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**The Federal Manufactured Home
Construction and Safety Standards--
Implications for Foam Panel Construction**

March 1997

A.D. Lee
D.W. Schrock
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MASTER

Prepared for the U.S. Department of Energy
Office of Energy Conservation and Renewable Energy
by Pacific Northwest National Laboratory
Under Contract DE-AC06-76RLO 1830

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SUMMARY

This report reviews the U.S. Department of Housing and Urban Development construction code for (HUD-code) manufactured homes, *Part 3280: Manufactured Home Construction and Safety Standards* (the HUD Code), to identify sections that might be relevant in determining if insulated foam core panels (or structural insulated panels, SIPs) meet the requirements of Part 3280 for use in manufactured home construction.

The U.S. Department of Energy and other parties are interested in the use of SIPs in residential construction, including HUD-Code manufactured homes, because the foam panels can have a higher effective insulation value than standard stud-framed construction and use less dimensional lumber. Although SIPs have not been used in manufactured housing, they may be well suited to the factory production process used to manufacture HUD-Code homes and the fact that they require less virgin timber may reduce the effect of volatile and increasing timber prices.

Part 3280 requirements for fire resistance, wind resistance, structural load strength, ventilation, transportation shock, and thermal protection are reviewed. A brief comparison is made between the HUD Code requirements and data collected from foam panel manufacturers.

ACKNOWLEDGMENTS

We would like to thank several SIP manufacturers and individuals for their assistance in providing the information used in this report. Fred Tuttle and Pam Cone of U.S. Building Panels, Tacoma, Washington, were very generous in the time they took to provide SIP information and their test reports. Brad Hancock, Rick St. Mary, and Chuck Maples of URSA Structural Systems, Pasco, Washington, were very helpful over a period of time in providing plant tours, product literature, and test reports. D. Scott Imholt of Northwest Structural Panels, Inc., Canby, Oregon, also provided similar information. Northwest Structural Panels is a "value-added" plant that provides final cutouts and assembly to "raw" panels. Drew and Jerry McDaniel of Precision Panel Structures in Eagle, Idaho, also provided very important insights into the possibilities of using SIPs in manufactured homes, particularly in the latter phases of preparing this report. We would also like to thank Russell Roeding, Steven Winter, and other representatives and members of the Structural Insulated Panel Association (SIPA) who have provided invaluable assistance throughout the preparation of this report and other related activities.

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1.0 INTRODUCTION

The purpose of this report is to review the construction code under which manufactured homes (referred to in the past as "mobile homes") are constructed to assess how it might affect the use of structural insulated foam core panels (SIPs) in this type of housing. This report identifies the key areas within the code that would impact the use of SIPs, but is intended only to highlight these areas for further investigation and consideration. This report was prepared by the Pacific Northwest National Laboratory for the U.S. Department of Energy (DOE), Industrialized Housing Program, which is conducted within the Office of Building Technology, State and Community Programs.

1.1 Background

Insulated foam core panels have existed since at least the mid-1930s and have been used in residential construction since 1952. At least 100 U.S. companies produce SIP panels. Andrews (1992) presents a thorough description of the technology and industry.

SIPs consist of a layer of foam sandwiched between two facings. Different types of foam can be used, but the most common is polystyrene (either expanded polystyrene, EPS, or extruded polystyrene, XPS). The usual facing is oriented strandboard (OSB), although other materials can be used. Panels are typically 4" or 6" thick, but they can be as thick as 10" or more. Panels are commonly produced in 4' by 8' sections. However, panels up to 24' are becoming more common as the availability of larger sheets of OSB increases.

SIPs can be produced and installed to require considerably less dimensional lumber than standard construction. This offers two primary advantages: reduced heat transfer due to fewer thermal bridges and diminished sensitivity to increases in lumber prices. In the manufactured housing industry, better thermal performance would help the industry meet tighter energy codes. Reduced dependence on dimensional lumber would help insulate housing production costs from recent increases and volatility in lumber prices.

This report examines issues related to a specific segment of the housing market: HUD-Code manufactured homes. These homes are not required to meet state building code requirements; instead, they fall under the jurisdiction of the U.S. Department of Housing

and Urban Development (HUD). Because of the potential benefits of using SIPs in manufactured homes and the growth in the HUD-Code home market, DOE and the manufactured housing industry have been investigating the use of foam panels in manufactured home construction. Manufactured homes are a growing sector of the new home market, now constituting over 30% of new single-family homes in the U.S.

From the perspective of the HUD-Code housing industry, SIPs should be especially attractive because SIPs open up new possibilities for manufactured home production-line manufacturing and automation processes. Currently, neither the SIP nor manufactured housing producers use highly automated production processes; however, integrating SIP systems into manufactured housing construction could present opportunities for increasing the production efficiency of HUD-Code housing and reducing the costs of SIPs.

