Volume II: Appendices

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Overcoming Barriers

To Innovation in the home building industry

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PD&R

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Appendix A: Literature Review Summary Sheets and Bibliographies
Innovation Adoption/Diffusion

Topic: Innovation Adoption/Diffusion
Reference: Nam, C. H. and C. B. Tatum. 1989. Toward Understanding of Product Innovation Process in Construction. *Journal of Construction Engineering and Management* 115, no. 4: 517-34
Reviewer: GKH

1.	Scope and content of the reference:
	This is a scholarly paper coming out of the Stanford Department of Civil Engineering in 1985. "After briefly emphasizing the significance of product innovation for the long-term health of the U.S. architect, engineering, and construction (AE&C) industry, this paper starts with a review of related research results from investigations of innovation in other industries, then describes a suggested model of the process for product innovation in construction. The last part extracts some practical applications from the model for increasing the rate of product innovation in construction, and implications for further research." (p. 518) This is the end of the Peter Drucker era and the start of the "Tom Peters era when there is lots of review and discussion about productivity and innovation in the manufacturing sector. The authors make the point that such theoretical studies of innovation in construction have been neglected. They conclude that few prior studies exist. They also point out that construction differs from manufacturing in important ways: immobility; complexity; durability; costliness; and the high risk of failure. (p.522). This thesis gives the impression that the mid-80s are a watershed for theories of innovation in construction; that the work on modeling this that has gone on before doesn't amount to much.
2.	Any theoretical model of innovation and/or barrier operation to consider based on the work:
	The authors propose a model of product innovation in construction by "probing" the nature of four key actors and relationships: 1) Owner's Demands: "Owner's demands are the market pull." (p.529) An owner can cause innovation by presenting an unusual problem or by simply demanding innovation. By being willing to participate in the design process, an owner can be far more important in building innovation than a simple "buyer" of a manufactured product. 2) Problems: "Problems are uncertainties that the designer/engineer/contractor cannot resolve with immediate applications of the technology they currently possess. Problems require them to explore alternative technologies. 3) Designer's Bank of Technology: Eight ways that design firms can increase their bank of technology: hiring people; company R&D; take design science from academia; look at closely related industries or organizations; learn from other design or construction companies; learn from foreign countries; learn from other industries; or respond to regulation and building code changes. 4) Contractor's Process Technology: Where as designers operate in a world that is based on reputation without price competition, contractors must operate in a world of price competition and price reduction. Only when the two cooperate is there a chance for innovation.
3.	How the reference helps define one or more of the four relevant categories of barriers:
	This article offers some general insight into the barriers Education and Risk. There is very little on Fragmentation and nothing on Cultural Values.
4.	How the reference better defines the extent to which consumers (builders at one level, ultimately

	home buyers) participate in making decisions or creating barriers:
	As discussed in section 2 above, these authors believe that a building owner can have a large effect on innovation. However, the authors appear to have more of a commercial building model in mind than a residential home building model. I am not sure that there model fits well with residential home buyers.
5.	How the reference supports the presented conclusions with reliable and sufficient experiential data:
	No experimental data is offered.
6.	How the reference differentiates energy and non-energy aspects of technology or system innovation:
	The article focuses on the building industry without reference to energy considerations.
7.	Potentially important references not previously cited:
	1) Nam, C.H., and Tatum, C.B. (1988). "Major characteristics of constructed products and resulting limitations of construction technology." *Construction Management and Economics*, London, U.K., 6(2), 133-148. 2) The references provide an excellent overview of the literature of innovation in manufacturing including the work of Drucker, Peters, and N. Rosenberg.
8.	Additional comments or summaries of other important information:
	If you buy the contention of this paper, it means that our current inquiry into important models of innovation in the construction industry doesn't have to look very hard in the period before 1985.

Topic: Innovation Adoption/Diffusion
Reference: Arditi, David and Serdar, Kale. 1997. Innovation in construction equipment and its flow into the construction industry. Journal of Construction Engineering & Management 123, no. 4: 371-78
Reviewer: WIW

1.	Scope and content of the reference:
	The construction equipment (earthmoving equipment) industry is "mature" (modest growth)—high competition for market share and incremental product and product process innovations. Concentrated, dominated by US firms, the construction industry is its largest customer. Demand shaped by megaprojects shifted to versatile and small equipment in mid-80s. Materials, metallurgy, mechanical systems, electronics, hydraulic systems innovations feed incremental equipment innovations. Impacts on bringing industry change considered in terms of a three-level taxonomy of innovative improvements—incremental (steady), radical (new products or processes), and revolutionary (significant economic changes). Importance of incremental changes often underestimated—may account for half of total benefits over predecessor technology. Many incremental changes seem '"invisible," such as reduced vibration leading to longer service life. Frequency of innovation in construction industry, in spite of noted barriers, is also underestimated. Incremental innovation may predominate in construction because of incremental nature of innovation in feeder industries. Industry rate and type of technological change are the result of environmental dynamics. Strategic positioning, production process, and market strategy respond to demand/market-pull; R&D represents technological push. Schumpeter emphasizes innovation based on technology push while Schmookler asserts that firms innovate to maximize profits in response to demand pull. Empirical studies are inconclusive, and environmental dynamics today may differ from 1970s when studies were conducted. For construction equipment the frequency of purchase is low, involves a high number of people, the risk of breakdown is high, and assembly-line production predominates. The rate of innovation increased for the industry while the technological life of equipment decreased to near its lower limit, indicating continuous incremental improvement driven by market forces rather than technology. An innovative new model can achieve a one year imitation period of competitive advantage for a manufacturer. Construction companies are technological innovators (new methods and processes, corporate structures, financing, inter-organization collaboration, and alternative product delivery systems) but rely on feeder industries (electronics, machinery, and chemicals sectors) for technical system innovations.
2.	Any theoretical model of innovation and/or barrier operation to consider based on the work:
	Description of intersectoral patterns of innovations builds on Schmookler invention matrix (maker sectors in columns, user sectors in rows). Innovations characterized as "process" (directed at improving mode of production within sector) or "product" (produced in one sector and used in another). Core sectors generate most innovations. Pavitt poses intersectoral flows among four groups: supplier dominated firms (use technologies developed by feeder industries, often focus on cost cutting, characteristic of construction companies); production-intensive firms (scale intensive, producing most of their own process technology, focusing on process improvements to reduce costs); or mechanical and instrument engineering firms, (focusing on performance and reliability improvements to products to be used in other sectors, characteristic

	of construction equipment manufacturers); science-based firms (focus on R&D for technological change, feed innovations to production-intensive firms); specialized equipment suppliers (provide equipment and instruments for production-intensive science-based firms, complementary and interdependent relationships). Porter poses cost leadership, focus, or differentiation as possible business strategies. Product differentiation has been identified as the primary strategy for the construction equipment industry. (See Sousa and Hambrick's taxonomy of production method and market context.) Woodward classifies production methods as small batch, assembly-line, and process. The assembly-line nature of construction equipment manufacture creates opportunities for continuous improvement.
3.	How the reference helps define one or more of the four relevant categories of barriers:
	Porter and Linde assert that properly designed regulations act as a catalyst for innovation and a demand-pull force on the construction equipment industry.
4.	How the reference better defines the extent to which consumers (builders at one level, ultimately home buyers) participate in making decisions or creating barriers:
	Market context may be represented by frequency of purchase, buyer-seller interaction (time and number of people involved in a purchase), and risk of product malfunction. Higher frequency implies less time and fewer people. Risk of malfunction is related to complexity (operating skills and number of parts) and uncertainty (under different conditions).
5.	How the reference supports the presented conclusions with reliable and sufficient experiential data:
	The study uses objective measures—the number of new models annually and the technological life of equipment models—to remove subjective bias in assessing the rate of innovation for the industry. Linear regression was performed on the variables for 8 types of equipment from 60 manufacturers over a 30 year period to test whether or not the rate of innovation increased in the construction equipment industry.
6.	How the reference differentiates energy and non-energy aspects of technology or system innovation:
	Not applicable.
7.	Potentially important references not previously cited:
	Several, see above. (45 references in all.)
8.	Additional comments or summaries of other important information:

Topic: Innovation Adoption/Diffusion
Reference: Rosenfeld, Yehiel. 1994. Innovative construction methods. Construction Management & Economics 12, no. 6: 521-241.
Reviewer: WIW

1.	Scope and content of the reference:
	Characteristics of capital intensiveness, legal responsibility, and fragmentation (represented by unbalanced risk and reward) lead to slow development and implementation of innovative construction techniques. Prefabrication and industrialization have never generally replaced traditional practices except in limited regions (Finland) or for limited periods of time in exceptional situations (such as the rebuilding of Europe), most recently in Israel in the 1990s. Sudden immigration multiplied demand for housing. The government actively shared the risk of development by guaranteeing purchase of a percentage of dwellings at an agreed price. Three types of non-conventional methods were adopted: previously discarded methods that (with risk sharing) could again be economically feasible; imported methods that had had success elsewhere; and promising innovations that lacked experience. Each method was evaluated in terms of: manufacturing and/or construction method; functionality and performance; process logistics; and strengths and limitations. A comparative analysis ranked the methods against 10 attributes: design flexibility, clumsiness, degree of prefabrication, equipment requirements on-site, capital intensiveness, project size dependency, confidence in long-term performance, skilled labor requirements, social implications, and speed of erection on-site.
2.	Any theoretical model of innovation and/or barrier operation to consider based on the work:
	None noted.
3.	How the reference helps define one or more of the four relevant categories of barriers:
	Flow charts of process logistics may offer opportunities to identify problem areas or needs for coordination and communication within or between trades.
4.	How the reference better defines the extent to which consumers (builders at one level, ultimately home buyers) participate in making decisions or creating barriers:
	Each method was evaluated in terms of: manufacturing and/or construction method; functionality and performance; process logistics; and strengths and limitations. A comparative analysis ranked the methods against 10 attributes: design flexibility, clumsiness, degree of prefabrication, equipment requirements on-site, capital intensiveness, project size dependency, confidence in long-term performance, skilled labor requirements, social implications, and speed of erection on-site.
5.	How the reference supports the presented conclusions with reliable and sufficient experiential data:
	Entirely anecdotal.
6.	How the reference differentiates energy and non-energy aspects of technology or system innovation:
	Not applicable.
7.	Potentially important references not previously cited:
	None noted.
8.	Additional comments or summaries of other important information:

Topic: Innovation Adoption/Diffusion
Slaughter, E. Sarah. 1998. Models of Construction Innovation. Journal of Construction Engineering and Management 124, no. 3: 226-31.
Reviewer: WIW

1.	Scope and content of the reference:
	Paper seeks to guide identification, acquisition, development, and implementation of innovations by construction firms. Summarizes benefits of innovation from macroeconomic (economic growth and productivity) to firm-level competitive advantage. Describes scale, complexity, product service life, temporary nature of industry alliances, regulation, and unique liabilities as differentiating construction innovation from manufacturing innovation. Defines a framework of construction innovation based on magnitude of change from current state-of-the-art and linkages to other construction components and systems.
2.	Any theoretical model of innovation and/or barrier operation to consider based on the work:
	Five models of innovation: incremental (small, easily accommodated, from within value chain); modular (significant change within component, but maintains existing links unchanged, easily implemented within an organization); architectural (small change in component, but significant change in links to other components and systems, requiring changes in external relationships); system (integrating multiple independent innovations to perform new functions or improve overall performance, typically from multiple sources requiring significant integration among industry participants); radical (breakthrough fundamentally changing industry product or delivery, most often from outside industry)
3.	How the reference helps define one or more of the four relevant categories of barriers:
	Indirect or implied reference to education, risk, and fragmentation.
4.	How the reference better defines the extent to which consumers (builders at one level, ultimately home buyers) participate in making decisions or creating barriers:
	Describes four considerations for implementing innovation: timing of commitment (when decided and to what degree resources will be used); degree of coordination (implicit, requiring informal negotiation and collaboration, or explicit, requiring contractual provisions and/or formal acceptance of risk or uncertainty); type and source of special resources (special equipment or trained personnel, most often only available outside existing organization); nature and level of supervision (organizational level, type of activity, and required competencies of supervisors).
5.	How the reference supports the presented conclusions with reliable and sufficient experiential data:
	Asserts theory with references to previous research and researchers. No empirical or case study evidence, as such.
6.	How the reference differentiates energy and non-energy aspects of technology or system innovation:
	Not applicable
7.	Potentially important references not previously cited:
	Schumpeter, J. (1934) *The theory of economic development*. Harvard University Press (32 references in all)
8.	Additional comments or summaries of other important information:
	None.

Topic: Innovation Adoption/Diffusion
Reference: Hassell, Scott, Anny Wong, Ari Houser, Debra Knopman and Mark Bernstein. 2003. Building Better Homes: Government Strategies for Promoting Innovation in Housing, RAND Science and Technology Policy Institute, Arlington, VA.
Reviewer: GKH

1.	Scope and content of the reference:
	Published in 2003, this is a landmark piece of work in the field. It takes a comprehensive look at previous work done in the field of innovation as it relates specifically to housing. It provides two good models for thinking about innovation in housing today. And, it makes important recommendations for how government support of innovation might proceed into the future. Principal sections address: • Problems with the old linear conceptual model for innovation. • A new, nonlinear model of housing innovation. • Summarizes the NAHBRC/Hassell model of the housing construction process. • Summarizes industry characteristics and motives that affect innovation in housing. • Summarizes previous federal efforts to promote innovation, and • Recommends new federal strategies to enhance innovation in housing.
2.	Any theoretical model of innovation and/or barrier operation to consider based on the work:
	First, following a careful literature search (see 7 below), the report begins by covering the limitations of previous models that view innovation in housing as a linear process. Second, the report proposes a new, less linear model for innovation in housing that highlights the importance of invention. This model addresses the importance of research, building a knowledge base, and addressing market forces. Third, the report summarizes previous work by the NAHB Research Center and by Hassell et al in describing the five stages of the housing construction process: • Land Development • Design • Pre-Construction • Construction • Post-Construction. Although either the second or third models could be a basis for the current project, it appears at this point that the description of the housing construction process could be most beneficial in organizing panel discussions.
3.	How the reference helps define one or more of the four relevant categories of barriers:
	This report goes out of its way to say that defining "barriers" and proposing to remove them is NOT the best way to promote innovation. They propose that it is much better to identify options that accelerate innovation. This is a departure from the classical linear model of innovation and becomes the basis for most of the report.
4.	How the reference better defines the extent to which consumers (builders at one level, ultimately home buyers) participate in making decisions or creating barriers:
	Chapter Four, "Industry Characteristics and Motives and Their Effect on Innovation, has an extensive section (p 50-62) that describes many aspects of builder's complex motivations in making decisions. Sections of the report on the importance of addressing market forces covers many aspects of home buyer concerns. This report is one of the best in the literature reviewed on these two topics.
5.	How the reference supports the presented conclusions with reliable and sufficient experiential data:
	The report is well researched and well footnoted. It meets what one would expect from a leading, national policy research organization.

6.	How the reference differentiates energy and non-energy aspects of technology or system innovation:
	Although energy–related texts are reviewed and addressed in the report, the focus of the report throughout is on housing innovation.
7.	Potentially important references not previously cited:
	The 12-page Bibliography included with this report is one of the best and most up to date of any document we reviewed.
8.	Additional comments or summaries of other important information:
	This document should have and will have an important influence on the current project.

Topic: Innovation Adoption/Diffusion
Reference: Holmen Enterprises Ltd. 2002. Innovation in the Housing Industry, National Research Council of Canada., Ottawa, Ontario, Canada.
Reviewer: GKH

1.	Scope and content of the reference:
	This is a "discussion paper" prepared in 2002 by a contractor (Holmen Enterprises Ltd.) for the National Research Council of Canada with support from the Canadian Home Builders Association. It is a practical work aimed at including a broad audience in a discussion about innovation in housing. It is a good presentation of definitions currently used in the industry. It does not present any data. Work is based on three sources of information: 1) Literature Review: The Bibliography provided is a nice, up to date summary of sources with emphasis on those from Canada. This is a good addition to our search for sources. See section 7 below. 2) Interviews: Unfortunately the author does not tell us how many persons were interviewed and does not provide a list of sources. 3) Expert Opinions: Unfortunately we are not given the list of experts consulted.
2.	Any theoretical model of innovation and/or barrier operation to consider based on the work:
	No theoretical model is presented. However, on page 8 there is a nice diagram of the "Relationships among Key Members of the Housing system." This could be a useful handout for our panels.
3.	How the reference helps define one or more of the four relevant categories of barriers:
	Education: The paper calls out the limited number of skilled workers in the sector but does not offer solutions for addressing the problem. (p.16) Information transfer was also discussed. Risk: This topic is discussed in some detail. I recommend pages 18-19 to the Risk team. Fragmentation was not discussed. Cultural Values were not discussed.
4.	How the reference better defines the extent to which consumers (builders at one level, ultimately home buyers) participate in making decisions or creating barriers:
	Consumers were discussed in this paper as a "contingent factor" meaning that they could either foster or impede innovation. (see page 20)
5.	How the reference supports the presented conclusions with reliable and sufficient experiential data:
	No data was presented. As mentioned above, it was troublesome not to see a list of those interviewed.
6.	How the reference differentiates energy and non-energy aspects of technology or system innovation:
	The article focused on the construction industry with little attention to energy.
7.	Potentially important references not previously cited:
	The Bibliography is divided into three sections: 1) Summaries of Reports about Innovation Applicable to Most Business Sectors. (Nam and Tatum, above, suggest that this is not such a useful enterprise.) 2) Summaries of Reports about Innovation Applicable to the Whole Construction Industry: This is a good section. Perhaps 5 selections merit investigation by our librarian. 3) Summaries of Reports about Innovation Applicable to the housing Sector of the Construction Industry Another good section. Perhaps 8 selections merit investigation by our librarian.
8.	Additional comments or summaries of other important information:

Topic: Innovation Adoption/Diffusion
Reference: Field, Charles G. and Goldberg, Burton. 2001. Commercialization of Innovation: Lessons Learned, NAHB Research Center, Inc., Upper Marlboro, MD.
Reviewer: GKH

1.	Scope and content of the reference:
	This 2001 report was prepared by the NAHB Research Center, Inc. for the HUD PATH Program. Based on two detailed case studies—EIFS and I-Joists—and two workshops with experts in these are related technologies, the authors draw conclusions about what worked, or didn't, in the diffusion of these two new technologies. From this analysis, the authors then propose a "framework" for considering diffusion of innovation more generally in the construction industry. The Executive Summary includes a long list of major recommendations resulting from this work.
2.	Any theoretical model of innovation and/or barrier operation to consider based on the work:
	The authors develop a "Framework for Study" (p.17-24) but stop short of calling it a new model of diffusion of innovation in the construction industry. According to this framework, the literature defines five attributes that influence the rate of adoption of a new construction related technology: • Compatibility • Trial-ability • Observability • Simplicity • Relative Advantage Each of these is defined and discussed in modest detail. This framework is also applied to the two case study technologies discussed in the report.
3.	How the reference helps define one or more of the four relevant categories of barriers:
	Education, Risk, and Fragmentation are all touched upon in recommendations made by this study. The case studies featured in this report are used to illustrate findings about each of these three categories. The categories are not studied theoretically or independently. There is no direct attention to Cultural Values as a category.
4.	How the reference better defines the extent to which consumers (builders at one level, ultimately home buyers) participate in making decisions or creating barriers:
	Within the context of the two case studies presented, there are detailed findings about how both builders and home buyers responded to these two new technologies. These descriptions are informative about how both groups make decisions and about how they define barriers. However, the limited number of cases makes it difficult to generalize.
5.	How the reference supports the presented conclusions with reliable and sufficient experiential data:
	In this report, the detailed investigation of the two case studies supported by expert workshops is compelling. The authors strike a nice balance between making recommendations based on what is presented in the case studies but stop short of constructing an entire new model of diffusion, which would be difficult given the limited data. This is a practical presentation.
6.	How the reference differentiates energy and non-energy aspects of technology or system innovation:
	This report focuses almost entirely on building systems and addresses energy issues only in passing.
7.	Potentially important references not previously cited:
	The authors make reference to the fact that a literature search was conducted as part of the study and that it was used by staff in preparing the report. Unfortunately, results of this literature review were not presented as an appendix to the report.

