at mid-span of studs. Overall wall assembly deflection at mid-span will include the contribution of the GWB to bending stiffness of the overall wall assembly.

B. Test Methods

Wind Pressure Tests

Applicable test methods include ASTM E330 (for general wall assembly pressure test applications) and ASTM D5206 (for vinyl siding applications). The test apparatus shall be in compliance with either ASTM E330 or ASTM D5206. These test methods shall be used and/or modified in the following manner:

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[2] For wall test frames, both bottom and top plates shall be doubled per ASTM D5206 for purpose of permitting proper bearing of the ends of the test specimen in the test chamber without interfering with cladding.

[3] Plate-to-plate fastening has been increased above the minimum 10d at 24"oc required by IRC Table R602.3(1) to ensure achieving peak capacity of the siding/foam sheathing system prior to any framing connection failure.

- Test approach shall comply with Procedure B for ASTM E330 and ASTM D5206 (ultimate load test).
- Load application and increments shall comply with ASTM D5206 and used consistently for all tests.
- Test specimens shall be a minimum nominal size of 4' x 8' for all tests.
- The number of test repetitions for each vinyl siding type and foam sheathing combination shall be in accordance with Section 3.C (Table 1).
- Test data collection shall, at a minimum, provide items listed under Section 1 and include applicable reporting requirements of the referenced test methods.
- 2-mil plastic film (air-barrier) per ASTM D5206 shall be installed to apply "positive" (inward) acting force across the foam sheathing only and "negative" (outward) acting force across the combination of foam sheathing and siding material (not as shown in ASTM D5206).
- Foam sheathing shall NOT have 2" diameter holes installed per ASTM D5206.
- Foam sheathing shall be attached to test frames with its long dimension parallel to the studs.

Foam Sheathing Bending Tests (small specimens)

Bending tests of foam sheathing (including facers as applicable) shall be conducted in accordance with ASTM C203-05a as further described in Section C.

C. Test Plan

Wind Pressure Testing

The required tests shall be executed and results reported in accordance with Table 1. During testing, progress updates shall be provided by e-mail (data) and by phone (to discuss data) with the FSC Technical Representative at the completion of each series of tests for a given foam sheathing product ID per Table 1, but no less than weekly. These reports need only summarize key results (e.g., peak pressure resistance and failure mode). Test specimen fabrication should occur more or less in even flow with the execution of tests (see Section 4 Schedule) to allow for specimen construction adjustments as needed based on previous results. A test schedule (see Section 4) shall be provided at least 2 weeks in advance of initiating the test program to allow witnessing of the first several tests and periodically during execution of the test plan.

TABLE 1. Test Plan[1]

Specimen Configurations		Test Repetitions		Comments
Foam Sheathing & Product ID	**Vinyl Siding Type**	**Neg. Pressure[2]**	**Pos. Pressure[2]**	
None[3]	Type 1	3	0	These tests confirm a baseline performance of siding only (compare to existing ER data)
	Type 2	3	0	
	Type 3	3	0	
½" ISO-A	None	0	2	The negative pressure test results shall be grouped by siding type (3 for each type); all six positive pressure tests shall be grouped for evaluation and reporting purposes.
	Type 1	1	0	
	Type 2	1	0	
	Type 3	1	0	
½" ISO-B	None	0	2	
	Type 1	1	0	
	Type 2	1	0	
	Type 3	1	0	
½" ISO-C	None	0	2	
	Type 1	1	0	
	Type 2	1	0	
	Type 3	1	0	
3/8" EPS-A	None	0	3	The negative pressure test results shall be grouped by siding type (4 for each type); all six positive pressure tests shall be grouped for evaluation and reporting purposes.
	Type 1	2	0	
	Type 2	2	0	
	Type 3	2	0	
3/8" EPS-B	None	0	3	
	Type 1	2	0	
	Type 2	2	0	
	Type 3	2	0	
½" XPS-A	None	0	2	The negative pressure test results shall be grouped by siding type (3 for each type); all six positive pressure tests shall be grouped for evaluation and reporting purposes.
	Type 1	1	0	
	Type 2	1	0	
	Type 3	1	0	
½" XPS-B	None	0	2	
	Type 1	1	0	
	Type 2	1	0	
	Type 3	1	0	
½" XPS-C	None	0	2	
	Type 1	1	0	
	Type 2	1	0	
	Type 3	1	0	
	TOTALS:	**39**	**18**	**= 57 TOTAL[1]**