Lack of familiarity with SIP technology, relatively high SIP costs, and uncertainty about code requirements have prevented the manufactured housing industry from using SIPs to date. In a prior report, Durfee, Lee, and Onisko (1993), presented a preliminary assessment of opportunities for using SIPs in manufactured homes. This report is a first step in addressing the code issues. Cost issues and familiarity with the technology will have to be addressed by working with members of both industries to gain actual experience with the technology.

The HUD Code for manufactured homes is *Part 3280: Manufactured Home Construction and Safety Standards* of the Code of Federal Regulations. This report reviews the HUD Code to identify sections that might be relevant in determining if structural insulated panels meet the requirements of Part 3280 for use in manufactured home construction.

1.2 Overview of This Report

In this report, we identify specific sections of Part 3280 that may be relevant in obtaining HUD approval to use foam core panels in manufactured homes. Sections of Part 3280 pertaining to fire resistance, wind resistance, structural strength, ventilation, structural integrity during and after transportation, and thermal protection are discussed in Chapter 2 of this report.

Chapter 3 discusses HUD's provisions for the construction of manufactured homes using non-conventional, innovative approaches. Chapter 4 discusses data we obtained

from the SIP industry on results of tests conducted on foam core panels. Chapter 5 lists additional issues for HUD's consideration when determining criteria for approving SIP construction. Chapter 6 contains references.

2.0 RELEVANT HUD-CODE REQUIREMENTS

For a manufactured home to satisfy Part 3280, several criteria must be met. The primary criteria include fire resistance, wind protection, structural integrity (including the effects of transportation), thermal protection, and ventilation. This report discusses each of these issues. Relevant sections of Part 3280 are excerpted and presented for reference. At the end of some sections, questions regarding how these requirements pertain to foam panel construction are presented. These questions highlight some of the code issues that will have to be addressed when SIPs are used.

The HUD Code frequently references codes, standards, and procedures produced by other organizations. For information purposes, we define here some of the acronyms referring to other organizations that appear in the HUD Code or are mentioned in this report:

- ANSI: American National Standards Institute
- ASCE: American Society of Civil Engineers
- ASTM: American Society for Testing and Materials
- BOCA: Building Officials and Code Administrators, International
- ICBO: International Conference of Building Officials
- SBCCI: Southern Building Code Congress International
- UL: Underwriters' Laboratories

2.1 Fire Resistance

Fire resistance standards appear in three sections: § 3280.203 "Flame spread limitations and fire protection requirements," § 3280.206 "Firestopping," and § 3280.207 "Requirements for foam plastic thermal insulating materials." Excerpts from these sections are provided below. Note that "the Department" refers to HUD.

§ 3280.203 Flame spread limitations and fire protection requirements.

(a) Establishment of flame spread rating. The surface flame spread rating of interior-finish material shall not exceed the value shown in § 3280.203(b) when tested by "Standard Test Method for Surface Burning Characteristics of Building Materials, ASTM E 84-91a"...However, the following materials need not be tested unless a lower rating is required by these standards.

(1) Flame-spread rating--76 to 200.

- (ii) 1/4-inch or thicker unfinished plywood with phenolic or urea glue;
- (iv) 3/8-inch or thicker unfinished particleboard with phenolic or urea binder;
- (2) Flame-spread rating--25 to 200
 - (iii) 5/16-inch or thicker unfinished gypsum wallboard (both latex- or alkyd-painted);
- (b) Flame-spread rating requirements.
 - (1) The interior finish of all walls shall not have a flame spread rating exceeding 200.
 - (2) Ceiling interior finish shall not have a flame spread rating exceeding 75.

QUESTION:

- 1) Are the flame-spread tests conducted on SIPs comparable to those required by the HUD Code and would they be accepted?

§ 3280.206 Firestopping, part (a) requires firestopping of at least 1-inch nominal lumber, 5/16-inch thick gypsum board, or the equivalent to cut off concealed draft openings between walls and partitions, including furred spaces, and the roof or floors.

QUESTIONS:

- 1) Since SIPs are filled entirely with foam, is this requirement relevant? Would plumbing or electrical chases be considered to be draft openings?
- 2) Does the oriented strand board in the panels meet this requirement?

§ 3280.207 Requirements for foam plastic thermal insulating materials.

(a) General. Foam plastic thermal insulating materials shall not be used within the cavity of walls (not including doors) or ceilings to be exposed to the interior of the home unless...