8.	Additional comments or summaries of other important information:
	This is a practical and very readable report. The case studies are well researched and well written. They provide excellent examples for many findings in the report and give credibility to the recommendations made. Details from these case studies could easily inform points of discussion on any future panel of experts. The "framework for study" provided is useful in comparing the two case studies but, wisely, stops short of trying to be a new model for diffusion.

Topic: Innovation Adoption/Diffusion
Reference: Hall, Bronwyn H. Innovation and Diffusion. Working Paper 10212, National Bureau of Economic Research, Cambridge, MA, January 2004. [http://www.nber.org/papers/w/10212
Reviewer: Dbh

1.	Scope and content of the reference:
	The contribution made by innovation and new technologies to economic growth and welfare is largely determined by the rate and manner by which innovations diffuse throughout the relevant population, but this topic has been a somewhat neglected one in the economics of innovation. This chapter, written for a handbook on innovation, provides a historical and comparative perspective on diffusion that looks at the broad determinants of diffusion, economic, social, and institutional, viewed from a microeconomic perspective. A framework for thinking about these determinants is presented along with a brief nontechnical review of modeling strategies used in different social scientific literatures. Published in 2004, this is the latest theory on diffusion of innovation. There is only one mention of the building industry related to plastic pipe as an example of regulatory lag to diffusion.
2.	Any theoretical model of innovation and/or barrier operation to consider based on the work:
	Conceptual frameworks: Sociological (Rogers): [Implicitly assumes that neither the innovation nor the technology it replaces changes during the diffusion process and that the new is better than the old.] 1. Relative advantage 2. Compatibility with adopter's way of doing things and with social norms. 3. Complexity. 4. Trial-ability. (Level of uncertainty). 5. Observability. (Level of uncertainty). Plus: 6. Decision made by individuals or central authority (fragmentation). 7. Communication channels (education). 8. Nature of social system of adopters (cultural) 9. Extent of change agents' promotion efforts (education). Economists view the process as cumulative decisions made in an environment of uncertainty (risk) and limited information (education). Modeling the diffusion rate: 1. Benefits received from new technology. They increase over time as the innovation is improved and adapted. (Relate this to Slaughter innovation by users vs. manufacturers). 2. Network effects, or the interfaces that diffuse information about the innovation and its benefits 3. Costs of adoption. 4. Information and uncertainty. 5. Market size, industry environment and market structure. This includes the regulatory environment.
3.	How the reference helps define one or more of the four relevant categories of barriers:
	It helps relate them to the theoretical models, as noted above.
4.	How the reference better defines the extent to which consumers (builders at one level, ultimately home buyers) participate in making decisions or creating barriers:
	"Although many have criticized the linear model that lies behind the division of innovative activity into three parts (invention, commercialization/innovation, diffusion) as oversimplified, it remains true that without invention it would be difficult to have anything to diffuse, so that the model still serves us as an organizing principle, even if we need to be aware of its limitations. Nevertheless, an important insight from the many historical case studies of individual inventions

	has been the extent to which the diffusion process enhances an innovation via the feedback of information about its operation or utility under varying conditions and across different users, information that can be used to improve it. A second major finding from this literature has been the possible feedback from differences in the rate or scale of adoption across geographic areas to the rates of improvement in the innovation."
5.	How the reference supports the presented conclusions with reliable and sufficient experiential data:
	This is a theoretical framework discussion that draws on examples from various diverse technologies.
6.	How the reference differentiates energy and non-energy aspects of technology or system innovation:
	Not applicable.
7.	Potentially important references not previously cited:
	There are 67 references, none of which appear to address the construction industry. There is no reference given to the comment on plastic pipe.
8.	Additional comments or summaries of other important information:

Innovation Adoption/Diffusion Bibliography (and anticipated usefulness score)

Innovation Articles	Score
Nam, C. H and C. B. Tatum. 1989. Toward Understanding of Product Innovation Process in Construction. *Journal of Construction Engineering and Management* 115, no. 4: 517-34	4
Arditi, David and Serdar Kale. 1997. Innovation in construction equipment and its flow into the construction industry. *Journal of Construction Engineering & Management* 123, no. 4: 371-78.	3
Rosenfeld, Yehiel. 1994. Innovative construction methods. *Construction Management & Economics* 12, no. 6: 521-241.	3
Slaughter, E. Sarah. 1998. Models of Construction Innovation. *Journal of Construction Engineering and Management* 124, no. 3: 226-31.	3
Brown, M. A. 1997. Performance Metrics for a Technology Commercialization Program. *International Journal of Technology Management* 13, no. 3: 229-44.	2
Dieperink, C., L Brand and W. Vermeulen. 2004. Diffusion of Energy-saving Innovations in Industry and the Built Environment: Dutch Studies as Inputs for a More Integrated Analytical Framework. *Energy Policy* 32, no. 6: 773-84.	2
Geroski, P. A. 2000. Models of Technology Diffusion. *Research Policy* 29, no. 4-5: 603-25.	2
Mullens, Michael A., Robert L. Armacost and William W. Swart. 1994. Benchmarking Construction Costs for Innovative Homebuilding Technologies. *Building Research Journal* 3, no. 2: 81-101.	2
Rogers, L. and J. P. Christofferson. 1999. A Systems Approach to Residential Construction: Development of a Production Manual. *Journal of Construction Education* 4, no. 1: 92-99.	2
Tatum, C. B. 1991. Incentives for Technological Innovation in Construction. *Preparing for Construction in the 21st Century: Proceedings of Construction Congress 1991*, 447-52New York: ASCE.	2
Toole, T. M. and T. D. Tonyan. 1992. The Adoption of Innovative Building Systems: A Case Study. *Building Research Journal* 1, no. 1: 21-26.	2
Christofferson, J. P. 1999. Managing Specification Information Flow through the Residential Construction Process. *Journal of Construction Education* 4, no. 1: 69-82.	1
Everett, J. G. and H. Saito. 1996. Construction Automation: Demands and Satisfiers in the United States and Japan. *Journal of Construction Engineering and Management* 122, no. 2: 147-51.	1
Gerwick. H. M., Jr. 1990. Implementing Construction Research. *Journal of Construction Engineering and Management* 116, no. 4: 556-63.	1
Lutz, James D., Luh-Maan Chang and Thomas R. Napier. 1990. Evaluation of New Building Technology. *Journal of Construction Engineering and Management* 116, no. 2: 281-99.	1
Manseau, A. 1998. Who Cares About Overall Industry Innovativeness? *Building Research and Information* 26, no. 4: 241-45.	1
Mitropoulos, P. and C. B. Tatum. 1999. Technology Adoption Decisions in Construction Organizations. *Journal of Construction Engineering and Management* 125, no. 5: 330-338.	1

Mitropoulos, P. and C. B. Tatum. 2000. Forces Driving Adoption of New Information Technologies. *Journal of Construction Engineering and Management* 126, no. 5: 340-348.	1
Slaughter, E. Sarah. 2000. Implementation of Construction Innovations. *Building Research and Information* 28, no. 1: 2-17.	1
Tatum, C. B. 1987. Process of Innovation in Construction Firm. *Journal of Construction Engineering and Management* 113, no. 4: 648-63.	1
Toole, T. M. The Technological Trajectories of Construction Innovation. *Journal of Architectural Engineering* 7, no. 4: 107-14.	1
Bakens, Wim. 1997. International trends in building and construction research. *Journal of Construction Engineering & Management* 123, no. 2: 102-4.	
Livesay, H. C., D. S. Lux and M. A. Brown. 1996. Human Factors and the Innovation Process. *Technovation* 16, no. 4: 173-86.	
Loosemore, M., H. Choo and J. Koh. 2002. Encouraging Research and Development in Construction Companies. *Journal of Professional Issues in Engineering Education and Practice* 128, no. 1: 25-29.	
Mills, T. H. 1999. Redline: Real-time Documentation Linking Images and Notations Electronically. *Journal of Construction Education* 4, no. 1: 83-91.	
Navon, Ronie, Paul W. Kelly and David W. Johnston. 1993. Human Factors in Introducing On-Site Construction Automation. *Journal of Construction Engineering and Management* 119, no. 4: 801-12.	
Seaden, G. and A. Manseau. 2001. Public Policy and Construction Innovation. *Building Research and Information* 29, no. 3: 182-96.	
Tatum, C. B., M. F. Bauer and A. W. Meade. 1989. Process of Innovation for Up/Down Construction at Rowes Wharf. *Journal of Construction Engineering and Management* 115, no. 2: 179-95.	
Teicholz, Paul. 2001. U.S. Construction Labor Productivity Trends, 1970-1998. *Journal of Construction Engineering and Management* 127, no. 5: 427-29.	
Warszawski, A. and R. Navon. 1998. Implementation of Robotics in Building: Current Status and Future Prospects. *Journal of Construction Engineering & Management* 124, no. 1: 31-41.	
Innovation Books	
Stoneman, Paul. 1983. *Economic Analysis of Technological Change*. Oxford, UK: Oxford University Press.	1
Innovation Conference Proceedings	
Farmer, Gene. The Use of Television for the Dissemination of Construction Information to the General Public. *Associated Schools of Construction: Proceedings of the 30th Annual Conference*.	2
Hutchings, D. Mark and Dennis L. Eggett. Non-Financial Indicators of Profitability for Small-Volume Home Builders. *ASC Proceedings of the 38th Annual Conference*, 343-54.	2
Brown, M. A. The Push and Pull of Innovation: Selecting a Successful Tech Transfer Technology. *ARCC Symposium on Building Partnerships for Technology Transfer*.	1
Christofferson, Jay P. Computer-Integrated Specification Information Flow Through the Residential Construction Process. *ASC Proceedings of the 33rd Annual Conference*, 173-86.	1

Kirk, W. Max. Regional Research Centers: Implementing Research & Development for the Construction Industry. *ASC Proceedings of the 26th Annual Conference*, 131-38.	1
Schexnayder, Cliff, Avi Wiezel and Indunil Seneviratne. The Use of the Internet by Construction Students and Professionals. *ASC Proceedings of the 35th Annual Conference* , 349-62.	1
Andersen, Kenneth. Managing Change in the Construction Arena with the Concerns-based Adoption Model. *ASC Proceedings of the 28th Annual Conference*, 73-78.	
Butler, Russell C., Jay P. Christofferson and D. Mark Hutchings. Factors Leading to Construction Company Success: Comparisons of the Perceptions of Production and Small-Volume Home Builders. *Associated Schools of Construction: Proceedings of the 39th Annual Conference*, 267-76.	
Syal, Matt and Jay Christofferson. Evolution of Management Techniques and Growth of Residential Construction Companies. *Associated Schools of Construction: Proceedings of the 30th Annual Conference*.	
Wiezel, Avi, Allan Chasey and Cliff Schexnayder. Building a Web Site for Construction Organizations. *ASC Proceedings of the 35th Annual Conference*, 285-98.	
Williams, Steve and Junshan Liu. Implementing Advanced Construction Layout Technologies Utilizing University/Industry Collaboration – A Case Study. *ASC Proceedings of the 39th Annual Conference*, pp 247-56.	
Dissertations	
McNicholas, Thomas Martin. 1994. "Potential Barriers to the Adoption of New Technology in the United States Construction Industry (Technology Lag)." Golden Gate University.	2
Obiso, Melissa Lynn. 1998. "Analysis of Means and Methods of Construction Improvement in Single Family Housing in Mid-Atlantic Rural University Towns." Virginia Tech.	
Innovation Reports	
Hassell, Scott, Anny Wong, Ari Houser, Debra Knopman and Mark Bernstein. 2003. *Building Better Homes: Government Strategies for Promoting Innovation in Housing*, RAND Science and Technology Policy Institute, Arlington, VA.	3
Holmen Enterprises Ltd. 2002. *Innovation in the Housing Industry*, National Research Council of Canada., Ottawa, Ontario, Canada.	3
Field, Charles G. and Goldberg, Burton. 2001. *Commercialization of Innovation: Lessons Learned*, NAHB Research Center, Inc., Upper Marlboro, MD.	added
Hall, Bronwyn H. *Innovation and Diffusion. Working Paper 10212*, National Bureau of Economic Research, Cambridge, MA, January 2004.	added

Appendix A: Literature Review Summary Sheets
Risk

Topic: Risk
Reference: Bernstein, Harvey M. 1992. Tort Liability: Limiting U. S. Innovation. Civil Engineering 62, no. 11: 6
Reviewer: wiw

1.	Scope and content of the reference:
	Safeguards for public safety and competitiveness have become barriers to innovation. Uncertainty of product liability and least cost contracts reward low risk design and stability in the building construction industry, which accounts for 8.4% of GNP. A measurable linkage between concern for liability and low levels of research in construction has not been shown, but a Conference Board survey indicates 36% of respondents discontinued existing products, 30% decided against introduction of new products, and 21% discontinued research because of liability concerns. Tort claims cost the US economy hundreds of billions of dollars each year, many times that in other countries.
2.	Any theoretical model of innovation and/or barrier operation to consider based on the work:
	None.
3.	How the reference helps define one or more of the four relevant categories of barriers:
	Risk: US construction lags in R&D spending, with, for example, Japan spending $800M annually, 15 times as much as US companies. Individual companies, the entire industry, government, and academia need to work together to demonstrate and adopt innovation in the US. The government led during the energy crisis. They should again, now, by absorbing some of the financial risk associated with innovation. The government needs to: create a better environment for innovation, encourage more private R&D investment, simplify regulation, protect intellectual property, participate in evaluation of innovation, reduce legal obstacles, and increase infrastructure investment.
4.	How the reference better defines the extent to which consumers (builders at one level, ultimately home buyers) participate in making decisions or creating barriers:
	Not applicable.
5.	How the reference supports the presented conclusions with reliable and sufficient experiential data:
	Not applicable.
6.	How the reference differentiates energy and non-energy aspects of technology or system innovation:
	Not applicable.
7.	Potentially important references not previously cited:
	None.
8.	Additional comments or summaries of other important information:

Topic: Risk
Reference: Toole, T. M. 1998. Uncertainty and Home Builders' Adoption of Technological Innovations. Journal of Construction Engineering and Management 124, no. 4: 323-32.
Reviewer: wiw

1.	Scope and content of the reference:
	The rate of technological change in the housing industry is wrongly perceived. The paper seeks to answer how innovation adopting firms are different than non-adopting firms and, further, how adopters of high uncertainty innovations differ from adopters of low-uncertainty innovations. The results apply to builders of less than 200 houses per year. Nine hypotheses of the relationship of uncertainty reduction to innovation adoption are presented and tested using multivariate regression analysis of over 100 interviews of homebuilders. Adoption is defined as use in at least 25% of opportunities for use. Non-diffused innovations are defined as having 2% to 40% market share. High uncertainty innovations are defined as those in which substantial information related to long-term performance, total installed cost, or acceptance by buyer, subcontractors, or local code officials is lacking. Low uncertainty innovations are those for which this information is available. Nine hypotheses are tested by evaluating answers to five questions (posed about 12 innovations; 6 high uncertainty, 6 low uncertainty): Will it perform as promised in all homes over a long period of time? How much money will it save or cost me? How much will potential buyers value or resist it? To what extent will it affect or be resisted by subcontractors? To what extent will it be resisted by local regulators?
2.	Any theoretical model of innovation and/or barrier operation to consider based on the work:
	• In diffusion theory, adoption is substantially influenced by relative advantage, which has two components: the ability of an innovation to improve the performance of a work task and the superiority of an innovation in allowing an organization to match its environment (allowing execution of strategic actions that increase the organization's performance). • Evaluating the task component of adoption is difficult for a home builder because: the end products vary considerably; there are long time frames and wide ranges of conditions in production; task end products consist of many interacting parts and/or dynamic subsystems (leading to potentially severe consequences); high levels of tacit knowledge and skills are required; and, interactions with a large number of diverse entities are required. • Organizational environments consist of five sectors: technology, supplier, regulatory, competitor, and customer. Sectors individually and as a group influence actions needed for profitability, growth, and other organizational goals. Munificence (degree of environmental hostility—low implies stiff competition and threats to survival), dynamism (unpredictable volatility in demand, prices, product characteristics, technologies—high because of extreme swings in demand for homebuilders), and complexity (measure of number of inputs, outputs, interactions, regulations—high because of number and diversity of external influencers for homebuilders) are key dimensions of environment affecting uncertainty. Home buyers, local building officials, and subcontractors are particularly significant sources of uncertainty for homebuilders. • History suggests to homebuilders that "building innovations are guilty (i.e. may not perform as promised) until proven otherwise. • Prospect theory, status quo bias, and regret bias decision mechanisms suggest that potential adopters missing critical information will choose not to adopt.

3.	How the reference helps define one or more of the four relevant categories of barriers:
	Risk and builder preferences (cultural values)
4.	How the reference better defines the extent to which consumers (builders at one level, ultimately home buyers) participate in making decisions or creating barriers:
	• Strong evidence that builders who are more apt to adopt both high uncertainty and low uncertainty innovations are those who reduce uncertainty by gathering and processing information about the innovations. Four of five hypotheses related to uncertainty reduction/information (first five above) were significant for at least one and/or the other of high uncertainty or low uncertainty innovations. Only geographic location of the remaining four hypotheses not related to information processing was significant. Squared R values indicate that 75% of explained variance was attributable to information processing while the remaining 25% was attributable to geographic location. • Propensity to adopt high uncertainty innovations early is significantly related to the number of sources, number of functions, and having a building trades perspective involved. Propensity to adopt low uncertainty innovations early is significantly related to the number of sources, a positive attitude toward innovation, and involvement of an A/E perspective. The amount and quality of information needed is higher for high uncertainty innovation adoption than low uncertainty innovation. • Builder behavior concerning adoption of new products is understandable given environmental characteristics of the industry. Reduction of uncertainty will be required in order to increase the rate of technical change. Manufacturers should reevaluate marketing to reduce uncertainty by increasing knowledge of sales staff and emphasizing see and touch demonstrations; improving storage and installation procedures; and providing meaningful warranties.
5.	How the reference supports the presented conclusions with reliable and sufficient experiential data:
	• Sources of information: builders more apt to adopt tap into more sources of information than non-adopters. High uncertainty adopters held other builders, in-house testing, and subcontractors important. Low uncertainty adopters held architects, homeowners, manufacturers, and subcontractors important. • Number of employees gathering information: no relationship to adoption. • Number of organizational functions (top management, office administration, sales, field supervision, crews, or designers) involved in adoption decisions: significantly related for adoption of high uncertainty innovations, but no significant relationship for low uncertainty innovations. • Professional backgrounds involved in innovation related activities: not significant for either high uncertainty or low uncertainty innovations for building trades, A/E college degree, and non-A/E college degree collectively. Building trades participation significantly related for high uncertainty innovations. A/E participation significantly related for low uncertainty innovations (highly deterministic analysis and decision making may lead to status quo bias). Non A/E participation not significantly related for high uncertainty or low uncertainty innovations. • Positive attitude about early adoption: not statistically significant for high uncertainty innovations, but significant for low uncertainty innovations. • Firm size: data were inconclusive. Note that only companies producing 180 homes or less(small to medium-sized firms) participated in the survey; data and analyzing do not test hypothesis for large firms. • Market segment: not significant (as measured by starter, average, or luxury homes segmentation) for adoption of either high uncertainty or low uncertainty innovations. (May reflect balance of included innovations between cost-saving (lower end of market, typically)

	and performance enhancing (higher end). • Number of years in business: no relationship to adoption of high uncertainty or low uncertainty innovations (despite strongly held opinions of some builders). • Geographic location: significantly related for both high uncertainty and low uncertainty innovations for several regions.
6.	How the reference differentiates energy and non-energy aspects of technology or system innovation:
	Not applicable
7.	Potentially important references not previously cited:
	Several; see appendix listing 31references in all.
8.	Additional comments or summaries of other important information:

Topic: Risk
Reference: Agarwal, R. and B. L. Bayus. 2002. The Market Evolution and Sales Takeoff of Product Innovations. Management Science 48, no. 8: 1024-42.
Reviewer: dbh

1.	Scope and content of the reference:
	30 consumer and industrial product innovations introduced in the U.S. over 150 years are examined to determine the relationship amongst "invention year," "commercialization year," innovator firm take-off year and sales takeoff year. As increased capacity produces price reduction, falling prices alone account for less than 5% of variance in sales takeoff. By contrast, nearly 50% of the same variance is seen due to new firm entry -- coincidental with product improvements (real and perceived), expanded distribution, heightened consumer awareness, advertising and promotion, etc. Prices may actually rise during crucial early years of R&D and fall only after a sales takeoff. Thus, increased demand, due to such non-price factors, is identified as the key driver to sales takeoff. The reference argues that outward shifting of supply and demand curves lead to market takeoff -- not particularly startling, except that the preponderance of earlier studies focused mostly or exclusively on supply side analysis.
2.	Any theoretical model of innovation and/or barrier operation to consider based on the work:
	Barriers not addressed. Economic model of sales takeoff, and firm entry takeoff.
3.	How the reference helps define one or more of the four relevant categories of barriers:
	Not applicable.
4.	How the reference better defines the extent to which consumers (builders at one level, ultimately home buyers) participate in making decisions or creating barriers:
	Innovation sales takeoff is a function of shifts in both supply and demand curves.
5.	How the reference supports the presented conclusions with reliable and sufficient experiential data:
	Empirical data is used extensively.
6.	How the reference differentiates energy and non-energy aspects of technology or system innovation:
	Not applicable.
7.	Potentially important references not previously cited:
	The 74 references are all to the basic diffusion literature. No new insights.
8.	Additional comments or summaries of other important information:
	Of the 30 innovations studied seven are home appliances (dishwasher, clothes washer, freon compressor, clothes dryer, garbage disposer, heat pump, and home microwave oven). However, no patterns for this group is identified. Risk not addressed.