Table Notes:

1. At the completion of Table 1 testing, two additional specimens each of the weakest and strongest assemblies (four tests total) shall be re-tested for negative pressure resistance only using foam sheathing installed with cap nails instead of standard roofing nails without caps (refer to Section 3.A.). The purpose of this additional testing is to explore the potential effect of enhanced foam sheathing attachment on overall cladding system performance.
2. Positive pressure tests (pulling the foam sheathing into the framing) are done using a negative pressure chamber, but with the wall exterior facing away from the negative pressure chamber (e.g., exposed to ambient pressure). Negative pressure tests (pulling the foam sheathing and siding away from the framing) simply aims the outside face of the wall (with siding and foam sheathing) into the negative pressure chamber.
3. The "None" condition provides a baseline ultimate negative pressure resistance value for vinyl siding alone and also serves as a confirmation of the manufacturer's ICC-ES report data. The result of these tests will be applied in accordance with the proposed design method outlined in Section 8.1 (Step 1).

NOTE: Data from the negative pressure tests of foam sheathing plus vinyl siding (grouped by foam sheathing and vinyl siding type) shall be used to verify the design method outlined in Section 8.1 (Steps 1 and 3), including a system strength adjustment factor, F, as described in Section 8.1 (Step 3), if justified. The data from positive pressure testing of foam sheathing (grouped by foam sheathing type) will be compared to small specimen bending test results (see below) and used for verification of positive pressure resistance design method outlined in Section 8.1 (Step 4) and development of a system strength adjustment factor, R, as described in Section 8.1 (Step 4), if justified.

Small Specimen Bending Strength Tests

For each foam sheathing type and manufacturer listed in Table 1, small specimens shall be prepared and tested in accordance with ASTM C203-05a following Method I, Procedure E (single point load on simply supported sample with constant displacement rate). A minimum of 3 repetitions for each foam sheathing type and manufacturer shall be tested (8 x 3 = 24 small specimen tests in total). The required samples shall be taken from the interior regions of three separate sheathing samples from each manufacturer and include facers as applicable. Reported results shall be grouped by foam sheathing type (blind to specific manufacturer results) with load-deflection plots shown together in a grouped plot and keyed to the product identifications of Table 1. Load deflection plots shall be continuous from load initiation to a point at which the load fails to increase with deflection or excessive deflection occurs (e.g., > span/5 deflection). Tabulated results shall include load at deflections of span/120, span/60, and span/30 as well as peak load and deflection. Thickness of material prior to testing shall also be measured and reported for each sample. All tests shall be conducted with the sample oriented to induce the bending stresses in a direction parallel to the short dimension of the foam sheathing panel (this generally represents the weakest bending direction and is consistent with placing the long dimension of the foam sheathing parallel to studs as planned for this test program).

4. SCHEDULE

The targeted date for initiation of this project is June 15, 2007 with an estimated duration of 12 weeks. Progress updates shall be provided after each phase of testing as indicated in the Section 3.C.

A proposed schedule for execution of this work from the time of approval is as follows:

0 weeks – project start-up (June 15, 2007)
2 weeks – test schedule submitted to FSC Technical Representative (June 29, 2007)
4 weeks – obtain sampled foam sheathing and vinyl siding products and purchased materials
6 weeks – complete fabrication and testing of “None” and “ISO” specimens (24 tests)
7 weeks – complete fabrication and testing of “EPS” specimens (18 tests) and small specimen bending tests (24 tests)
8 weeks –complete fabrication and testing of “XPS” specimens (15 tests)
9 weeks – draft test report based on Table 1 test plan (August 17, 2007)
10 weeks – complete additional four tests per Table 1, Note 1 and letter report of results
12 weeks – final test report (September 7, 2007)

If this proposed schedule is not feasible, the respondent shall indicate an alternative schedule. However, the intent is to use results from this testing to help in the formulation and justification of an ICC code change proposal due on August 20, 2007.