- (1) The foam plastic insulating material is protected by an interior finish of 5/16-inch thick gypsum board or equivalent material...or
- (3) The foam plastic insulating material has been previously accepted by the Department for use in wall and/or ceiling cavities of manufactured homes...or
- (4) The foam plastic insulating material has been tested as required for its location in wall and/or ceiling cavities in accordance with testing procedures described in the Illinois Institute of Technology Research Institute (IITRI) Report, "Development of Mobile Home Fire Test Methods to Judge the Fire Safe Performance of Foam Plastic, J-6461," or other full-scale fire tests accepted by the Department, and it is installed in a manner consistent with the way the material was installed in the foam plastic test module. The material shall be capable of meeting the following acceptance criteria required for their location.

(i) Wall assemblies. The foam plastic system shall demonstrate equivalent or superior performance to the control module as determined by:

- (A) Time to reach flashover

(B) Time to reach an oxygen level of 14%, a carbon monoxide level of 1%, a carbon dioxide level of 6%, and a smoke level of 0.26 optical density/meter measured at 5 feet high in the doorway;

(ii) Ceiling assemblies. ...equivalent or superior performance to the control module [in] intensity of cavity fire and post-test damage.

(iii) Post-test damage assessment for wall and ceiling assemblies.

(b) All foam plastic thermal insulating materials used in manufactured housing shall have a flame spread rating of 75 or less (not including outer covering or sheathing) and a maximum smoke-developed rating of 450.

2.2 Wind Resistance

Two primary sections covering wind protection are § 3280.305 "Structural design requirements" and § 3280.306 "Windstorm protection." Excerpts of these sections are provided below.

§ 3280.305 Structural design requirements.

(a) General. Each manufactured home shall be designed and constructed as a completely integrated structure capable of sustaining the design load requirements of this standard, and shall be capable of transmitting these loads to stabilizing devices without exceeding the allowable stresses or deflections. Roof framing shall be securely fastened to wall framing, walls to floor structure, and floor structure to chassis to secure and maintain continuity between the floor and structure, so as to resist wind overturning, uplift, and sliding as imposed by design loads in this part.

[Design wind loads are provided for various building components by wind zone region. The entire Pacific Northwest and most of the continental United States is in the least restrictive Zone I. The more restrictive Zones II and III are along the Atlantic and Gulf Coasts and Hawaii and Alaska.]

§ 3280.306 Windstorm protection.

(a) Provisions for support and anchoring systems. Each manufactured home shall have provisions for support/anchoring or foundation systems that, when properly designed and installed, will resist overturning and lateral movement (sliding) of the manufactured home as imposed by the respective design loads. For Wind Zone I, the design wind loads to be used for calculating resistance to overturning and lateral movement shall be the simultaneous application of the wind loads indicated in § 3280.305(c)(1)(i), increased by a factor of 1.5. The 1.5 factor of safety for Wind Zone I is also to be

applied simultaneously to both the vertical building protection, as horizontal wind load, and across the surface of the full roof structure, as uplift loading. For Wind Zones II and III, the resistance shall be determined by the simultaneous application of the horizontal drag and uplift wind loads, in accordance with § 3280.305(c)(1)(ii). The basic allowable stresses of materials required to resist overturning and lateral movement shall not be increased in the design and proportioning of these members. No additional shape or location factors need to be applied in the design of the tiedown system. The dead load of the structure may be used to resist these wind loading effects in all Wind Zones.

(b)...the manufacturer shall provide printed instructions with each manufactured home specifying the location and required capacity of stabilizing devices on which the design is based. The manufacturer shall provide drawings and specifications of the anchoring systems certified by a registered professional engineer or architect specifying at least one acceptable system of anchoring. The anchoring system must also resist forces as specified in ASTM Standard Specification D3953-91.

2.3 Structural Testing

The general requirements for the structural testing are described in § 3280.303 "General requirements." More specific requirements are discussed in § 3280.401, § 3280.402 and § 3280.403.

§ 3280.303 General requirements.

(c) Structural analysis. The strength and rigidity of the component parts and/or the integrated structure shall be determined by engineering analysis or by suitable load tests to simulate the actual loads and conditions of application that occur. (See subparts E and J.) [Subpart E of the code is for testing requirements and Subpart J is for transportation requirements.]

(e) New materials and methods. (1) Any new material or method of construction not provided for in this standard and any material or method of questionable suitability proposed for use in the manufacture of the structure shall nevertheless conform in performance to the requirements of this standard. (2) Unless based on accepted engineering design for the use indicated, all new manufactured home materials, equipment, systems or methods of construction not provided for in this standard shall be subjected to the tests specified in paragraph (g) of this section.

(g) Alternative test procedures. In the absence of recognized testing procedures either in these standards or the applicable provisions of those standards incorporated by reference, the manufacturer electing this option shall develop or cause to be developed testing procedures to demonstrate the structural properties and significant characteristics of the material, assembly, subassembly component or member. Such testing procedures shall become part of the manufacturer's approved design. (Refer to § 3280.3)

(1) Testing procedures so developed shall be submitted to the Department for approval.