Topic: Risk
Reference: Jensen, R. 2003. Innovative Leadership: First-mover Advantages in New Product Adoption. Economic Theory 21, no. 1: 97-116.
Reviewer: Dbh

1.	Scope and content of the reference:
	This paper analyzes innovation adoption when uncertainty about its profitability cannot be resolved immediately. It does so by mathematical game theory.
2.	Any theoretical model of innovation and/or barrier operation to consider based on the work:
	Mathematical game theory making assumptions about information becoming equally and immediately available to all competitors whose uncertainty relates to the demand.
3.	How the reference helps define one or more of the four relevant categories of barriers:
	Uncertainty about profitability when facing competing firms may not be a good model for the homebuilding industry.
4.	How the reference better defines the extent to which consumers (builders at one level, ultimately home buyers) participate in making decisions or creating barriers:
	Demand is not analyzed in this model, and is assumed to be stochastic.
5.	How the reference supports the presented conclusions with reliable and sufficient experiential data:
	No experiential data. This is theory.
6.	How the reference differentiates energy and non-energy aspects of technology or system innovation:
	Not applicable.
7.	Potentially important references not previously cited:
	None.
8.	Additional comments or summaries of other important information:
	This paper suggests that innovative leadership does not necessarily imply early adoption. A wait and see strategy may be more profitable for a leader. Thus, understanding the uncertainty may slow diffusion.

Topic: Risk
Reference: Lunch, Milton F. 1994. Liability Issues Lurk in Product Specification. Building Design & Construction 35, no. 4: 34-36
Reviewer: wiw

1.	Scope and content of the reference:
	Contractors, manufacturers, and even owners may be targets for negligence when building components fail to perform satisfactorily. “Standard of care” may require actual testing of products to confirm performance rather than reliance on manufacturer or third-party information. “Responsibility between prime and consultant” leads to pass-through of negligence liability to the prime even if not directly involved in decisions of a consultant, or even if defects are part of a manufacturers design. “Manufacturer’s potential liability” exists in cases of negligent design or misrepresentation (including in ‘free’ publications), even if others contribute to a failure. “Owner’s potential liability” evolves from the Spearin Doctrine, which holds that projects are built to plans and specifications prepared by the owner and that the owner is responsible for the consequences of defects in plans and specifications. “Handling of substitutions” leads to potential liabilities by all decision makers in the use of newer/substitute materials that have not been tested by experience.
2.	Any theoretical model of innovation and/or barrier operation to consider based on the work:
	None.
3.	How the reference helps define one or more of the four relevant categories of barriers:
	Liability risk.
4.	How the reference better defines the extent to which consumers (builders at one level, ultimately home buyers) participate in making decisions or creating barriers:
	Not applicable.
5.	How the reference supports the presented conclusions with reliable and sufficient experiential data:
	Not applicable.
6.	How the reference differentiates energy and non-energy aspects of technology or system innovation:
	Not applicable.
7.	Potentially important references not previously cited:
	None.
8.	Additional comments or summaries of other important information:

Topic: Risk
Reference: White, Nancy J. and Nancy Holland. Statutes of Repose: Protection for Manufacturers and Material Suppliers. ASC Proceedings of the 32nd Annual Conference , pp 223-30
Reviewer: Dbh

1.	Scope and content of the reference:
	This paper discusses Statutes of Repose that have been adopted by most states to protect architects, engineers and constructors from lawsuits arising after a specific number of years after completion of a construction project. Unlike Statutes of Limitation, which bar claims after they have risen, Statutes of Repose bar claims before they have arisen. The extent to which a statute of repose protects manufacturers and material suppliers varies greatly among the states. State courts have developed two theories to determine if a particular manufacturer or material provider is protected: the improvement analysis and the activity analysis. The authors describe the latter as superior, and recommend that all states adopt an activity analysis, which will extend the protection of the statute of repose to entities which install their products into/onto real property improvements.
2.	Any theoretical model of innovation and/or barrier operation to consider based on the work:
	This paper does not address innovation, or the liability of parties specifically related to innovative products or materials.
3.	How the reference helps define one or more of the four relevant categories of barriers:
	It does not define risk as a barrier to innovation, but discusses a certain type of general limitation of risk.
4.	How the reference better defines the extent to which consumers (builders at one level, ultimately home buyers) participate in making decisions or creating barriers:
	The risk of lawsuits is clearly a barrier to innovation, and it is ultimately consumers who sue.
5.	How the reference supports the presented conclusions with reliable and sufficient experiential data:
	The paper provides examples of statutory language and court opinions to support it argument.
6.	How the reference differentiates energy and non-energy aspects of technology or system innovation:
	Not applicable.
7.	Potentially important references not previously cited:
	The references provided are all to cases.
8.	Additional comments or summaries of other important information:
	This paper suggests that innovators should target their innovations to states that apply the activity analysis to their statutes of repose (Texas, North Dakota, Missouri, and Pennsylvania).

Topic: Risk
Reference: Bevan, John P. 2002. New Standards, Procedures, Defenses Enacted for Housing Construction Defect Disputes in California, Thelen Reid & Priest LLP, San Francisco, CA.
Reviewer: Fk

1.	Scope and content of the reference:
	This reference details some of the major provisions of California SB 800, a complex law enacted in 2002, establishing new standards and procedures for legal action brought by homeowners against builders. The statute also mandates a lengthy pre-litigation procedure for builders, (including subcontractors, material suppliers, product manufacturers and design professionals) to repair alleged defects, to mediate, or to make a cash settlement before the homeowner can file for court action.
2.	Any theoretical model of innovation and/or barrier operation to consider based on the work:
	Risk (liability for construction defects) is the subject. Education of homeowners and builders is implied with an admonition that builders give "close examination to the text of [the law's] various sections," so they or their subcontractors may be prepared to handle claims made under the statute.
3.	How the reference helps define one or more of the four relevant categories of barriers:
	In terms of operationalizing liability risk, SB 800 provides lengthy, new definitions for many types of actionable deficits for such categories as water, structural, soil, fire-protection, electrical, sewer and plumbing, manufactured component items as well as newly defined standards for a long list of construction components.
4.	How the reference better defines the extent to which consumers (builders at one level, ultimately home buyers) participate in making decisions or creating barriers:
	SB 800's pre-litigation process enforces communication between owner and builder to jointly approach a remedy of defects before legal action may be filed.
5.	How the reference supports the presented conclusions with reliable and sufficient experiential data:
	It doesn't. It simply describes the new law and advises that owners and builders be aware of the statute's new definitions and strictly construed timetables.
6.	How the reference differentiates energy and non-energy aspects of technology or system innovation:
	It doesn't, except to define electric and heating issues separately. System innovation is only inferentially dealt with as a potential failure issue which could lead to litigation.
7.	Potentially important references not previously cited:
	None.
8.	Additional comments or summaries of other important information:
	The pre-litigation process, although placing the burden of response primarily on the builder, offers a "way out" of court and a mechanism for the demand side of the market (owners) to make known their concern to the supply side.

Risk Bibliography (and anticipated usefulness score)

Risk Articles	Score
Bernstein, Harvey M. 1992. Tort Liability: Limiting U. S. Innovation. *Civil Engineering* 62, no. 11: 6.	4
Toole, T. M. 1998. Uncertainty and Home Builders' Adoption of Technological Innovations. *Journal of Construction Engineering and Management* 124, no. 4: 323-32.	4
Agarwal, R. and B. L. Bayus. 2002. The Market Evolution and Sales Takeoff of Product Innovations. *Management Science* 48, no. 8: 1024-42.	2
Jensen, R. 2003. Innovative Leadership: First-mover Advantages in New Product Adoption. *Economic Theory* 21, no. 1: 97-116.	2
Lunch, Milton F. 1994. Liability Issues Lurk in Product Specification. *Building Design & Construction* 35, no. 4: 34-36.	2
Engineers Seek Better Way to Market New Building Technology. 1996. *Civil Engineering* 66, no. 9: 26-27.	1
Lunch, Milton F. 1999. Architect Held Liable for Product Specification. *Building Design & Construction* 40, no. 12: 29.	1
Sedam, Scott. 2003. Taking the J.D. Power Cure. *Professional Builder* 68, no. 12: 41-43.	1
Shook, Steven Ross. 1997. "Innovation and the United States Residential Construction Industry: An Integrated Model of Determinants of Firm Innovativeness for Engineered Wood Products." University of Washington.	1
Chu, Jeffrey M., Esq. 2002. Senate Bill 800—Sacramento Establishes Standards For Residential Construction Defects. *Construction Law Alert*.	
Rogers, E. Mabry and J. David Pugh. 1990. Engineers and New Technology: Legal Considerations. *Education and Continuing Development for the Civil Engineer: Setting the Agenda for the 90's and Beyond, Proceedings of the National Forum*, 961-67New York: ASCE.	
Risk Conference Proceedings	
White, Nancy J. and Nancy Holland. Statutes of Repose: Protection for Manufacturers and Material Suppliers. *ASC Proceedings of the 32nd Annual Conference*, pp 223-30.	2
Risk Reports	
Bevan, John P. 2002. *New Standards, Procedures, Defenses Enacted for Housing Construction Defect Disputes in California*, Thelen Reid & Priest LLP, San Francisco, CA.	2

Appendix A: Literature Review Summary Sheets
Fragmentation

Topic: Fragmentation
Reference: Blackley, D. M. and E. M. Shepard. 1996. The Diffusion of Innovation in Home Building. Journal of Housing Economics 5, no. 4: 303-22.
Reviewer: Dbh

1.	Scope and content of the reference:
	Investigation of the factors that influence the propensity to adopt ten innovative methods and materials for a sample of 417 home building concerns obtained from the 1987 NAHB Builders' Profile Survey. A diffusion index reflecting the number of innovations used is the dependent variable, and ten characteristics of the builders are independent variables.
2.	Any theoretical model of innovation and/or barrier operation to consider based on the work:
	No theoretical model. This is looking for statistical correlations using an ordered probit framework. Propensity to adopt innovations may support indirect barriers analysis.
3.	How the reference helps define one or more of the four relevant categories of barriers:
	Risk: Two variables that correlated with propensity to adopt innovation were size of the firm and operating in multiple markets. Both of these may relate to greater risk tolerance. Fragmentation: Study results do not support the hypothesis that fragmentation reduces the likelihood of adopting innovations. However, the measure for horizontal fragmentation was the percentage of work subcontracted, and the measure for vertical fragmentation was the extent of non-building business (i.e., architecture, engineering, real estate, design, and finance). We believe that these are crude proxies for fragmentation. For example, they ignore the relationship between manufacturers, suppliers and builders. The other builder characteristics do not easily relate to the four categories of barriers.
4.	How the reference better defines the extent to which consumers (builders at one level, ultimately home buyers) participate in making decisions or creating barriers:
	Discusses correlation between propensity to adopt innovations and the following additional characteristics: management intensity (inverse), unionization (none), local codes and climate (positive), owner characteristics (positive), lower priced houses (positive), and use of industrialized building (positive).
5.	How the reference supports the presented conclusions with reliable and sufficient experiential data:
	This is a statistical study. The assumptions regarding both the diffusion of innovation (number of innovations used from a list of 10) and the builder characteristic variables may be crude and over-simplified. Also, the ten innovations are at the lower end of the innovation scale.
6.	How the reference differentiates energy and non-energy aspects of technology or system innovation:
	Non-energy innovations: plumbing provisions of 1986 CABO code, 24" stud spacing, two-stud corners, in-line off-center joists, composite wood I-beams, open wall panels, closed wall panels. Possible energy innovations: foam structural panels. Energy innovations: condensing furnaces, solar-assisted water heaters.

7.	Potentially important references not previously cited:
	Of 20 references the following may be important: Goldberg and Shepard (1990), *Diffusion of Innovation in the Housing Industry*, NAHB Research Center Report #4051. Willis (1979), *The Effects of Cyclical Demand on Industry Structure and the Rate of Technological Change: An International comparison of the House Building Sectors in the United States, Great Britain, and France*, Ph.D. dissertation, Yale University. Greer (1992), *Industrial Organization and Public Policy*, 3rd ed., New York, Macmillan.
8.	Additional comments or summaries of other important information:
	In explaining the effect of management intensity, this paper seems to support Slaughter that builders with workers participating in both management and construction are likely to adopt and adapt innovations. It doesn't discuss the issue of feedback to manufacturer innovators.

Topic: Fragmentation
Reference: Slaughter, E. Sarah. 1993. Builders as Sources of Construction Innovation. Journal of Construction Engineering and Management 119, no. 3: 532-49
Reviewer: Dbh

1.	Scope and content of the reference:
	Innovation in the construction industry occurs to a much greater extent than is usually recognized, and the sources of these innovations are more likely to be people working on-site rather than manufacturers or research laboratories. 34 innovations to a single technology, the stressed-skin panel, are examined, and it is found that the vast majority of these were developed by builders rather than manufacturers. These builder innovations were significantly different from those produced by the manufacturers. The builders' innovations explicitly integrate the panel into the total building system; the manufacturers' innovations are confined to the panels themselves. A third finding is that manufacturers commercialized few of the builder' innovations—particularly avoiding those that involved connection of the panels to other systems—despite their potential for substantial improvement in the performance of the panel overall. The research is based on a detailed, field-based study of innovations. Data collected through in-depth personal interviews.
2.	Any theoretical model of innovation and/or barrier operation to consider based on the work:
	This paper addresses the important theoretical model discussed by Bronwyn Hall (*Innovation and Diffusion*) on the importance for innovation feedback and subsequent modifications to the innovation.
3.	How the reference helps define one or more of the four relevant categories of barriers:
	Fragmentation: The value of builder innovations does not result in broad-based improvement to the basic innovation because the manufacturers do not adopt them for commercialization. Risk: Author points out that builders' risk is local and limited, while manufacturers' risk is extensive and may expand if they address panel interfaces. This may explain her findings. Not discussed by the author is that builder innovation may violate the building code requirement to install per manufacturers' instructions, creating additional risk to the builder. Education: "The policy implication of this research is in many ways more significant than the research impacts. If, as is demonstrated in this research, builders are responsible not only for the vast majority of innovations that improve construction technologies but are also the sole source of innovations that integrate the different systems, then policies to improve the development and implementation of new technologies in construction must explicitly recognize this phenomenon. Policy programs could focus on providing detailed technical information and training directly to the users; these actions could more significantly improve technology development than subsidies and research programs directed at manufacturers. For example, a program could incorporate aspects of the U.S. Department of Agriculture's Extension Agent Program, in which knowledgeable field personnel act as liaisons between research and implementation…"
4.	How the reference better defines the extent to which consumers (builders at one level, ultimately home buyers) participate in making decisions or creating barriers:
	Builders are using their experience to solve project-specific problems. Their innovations are for low-cost and rapid implementation. Manufacturers lack the necessary field experience.
5.	How the reference supports the presented conclusions with reliable and sufficient experiential data:
	The study may draw conclusions based on one technology only, the stressed-skin panel. The author makes a small case that this technology is typical, but it may not be convincing.
6.	How the reference differentiates energy and non-energy aspects of technology or system innovation:

	Innovations are in product connections, integration with other systems, and product improvements. Energy aspects of the technology not addressed. However, this technology includes the integration of insulation, which should be considered energy-related.
7.	Potentially important references not previously cited:
	Of 46 references the following may be important: *Construction Review*, (1990). U.S. Department of Commerce, (March-April) Tatum (1986), *Potential mechanisms for construction innovation*, J. Construction and Engineering Management, ASCE, 112(2), 178-191. *Technology, trade and the U.S. residential construction industry*, (1986), U.S. Congress Office of Technology Assessment, Washington, D.C.
8.	Additional comments or summaries of other important information:

Topic: Fragmentation
Reference: Slaughter, E. Sarah. 1991. "Rapid" Innovation and Integration of Components: Comparison of User and Manufacturer Innovations Through a Study of Residential Construction. Massachusetts Institute of Technology
Reviewer: Dbh

1.	Scope and content of the reference:
	This is the PhD thesis that provided the basis for the Journal of Construction Engineering and Management article reviewed above.
2.	Any theoretical model of innovation and/or barrier operation to consider based on the work:
	See discussion of Journal article.
3.	How the reference helps define one or more of the four relevant categories of barriers:
	See discussion of Journal article.
4.	How the reference better defines the extent to which consumers (builders at one level, ultimately home buyers) participate in making decisions or creating barriers:
	Three principal causes are identified to explain the far greater number of innovations from the users than from the manufacturers: 1. The cost of user solutions is low. Ad hoc responses to problems encountered in the course of a construction project. Rapidly fabricated using materials on hand at job site. The time from discovery of problem to installation of solution was ½ day on average. User has timely information. 2. The cost of delay for users is high and manufacturer solutions delivered to the site would take longer. (Average delay 44 days.) Manufacturer hasn't got timely information from field. The cost of regulatory approval is less for users than for manufacturers. She explains this: "the builder either can demonstrate that an innovation meets the specified code or performance requirement, or can provide field test evidence to the satisfaction of the local inspector. In contrast, manufacturers delivering products can b required to provide test data demonstrating code compliance for each locality served." This explanation is not persuasive; the average ½ day delay for builders cannot include any code approval, and the discussion of manufacturer approvals appears to be ignorant of the model code evaluation services. Slaughter also relates this to the different nature of liability between the builder and manufacturer. This discussion is also disingenuous. Many manufacturers warranties are limited, and builders are required by code to install per manufacturers instructions.
5.	How the reference supports the presented conclusions with reliable and sufficient experiential data:
	Stressed skin panel were introduced in residential construction in 1945. Their use reportedly was boosted by the energy crisis of the 1970s. Yet after 40 and 10 years plus respectively, this technology in this study was used in 5,000 houses per year. This is less than 1% of the market. It raises the question of whether it is fruitful to study a technology so weak in its diffusion.
6.	How the reference differentiates energy and non-energy aspects of technology or system innovation:
	See discussion of the Journal article.
7.	Potentially important references not previously cited:
	The bibliography is much more extensive than in the Journal article, but not reviewed in detail.
8.	Additional comments or summaries of other important information:

Topic: Fragmentation
Reference: Bossink, B. A. G. 2002. The Development of Co-innovation Strategies: Stages and Interaction Patterns in Interfirm Innovation. R & D Management 32, no. 4: 311-20.
Reviewer: Dbh

1.	Scope and content of the reference:
	This study reports on a Dutch government-driven program for innovation in sustainability in the house building sector of the construction industry. The program encourages co-innovation by different organizations. The research consists of study of documents, in-depth interview, and in-depth observations. This is a "green Operation Breakthrough."
2.	Any theoretical model of innovation and/or barrier operation to consider based on the work:
	A model is described of the four stages of co-innovation strategy development: (I) autonomous strategy making: organizations develop strategies on their own, (II) co-operative strategy making: organizations concentrate on developing innovation strategies in close co-operation with other organizations, (III) founding an organization for co-innovation: organizations found a joint organization in which they develop co-innovation programs, and (IV) realization of innovations: organizations develop innovations, based on the co-innovation strategies and programs.
3.	How the reference helps define one or more of the four relevant categories of barriers:
	This is a study of a government program to overcome fragmentation, and is not directly applicable in the U.S.
4.	How the reference better defines the extent to which consumers (builders at one level, ultimately home buyers) participate in making decisions or creating barriers:
	The following participants are interviewed: local authority, architectural firm, construction company, public housing local authority, real estate agency, consultant's firm, and housing corporation.
5.	How the reference supports the presented conclusions with reliable and sufficient experiential data:
	That may be how things are done in the Netherlands.
6.	How the reference differentiates energy and non-energy aspects of technology or system innovation:
	The study looks at the interactions between the co-operating entities, not the sustainability innovations themselves.
7.	Potentially important references not previously cited:
	None of 88 references.
8.	Additional comments or summaries of other important information:
	It may be interesting to compare the Dutch program with sustainability programs in the U.S.