5. FORM OF THE FINAL PRODUCT

The contractor shall submit digital files of the draft and final test reports (MS Word document and .PDF document) to facilitate the review and approval of the test report. Any publication or distribution of the draft or final reports shall be at the sole discretion of the FSC.

6. QUALIFICATIONS

All proposals must be accompanied by a brief summary of relevant project and qualifications and a resume of personnel who will work on the project. The resume should identify those qualities and experiences which relate to the nature of this project.

7. PROPOSAL SUBMITTAL & CLIENT CONTACT

Proposals shall be received no later than June 12, 2007 (e-mail is preferable with hard copy by mail to follow) to the FSC Technical Representative:

Jay Crandell, P.E.
FSC Technical Director / Consultant
5095 Sudley Rd.
West River, MD 20778
jcrandell@aresconsulting.biz
410-867-9617

8. APPLICATION OF TEST DATA

Results from this test program will be used by the FSC to verifying a design approach for applications where vinyl siding is installed over foam sheathing. This 5-step design approach addresses both positive and negative design wind pressures. Positive design wind pressures are generally lower in magnitude than negative design wind pressures and they act in a direction from outside to inside (i.e., push the siding and exterior sheathing into the framing toward the building interior). Negative design wind pressures act in an outward direction (suction) and work to pull the siding and sheathing away from the wall framing. Both load conditions must be addressed by design as required by code.

For vinyl siding, positive wind pressures have generally been ignored because the vinyl resistance is higher in this direction (does not rely on nail attachment and nail tab strength) and the design wind pressure magnitude is lower. However, for foam sheathing both wind pressure loading conditions must be considered. In the negative pressure loading, the foam sheathing acts with and bears against the vinyl siding and its attachments. Thus, the two components act as a system in resisting the greater portion of wind pressure acting on the foam sheathing layer as well as the smaller portion acting on the vinyl siding layer. In the positive pressure direction and because the greater wind pressure differential acts across the foam sheathing layer (due to its air-barrier quality) it gets pushed inward independently from the siding which is more air-permeable and flexible.

These effects are appropriately addressed in the design methodology. Thus, the design methodology represents a general advancement in the application of design wind pressures to multi-layered building envelop systems and determination of resistance of those layers. The key to practical and accurate solutions is the use of pressure equalization factors (PEF) that determine the portion of wind load that occurs on individual layers of a wall based on the relative stiffness and air-permeability of each layer in response to dynamic wind pressure pulses that occur in actual wind events. In addition, system effects must be properly addressed as explained in the design method that follows.

STEP 1: Determine Approved Ultimate Negative Pressure Value for Selected Vinyl Siding Product

$P_{v,ult} = P_{v,eff} \times 1.5 \times PEF_v$

where,

$P_{v,ult}$ = a vinyl siding product's tested peak (ultimate) negative pressure resistance value (based on ASTM D2506, average of 3 tests)

$P_{v,eff}$ = a vinyl siding's effective design pressure resistance for use with a "solid" wall assembly per ASTM D3679, Annex A, Section A1.2.2); this value is typically reported in ICC-ES Evaluation Reports for vinyl siding products

1.5 = safety factor per ASTM D3679 (and ASTM E330) for non-structural building envelop components (e.g. cladding, curtain walls, windows and doors, etc.)

PEF_v = pressure equalization factor associated with $P_{v,eff}$ value reported in vinyl siding manufacturer's ICC-ES Evaluation Report; the value may be either 0.5 or 0.36 depending on which version of ASTM D3679 was used by ICC-ES in approving a specific vinyl siding product's $P_{v,eff}$ value (confirmation required); on occasion the ICC-ES Evaluation Report may additionally include the $P_{v,ult}$ value.