(2) Upon notification of approval, the alternative test procedure is considered acceptable.

(3) Such tests shall be witnessed by an independent licensed professional engineer or architect or by a recognized testing organization. Copies of the test shall be kept on file by the manufactured home manufacturer.

QUESTION:

What test procedure would be required? Do any of the tests already used by specific foam panel manufacturers meet the requirements?

§ 3280.401 Structural load test.

Every structural assembly tested shall be capable of meeting the Proof Load Test or the Ultimate Load Test as follows:

(a) Proof load tests. Every structural assembly tested shall be capable of sustaining its dead load plus superimposed live loads equal to 1.75 times the required live loads for a period of 12 hours without failure. Tests shall be conducted with loads applied and deflections recorded in 1/4 design live load increments at 10-minute intervals until 1.25 times design live load plus dead has been reached. Additional load shall then be applied continuously until 1.75 times design live load plus dead load has been reached. Assembly failure shall be considered as design live load deflection (or residual deflection measured 12 hours after live load removal) which is greater than the limits set in § 3280.305(d), rupture, fracture, or excessive yielding. [Section § 3280.305(d) sets deflection limits of L/240 for the floor, L/180 for the roof and ceiling, L/180 for headers, beams, and girders, and L/180 for walls. L is defined in the discussion of § 3280.402 Test procedure for roof trusses.] An assembly to be tested shall be of the minimum quality of materials and workmanship of the production. Each test assembly, component, or subassembly shall be identified as to type and quality or grade of material. All assemblies, components or subassemblies qualifying under this section shall be subject to a continuing qualification testing acceptable to the Department.

(b) Ultimate load tests. Ultimate load tests shall be performed on a minimum of three assemblies or components to generally evaluate the structural design. Every structural assembly or component tested shall be capable of sustaining its total dead load plus

the design live load increased by a factor of safety of at least 2.5. A factor of safety greater than 2.5 shall be used when required by an applicable reference standard in § 3280.304(b)(1). Tests shall be conducted with loads applied and deflections recorded in 1/4 design live load increments at 10-minute intervals until 1.25 times design live load plus dead load has been reached. Additional loading shall then be applied continuously until failure occurs or the total of the factor of safety times the design live load plus the dead load is reached. Assembly failure shall be considered as design live load deflection greater than the limits set in § 3208.305(d), rupture, fracture, or excessive yielding. Assemblies to be tested shall be representative of average quality or materials and workmanship of the production. Each test assembly, component, or subassembly shall be identified as to type and quality or grade of material. All assemblies, components, or subassemblies qualifying under this section shall be subject to periodic qualification test program acceptable to the Department.

§ 3280.402 Test procedure for roof trusses.

(a) Roof load tests. The following is an acceptable test procedure, consistent with the provisions of § 3280.401, for roof trusses that are supported at the ends and support design loads. Where roof trusses act as cantilevers, or support concentrated loads, they shall be tested accordingly.

(b) General. Trusses may be tested in pairs or singly in a suitable test facility....

(2) Truss deflections will be measured relative to a taut wire running over the support and weighted at the end to insure constant tension or other approved methods.

(c) Nondestructive test procedure -- (1) Dead load plus live load.

(i) Noting figure A-1, measure and record initial elevation of the truss in test position at no load.

(ii) Apply load units to the top chord of the truss equal to the full dead load of roof and ceiling. Measure and record deflections.

(iii) Maintaining the dead load, add live load in approximate 1/4 design live load increments. Measure the deflections after each loading increment. Apply incremental loads at a uniform rate such that approximately one-half hour is required to establish the total design load condition. Measure and record the deflections five minutes after the loads have been applied. The maximum deflection due to design live load (deflection measured in step (iii) minus step (ii)) shall not exceed $L/180$, where L is a clear span measured in the same units.

(iv) Continue to load truss to dead load plus 1.75 times the design live load. Maintain the loading for 12 hours and inspect for failure.

(v) Remove the total superimposed live load. Trusses not recovering to at least the $L/180$ position within 12 hours shall be considered as failing.

(2) Noting Figure A-1, apply the load units to the top chord of the truss assembly equal to full dead load of roof and ceiling. Measure and record deflections in 1/4 design live

load increments at 10-minute intervals until 1.25 times design live load plus dead load has been reached.

(3) Additional loading shall then be applied continuously until failure occurs or the factor of safety times the design live load plus dead load is reached.

(5) The assembly shall be capable of sustaining the dead load plus the applicable factor of safety times the design live load (the applicable factor of safety for wood trusses shall be taken as 2.50).