Topic: Fragmentation
Reference: Nooteboom, B. 1994. Innovation and Diffusion in Small Firms - Theory and Evidence. Small Business Economics 6, no. 5: 327-47.
Reviewer: Dbh

1.	Scope and content of the reference:
	Not available.
2.	Any theoretical model of innovation and/or barrier operation to consider based on the work:
3.	How the reference helps define one or more of the four relevant categories of barriers:
4.	How the reference better defines the extent to which consumers (builders at one level, ultimately home buyers) participate in making decisions or creating barriers:
5.	How the reference supports the presented conclusions with reliable and sufficient experiential data:
6.	How the reference differentiates energy and non-energy aspects of technology or system innovation:
7.	Potentially important references not previously cited:
8.	Additional comments or summaries of other important information:

Topic: Fragmentation
Reference: Hutchings, D. Mark and Jay P. Christofferson. Management Practices of Residential Construction Companies Producing 25 and Fewer Units Annually. ASC Proceedings of the 37th Annual Conference , 149-58.
Reviewer: Dbh

1.	Scope and content of the reference:
	To better understand the management practices of home builders who reportedly build 11 to 25 homes per year, a survey was mailed to 1,114 of these residential contractors who were randomly selected from the membership rolls of the National Association of Home Builders. Topics of interest addressed by the survey included construction management, accounting and planning, scheduling and estimating methods, software usage, and customer and employee relations. Most of the respondents reported excellent relationships with clients; however, relationships with employees, subcontractors, and suppliers did not seem to be as strong. It is interesting to note that some tasks, which are easily automated, such as scheduling and estimating, were usually completed by hand.
2.	Any theoretical model of innovation and/or barrier operation to consider based on the work:
	This study bears no relationship to technology innovation in housing, except for management practices.
3.	How the reference helps define one or more of the four relevant categories of barriers:
	Fragmentation: It is interesting that very few small builders cultivate any relationship with suppliers. This reinforces Slaughter on innovation by builders.
4.	How the reference better defines the extent to which consumers (builders at one level, ultimately home buyers) participate in making decisions or creating barriers:
	"Good customer relations seemed to be very important to most builders. More than 75 percent of the respondents used written specifications and held formal pre-construction meetings. For most it was important to meet scheduled closing dates, to implements formal home demonstrations or walkthroughs and to use detailed contracts."
5.	How the reference supports the presented conclusions with reliable and sufficient experiential data:
	This was a simple survey.
6.	How the reference differentiates energy and non-energy aspects of technology or system innovation:
	Not applicable.
7.	Potentially important references not previously cited:
	None of 12 references.
8.	Additional comments or summaries of other important information:

Topic: Fragmentation
Reference: Yates, J. K., and Leslie C. Battersby. 2003. Master Builder Project Delivery System and Designer Construction Knowledge. Journal of Construction Engineering and Management 129, no. 6: p.635, 10p.
Reviewer: Dbh

1.	Scope and content of the reference:
	This research is concerned with construction knowledge of design professionals. It included a survey of architecture, engineering, and construction professionals from the San Francisco Bay Area. While not specifically state, it appears to deal with commercial construction.
2.	Any theoretical model of innovation and/or barrier operation to consider based on the work:
	Innovation is not addressed.
3.	How the reference helps define one or more of the four relevant categories of barriers:
	This report includes “construction industry fragmentation” in its abstract, which is probably how it was selected. However, what it means by fragmentation is the separation of the design and construction functions. Not really relevant to this study.
4.	How the reference better defines the extent to which consumers (builders at one level, ultimately home buyers) participate in making decisions or creating barriers:
	Not applicable.
5.	How the reference supports the presented conclusions with reliable and sufficient experiential data:
	The concept of “master builder” is somewhat ambiguous.
6.	How the reference differentiates energy and non-energy aspects of technology or system innovation:
	Not applicable.
7.	Potentially important references not previously cited:
	None of 20 references.
8.	Additional comments or summaries of other important information:
	The training of designers in technology is done mostly through professional associations and trade associations.

Topic: Fragmentation
Reference: 2001. Supply Chains in Residential Construction, Research Series Report 03. AZ Path, Del E. Webb School of Construction, Tempe, AZ.
Reviewer: Dbh

1.	Scope and content of the reference:
	The purpose of this paper was to explore two significant supply chains in residential construction, lumber and roof tile, and map them using standard supply chain map symbols. A second goal was to analyze the supply chain, suggest possible improvements, and finally test those suggestions. First of all, a review of literature briefly explains supply chains, supply chain management, and integrating suppliers. Then a description is provided on how supply chain management has applications in the construction industry, especially in the residential arena. The research consisted of interviews with a homebuilder, subcontractors, distributors, and suppliers. The information gathered was used to produce a supply chain map of both lumber and roof tile. An analysis on how lumber prices are determined between the homebuilder and the framing subcontractor is done. An Excel simulation was designed and executed with several different pricing scenarios and price determination techniques. The aim of this model was to explore whether a strategic alliance is a beneficial option for these two organizations. The results…suggest considerable advantages for both organizations.
2.	Any theoretical model of innovation and/or barrier operation to consider based on the work:
	This report examines conventional products and suggests that supply chain models for conventional products are very variable. For innovations, not addressed in this study, they are probably indeterminate.
3.	How the reference helps define one or more of the four relevant categories of barriers:
	No direct help. The study may imply that innovators forced to obtain materials for innovative products through traditional material supply chains may not be able to realize the full cost advantages of their innovations due to markups throughout the chain, but this is hypothetical.
4.	How the reference better defines the extent to which consumers (builders at one level, ultimately home buyers) participate in making decisions or creating barriers:
	Not applicable.
5.	How the reference supports the presented conclusions with reliable and sufficient experiential data:
	This is a very theoretical study.
6.	How the reference differentiates energy and non-energy aspects of technology or system innovation:
	Doesn't address innovation.
7.	Potentially important references not previously cited:
	None of the four references, all of which are related to PATH.
8.	Additional comments or summaries of other important information:
	It would have been interesting to superimpose a wood or tile innovation onto the supply chain models.

Fragmentation Bibliography (and anticipated usefulness score)

Fragmentation Articles	Score
Blackley, D. M. and E. M. Shepard. 1996. The Diffusion of Innovation in Home Building. *Journal of Housing Economics* 5, no. 4: 303-22.	4
Slaughter, E. Sarah. 1993. Builders as Sources of Construction Innovation. *Journal of Construction Engineering and Management* 119, no. 3: 532-49.	4
Slaughter, E. Sarah. 1991. "Rapid Innovation and Integration of Components: Comparison of User and Manufacturer Innovations Through a Study of Residential Construction." Massachusetts Institute of Technology.	4
Bossink, B. A. G. 2002. The Development of Co-innovation Strategies: Stages and Interaction Patterns in Interfirm Innovation. *R & D Management* 32, no. 4: 311-20.	3
Nooteboom, B. 1994. Innovation and Diffusion in Small Firms - Theory and Evidence. *Small Business Economics* 6, no. 5: 327-47.	3
Hutchings, D. Mark and Jay P. Christofferson. Management Practices of Residential Construction Companies Producing 25 and Fewer Units Annually. *ASC Proceedings of the 37th Annual Conference* , 149-58.	2
Yates, J. K., and Leslie C. Battersby. 2003. Master Builder Project Delivery System and Designer Construction Knowledge. *Journal of Construction Engineering and Management* 129, no. 6: p.635, 10p.	2
Chiang, Yat-Hung and Bo-Sin Tang. 2003. Submarines Don't Leak, Why Do Buildings?' Building Quality, Technological Impediment and Organization of the Building Industry in Hong Kong. *Habitat International* 27, no. 1: 1-17.	1
Kale, Serdar and David. Arditi. 2002. Competitive Positioning in United States Construction Industry. *Journal of Construction Engineering and Management* 128, no. 2: 238-47.	1
O'Brien, W. J., L. Soibelman and G. Elvin. 2003. Collaborative Design Processes: An Active and Reflective Learning Course in Multidisciplinary Collaboration. *Journal of Construction Education* 8, no. 2: 78-93.	1
Puddicombe, Michael S. 1997. Designers and Contractors: Impediments to Integration. *Journal of Construction Engineering and Management* 3, no. 3: p 245, 8 pp.	1
Stock, G. N., N. P. Greis and W. A. Fischer. 2002. Firm Size and Dynamic Technological Innovation. *Technovation* 22, no. 9: 537-49.	1
Tatum, C. B. 1989. Organizing to Increase Innovation in the Construction Firm. *Journal of Construction Engineering and Management* 115, no. 4: 602-17.	1
Tether, B. S. 2002. Who Co-operates for Innovation, and Why - An Empirical Analysis. *Research Policy* 31, no. 6: 947-67.	
Fragmentation Dissertations	
Pflueger, John C. 1991. "A Design Method for Cross-Disciplinary Coordination and Innovation (Construction Industry)." Massachusetts Institute of Technology.	
Fragmentation Reports	
2001. *Supply Chains in Residential Construction,* Research Series Report 03. AZ Path, Del E. Webb School of Construction, Tempe, AZ.	4

Appendix A: Literature Review Summary Sheets
Education

Topic: Education
Reference: Laborde, Maria and Victor Sanvido. 1994. Introducing New Process Technologies into Construction Companies. Journal of Construction Engineering and Management 120, no. 3: 488-508.
Reviewer: GKH

1.	Scope and content of the reference:
	A 1994 paper prepared by authors from Eli Lilly and Penn State University with funding from the National Science Foundation. This paper focuses on diffusion of innovation within a construction company: "how does a construction company break away for its traditional ways and introduce a new technology." The paper consists of six main parts: 1) Definition of key terms related to innovation. 2) Review of 5 existing models to describe innovation within a firm: ■ Rogers (1983) ■ Shaffer (1985) ■ Tatum (1987) ■ Construction Industry Institute (CII)/Haggard (1991) ■ de la Graza and Mitropoulos/ T^2 (1991) 3) Selection of 6 case studies of successful innovation as the basis for a new model (interview data) 4) Presentation of a new 4-step Innovation Process Model: ■ Step 1: Identification ■ Step 2: Evaluation ■ Step 3: Implementation ■ Step 4: Feedback. 5) Application of the new model to both a small and a large contractor. 6) A proposal for a new organization to promote construction excellence (PACE).
2.	Any theoretical model of innovation and/or barrier operation to consider based on the work:
	Five previous models of diffusion were briefly but effectively described. A new model for implementing the innovation process into both large and small construction firms is proposed.
3.	How the reference helps define one or more of the four relevant categories of barriers:
	Education and Risk are both discussed in describing how both a large and a small construction firm look at innovation. They are not defined strictly as barriers. Neither fragmentation nor cultural values are addressed.
4.	How the reference better defines the extent to which consumers (builders at one level, ultimately home buyers) participate in making decisions or creating barriers:
	This paper focuses solely on the construction firm. The authors list three motivations for innovation on a specific project: 1) "To solve a problem that has not been identified before;" 2) "To keep the company competitive in the marketplace;" and 3) "To have the company be recognized as a leader in the industry."
5.	How the reference supports the presented conclusions with reliable and sufficient experiential data:
	Interview results from the six case studies used to prepare the author's model are well presented in tables and figures. The data is both simple and compelling.
6.	How the reference differentiates energy and non-energy aspects of technology or system innovation:

	The paper focuses on innovation in construction firms entirely. Energy is not addressed.
7.	Potentially important references not previously cited:
	Specific references for the five previous models reviewed are provided.
8.	Additional comments or summaries of other important information:
	This is an excellent summary of diffusion models form the 1980s and early 1990s.

Topic: Education
Reference: Mead, Stephen P. 2001. Developing Benchmarks for Construction Information Flows. Journal of Construction Education 6, no. No. 3: 155-66.
Reviewer: Wiw

1.	Scope and content of the reference:
	Information flows in construction include design and technical data, contractual arrangements, and information to manage and control the process. Time frames for transmission, receipt, and action response are increasingly compressed. The study presents an approach to benchmarking information flows in construction—identifies key information components and outlines an approach to analysis—to monitor and improve the efficiency of construction communications. (The study is geared to commercial construction but may provide insights to homebuilding communications.)
2.	Any theoretical model of innovation and/or barrier operation to consider based on the work:
	The essence of benchmarking is measurement of a given process against an identified standard. In construction, benchmarking can be accomplished by measuring the process cycle times of specific information flows. Once established, cycle times may be monitored and improved. Information is defined as the data and messages transmitted between people within a communication network. In the 'resource' model of information, information can be created, transmitted, stored and received like material on a assembly line. Much of construction information fits this model and remains relatively static throughout the process. In the 'perception'' model, information is seen as dynamic and constantly undergoing interpretation (often differently) by users of the information. The way information is handled is affected by the perspective of the user. Construction information can be classified in 3 categories: technical information (designs and technical evaluations that define a building); commercial information (contract and cost details); and management and control information (logs, design changes, and schedules).
3.	How the reference helps define one or more of the four relevant categories of barriers:
	Information benchmarking may "help improve productivity, reduce project durations, and improve communication performance."
4.	How the reference better defines the extent to which consumers (builders at one level, ultimately home buyers) participate in making decisions or creating barriers:
	A matrix arraying cumulative frequency of information needs versus information users may provide insight to information priorities.
5.	How the reference supports the presented conclusions with reliable and sufficient experiential data:
	A single case study example was developed for analysis. The case was narrowly defined.
6.	How the reference differentiates energy and non-energy aspects of technology or system innovation:
	Not applicable.
7.	Potentially important references not previously cited:
	None noted.
8.	Additional comments or summaries of other important information:

Topic: Education
Reference: Nadel, Barbara A. Building Products: How Architects Find Ideas and Information. Architectural Record: Advertising Supplement provided by McGraw-Hill, [http://archrecord.construction.com/ resources/conteduc/archives/0312sweets-1.asp.]
Reviewer: GKH

1.	Scope and content of the reference:
	This short article in an advertising supplement to Architectural Record is a brief but interesting look into the specific subject of how Architects find information. The article is based largely on a 2003 survey by an unnamed "national market research company" and by anecdotes from architects interviewed for the piece. It is very useful as a sort of checklist for all of the various outlets for information that might be used to educate this important segment of the homebuilding industry. Sources of information discussed include: • Print Catalogues • Manufacturer Websites • Libraries: Real and Virtual • Sales Representatives • Trade Shows and Conventions • Publications • Office Seminars • Clients • (Formal) Education or Classes, and • Product Related Litigation.
2.	Any theoretical model of innovation and/or barrier operation to consider based on the work:
	No models were addressed in this work.
3.	How the reference helps define one or more of the four relevant categories of barriers:
	Although barriers were not addressed directly, time limitations on building designers can certainly be inferred as a barrier to education from reading the piece. For example, "the search for product information lasts an average of 19.4 minutes."
4.	How the reference better defines the extent to which consumers (builders at one level, ultimately home buyers) participate in making decisions or creating barriers:
	This article does not address builders or homebuyers. It does define architects as key decision makers in the design and construction process.
5.	How the reference supports the presented conclusions with reliable and sufficient experiential data:
	The data presented in the article is interesting and amusing but it is not highly reliable. There is no discussion of how the data was collected.
6.	How the reference differentiates energy and non-energy aspects of technology or system innovation:
	Energy was no addressed in this article.
7.	Potentially important references not previously cited:
	None.
8.	Additional comments or summaries of other important information:
	This article is light but sobering in addressing the many sources but little time architects have to find product information.

Topic: Education
Reference: Burnett, Eric, Jr. and Robert W. Buddenbohn. 1999. Training and Education Needs Assessment for the Home Building and Remodeling Industry in Pennsylvania, Pennsylvania Housing Research Center, University Park, PA
Reviewer: GKH

1.	Scope and content of the reference:
	Developed in 1999 at one of the PATH supported National Consortium of Housing Research Centers, Penn State, this study is really a thoughtful attempt to define a badly needed research effort into the educational, training, and technology transfer needs of the homebuilding industry. With limited funds available, the authors focused on the needs of Pennsylvania as a model of what is needed throughout the US. After concluding that no report or document contained reliable data that could be used for comprehensive planning, the authors contacted over 90 individuals to obtain an overview of the current situation and need for education in the industry.
2.	Any theoretical model of innovation and/or barrier operation to consider based on the work:
	Although not a full blown theoretical model, the authors do present "eight stages of knowledge and skill development" as the basis for further research: 1) Awareness of the building industry/career opportunities, 2) Basic knowledge and life skills, 3) Trade-related basic knowledge and skill development, 4) Trade-related intermediate knowledge and skill development, 5) Trade-related advanced knowledge and skill development, 6) Supervisory knowledge and skill development, 7) Business/entrepreneurial knowledge—basic, and 8) Business/entrepreneurial knowledge—industry-specific.
3.	How the reference helps define one or more of the four relevant categories of barriers:
	This entire document addresses the barrier of Education. In passing it also deals somewhat with the barrier of Fragmentation.
4.	How the reference better defines the extent to which consumers (builders at one level, ultimately home buyers) participate in making decisions or creating barriers:
	This topic is not really addressed in this study.
5.	How the reference supports the presented conclusions with reliable and sufficient experiential data:
	The point of the study is that not enough reliable data exists to even discuss the construction industry education needs in Pennsylvania. However, in trying to outline an approach to tackling the problem, the authors consult with over 90 individuals and present a highly credible proposal for needed research on this topic. The sections on "Training and Education Competency Needs" (p. 123) and the Appendix with survey responses by trade and sub-trade are particularly good.
6.	How the reference differentiates energy and non-energy aspects of technology or system innovation:
	This study deals completely with education needs of the construction industry.
7.	Potentially important references not previously cited:
	The 3-page Bibliography provided in the Appendix is an excellent summary of what is currently available even though, unfortunately, the authors conclude that it is too little and too out of date.
8.	Additional comments or summaries of other important information:

Education Bibliography (and anticipated usefulness score)

Education Articles	Score
Laborde, Maria and Victor Sanvido. 1994. Introducing New Process Technologies into Construction Companies. *Journal of Construction Engineering and Management* 120, no. 3: 488-508.	4
Mead, Stephen P. 2001. Developing Benchmarks for Construction Information Flows. *Journal of Construction Education* 6, no. No. 3: 155-66.	2
Morgenstern, R. D. and S. Al-Jurf. 1999. Can Free Information Really Accelerate Technology Diffusion? *Technological Forecasting and Social Change* 61, no. 1: 13-24.	2 (na)
Nadel, Barbara A. Building Products: How Architects Find Ideas and Information. *Architectural Record*: Advertising Supplement provided by McGraw-Hill, [http://archrecord.construction.com/ resources/conteduc/archives/0312sweets-1.asp.]	2
Rowings, James E., Mark O. Federle and Sara A. Birkland. 1996. Characteristics of the Craft Workforce. *Journal of Construction Engineering & Management* 122, no. 1: 83-90.	1
Toole, T. M. 1998. Uncertainty and Home Builders' Adoption of Technological Innovations. *Journal of Construction Engineering and Management* 124, no. 4: 323-32.	1
Mulligan, Donald E. and Kraig Knutson. 2000. Construction and Culture: A Built Environment. *Journal of Construction Education* 5, no. 2: 116-22.	
Song, J., P. Almeida and G. Wu. 2003. Learning-by-Hiring: When is Mobility More Likely to Facilitate Interfirm Knowledge Transfer? *Management Science* 49, no. 4: 351-65.	
Education Books	
Construction Education: The Bright New World of E-Learning. 2002. Alexandria, VA: Society of Marketing Professional Services.	1
Education Reports	
Burnett, Eric, Jr. and Robert W. Buddenbohn. 1999. *Training and Education Needs Assessment for the Home Building and Remodeling Industry in Pennsylvania*, Pennsylvania Housing Research Center, University Park, PA.	4
Anderson, Soren T., Newel, R. G. 2003. *Information Programs for Technology Adoption*, Resources for the Future, Washington, DC.	added