NOTE: The negative pressure test results in accordance with Table 1 will be compared to the $P_{v,ult}$ value determined above using $P_{v,eff}$ values reported in the applicable vinyl siding manufacturer's ICC-ES Evaluation Report. To the extent that the tests with foam sheathing and vinyl siding combined indicate a consistent increase in ultimate pressure resistance over vinyl siding alone, a modest strength increase factor (greater than 1.0) may be proposed (see Step 3 below).

STEP 2: Select Appropriate PEF_{vf} for Application of Vinyl Siding Over Foam Sheathing

TABLE 2.
Pressure Equalization Factors (PEF_{vf})
for use with Vinyl Siding and Foam Sheathing Cladding System[1]

Wall Assembly Condition	PEF_{vf} for Vinyl Siding + Foam Sheathing Cladding System	Typical Application
(W1) Vinyl siding + less than or equal to ½"-thick exterior foam sheathing + ≥½" interior GWB)	0.5	Building exterior walls with minimum ½" GWB interior finish
(W2) Vinyl siding + greater than or equal to ½"-thick exterior foam sheathing + ≥1/2" interior GWB	0.7	Building exterior walls with minimum ½" GWB interior finish
(W3) Vinyl siding + foam sheathing (any thickness) placed directly against structural sheathing or concrete/masonry wall	0.4[2]	Building exterior walls with wood structural panel sheathing on light-framing or masonry/concrete walls
(W4) Vinyl siding + foam sheathing (any thickness) and no interior finish	1.0[3]	Gable roof end wall enclosing unfinished attic space

Table Notes:

1. The recommended Pressure Equalization Factors (PEF) in Table 2 are based on a review of recognized literature addressing dynamic wind pressure equalization effects on relevant wall assemblies (refer to Attachment A). This consideration of pressure equalization effects, as discussed in Attachment A, is in accordance with general guidance provided in ASCE 7-05 Section 6.5.2.2. The PEF values in Table 2 are based on the same test data used in ASTM D3679-06a (Annex A1) for vinyl siding applied to various wall systems; however, the PEF factors in Table 2 are based on peak dynamic pressure differentials occurring across the exterior sheathing layer, not just the vinyl siding (refer to Attachment A).
2. The 0.4 value is based on an assumption that the pressure differential across a dual-layer exterior sheathing (foam sheathing over structural sheathing) is shared equally by both layers. Thus, the PEF is determined as follows: 0.7 x ½

= 0.35, round up to 0.4. This dual-layer sheathing condition was not addressed in the reviewed literature on pressure equalization effects (refer to Attachment A).

3. A PEF of 1.0 is for the condition of no (or negligible) pressure reduction across the foam sheathing and vinyl siding system because the system is essentially acting as a single, composite layer in the negative pressure (wind load) direction. In the positive pressure direction a small pressure reduction (e.g., PEF of ~0.95) may be applicable to the foam sheathing layer acting alone (bending inward separately from the siding). However, this "single wall" condition was not addressed in the reviewed literature on pressure equalization effects (refer to Attachment A).

STEP 3: Determine Effective Negative Pressure Design Value for Vinyl Siding and Foam Sheathing Cladding System

$P_{vf,ult} = P_{v,ult} \times F$
and
$P_{vf,eff} = P_{vf,ult} / (1.5 \times PEF_{vf})$

where,

$P_{vf,ult}$ = ultimate negative pressure resistance of vinyl siding and foam sheathing cladding system as adjusted by F, if applicable.

$P_{v,ult}$ = as defined in Step 1

F = system strength adjustment factor based on ratio of $P_{vf,ult}$ test results to $P_{v,ult}$ test results (assumed to be 1.0 unless otherwise determined based on test results).

$P_{vf,eff}$ = effective design negative pressure resistance of vinyl siding and foam sheathing cladding system.

PEF_{vf} = applicable pressure equalization factor from Table 2 (Step 2).

STEP 4: Determine Allowable Positive Pressure Design Value for Foam Sheathing (applicable only when foam sheathing spans across an open stud cavity)

In the positive pressure direction, foam sheathing and siding do not necessarily act as a composite system in resisting the applied wind load and each layer should be considered to independently resist its portion of the total design wind pressure acting across the overall wall system. When the foam sheathing is not backed by a structural sheathing or a "solid" wall (e.g., concrete/masonry), then it must independently resist its share of the positive wind pressure differential (wind load) across the wall system in accordance with the use of PEF_{vf} factors of Table 2.