QUESTION:

What is the appropriate factor of safety for foam core panel construction without any truss support?

(e) Trusses qualifying under the non-destructive test procedure. Tests 3280.402(c) (1) and (2) (when required), shall be subject to a continuing qualification testing program acceptable to the Department. Trusses qualifying under the destructive test procedures, Tests 3280.402(c) (2) (when required), and (d), shall be subject to periodic tests only.

QUESTION:

Foam core panel construction does not require a truss system; do these requirements still apply?

2.4 Ventilation Standards

Requirements affecting ventilation or air infiltration in manufactured homes appear in two places: Subpart B and Subpart F. The ventilation standards assume that manufactured home construction provides 0.25 air changes per hour through infiltration and exfiltration. However, it should be noted that since foam core panel construction is tighter than conventional frame construction, it may result in less than 0.25 air changes per hour. Subpart B "Planning Considerations" is excerpted below.

§ 3280.103 Light and Ventilation

(b) Whole house ventilation. Each manufactured home shall be capable of providing a minimum of 0.35 air changes per hour continuously or at an equivalent hourly average rate. The following criteria shall be adhered to.

(1) Natural infiltration and exfiltration shall be considered as providing 0.25 air changes per hour.

(2) The remaining ventilation capacity of 0.10 air change per hour or its hourly average equivalent shall be calculated using 0.035 CFM per square foot of interior floor space.

(3) The remaining ventilation capacity may be provided by: a mechanical system, or a passive system, or a combination passive and mechanical system.

QUESTION:

Since foam core panels are likely to be tighter than conventional frame construction, the assumed infiltration and exfiltration air changes per hour may be overstated. If this is the case, do the ventilation requirements need to be increased?

Subpart F, "Thermal Protection," deals with sealing the home to minimize heat loss and gain. This section is excerpted below.

§ 3280.505 Air Infiltration

(a) Envelope air infiltration. The opaque envelope shall be designed and constructed to limit air infiltration to the living area of the home. Any design, material, method or combination thereof which accomplishes this goal may be used...

(2) Joints between major envelope elements. Joints not designed to limit air infiltration between wall-to-wall, wall-to-ceiling and wall-to-floor connections shall be caulked or otherwise sealed.

2.5 Transportation Structural Requirements

Subpart J of the HUD Code specifies requirements for designing the structure to withstand adverse effects of transportation shock and vibration without degradation to the integrity of the structure. Although foam panels are structurally sound, systems assembled completely or partially with panels may have properties that affect transportation durability differently than standard construction. Section 3280.901 gives the scope of the requirements. More detail on the requirements is given in the following section:

§ 3280.903 General requirements for designing the structure to withstand transportation shock and vibration.

(a) ...the manufactured home shall be designed, in terms of its structural, plumbing, mechanical and electrical systems, to fully withstand such transportation forces during its intended life.

(b) Particular attention shall be given to maintaining watertight integrity and conserving energy by assuring that structural components in the roof and walls are capable of resisting highway shock and vibration forces during transportation.

(c) In place of an engineering analysis, either of the following may be accepted:

(1) Documented technical data of suitable highway tests which were conducted to simulate transportation loads and conditions; or (2) acceptable documented evidence of actual transportation experience which meets the intent of this subpart.

QUESTION:

What specific simulations, tests, and transportation experience would be required to meet the transportation requirements?.

2.6 Thermal Protection

Subpart F of the HUD Code specifies thermal protection requirements for manufactured homes. Three regional zones are defined in the code, and some, but not all, requirements vary by zone. Zone 1 consists of the seven southernmost states. Zone 2 states include California and states in a central east-west band across the country. Northern tier states are in Zone 3. Subpart F has three main sections related to thermal protection including condensation control, air infiltration, and heat loss/heat gain. Air infiltration requirements were presented earlier. The sections discussing condensation and heat loss and gain are excerpted below.

§ 3280.504 Condensation control and installation of vapor retarders.

(a) Ceiling vapor retarders. (1) In Uo Value Zones 2 and 3, ceilings shall have a vapor retarder with a permanence of not greater than 1 perm...installed on the living space side of the roof cavity.

(2) For manufactured homes designed for Uo Value Zone 1, the vapor retarder may be omitted.

(b) Exterior walls. (1) Exterior walls shall have a vapor barrier not greater than 1 perm installed on the living space side of the wall.....

§ 3280.506 Heat loss/heat gain.

The manufactured home heat loss/heat gain shall be determined by methods outlined in §§ 3280.506 and 3280.509...