Appendix A: Literature Review Summary Sheets
Industry Participant Preferences

Topic: Industry Participant Preferences
Reference: Torbica, Zeljko M. and Robert C. Stroh. 2001. Customer Satisfaction in Home Building. Journal of Construction Engineering and Management 127, no. 1: 82-86.
Reviewer: Wiw

1.	Scope and content of the reference:
	New residential housing spending is greater than $200B annually. 1.2M-1.5M new units needed annually to meet population growth demand (augmented by government promotion of home ownership as a societal goal). Home builders are focusing on customer satisfaction to gain competitive advantage. Study seeks to identify variables affecting home-buyer satisfaction, relative weights, and what improvements would have greatest impact. Traditionally, company performance was based solely on "completion within schedule and budget." Recently, quality and customer satisfaction have been added to financial metrics as measures of company performance. Regression analysis indicates that 70% of the variation in overall home-buyer satisfaction is attributable to variation in design, quality, and service variables.
2.	Any theoretical model of innovation and/or barrier operation to consider based on the work:
	A home-buyer satisfaction model consisting of 3 components is proposed: product performance, as represented by both house design and house quality, and service performance (customer service provided by the builder before, during, and after product delivery). The model assumes that satisfaction encompasses the experience surrounding acquisition in addition to the product itself. Often service is overlooked as an element of what a firm is selling. The components are independent in that performance in one aspect does not compensate for lack of performance in the others.
3.	How the reference helps define one or more of the four relevant categories of barriers:
	Current literature suggests product and service performance and customer expectations as prerequisites to customer satisfaction. In construction, customer satisfaction is known, if at all, only very late or after completion of product delivery.
4.	How the reference better defines the extent to which consumers (builders at one level, ultimately home buyers) participate in making decisions or creating barriers:
	A survey instrument consisting of 51 separate measures was developed. After examination of reliability and validity of the measures, a Likert-type scale was employed to represent the range of possible responses to each. Measures outside home builder control (competitor strength, for example) were excluded. 16 of 20 randomly selected builders from 50 largest Florida builders participated in ensuing survey. Overall satisfaction was not directly assessed, but inferred from scores on 3 dimensions described above design, quality, service). Regression indicates that the service component has the greatest impact on overall satisfaction, about twice the influence of design factors, three times that of quality factors. Conversely, consumers are least satisfied with service, followed by quality, and most satisfied with house design factors.
5.	How the reference supports the presented conclusions with reliable and sufficient experiential data:
	Comprehensive survey and significant response rate.
6.	How the reference differentiates energy and non-energy aspects of technology or system

	innovation:
	Not applicable.
7.	Potentially important references not previously cited:
	Esccles, Maloney (16 in all)
8.	Additional comments or summaries of other important information:

Topic: Industry Participant Preferences
Reference: McNulty, Maureen. 2003. The Anatomy of Innovation. Professional Builder 68, no. 6: 47-50.
Reviewer: W

1.	Scope and content of the reference:
	Case study of small-scale builder innovation focusing on energy technologies and performance.
2.	Any theoretical model of innovation and/or barrier operation to consider based on the work:
	None.
3.	How the reference helps define one or more of the four relevant categories of barriers:
	Alludes to the difficulty in communication and collaboration among on site trades when integrating innovation with standard practices. Guidance is surprisingly general in nature and simplistic given apparent builder audience (adoption of innovation involves complex business decisions regardless of firm scale?).
4.	How the reference better defines the extent to which consumers (builders at one level, ultimately home buyers) participate in making decisions or creating barriers:
	Reinforces notion of strong builder role in implementing nearly continuous incremental innovation on-site.
5.	How the reference supports the presented conclusions with reliable and sufficient experiential data:
	None.
6.	How the reference differentiates energy and non-energy aspects of technology or system innovation:
	Almost exclusively energy technology focused (somewhat surprising given PATH as source).
7.	Potentially important references not previously cited:
	None.
8.	Additional comments or summaries of other important information:

Topic: Industry Participant Preferences
Reference: Sirmans, G. Stacy, Kenneth G. Bacheller and David A. Mcpherson. 2003. The Value of Housing Characteristics, National Center for Real Estate Research, National Association of Realtors, Washington, DC.
Reviewer: Wiw

1.	Scope and content of the reference:
	Property value is affected by physical characteristics and location, conditions of sale, market conditions, and financing. Hedonic regression analysis is used to explain value as well as estimate it. (Hence, valuation of characteristics may be considered an objective measure of buyer preferences.) Oaxaca decomposition determines the extent to which property price differences in different areas result from differences in characteristics or differences in pricing of characteristics.
2.	Any theoretical model of innovation and/or barrier operation to consider based on the work:
	The study evaluated ~29k transactions and develops an empirical model to estimate the value of a number of property characteristics.
3.	How the reference helps define one or more of the four relevant categories of barriers:
	Indirectly only. Cultural values as represented by buyer preferences.
4.	How the reference better defines the extent to which consumers (builders at one level, ultimately home buyers) participate in making decisions or creating barriers:
	A limited number of products/systems are recognized as characteristics within the study, perhaps implying that innovations may rarely elevate to buyer concerns that will affect property valuation and price. Included are exterior finish, roof material and pitch, wiring capacity, HVAC and cooking fuels, ceiling and attic fans, water treatment, security and cable TV systems, floor surfaces, and kitchen appliances.
5.	How the reference supports the presented conclusions with reliable and sufficient experiential data:
	Comprehensive data and analysis.
6.	How the reference differentiates energy and non-energy aspects of technology or system innovation:
	Not applicable.
7.	Potentially important references not previously cited:
	Extensive, though unlikely directly applicable (~180 references in all).
8.	Additional comments or summaries of other important information:

Topic: Industry Participant Preferences
Reference: Koebel, Theodore. 2003. The Diffusion of Innovation in the Residential Building Industry, Virginia Polytechnic and State University, Blacksburg, VA
Reviewer: Wiw

1.	Scope and content of the reference:
	Seminal study with implications across many topics—cultural values aspect of results focuses on builder preferences, communication, and innovation adoption practices. Industry concentration, while often described as diffuse, exhibits classic Pareto distribution, largest 20% of firms produce 80% of new housing. (Trend appears to be toward increasing concentration as large firms become larger, largest 10% produce 66%?) Recommends research and promotion targeting extended to early adopters and early majority even though representing up to 50% penetration. (Can this level of adoption support 'innovation' characterization?)
2.	Any theoretical model of innovation and/or barrier operation to consider based on the work:
	Bass diffusion model (s-curve distribution). Rogers' model of innovation adoption: innovators, early adopters, early majority, late majority, laggards. Rogers' and Shoemaker's information awareness model: awareness, interest, evaluation, trial, adoption.
3.	How the reference helps define one or more of the four relevant categories of barriers:
	Demographic information may be useful for fragmentation. Builder preferences will be determinant in evaluating (builder) cultural values.
4.	How the reference better defines the extent to which consumers (builders at one level, ultimately home buyers) participate in making decisions or creating barriers:
	Innovation information sources rated influential to highly influential: sales/supplier reps, 84%; subcontractor advice, 75%; trade publications, 67%; homebuyers, 60%; other builders, 59%. Segmented further by stage of diffusion. Highest rated benefits of innovations: quality compared to alternatives, reduced call-backs, compatibility with preferred practices, and consumers' preferences. Highest rated potential problems: initial cost, continuing cost, acceptance by inspectors, and uncertainty/risk. Analysis of diffusion of construction technologies shows dramatic increases for ten technologies tracked by the NAHB annual builder practices survey. Comparison of average prices shows cost above average for 8 of ten technologies.
5.	How the reference supports the presented conclusions with reliable and sufficient experiential data:
	Robust and comprehensive survey, multivariate analysis, and report of results. However, data tables seem more fruitful than the combination variable analysis and conclusions for higher and lower levels of adoption. The sample was not stratified by firm size, which may be very important to ultimate rate of adoption of innovation (Pareto and demographics)—it may be instructive to revisit the data and weight responses by number of employees or annual house production.
6.	How the reference differentiates energy and non-energy aspects of technology or system innovation:
	Not applicable.
7.	Potentially important references not previously cited:
	Bass, Rogers (~80 in all).
8.	Additional comments or summaries of other important information:

Industry Participant Preferences Bibliography (and anticipated usefulness score)

Preferences Articles	Score
Torbica, Zeljko M. and Robert C. Stroh. 2001. Customer Satisfaction in Home Building. *Journal of Construction Engineering and Management* 127, no. 1: 82-86.	3
McNulty, Maureen. 2003. The Anatomy of Innovation. *Professional Builder* 68, no. 6: 47-50.	2
Brown, M. A. 1980. Attitudes and Social Categories - Complementary Explanations of Innovation-Adoption Behavior. *Environment & Planning A* 12, no. 2: 175-86.	1
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Brown, M. A. 1984. Change Mechanisms in the Diffusion of Residential Energy-Conservation Practices - An Empirical-Study. *Technological Forecasting and Social Change* 25, no. 2: 123-38.	
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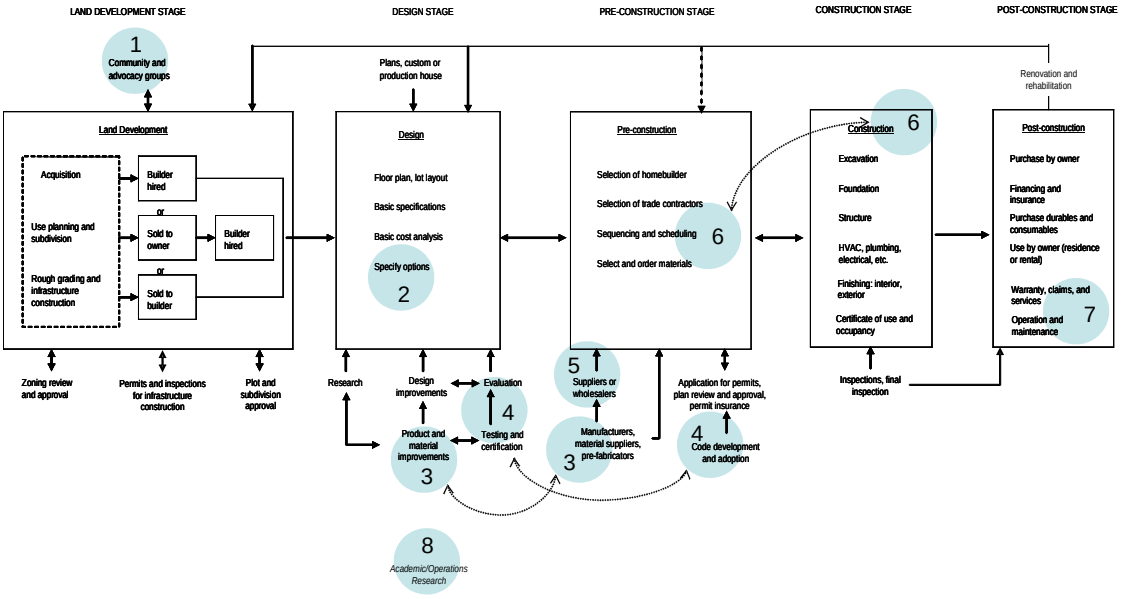
Preferences Reports	
Sirmans, G. Stacy, Kenneth G. Bacheller and David A. Mcpherson. 2003. *The Value of Housing Characteristics,* National Center for Real Estate Research, National Association of Realtors, Washington, DC.	3
Sirmans, G. Stacy, Kenneth G. Bacheller and David A. Mcpherson. 2003. *The Composition of Hedonic Pricing Models, A Review of the Literature,* National Center for Real Estate Research, National Association of Realtors, Washington, DC.	added
Koebel, Theodore. 2003. *The Diffusion of Innovation in the Residential Building Industry,* Virginia Polytechnic and State University, Blacksburg, VA	added

Appendix B: Seat by Area

For "Risk as a Barrier to Innovation," eight critical seats at the table were identified, with builder perspectives represented by both national and regional firms.

- Seat #1-Community Advocacy Group (Architectural Review Board)
- Seat #2- Errors and Omissions Insurance for Architects and Engineers
- Seat #3-Manufacturer: Legal/Insurance/Finance
- Seat #4-Evaluation/Testing/Codes
- Seat #5-Supplier/Wholesaler
- Seat #6a-National Builder, and Seat #6b-Regional Builder
- Seat #7-Inspection Services
- Seat #8-Academic/Operations Research

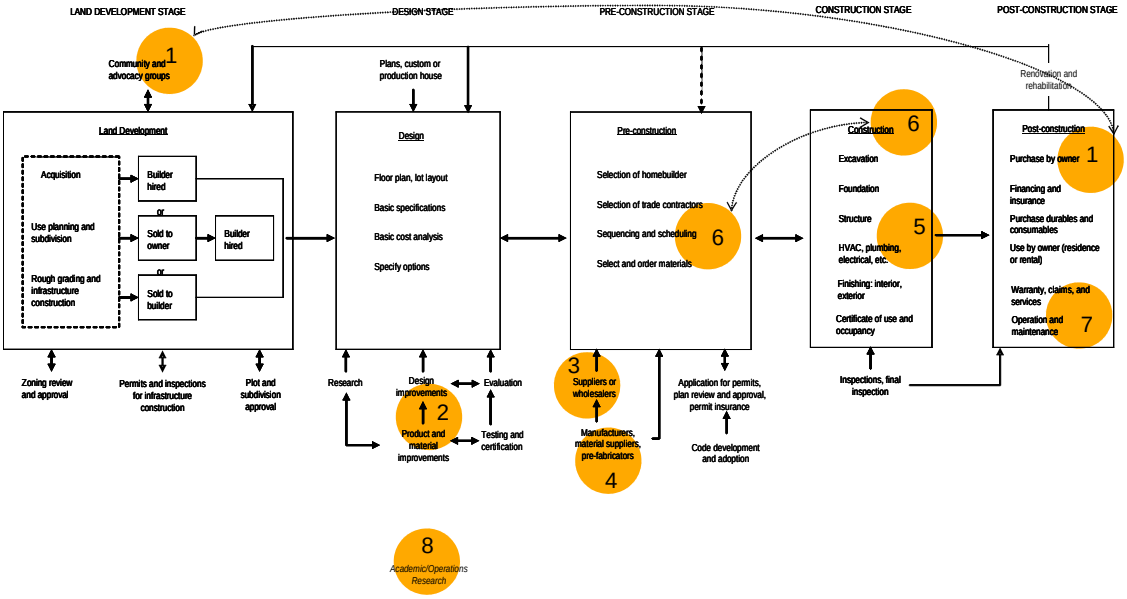
Risk 'Seats'



For "Preferences as a Barrier to Innovation," eight critical seats at the table were identified:

- Seat #1- Owner Advocate/Appraiser
- Seat #2- Designer/AE
- Seat #3- Supplier (Shipper/Wholesaler/Retailer)
- Seat #4- Manufacturer: Market Research
- Seat #5-Trades/Unions Representative
- Seat #6- Builder
- Seat #7- Consumer Protection (CPSC)
- Seat #8-Academic/Operations Research

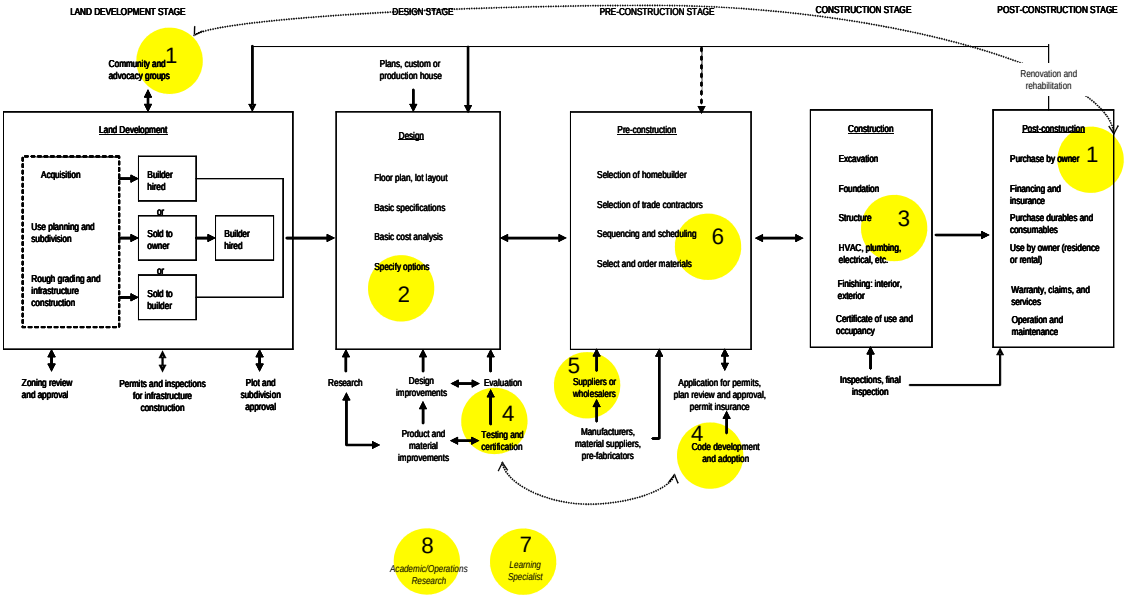
Preference 'Seats'



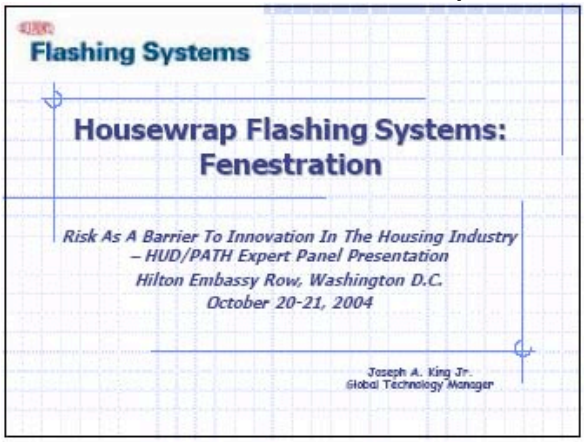
For "Education/Communication as a Barrier to Innovation," eight critical seats at the table were identified:

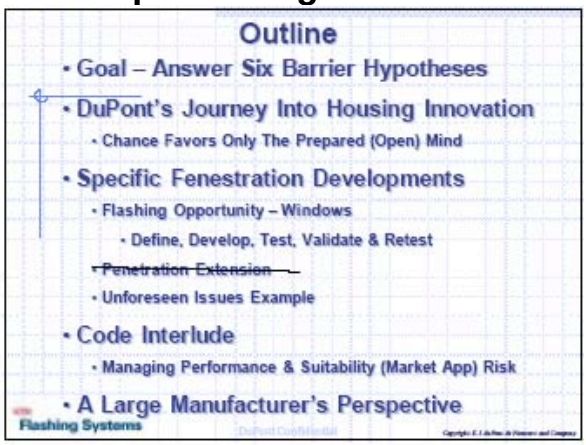
- Seat #1- Media: Real Estate
- Seat #2- Specifier
- Seat #3- Trades/Unions
- Seat #4- Evaluation/Testing/Codes
- Seat #5- Supplier (Buyer)
- Seat #6 - Builder
- Seat #7- Learning Specialist
- Seat #8-Academic/Operations Research

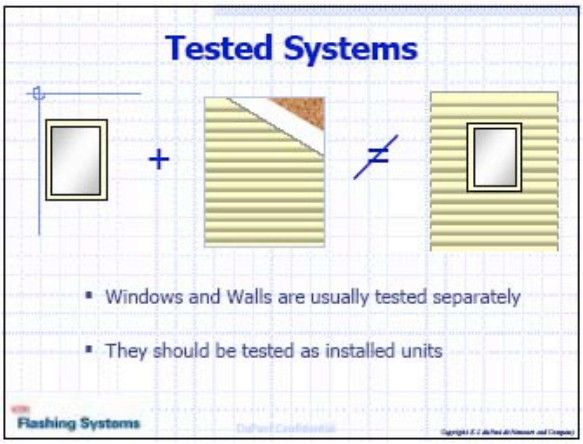
Education/Communication 'Seats'

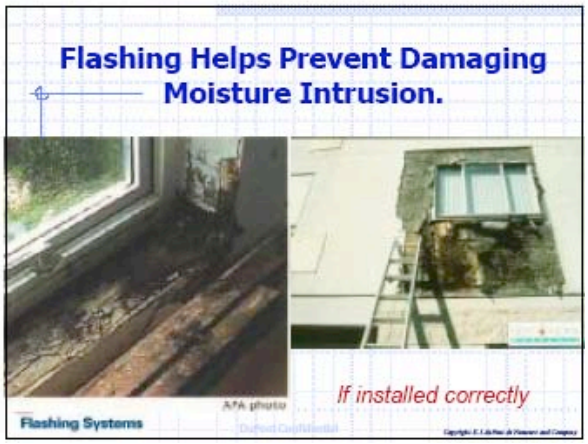


Appendix C: Innovation Presentations
Risk Panel, DuPont Housewrap Flashing









Market Risk Mitigation:
Understanding Market Needs & Habits

Focus Groups
Current Situation

Focus Groups
Value Proposition for Development Candidates

Windows/Doors
& sills are problem areas

Flashing Systems

Market Opportunity For Improved Flashing?