The design positive pressure resistance of foam sheathing shall be determined as follows based on ASTM C203-05a index bending strength (unless the test program indicates other failure modes can limit foam sheathing resistance to positive wind pressure):

(A) The applied bending stress, f_b, from design wind pressure load is determined as follows (assuming simple span beam theory and isotropic homogenous material):

$f_b = M/S$

where,

$M = 1/8\ w\ L^2$ = bending moment for single span or continuous two span between studs (lb-in)

L = stud spacing or span of foam sheathing (inches)

$w = p \times b \times 1ft^2/144in^2 \times PEF_{vf} = p \times 12in \times 1/144 \times PEF_{vf} = p \times 1/12 \times PEF_{vf}$ = uniform line load on 12-in unit width, b, of foam sheathing (lb/in)

p = design wind pressure (psf) per ASCE 7-05 or IRC Table R301.2(2)

$S = 1/6\ b\ t^2 = 1/6\ (12\ in)\ t^2 = 2\ t^2$ = section modulus of 12-in unit width of foam sheathing (in^3)

t = thickness of foam sheathing (in)

(B) Determine allowable design stress, $F_{b,all}$, for the foam sheathing material as follows:

$F_{b,all} = F_{b,ult} / 1.5$

where,
$F_{b,ult} = (F_r) \times R$
F_r = modulus of rupture (extreme fiber stress at peak flexural load) based on average of three ASTM C203 tests (3-point loading) for the foam sheathing product under consideration[4]
R = system effect based on ratio of positive pressure peak capacity of wall specimens tested in accordance with Table 1 to that determined from ASTM C203 tests for the respective foam sheathing materials included in the test plan. (to be determined).

(C) Determine effective positive pressure design value, $p_{vf,eff}$

Using equations for steps A and B above, solve for the maximum allowable design wind pressure as follows:

$F_{b,all} \geq f_b$

$(F_r \times R)/1.5 \geq M/S = 1/8\ w\ L^2 / (2\ t^2) = 1/16\ (p \times 1/12 \times PEF_{vf})\ L^2 / t^2 = 1/192\ [(p \times PEF_{vf})\ L^2 / t^2]$

$p_{vf,eff} = 128\ t^2 (F_r \times R) / (L^2 \times PEF_{vf})$ ← *Use this equation*

With data provided to define t (foam sheathing thickness, in), F_r (ASTM C203 modulus of rupture, psi, for the given foam sheathing product and thickness with facings, if applicable), R (system factor as described above), L (stud spacing, in), and PEF_{fv} (pressure equalization factor per Table 2), the effective positive pressure design resistance, $p_{vf,eff}$, can be determined and then compared to required wind pressure load in Step 5.

STEP 5: Compare Effective Design Values for Negative ($P_{vf,eff}$) and Positive ($p_{vf,eff}$) Pressure Resistance to Required Pressure Load (Table 3) to Determine Wind Speed and Exposure Limit

TABLE 3
Design Wind Pressure Load
Per IRC Table R301.2(2)
(psf)[1]

Wall Pressure Zone	90 mph				100 mph				110 mph			
	Exposure B		Exposure C		Exposure B		Exposure C		Exposure B		Exposure C	
	Pos.	Neg.	Pos.	Neg.	Pos.	Neg.	Pos.	Neg.	Pos.	Neg.	Pos.	Neg.
End	14.6	-19.5	20.4	-27.3	18.0	-24.1	25.2	-33.7	21.8	-29.1	30.5	-40.7
Interior	14.6	-15.8	20.4	-22.1	18.0	-19.5	25.2	-27.3	21.8	-29.1	30.5	-33.0

1. Table values are based on ASCE 7 components and cladding wind loads as presented in 2006 IRC Table R301.2(2) for a mean roof height of 30 feet, an effective tributary area, a, of 10 sq ft, and an enclosed building. For a greater or lesser mean roof height, multiply table values by an appropriate factor from IRC Table R301.2(3). To determine design wind pressure for a wind speed outside the range of Table 3, multiply the design pressure for 100 mph wind speed by $(V/100)^2$ where V is the wind speed of interest.