(a) Coefficient of heat transmission. The overall coefficient of heat transmission (U_o) of the manufactured home...shall not exceed the Btu/(hr.) (sq.ft.)(F) of the manufactured home envelope...below:

Zone 1 0.116

Zone 2 0.096

Zone 3 0.079

QUESTIONS:

Do the required calculation procedures properly account for the characteristics of foam panels? Will they give an accurate estimate of the heat transmission coefficient?

3.0 ALTERNATIVE CONSTRUCTION COMPLIANCE

The HUD Code provides flexibility to accommodate innovations in manufactured housing construction through a special process in the code. It has provisions for permitting the construction and sale of homes that do not meet the exact specifications of the HUD Code discussed in the previous chapter. Despite extensive use of SIPs in site-built housing, they are an untried technology in manufactured housing so it might be appropriate in the early stages of using SIPs in manufactured homes to follow these special provisions in the HUD Code.

These provisions specifically permit alternative construction "for purposes of research, testing or development of new techniques or designs." These provisions appear in § 3282.14 "Alternative construction of manufactured homes." Such construction has to provide performance equivalent to that required by the code. A request for this exemption must be submitted to HUD and must include 1) a copy of the design, 2) an explanation of how the design fails to conform with the code, 3) an explanation of how the design will provide the same level of performance, 4) data adequate to support the request, 5) a letter from the DAPIA (Design Approval Primary Inspection Agency) stating that the design meets the code in all other respects, and 6) additional information. For homes built under this provision for research, testing, or development purposes, HUD may require them to be brought into compliance with the code if they do not provide the levels of safety, quality, and durability achieved under the code.

Although the HUD Code does contain these provisions, they might not be the best or most desirable way to gain initial approval of manufactured home foam panel construction. The industry might find it preferable to use the conventional HUD-Code requirements to demonstrate that SIP construction meets the performance specifications of the standards discussed in the previous chapter.

4.0 COMPARISON WITH FOAM PANEL DATA

After identifying specific HUD-Code requirements that might be relevant to the utilization of foam panels in manufactured homes, we contacted foam panel producers in the Pacific Northwest in 1995 to obtain test results and other information that might be related to the HUD-Code specifications. Two companies provided access to their test and product information: U.S. Building Panels, Tacoma, WA, and URSA Structural Systems, Pasco, WA. URSA is a licensee of Insulspan, using the Insulspan technology, manufacturing procedures, and product specifications. Insulspan literature indicates that their product is covered by three agencies' research reports: BOCA #85-49, SBCCI #84102, and HUD's Structural Engineering Bulletin No. 1079 (January 28, 1985). As we had expected, none of these reports or other test reports that we encountered were specifically for HUD-Code manufactured housing.

The following sections discuss the foam panel product information that was most closely related to the specific sections of the HUD Code discussed earlier. Because our search for information was very limited and ended in 1995, we caution the reader that the observations here should not be construed as final determinations on the demonstrated ability of SIPs to meet the HUD Code. Rather, our observations should help target areas upon which further investigations should focus.

4.1 Fire Resistance

From the data obtained, no specific SIP testing was done that applied to firestopping requirements (§ 3280.206). It is doubtful whether this requirement is relevant to SIP construction, however, and HUD will have to decide whether the firestopping criterion applies to foam core panels.

Section 3280.203 specifies flame spread ratings for interior-finish materials and § 3280.207 specifies ratings and other criteria for foam plastic used as an insulating material. Based on default values provided in the HUD Code, it appears that the OSB usually used on most SIPs would meet the wall interior-finish material flame spread requirement and, when covered with gypsum board, would meet the ceiling finish material requirement.

Section 3280.207 permits the use of foam insulating materials if it meets two conditions. The first condition provides alternative criteria that can be met including:

having prior HUD approval, or meeting specified test requirements, or using a 5/16-inch gypsum interior finish. Installation of interior gypsum, or possibly an equivalent finish, would appear to meet this requirement.

The second condition required for the use of foam insulating material is that it meet specific flame spread (<75) and smoke-developed (<450) rating requirements. The Code requires performance testing under ASTM E 84-91a. URSA provided information from their franchiser, Insulspan, which stated that their foam had a flame spread rating of 5 and a maximum smoke-developed rating of 85, both well below the Code requirements. These tests were reported by BOCA Evaluation Services (BOCA 1987) based on Underwriters Laboratories, Inc., test procedure UL723, however, rather than the ASTM test. It is unclear whether HUD would accept the UL723 results in lieu of results from the ASTM procedure.

Other literature for Insulspan indicated that their foam had been tested using ASTM E 84. This information did not provide the test results, however.

Another evaluation report, ICBO (1995) indicated that similar foam had a flame-spread rating of less than 25 and a smoke-density rating of less than 450. However, the report does not specify the test procedure used nor clarifies whether the results are comparable with the HUD-Code requirements.