- Water intrusion at windows and doors is a serious issue
  - Major source of litigation / new legislation
  - Majority of problems related to improper installation
- Strong fit with Tyvek® Weatherization Systems offering and core focus
- Requested by our customers.
- Large Market Space w/ no clear market leader

Flashing Systems

Market & Performance Risk Mitigation via Systematic Product Development Process

Focus Groups	Builder/Installer Opinions on Current Products
Diagnostic Wall Test	Analysis of Current Products/ Installation Methods
R&D	Development Candidates
Focus Groups	Value Proposition, Likes/Dislikes
Performance Wall Test	Performance of New Product vs. Current Products

Flashing Systems

Performance Risk Mitigation: Concurrent Development of Flashing Material and Installation Method

Material Concept Development:

Focus Group Concept Evaluation

Material and Process Development

Installation Development

Diagnostic Wall Test - Standard Installation Techniques

Performance Testing of Material / Installation System

Flashing Systems

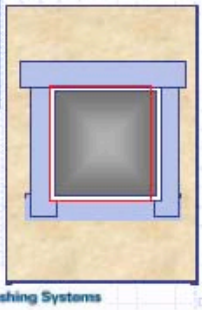
Understand Current Window Installation & Flashing Details: Diagnostic Wall Test

- Existing materials
  - Polyethylene coated paper / non-adhesive
  - Bitumen
- Existing methods
  - 2-D (Flange) flashing
  - 3-D (Wrapped Opening) flashing
  - Windows installed before and after weather barrier

Flashing Systems

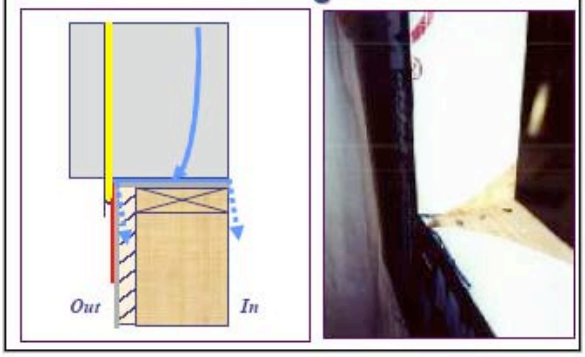
Traditional Window Flashing Methods

ASTM E2112 Base Method - Barrier System



Flashing Systems

2-D Flashing / Caulked Bottom Flange



Barrier System Caulking and Flashing does not "forgive" leaks at the window and window-wall interface

Benchmarking Test - Key Learnings

- Framing Quality Can Create Inconsistencies
- Ease of Working w/ Materials Impacts Mistakes
- Exterior Caulk Fails Over Time…Flashing Should be Tested Without Cladding
- Sequence to Minimize #'s of Holes in Flashing
  - Window Before Jamb Flashing
  - Minimize Fasteners on Window Jamb
- "Failures" Result in Water at Bottom Corners
  - Need Most Protection
  - Difficult to Cover without seams/holes

Flashing Systems

Market Wants Easy-to-Use, Forgiving System: Advantages Self-Adhered Flashings….

When installed and used properly, Self-Adhered Flashings:

- Provide a broad moisture seal at the window-wall interface (extension of the sealant)
- Are easy to install (peel and stick)
- Are versatile for many different installation methods and openings (shapes / sizes / etc)
- Maintain their seal through joint movement between dissimilar materials (durable topsheet)
- Provide a much more durable seal than a caulk joint (which is the basis for non-SAF methods)

Flashing Systems

But . . . there are also Concerns about Self-Adhered Flashing (SAF) Products

- "It doesn't always stick" (many examples of SAFs falling off the wall)
- "How do I know SAFs are still working effectively behind the siding after many years of thermal cycles & environmental exposure?"
- Self-Adhered Flashings can ooze and result in staining cladding surfaces & interactions with caulk
- Lack of a standard for material properties - anything can be a SAF
- Lack of a standard for installation conditions to ensure performance

Flashing Systems

Mitigating Performance Risk:
Keys to Successful Use of Self-Adhered Flashing Products

- Continuity of window-wall interface
- Shingling / lapped correctly
- Installed Systems Testing: window-wall installation as a complete system
- Moisture Management: Provide a Drainage Path for leaks
- Installation conditions (real life) that promote adhesion
- Material choice - durability & robustness
- Education: Provide hands-on training & support on site

Flashing Systems

DuPont Flashing Systems

- DuPont FlexWrap™ was commercialized in Feb of 2001
  - Primary application is for sills, round top and custom shapes
- DuPont StraightFlash™ commercialized June 2002
  - Designed to complement FlexWrap™ and be used where conformability is not required
  - 4" product designed to flash the jambs and heads of rectangular window

Flashing Systems

DuPont FlexWrap™

Flexes to conform or mold to any geometric shapes

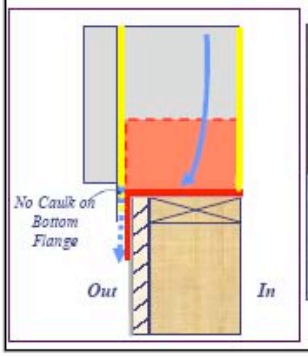
Flashing Systems

DuPont StraightFlash™

- Complementary product to complete system
- Designed for straight runs where conformability is not required
- Consists of non-elastic laminate and butyl adhesive

Flashing Systems

3-D Flashing / Bottom Flange Not Caulked

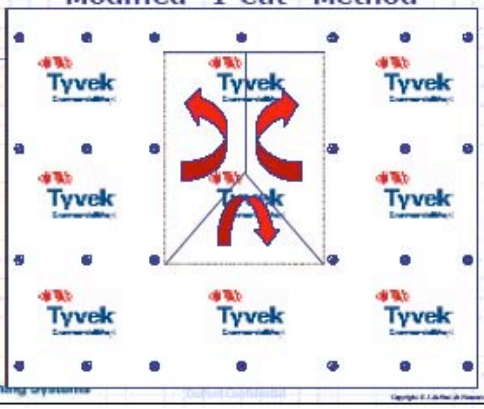


Detailed Installation Techniques

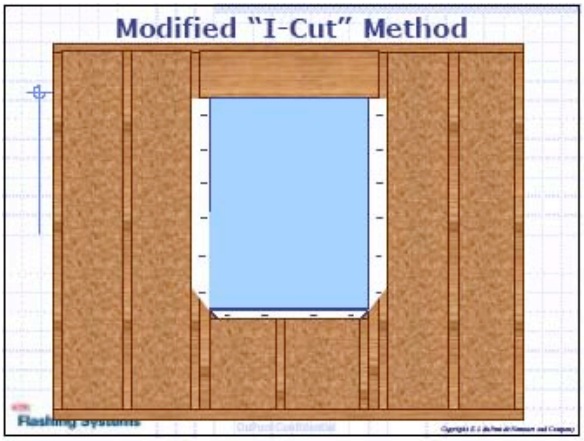
Example: Flanged window / wood frame after the weather resistive barrier has been installed.

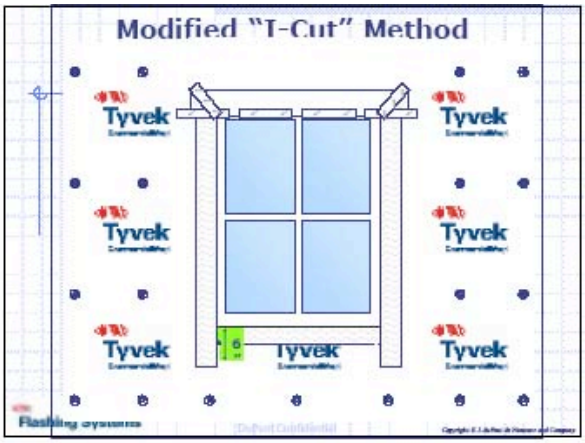
Flashing Systems

Modified "I-Cut" Method



Flashing Systems


Modified "I-Cut" Method
Flashing Systems


Modified "I-Cut" Method
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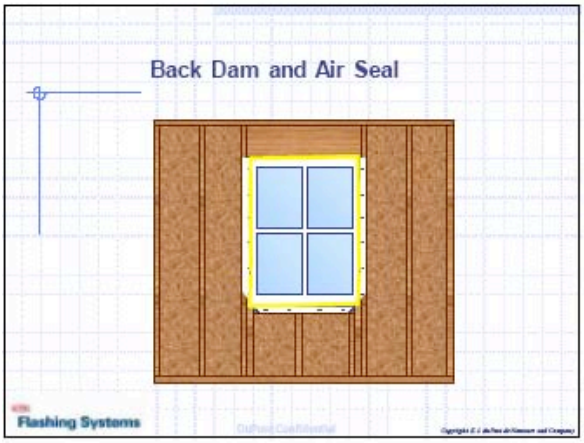
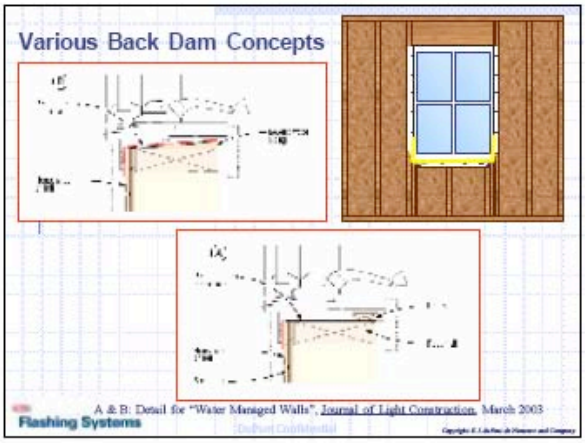
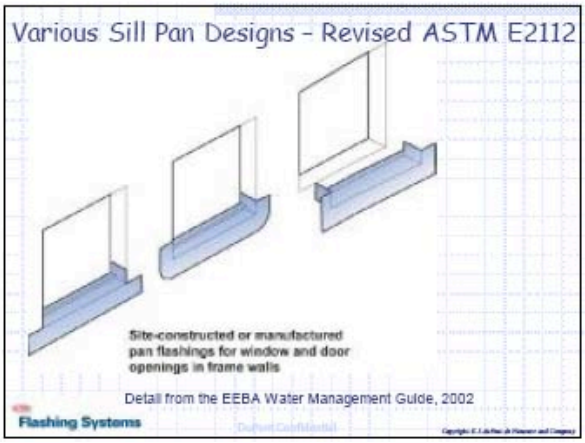
Flashing Systems

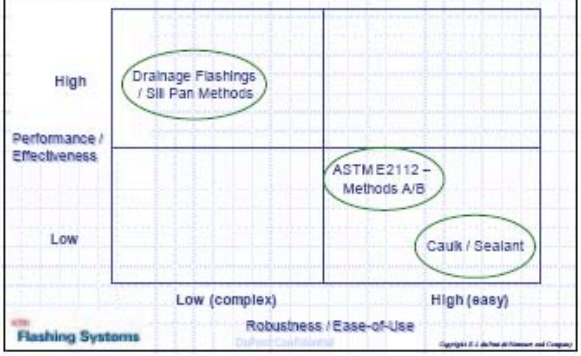

Back Dam and Air Seal
Flashing Systems


Various Back Dam Concepts
A & B: Detail for "Water Managed Walls", Journal of Light Construction, March 2003
Flashing Systems


Flexible Sill Pan With Back Dam – Not Yet Required, But A Good Idea
Insulation foam with FlexWrap™ sill pan
Sill pan should Always drain to Weather-Resistive Barriers
Readily drains to the front
Flashing Systems


Various Sill Pan Designs - Revised ASTM E2112
Site-constructed or manufactured pan flashings for window and door openings in frame walls
Detail from the EEBA Water Management Guide, 2002
Flashing Systems

Market Adoption Risk:
The Evolution of Window Installation Methods



Flashing Systems

Detailed Testing & Development

Flashing Systems

Installation Method / Material Development

- Protect bottom corners into the rough opening
- "Moldable" Self-adhesive flashing (SAF)
  - seamless 3-dimensional flashing on sill and 6" up either side rough opening
  - single piece continuous head flashing for round-top window applications.
- Creation of a weep system by not applying caulk on bottom flange
- Self-adhesive flashing applied over jamb and head flanges.
- Air seal and back dam by interior caulk joint

Flashing Systems

Installed Window – Wall Testing Protocol

REF: Weston T. A., et al. "Performance Testing of Window Installation and Flashing Details" 2002 Symposium on Improving Building Systems in Hot & Humid Climates, May

Flashing Systems

Wall System Testing Goals

- **Phase I** : Installation Method and Performance Specification
- **Phase II**: Durability of Installed Product
- **Phase III**: Installation Variants

Flashing Systems

Phase I : Installation Method and Performance Specification

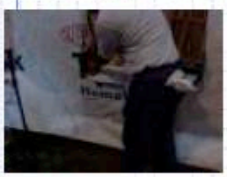
Air Infiltration / Exfiltration Test (ASTM E283)
Measure infiltration and exfiltration at
.1" H_2O (25 Pa) (15 mph)
.3" H_2O (75 Pa) (25 mph)
1.2" H_2O (300 Pa) (50 mph)

Water Infiltration (ASTM E331)

- Standard water flow rate
- Infiltration pressure of .1" H_2O (15 mph) for 15 min
- Infiltration pressure of .3" H_2O (25 mph) for 15 min
- Moisture sensors will be installed and monitored during spraying along with visual observations.

Flashing Systems

Phase I : Installation Method and Performance Specification



Flashing Product
- FlexWrap™ prototypes
- Competitive products

Installation Methods

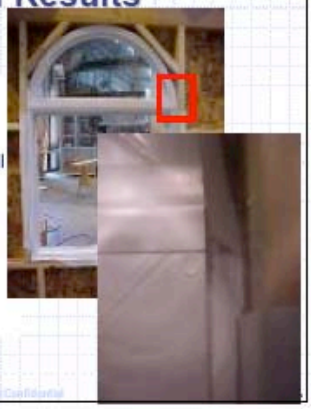
Window installation
- before WRB
- after WRB

Window type
- flanged
- non-flanged

Flashing Systems

Phase I Results

- FlexWrap™ / installation performed well- no leaks
- Water leaks occurred at mull joint
- Caulk positioning provided "forgiveness" for window leak



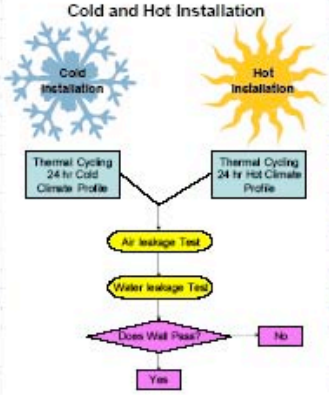
Flashing Systems

Phase II - Durability

- Repeat Air Infiltration / Exfiltration
- Repeat Water Infiltration
- ASTM E 330 – Wind Loading
  - Infiltration load at 2" H_2O (65 mph) for 1 hour
  - Exfiltration load at 2" H_2O (65 mph) for 1 hour
- Repeat Water Infiltration

Flashing Systems

Cold and Hot Installation



- Condition materials for minimum of 1 hour
- Install window
- Thermal cycle for 24 hours
- Test Air Infiltration / Exfiltration (ASTM E 283) and Water Leakage (ASTM E 331)

Phase II: Durability

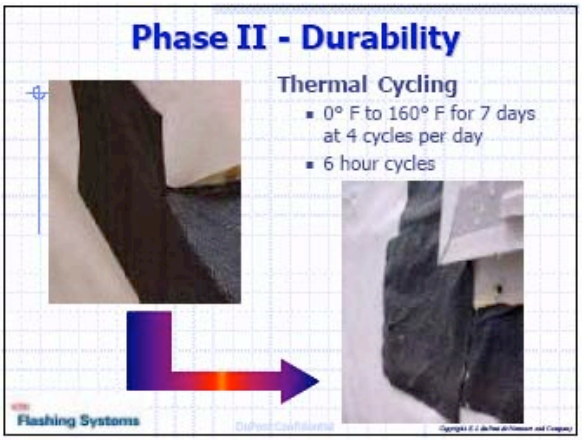
Thermal Cycling
0'F – 160 'F, seven days cycling

6 hour cycles

Accelerated aging +
ASTM E1677 evaluation

Retest walls for water and air infiltration

Flashing Systems


Phase II - Durability
Thermal Cycling
0° F to 160° F for 7 days at 4 cycles per day
6 hour cycles
Flashing Systems

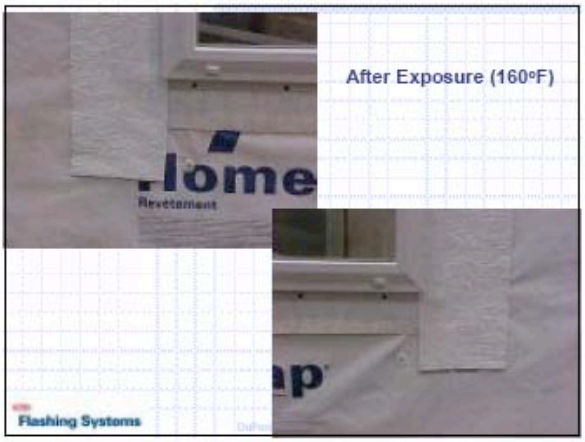

What Temperature Exposures Do SAFs Experience After Installation?
Measured on wood siding on 80° F day in Northern California
Flashing Systems


Window after 180°F exposure
Flashing Systems


Traditional Peel 'n Stick after Thermal Cycling
Flashing Systems


As Installed
After Air, Water, Durability and Thermal Exposure
Flashing Systems


After exposure (160°F)
Flashing Systems



Chemistry of Butyl vs Asphalt (Bitumen) Based Adhesive Systems

Flashing Systems

Asphalt Basics

- Natural products
  - Has been in use since 625 B.C.!
  - From asphalt lakes/deposits or heavy oil of petroleum
  - Complex mixture of organic compounds with high unsaturation
  - Relative low molecular weight
  - May contain nitrogen, sulfur, heavy metals in additional to carbon, hydrogen and oxygen
  - Inherent unpleasant odor

- Key applications
  - Road building materials
  - Roofing felt
  - Sealants

Flashing Systems

Asphalt-based Adhesives

- Key advantages:
  - Cheap!
- Key issues:
  - Narrow operating temperature range
    - Brittle/poor adhesion at low temperature
    - Ooze/flows at high temperature
  - Poor chemical stability
    - Sensitive to UV radiation
    - Sensitive to thermal aging
  - Stains easily
  - Adhesives may become brittle overtime due to loss of VOC
  - Questionable seal overtime
  - Unpleasant odor

Flashing Systems

Butyl Rubber Basics

- Synthetic elastomers
  - First commercialized in 1942
  - Monomers: isobutylene (>95%) and isoprene (<5%)
  - Low/no unsaturation, little by-products
  - Many grades available to cover a broad molecular weight range (both cured and uncured)
- Key applications
  - Inner tubes for tires
  - Sealants (windows)
  - Automotive suspension bumpers
  - Electrical insulation
  - Rubber sheeting for external use
  - Elastomeric seal for hydraulic systems

Flashing Systems

Butyl Rubber-based Adhesives

- Key advantages
  - Broad operating temperature window
    - Flexible/good adhesion at low temperature
    - Resists oozing/flowing at high temperature
  - Excellent chemical/physical adhesion to substrates
    - Adhesion grows with time -- repositionability!
  - Excellent weather resistance
  - Excellent chemical/moisture resistance
  - Excellent stretchability
  - No solvents/VOCs
  - No odor
- Key disadvantages
  - More expensive

Flashing Systems

Performance Comparisons

	Butyl Adhesives	Modified Asphalt Adhesives*
1) Use Temperature Range		
Low temperature flexibility	good to excellent	poor to good
High temperature flow-resistance	stable to 180+ F	ozzes above 120-140 F
2) Chemical stability		
UV-stability	stable	causes degradation
Thermal Aging	stable above 200 F	causes degradation
Compatibility with sealants / substrates	generally inert	poor with solvents & elastomers
3) Adhesive performance		
Repositionability	generally yes	no
Product stains	not likely	yes
4) Sealability performance	stable over time	time dependant - can become brittle
5) Product ingredients	synthetic - easy to control	natural - hard to control (often waste stream)
6) Product odor	no	strong

* Note: Depending on specific formulation, the performance of polymer-modified Asphalt could be better than described here in general.