[4] For some foam sheathing products, the F_r value may differ depending on bending direction along long dimension or short dimension of the foam sheathing panel. Thus, the appropriate F_r value to use will depend case-specifically on the orientation of these foam sheathing panels relative to framing members (horizontal vs. vertical application of panels relative to wall studs).

ATTACHMENT A

A Brief Literature Review
on Pressure Equalization of Air-permeable Claddings
and Multi-Layered Wall Systems

Jay H. Crandell, P.E.
April 28, 2007

ASTM D 3679-06a, *Standard Specification for Rigid Poly (Vinyl Chloride) (PVC) Siding*, American Society of Testing and Materials, West Conshohocken, PA. 2006.

> ASTM D3679 Annex A1 gives pressure equalization factor of 0.36 for vinyl siding. ASCE 7 components and cladding wind pressure (pressure differential across the entire building envelope) is multiplied by the PEF to determine a design wind pressure for the vinyl siding (cladding) layer. Test method and results for 24 different wall assemblies and rate of dynamic negative pressure loading are described in a separate report reviewed below (ATI, 2002).

ATI, 2002. *Pressure Equalization Factor Project*, ATI Report No. 01-40776.01, prepared by Architectural Testing Inc. for Vinyl Siding Institute, Washington, DC. September 5, 2002.

> This report presents the test method and results for dynamic wind pressure testing of 24 different light frame wall assemblies with gypsum wall board finish (on ambient pressure side of wall), wall cavity between framing members, exterior sheathing (1/2" plywood or ½" polystyrene foam sheathing), and various types of vinyl siding applied directly over the exterior sheathing on the negative pressure side of the wall. Variations with and without an air-barrier applied to the exterior sheathings were also investigated.
>
> A single dynamic negative pressure fluctuation was created by a multi-chambered test apparatus and quick-acting vents to "dump" a negative pressure chamber into the wall test chamber. Using the test apparatus, three different dynamic loading conditions were investigated for each wall assembly to determine sensitivity to rate of negative pressure changes and peak magnitude of dynamic pressure differential created across the overall wall system. This resulted in pressure change rates from roughly 80 psf/sec to as much as 240 psf/sec. In terms of effective rate of change of wind speed: roughly 320 mph/sec to 615 mph/sec. Maximum instantaneous pressure differential across the wall ranged from about 10 psf (low test condition) to 35 psf (high test condition) corresponding to gust wind speeds of approximately 70 mph to 130 mph.
>
> The study found pressure equalization factors (PEF) ranging from 0.03 to 0.18 for the vinyl siding layer of the three-layered wall systems tested (also including an additional air-barrier building wrap layer in some cases). PEF is determined as the ratio of peak pressure differential across the siding to the pressure differential across the overall wall system at the same time. From this data, a conservative PEF of 0.36 was recommended for vinyl siding applications (0.36 is twice the largest recorded PEF giving the least amount of pressure reduction relative to the overall wall system pressure differentials recorded).
>
> The study also included a pressure tap in the wall cavity, thus the data indicate a maximum PEF (least pressure equalization) across the sheathing of about 0.7 for ½" plywood sheathing and 0.4 for ½" polystyrene foam sheathing. This difference is most likely due to the difference in dynamic response

of these two sheathing materials rather than any difference in ventilation pathways through the sheathing surface. Assuming that a PEF of 0.1 conservatively represent the portion of total wall pressure differential acting on the vinyl siding, the above PEF values for exterior sheathings would suggest that the PEF for the ½” gypsum panel interior finish ranges from 0.2 (= 1.0 – 0.1 – 0.7) when ½” plywood sheathing is used to 0.5 (= 1.0 – 0.1 – 0.4) when ½” polystyrene foam sheathing is used. Thus, a PEF for gypsum panels for this type of light frame “double wall” system (sheathing on both sides) could be reasonably characterized as 0.5.