Insulspan literature also referenced other fire resistance tests and results. The foam core panels met the conditions of acceptance of the ASTM E 119 test standard for one hour for a load-bearing wall. In addition, the wall assembly withstood the hose stream test for the specified period with no passage of water beyond the unexposed surface. Also, approximately 20 hours after the fire test, the wall was subjected to a load of 2,500 lbs per linear foot with no noticeable deflection. Insulspan also reported tests under an Underwriters Laboratory procedure (UL 83), a 30-minute test evaluating resistance of roof deck construction to internal fire exposure. The company also indicated that its panels had undergone ignition and flash point temperature testing (ASTM 1985).

In summary, compliance with HUD-Code fire resistance requirements requires further clarification.

- Firestopping requirements need to be reviewed by HUD to determine whether they should apply to foam panel construction.
- The interior finish flame spread requirements are likely to be satisfied by the OSB layer on SIPs for walls, and satisfied for the ceiling if a layer of gypsum is

applied. Tests might be required for other types of panel surface materials, but test data are probably available for most other surface materials that show whether they satisfy the HUD Code.

- Some uncertainty remains about whether SIPs using an EPS core meet the HUD-Code requirements for foam insulation materials. When a layer of gypsum is applied, part of the requirement is met, but other ways of meeting this requirement need to be investigated. We did not find conclusive, generic documentation that EPS met the specific flame spread requirements. The main issues were whether the tests that have been conducted on some materials used a procedure consistent with the HUD-Code requirement and whether test results could be applied generically to other EPS products. We found no information about tests on other types of foam materials.

4.2 Wind Resistance

The HUD Code requires in Wind Zone I that a manufactured home and each of its wind-resisting components shall be designed for horizontal wind loads of not less than 15 pounds per square foot (psf) and a set uplift load of not less than 9 psf. For high wind areas, Wind Zones II and III, the manufactured home shall be designed by a professional engineer or architect. The manufactured home must resist the design wind loads for Exposure C specified in ANSI/ASCE 7-88, "Minimum Design Loads for Buildings and Other Structures," for a 50-year recurrence interval, and a design wind speed of 100 mph, as specified for Wind Zone II, or 110 mph, as specified for Wind Zone III. The other possibility for design specifications in Wind Zones II and III is to design the home according to the Table of Design Wind Pressures in § 3280.305 of the HUD Code.

One manufacturer, Insulspan, lists allowable loads on foam core panels for transverse winds. The wind pressures tabulated range from 15 to 30 psf. The tests included multiple panel thicknesses as well as multiple facing thicknesses. The panels ranged from 8 to 16 feet in length. The information we received did not mention what test method was used or whether the panels were manufactured using HUD requirements for materials and installation. The HUD Code requires that the homes, not just the panels, be tested transversely to withstand ± 39 psf in Wind Zone II, and ± 47 psf in Wind Zone III. This manufacturer would have to conduct more thorough transverse tests to meet the HUD Code since the highest wind pressure tested was 30 psf for a panel only and not for a home.

Another table of axial loads by wind force was published by the same manufacturer (Insulspan). The panels spanned from 4 to 28 feet. The EPS core was 9 and 3/8 in. thick, and each OSB or 5-ply plywood facing was 3/8 in. thick. The maximum allowable wind speed and wind pressure used were 108.5 mph and 30 psf, respectively. The HUD Code cannot be directly compared with this performance, however. As a result, it is recommended that further testing be done on actual homes, not just panels.

The test results that we have do not include any data on windstorm protection. Therefore, we would recommend that when the testing is done for the structural design requirement for wind resistance, windstorm protection testing be done simultaneously.

4.3 Structural Testing

To test structural strength, HUD requires that a certain load be applied and the structure checked for failure by the amount of deflection that occurs. Failure for floors is considered to be a deflection of L/240 (the clear span length divided by 240) or greater. Roofs, ceilings, headers, beams, girders, walls, and partitions are considered to have failed at L/180.

One company that conducts tests for SIP manufacturers, PFS Corp., has tested panels from a number of manufacturers. Their approach usually uses a method similar to HUD's required procedure except that it applies the load until failure. The load at failure along with the load at L/240 are recorded. Reviewing these test data should provide the information required to determine if these panels meet the HUD Code. In most of the tests, PFS Corp. used ASTM E 72, Section 11 as its test procedure.

Some of the structural testing procedure results reported by different SIP manufacturers include the following:

- ASTM-E72-80 Compressive Load-Wall; Transverse Load-Roof; Concentrated Load-Roof.
- ASTM-E695-79 Impact Load.
- ASTM-E564-76 Racking Resistance-Shear Value.