Flashing Systems

Potential Performance Issues

- Adhesive Durability - Why Butyl?
- Caulk Compatibility
- Enhancing performance with primers

Flashing Systems

Durability Considerations of Self-Adhered Flashings

Must withstand UV exposure until covered by siding (per manufacturer's recommendation)

Must be able to maintain adequate adhesion and moisture seal through environmental cycles (temperature and moisture exposure)

Must maintain integrity (adhesive & topsheet) through thermal cycles and resulting joint movement / settling of building

Flashing Systems

Competitive Products after Accelerated UV Aging for 14 days in Atlas Weatherometer

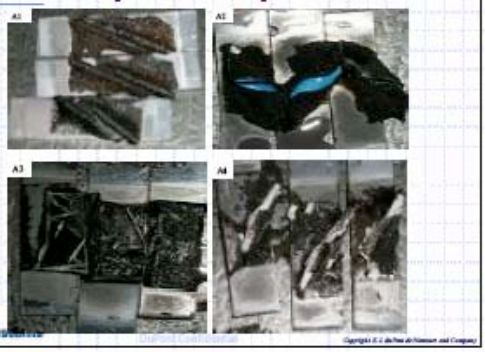
Flashing Systems

Weatherometer Flashing Testing – Samples adhered to rigid vinyl

- Cycle:
  - 120 min light (70ºC - 50% RH)
  - 60 min dark (38ºC - 95% RH)
  - 40 min light (70ºC - 50% RH)
  - 20 min light + front spray (70ºC, 45ºC H_20@12ºC wet bulb)
  - 60 min light (70ºC - 50% RH)
  - 60 min dark + back spray (38ºC, 45ºC H_20)
- The above cycle generates 32kJ/day of energy

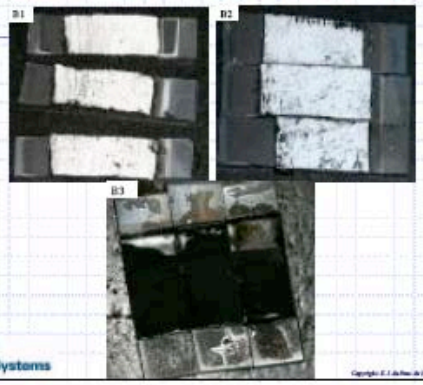
Flashing Systems

14 Week Exposure – Modified Asphalt Samples



Flashing Systems

14 Week Exposure – Butyl Samples



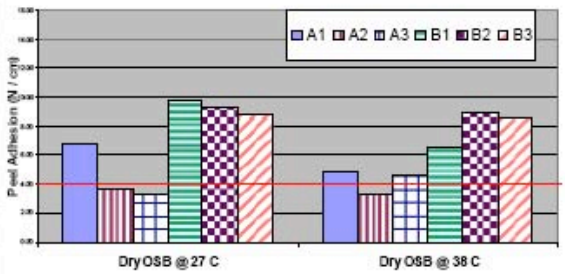
Flashing Systems

Field Examples of Oozing & Degradation of Asphalt Based Self-Adhered Flashings

What is an Acceptable Adhesion Level?

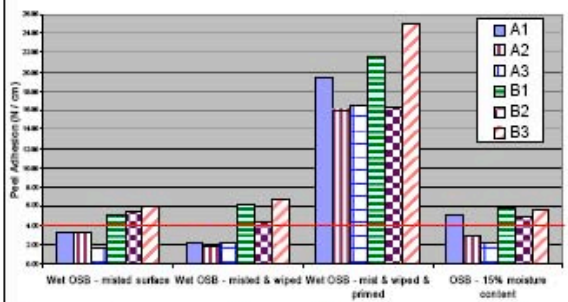
- End use requirement: Does the SAF adequately stick to the wall and maintain its moisture seal?
- No performance based measurement exists
- Examined several substrates at a range of temperatures and surface conditions (moist, dusty)
- Full Study reported at ASTM Symposium on the Performance and Durability of the Window-Wall Interface, Salt Lake City, April 18, 2004

Adhesion Test Results: Dry OSB at 27°C & 38°C (77°F & 100°F)



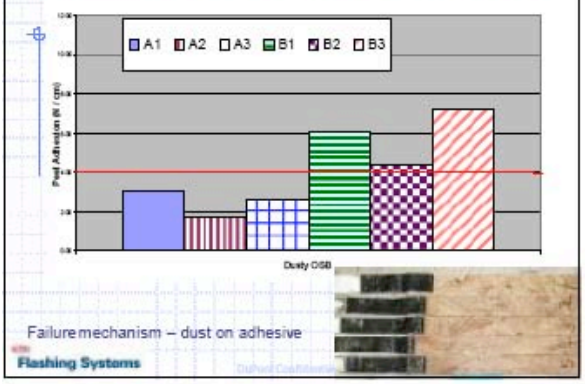
Flashing Systems

Adhesion Test Results: Wet OSB at 27°C



Flashing Systems

Adhesion Test Results: Dusty OSB at 27° C



Failure mechanism – dust on adhesive

Flashing Systems

Building Code Purpose

Sets forth requirements to protect public health, safety and general welfare as they relate to construction and the occupancy of a building. These codes include specific requirements for building materials, fire protection, **weather protection (moisture, wind),** structural design, light and ventilation, heating and cooling, sanitary facilities and **energy conservation.**

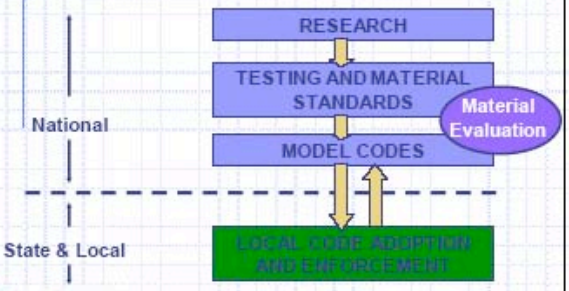
Flashing Systems

Future Flashings Market Risk

- Trend towards recommending pan flashings
  - ASTM E 2112, EEBA Water Management Guide
- Requirements increasingly shifting toward window manufacturer specifications
  - California SB800 and "right-to-correct laws"
  - ASTM E 2112
  - IRC

Flashing Systems

Code Development and Implementation



Flashing Systems

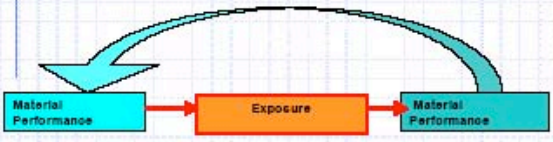
Materials / Systems Can Comply With Code Three Ways:

- Compliance to a direct reference
- Compliance through a referenced standard
- Compliance as an approved alternate material

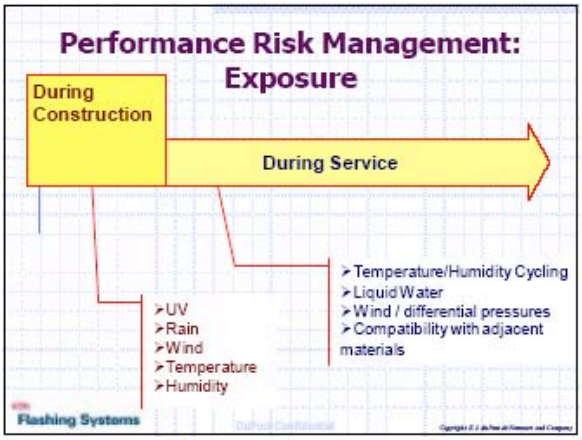
Product Developers Need To Understand How To Use This To Their Advantage

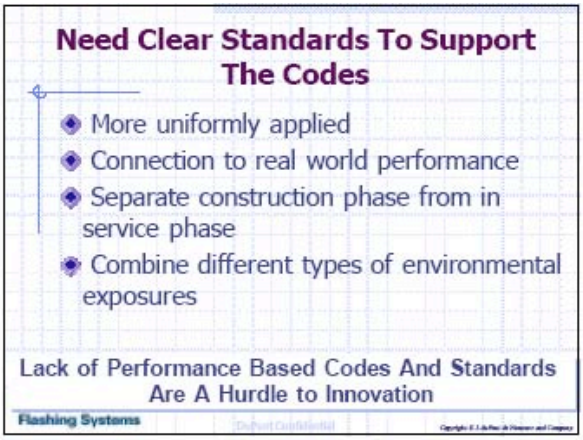
Flashing Systems

Performance Risk Management: Durability – Standards Development



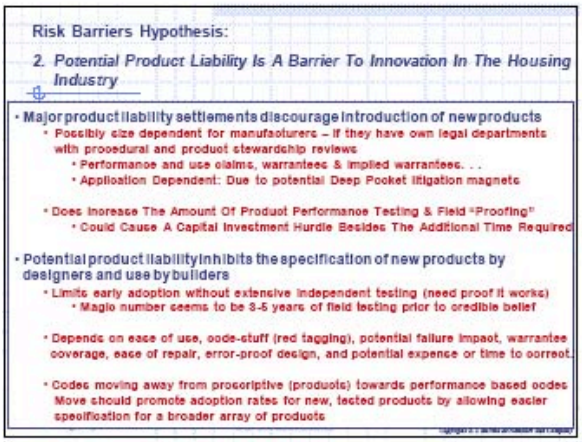
Flashing Systems


Performance Risk Management: Exposure
During Construction
During Service
➢UV
➢Rain
➢Wind
➢Temperature
➢Humidity
➢Temperature/Humidity Cycling
➢Liquid Water
➢Wind / differential pressures
➢Compatibility with adjacent materials
Flashing Systems

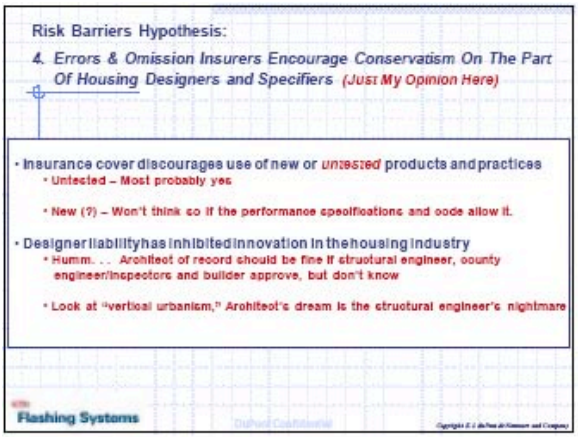

Need Clear Standards To Support The Codes
More uniformly applied
Connection to real world performance
Separate construction phase from in service phase
Combine different types of environmental exposures
Lack of Performance Based Codes And Standards Are A Hurdle to Innovation
Flashing Systems

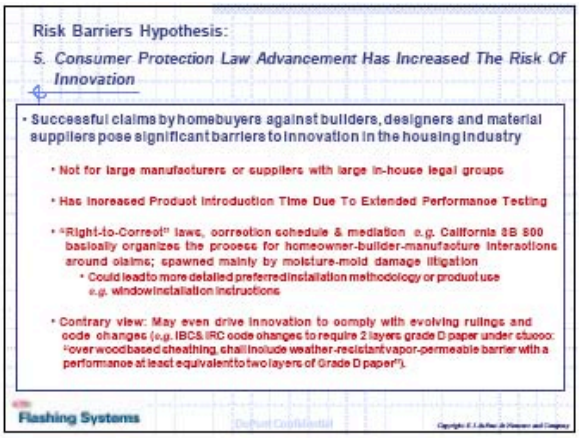

Risk Barriers Hypotheses: Fredrick Krimgold's Initial 6 Categories
- Highly Perspective Dependent -
Designer/Specifier
Builder
Manufacturer
Owner/Funder
1. Small
Medium
Large
DuPont
Goal
6. Small
Medium
Large
DuPont
Flashing Systems

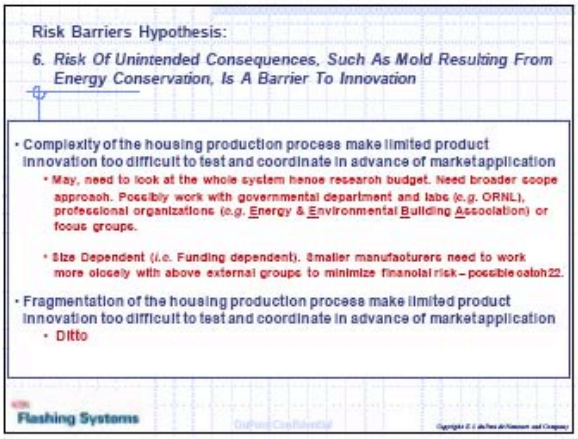

Risk Barriers Hypothesis:
1. Market Risk Is A Significant Barrier To Innovation In The Housing Industry
• Venture Capital Is Difficult To Acquire (Size Dependent)
• Not For Larger Manufactures, Suppliers, National Builders, Architectural Firms . . .
• For Small to Mid-size, possibly product category dependent
• Many Housing Technology Innovations Fail In The Market (One of 3 Reasons)
• Push vs. Pull with little to no market research: Internal idea vs. Mkt need
• Seduced by cleverness or "high tech" materials
• Inappropriate installation methodology or application
• Quality, supply, and distribution inappropriate or unreliable
• High Failure Rate Of Innovations Inhibits Introduction of New Products
• Size Dependent by firm and product expectation (e.g Market, Revenue, Penetration Rate, . .)
• Those firms that can afford large numbers of trials will continue sampling
• Go-to-market Strategies and tactics may change
Flashing Systems


Risk Barriers Hypothesis:
2. Potential Product Liability Is A Barrier To Innovation In The Housing Industry
• Major product liability settlements discourage introduction of new products
• Possibly size dependent for manufacturers – if they have own legal departments with procedural and product stewardship reviews
• Performance and use claims, warrantees & implied warrantees. . .
• Application Dependent: Due to potential Deep Pocket litigation magnets
• Does Increase The Amount Of Product Performance Testing & Field "Proofing"
• Could Cause A Capital Investment Hurdle Besides The Additional Time Required
• Potential product liability inhibits the specification of new products by designers and use by builders
• Limits early adoption without extensive independent testing (need proof it works)
• Magic number seems to be 3-5 years of field testing prior to credible belief
• Depends on ease of use, code-stuff (red tagging), potential failure impact, warrantee coverage, ease of repair, error-proof design, and potential expence or time to correct.
• Codes moving away from prescriptive (products) towards performance based codes Move should promote adoption rates for new, tested products by allowing easier specification for a broader array of products


Risk Barriers Hypothesis:
3. The Volatility Of The Housing Market Poses A Barrier To The Introduction Of New Products
• Markets are unpredictable and adoption rates are uncertain (product dependent)
• For manufacturers selling non-commodity products, supply and volatility of raw materials have (possibly) a bigger impact
• For builders that are contractually bound, the same is true (e.g. plywood, OSB, cement...)
• Probably shows strong regionality (e.g. silicon valley vs. San Francisco Bay Area as a whole)
• Volatile markets tend to foster conservatism in product selection (human behavior)
• Similar to the second part of hypothesis 2; builders and architects work from experience to get (within code):
• Desired performance and aesthetics
• Require more extensive 3rd Party testing or extended field trials
• Higher resistance to change local variance if not supported by current code
Flashing Systems


Risk Barriers Hypothesis:
4. Errors & Omission Insurers Encourage Conservatism On The Part Of Housing Designers and Specifiers (Just My Opinion Here)
• Insurance cover discourages use of new or untested products and practices
• Untested – Most probably yes
• New (?) – Won't think so if the performance specifications and code allow it.
• Designer liability has inhibited innovation in the housing industry
• Humm. . . Architect of record should be fine if structural engineer, county engineer/inspectors and builder approve, but don't know
• Look at "vertical urbanism," Architect's dream is the structural engineer's nightmare
Flashing Systems


Risk Barriers Hypothesis:
5. Consumer Protection Law Advancement Has Increased The Risk Of Innovation
• Successful claims by homebuyers against builders, designers and material suppliers pose significant barriers to innovation in the housing industry
• Not for large manufacturers or suppliers with large in-house legal groups
• Has Increased Product Introduction Time Due To Extended Performance Testing
• "Right-to-Correct" laws, correction schedule & mediation e.g. California SB 800 basically organizes the process for homeowner-builder-manufacture interactions around claims; spawned mainly by moisture-mold damage litigation
• Could lead to more detailed preferred installation methodology or product use e.g. window installation instructions
• Contrary view: May even drive innovation to comply with evolving rulings and code changes (e.g. IBC& IRC code changes to require 2 layers grade D paper under stucco: "over wood based sheathing shall include weather-resistant vapor-permeable barrier with a performance at least equivalent to two layers of Grade D paper").
Flashing Systems


Risk Barriers Hypothesis:
6. Risk Of Unintended Consequences, Such As Mold Resulting From Energy Conservation, Is A Barrier To Innovation
• Complexity of the housing production process make limited product innovation too difficult to test and coordinate in advance of market application
• May, need to look at the whole system hence research budget. Need broader scope approach. Possibly work with governmental department and labs (e.g. ORNL), professional organizations (e.g. Energy & Environmental Building Association) or focus groups.
• Size Dependent (i.e. Funding dependent). Smaller manufacturers need to work more closely with above external groups to minimize financial risk – possible catch 22.
• Fragmentation of the housing production process make limited product innovation too difficult to test and coordinate in advance of market application
• Ditto
Flashing Systems

Appendix C: Innovation Presentations
Risk Panel, SIPA

SIPA
Structural Insulated Panel Association

Structural Insulated Panels

HUD/PATH Barriers Research
October 20-21, 2004

Introductions

Bill Wachtler
Executive Director, COO
SIPA
Ken Hawkins
General Manager,
Premier Building Systems

Agenda

- SIPA & SIPs - definition
- Types of construction
- Market applications
- Risk assessment
- Q and A

What is SIPA ?

The Structural Insulated Panel Association (SIPA) is a non-profit association representing manufacturers, suppliers, fabricator/ distributors, design professionals, and builders committed to providing quality structural insulated panels for all segments of the construction industry.

SIPA

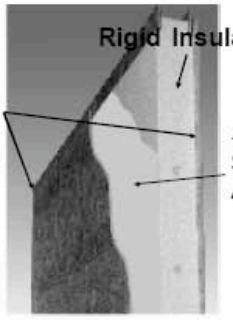
Membership

Manufacturers	29
Suppliers	33
Fabricator/Distributors	22
Associate Members	16
Builder Members	121
Design Professionals	21
Total	242

SIPA

What are Structural Insulated Panels ?

OSB Facings
Metal
Concrete



Where are we now?

Better measurements still needed but our best estimate shows....