Carll, C. et al. 1998. *Performance of Backprimed and Factor Finished Hardboard Siding – Final Report*, USDA Forest Service, Forest Products Laboratory, Madison, WI. February 1998.

This full-scale experiment in actual wind events indicates that the interior finish (GWB) and exterior wall sheathing plus air-barrier each share no more than about 50% (PEF = 0.5) of the instantaneous peak total components and cladding wind load acting across a typical three-layered wall system with lap siding, exterior sheathing with air-barrier wrap, and interior GWB finish. This finding is reasonably consistent with the VSI/ATI study mentioned above where a PEF of 0.7 was determined for plywood sheathing. It also demonstrates that the VSI/ATI study tended to produce conservative results (higher PEF factor) relative to conditions observed in full-scale monitoring of a building wall system in actual wind events. The maximum instantaneous pressure differential across the hardboard lap siding only was about 67% of the total wall pressure differential from inside to outside at gust condition caused by a thunderstorm event. This finding suggests that hardboard lap siding may not experience the degree of pressure equalization determined for vinyl siding in the VSI/ATI study mentioned above. This difference in PEF performance may be attributed to the different response characteristics (e.g., stiffness) and ventilation that occurs with these two siding types. However, the combined peak dynamic pressure differential across the lap siding and sheathing plus air-barrier was no more than about 50% of the total pressure differential across the wall system.

Rousseau, M.Z., Poirier, G.F. and Brown, W.C. 1998. Pressure Equalization in Rainscreen Wall Systems, Construction Technology Update No. 17, Institute for Research in Construction, National Research Council of Canada, July 1998. http://irc.nrc-cnrc.gc.ca/pubs/ctus/ctu17e.pdf

“In a project jointly sponsored by Canada Mortgage and Housing Corporation (CMHC) and several wall system manufacturers, IRC used its unique dynamic wall testing facility to study the relationship between the three components (listed above) as a function of the physical characteristics of different wall assemblies subjected to static and dynamic air pressures. Specimens of precast concrete panels, brick veneer/stud wall assemblies and exterior insulation and finish systems (EIFS) were examined for their pressure-equalization performance.” [references are included in the list below]

ADDITIONAL LITERATURE

<u>From Canadian Rainscreen Cladding Research:</u>

Poirier, G.F. and W.C. Brown. Pressure Equalization and the Control of Rainwater Penetration under Dynamic Wind Loading, Construction Canada, March/April 1994, p. 45-47

Inculet, D. and D. Surry. The Influence of Unsteady Pressure Gradients on Compartmentalization Requirements for Pressure-Equalized Rainscreens. Canada Mortgage and Housing Corporation, June 1996.

Skerlj, P.F. and D. Surry. A Study of Mean Pressure Gradients, Mean Cavity Pressures, and Resulting Residual Mean Pressures across a Rainscreen for a Representative Building. CMHC Report, September 1994. Canada Mortgage and Housing Corporation, Ottawa.

A Study of Mean Pressure Gradients, Mean Cavity Pressures, and Resulting Residual Mean Pressures across a Rainscreen for a Representative Building. CMHC Research & Development Highlights Technical Series 96-207, Canada Mortgage and Housing Corporation, Ottawa.

Inculet, D. and D. Surry. Optimum Vent Locations for Partially-Pressurized Rainscreens. CMHC report BLWTSS30-1997, September 1997, 183 p.

Brown et al. Field Testing of pressure-equalized rainscreen walls. ASTM. STP 1034, 1991.

Kumar, K.S., Sathopoulos, T., Wisse, J.A., "Field measurement data of wind loads on rainscreen walls," Journal of Wind Engr and Industrial Aerodynamics, Volume 91, Issue 11, November 2003, pp 1401-1417.

From ASCE 7-05 Section C6.5.2.2:

Cheung, J. C. J., and Melbourne, W.H. (1986). "Wind loadings on porous cladding." Proc. 9th Australian Conference on Fluid Mechanics, p.308

Haig, J.R. (June 1990). "Wind Loads on Tiles for USA." Redland Technology Limited, Horsham, West Sussex, England.

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