SIP manufacturers usually have extensive data on the structural strength of their panels and the panels are inherently very strong. Determining compliance with the HUD Code would require an analysis of the actual loads on each component in a

specific building design application and verification of consistency between the test method employed and the method required by the HUD Code.

4.4 Ventilation Standards

Structures constructed with foam panels typically have lower air leakage than structures built with standard frame construction. Judkoff et al. (1994), for example, compared a modular office constructed with SIPs with another one built with frame construction. Their results showed that the leakage area of the SIP building was about one-third the leakage area of the other building, and the infiltration rate was less than half. Since the HUD-Code ventilation requirements are based on assumptions for frame-construction, it may be appropriate to conduct infiltration measurements on manufactured homes constructed with SIPs and modify the HUD-Code requirements to ensure adequate ventilation.

4.5 Transportation Effects

No test data for manufactured homes built with foam panels were available; however, data on modular offices built with conventional framing techniques and foam panels were available. The report mentioned earlier, Judkoff et al. (1994), presented data for a foam core panel modular office and a conventional frame modular office. The offices were identical except for building materials and construction techniques. The homes were tested in Texas before transport and in Colorado after the trip.

Five different types of tests were conducted. These included a blower door test, tracer-gas test, co-heating (calorimeter) test, infra-red imaging test, and a short-term energy monitoring test. All the results indicated that the foam core panel module performed significantly better than the frame office after transportation. For example, the air leakage tests mentioned earlier indicated that the foam panel office's leakage area did not increase measurably after transport. The frame office showed little change in the leakage area of the envelope (although it was nearly three times the leakage area for the SIP building), but the duct leakage area nearly doubled due to transportation.

There is little information available on transportation effects that are relevant to a SIP manufactured home. The limited information from Judkoff et al. (1994) is useful because the modular buildings were attached to a chassis similar to those used in homes built under the HUD Code. The former owner of the company that built the units

indicated that no cracks appeared in the units after they were transported and this was an improvement over units of conventional construction.^(a) Although these positive results suggest that transportation damage might not be a significant concern, the results are too limited to be conclusive. Consequently, the issue of transportation effects on structural integrity is probably the biggest remaining area of uncertainty that SIP HUD-Code home construction will have to address. Opinions still vary about the potential effects of transportation and clarification of these effects will require actual transportation tests and possibly detailed modeling and analysis.

(a) Personal communication with Richard Harmon, March 5, 1997.

5.0 SUMMARY OF ISSUES FOR FURTHER CONSIDERATION

To construct and sell HUD-Code manufactured homes with foam panels the specific requirements of the Code must be addressed. In this report we have attempted to identify the sections of the HUD Code that may impact the use of foam panels most directly.

Each manufactured home built under the HUD Code has to have design and engineering approval granted by an authorized DAPIA. These organizations have the expertise and experience necessary to assess whether the characteristics of SIPs meet the HUD Code, whether available test data are adequate, and whether and what additional tests and analyses are required. The effort required to answer these questions is unknown until a manufacturer chooses to design and construct a home with SIPs. It is possible that the first use of SIPs in manufactured homes may be limited to only one or two components (such as walls and floors), and this would reduce the effort required to obtain DAPIA approval.

Ultimately, HUD may have to address some of the specific issues highlighted here. Throughout this report, we have identified specific issues that will have to be addressed either by the DAPIA or HUD. For convenience, the key issues and remaining questions are summarized below:

- 1) Is the firestopping requirement in the Code applicable to foam panel construction?
- 2) Are the flame-spread tests that have been conducted on SIPs comparable to those required by the HUD Code and would they be accepted by the DAPIAs and HUD?
- 3) Do the tests of foam panel structural strength that have already been conducted satisfy the HUD-Code testing requirements?
- 4) How can the HUD-Code truss support requirements be adapted to the application of foam panels so that they capture the intent of the Code?
- 5) Should the HUD-Code ventilation requirements be modified given that SIP construction is likely to be tighter than conventional construction? What, if any, additional data are required to justify any changes?
- 6) What simulations, tests, and transportation experience will be necessary to verify that homes constructed with SIPs meet the HUD-Code transportation requirements?

- 7) Do the required thermal performance calculation procedures properly account for the characteristics of foam panels? Will they give an accurate estimate of the heat transmission coefficient?
- 8) HUD has previously approved foam core panels for use in site-built homes. Can this approval be used in gaining approval for HUD-Code manufactured homes?
- 9) What steps would be required to obtain HUD-Code approval for one or a few manufactured homes using foam panels constructed under a demonstration project? Would the alternative construction approval process for research and development purposes be the best approach?
- 10) What steps would have to be taken to receive general approval for using foam panels so that minimal review would be required in the future?
- 11) Are there any HUD-Code requirements in addition to those discussed here that might affect the use of foam panels?

6.0 REFERENCES

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