- *51 Million sq. ft. in 2003*
- *10-15% increase annually*
- *70% residential*
- *30% commercial*
- *12,000 – 14,000 single family units*
- *2,300 – 2,500 nonresidential buildings*

Wall Systems

A Superior Building Product for Walls:

- *Fast*
- *The more complicated the design, the easier it is to build*
- *Control over materials and labor*
- *Solves problems prior to construction*
- *Straighter and truer walls*
- *Tighter construction*

Roof Systems

A Superior Building Product for Roofs

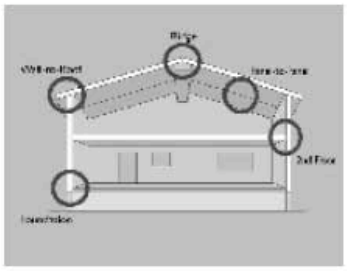
- *Cathedral and vaulted ceilings*
- *Much faster dry-in*
- *Shed roof designs*
- *Open vaulted hip roofs*
- *Greater spans*
- *Pre-insulated*
- *Engineered*

SIP Floor Systems

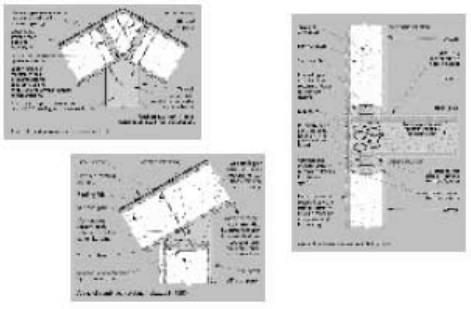
A Superior Building Product for Floors

- *Clean crawl spaces*
- *Floors that are pre-insulated*
- *Simple, easy, and fast*
- *Efficient over unconditioned garages*
- *Floors that will not squeak*

Technical

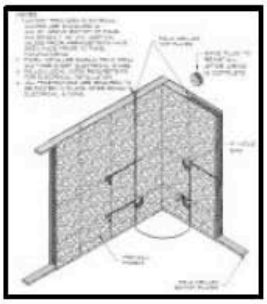


Technical



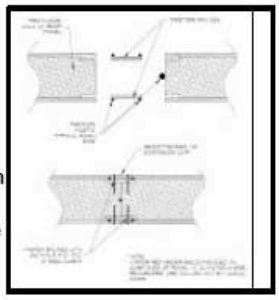
Connections

Electrical Chases



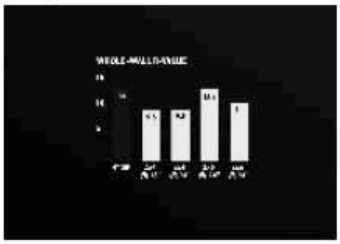
Spline Types

- Type S or Surface spline (OSB).
- This is preferred because it is a thermally broken spline.
- No heat loss through conduction.
- Not all SIP mfg. have this type spline.



Oak Ridge National Laboratory Studies

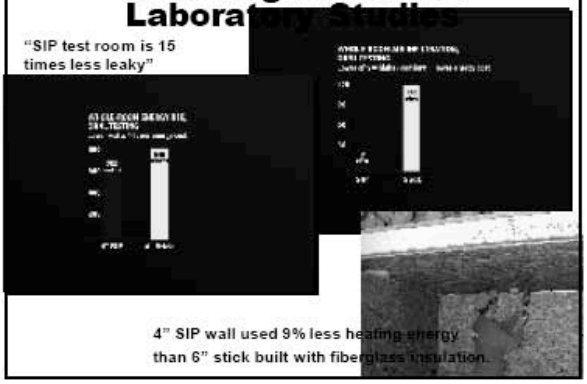
4" SIP wall out performs 6" stud wall with R-19 fiberglass



* 2X6 @ around [redacted] ompression

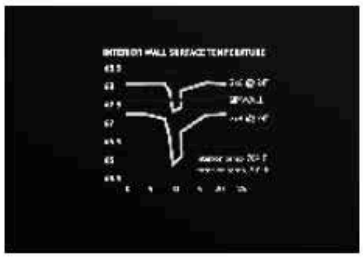
Oak Ridge National Laboratory Studies

"SIP test room is 15 times less leaky"



4" SIP wall used 9% less heating energy than 6" stick built with fiberglass insulation.

Oak Ridge National Laboratory Studies



More even temperature and comfort

3 Simple-Affordable SIP Near Net Zero Energy Houses built and occupied

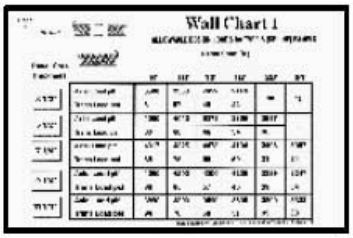
- SIPA / TVA / DOE / Habitat for Humanity
- Annual heating cost $92, cooling $74
- 45 cents per day
- 82 cents per day for total energy with plug loads

ICBO NES Compliant

Code Recognized

Load Charts

Wall load design chart for combined axial & bending.
Load charts are broken out by spline type.



Continuous Processing CAD/CAM

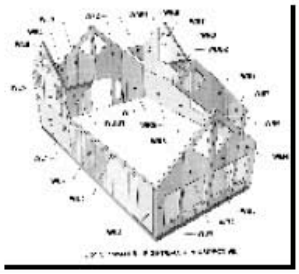
1. Starts with any CAD drawing.

Continuous Processing CAD/CAM

2. SIP Software converts elevations into SIP shop drawings and material lists.

Continuous Processing CAD/CAM

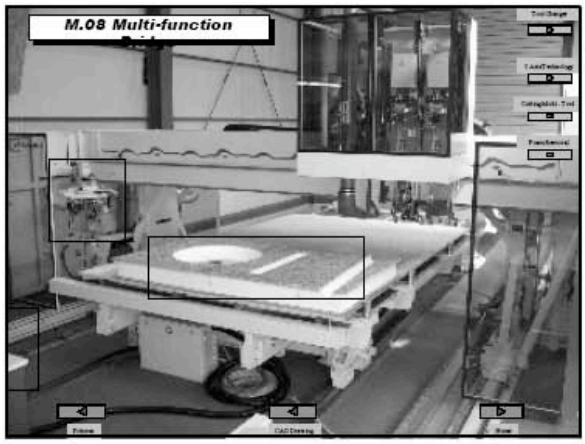
Two or Three dimensional



Continuous Processing

Computer Developed Design and Computer directed manufacturing

CAD/CAM


M.08 Multi-function


Custom Home Market
Fenner Residence
Sun Builders, Nevada City, CA


Custom Home Market
NiagaraResidence


Custom Home Market
Oak Valley Construction
Photo Courtesy: Insulspan


Face Design
Category 1:
Single Family Homes ~
Over 3,000 sq. ft.
Category Winner
Bradford Point Residence 1


PanelPros, Inc.
Category 2:
Single Family Homes ~
Under 3,000 sq. ft.
Category Winner

Production Home Market

Pulte Homes

Nonresidential Market

Nonresidential Market

Nonresidential Market

Nonresidential Market

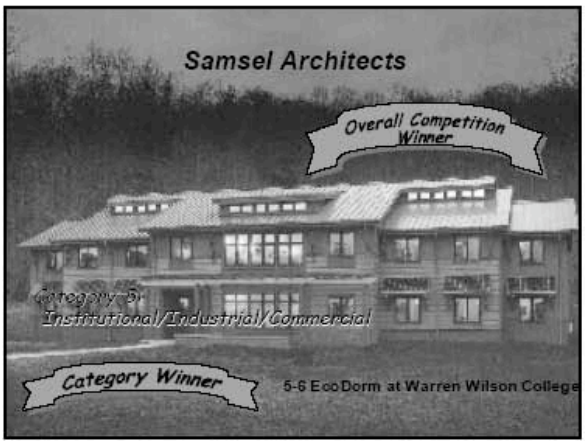
St. Alexander's Church
Niagara, ON

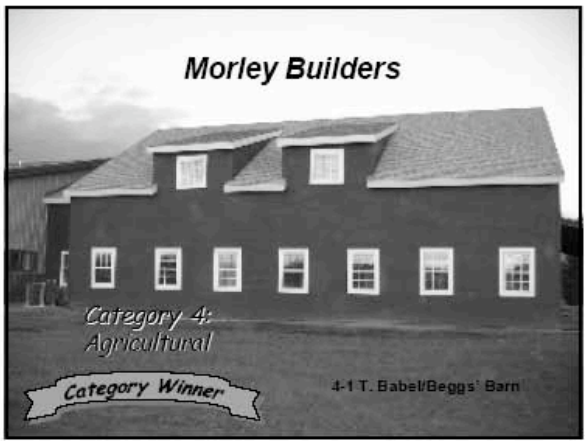
PhotoCourtesy:
Thermapan, Inc.

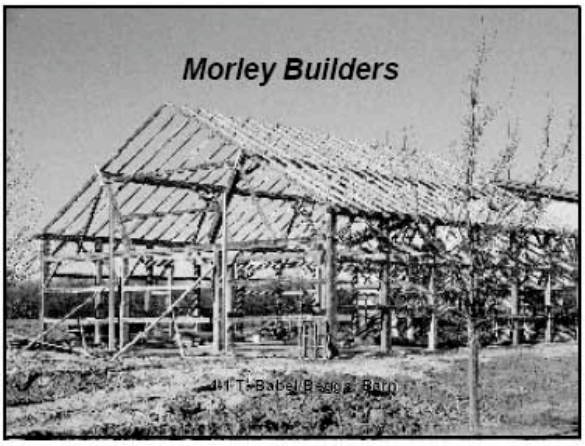
Nonresidential Market

Nonresidential Market

Nonresidential Market







Clays Construction Offices

Value Proposition

Builders

SIPs provide design flexibility, durability, and high thermal performance, making it easier to meet energy code requirements. SIPs can improve profitability and efficiency by speeding up dry-in and cycle time, and reducing on-site labor, material waste, and callbacks

Value Proposition

Homebuyers

A SIP home is extremely energy efficient, quiet, safe and sound. SIPs are environmentally friendly (green), enhance indoor air quality, and provide built in quality, comfort, protection for your loved ones, and guaranteed lower monthly energy bills making long-term ownership more affordable

Appendix C: Innovation Presentations
Risk Panel, Premier SIPs

Risk as a Barrier to Introduction of New Technologies in the Housing Industry

Ken Hawkins
Premier Building Systems

Core issues

- Business Environment
- Perceptions of Legal issues (fear)
- Perceptions of Insurance issues (fear)
- Fragmentation of Builder market
- Channel issues
- Dealing with the "trades"
- Design v. convert
- People just don't trust the building trades
- Lack of critical mass

Business Environment

Quality of materials (wood products) is declining

Availability of those products is diminishing

Labor costs are skyrocketing, especially benefits packages including payroll taxes

Trained labor pool is diminishing

Construction is just not sexy enough

Energy costs are rising

The Legal Environment

- Class action lawsuits are perceived to be rampant
- Deep pockets are scared "Target on my back"
- Fragmentation makes national builders uneasy—if the supply chain fails, who is responsible?

Insurers

- Perception: Insurers are afraid of the class action lawsuit.
- Perception: Insurer reserves are low and therefore rates are high.
- Perception: Insurers want nothing to do with building trades.
- Who is responsible for future liability—the builder or the trades?

Builders

- Big ones, little ones, all kinds
- Rules are different in each state and often in each municipality.

Profile of builders has changed dramatically…no longer a craftsman.

Builders tend to be very transaction oriented and often lack the vision needed to bring on new technologies

Goals may differ from consumer goals

Channel issues

- How do we get to market?
- New products often mean new technologies and new installation methods
- Different geographies demand different solutions
- Fragmentation vertically, horizontally
- Grossly undercapitalized

Dealing with the Trades

- "I done it this way for 30 years"
- Accustomed to one-for-one solutions
- How do we get them trained?
- How do we get them to 'think'?
- Some relationship are threatened by innovation—now we are adversarial
- Installation issues are pervasive

Design v. Convert

- How easy is it to get specified?
- Do architects and engineers understand field issues well enough to evaluate implementation costs?
- Without critical mass, conversion and design technology languish

Critical Mass

- How long does it take to achieve critical mass and begin to achieve economies of scale?
- Who sets the standards?
- What is the goal (time savings, overall quality, energy savings)?

- 10/ 20/ 04

So, WHAT IS THE RISK?

Design Professional

- Risk

Will it work?

What will the builder, installer say?

What is my liability?

Solution:

Get information out broadly, get Designers and other professionals the answers on downstream activities

Overcoming Barriers

Builders-big

- "I've got a 'bulls eye' on my back"
- How do we make changes in ongoing projects? Energy bills!!
- If you go 'under' what will I do?
- Systems costs are frequently hidden…
- How do we spread it across the nation?
- Solutions: Proscriptive method of analyzing solutions

Builders-small

- What if it doesn't work like I expected?
- What happens if the supply chain fails?
- Solution: Stronger institutional endorsement

Supply Chain

- Inventory
- Marketing expertise
- Training
- Transportation
- Obsolete current product—last week the old product was the best…but now?

Insurers

- Will it work?
- Unintended consequences?
- What happens if mfr can't sustain the business?

Investors

- Not very sexy
- Not particularly trusting of Construction industry
- 'Cottage industry' perception
- National v. regional issues (Cal v. Texas)
- How do we measure potential in a cottage industry?

What would I like to see?

Tax policy that encourages energy efficiency.

Fewer institutional obstacles—make it easy.

Group—architects, designers, government agency—that can fast track new products

Systems evaluation by Insurers

Appendix C: Innovation Presentations
Risk Panel, Eco-Block ICFs

Simpler. Faster. Better.

Risk as a Barrier to Innovation in Housing Industry – October 2004

Sheldon Wortman, P.Eng. – Technical Director

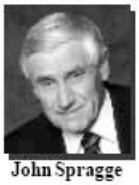
Simpler. Faster. Better.

- ECO-Block®
- Insulating Concrete Forms
- Housing Market Risks
- Product Liability Risk
- Designers Liability & Risk
- Consumers Risk

- ECO-Block® ICF Benefits & Features

1997

Jim Moore



John Spragge

Original Company Founded by Jim Moore and John Spragge

➢1998

- March - First Production at LifeLike Products in Baltimore, MD
- May - ECO Block, LLC founded by Jim Moore, John Spragge, Jan Moore, and E. J. Parks located in Fort Lauderdale, FL.
- June - Production began at LifeLike Products, Miami, FL.
- August – Began production at Polymos in Montreal, Canada
- September – Began production at Beaver Plastics in Chilliwack, BC
- November - Began Production at LifeLike Products, Waxahachie, TX

➢1999

- March – First of 9 Patents Issued
- July – Dallas Operations Office Opens
- October – Began Manufacturing in Western U.S.
- December – Began Manufacturing in North Central U.S.

➢2000

- 106 Distributors
- January – Canada Office Opens
- February – ECO-Block became registered provider for AIA Continuing Education Program.
- Began production at Marko plant in Salt Lake City, UT.
- November – Introduced OSHA compliant bracing system

➢2001

- February – Introduced Commercial Block
- May – Introduced Latching web and connector.
- August – Established ICF Support to promote ancillary ICF Products
  - Introduced ECO-Buck system (now Universal Buck)
- September – Introduced 45 and 90 degree panel connectors.

➢2002

- January – Began manufacturing at Contour Products in Kansas City, KS.
- February – Launched Green Building initiative.
- March 18, 2002 – Death of John Spragge.
- March – Established Technical Services Support Function.
- March – Began molding operations in Atlanta, GA area.
- August – Established National Training Program.

➢2003

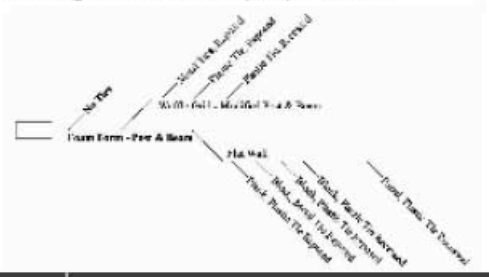
- January – Established formal QA/QC Program.
- February – Distributor representation in all 50 states.
- April – Formed ECO-Block International.
- July 27, 2003 – Death of Jim Moore.
- November – Transfer of Technology Agreement signed with Australia.
- December – ECO-Block consolidated operations in Dallas, TX.

ECO-BLOCK®, LLC – U.S. Patents

TITLE	SERIAL NO.	PATENT NO/ ISSUE DATE	STATUS
Concrete Form System and Method (Corner Web Member)	09/427,373	6,318,040 11/2001	Granted
Concrete Form System and Method (Ledge Assembly)	09/427,374	6,336,301 01/0002	Granted
Concrete Form System and Method (Connector Link)	09/426,572	6,314,697 11/1301	Granted
Insulated Concrete Form (Method of Making Tilt-Up)	09/668,437	6,170,220 01/0501	Granted
Insulated Concrete Form (System & Tilt-Up Structure)	09/654,024	6,363,683 04/0202	Granted
Tilt-Up Wall (Wet Set Method and Structure with Anchors)	09/821,299	6,481,178 11/1902	Granted
Concrete Structure Formed Using Plywood Sheet and EPS Side Panel	09/848,736	6,526,713 03/0403	Granted
Latching Design for Web Members and Connectors Used in a Concrete Structure	09/848,595	6,438,918 08/2702	Granted
Concrete Form System	08/899,960	5,887,401 03/3699	Granted

ECO-Block® ICF System

Insulating Concrete Form (ICF) Evolution

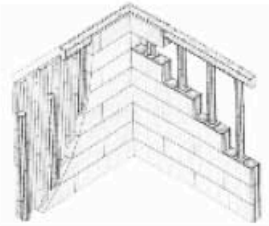


ECO-Block® ICF System

Insulating Concrete Form (ICF) Evolution

Post & Beam – Screen Grid

- Post - Vertical Concrete Core
- Beam - Horizontal Concrete core
- Large areas without concrete
- Engineering is Complex
- No fastening surfaces for interior or exterior finishes

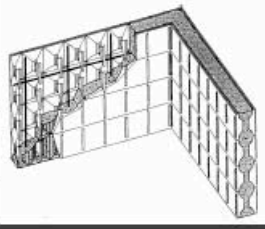


ECO-Block® ICF System

Insulating Concrete Form (ICF) Evolution

Waffle Wall – Mod. Post & Beam

- Similar To Post And Beam
- Concrete Resembles Waffle Grid
- Engineering is Relatively Complex
- Form Ties Added To Hold Opposing Faces Of EPS
- Metal Ties Were Difficult To Cut And Handle. Poor Thermal Bridging
- Plastic Ties Are Easier to Cut And Handle, Limited Thermal Bridging
- Tie Serves As A Surfaces For Interior Or Exterior Finishes To Be Attached

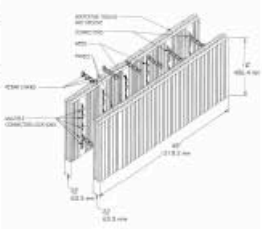


ECO-Block® ICF System

Insulating Concrete Form (ICF) Evolution

Flat Walls

- Flat Wall Forms Were Evolving Shortly After The Modified Post And Beam
  - One Major Difference
- Utilizes A Homogeneous Concrete Core To Permit Engineering Principles For Design Of Concrete Structures To Be Utilized
- Interior & Exterior Finishes Easily Attached
- Ships Flat, Great Design Flexibility Allows For Walls 4" and greater



ECO-Block® ICF System

What are Insulating Concrete Forms?

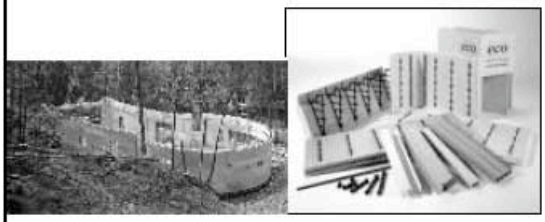
- ICFs are lightweight, highly durable foam blocks (forms) composed of expanded polystyrene (EPS).
- They are stacked up and filled with concrete resulting in a monolithic, steel reinforced, concrete wall with insulation in place.

ICFs Combine Several Steps of Building Construction

- Concrete Form
- Insulation
- Vapor & Air Barrier
- Furring Strips
- Electrical/Mechanical Chases

ECO-Block® ICF System

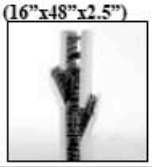
The ECO-Block system consists of simple, easy to assemble components. That can make any shape or size concrete wall.

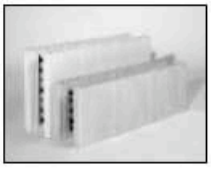


ECO-Block® ICF System

EPS Side Panels with embedded webs
Pre-molded 45° and 90 ° corners
Brick-Ledge Panel
Two Sizes Available

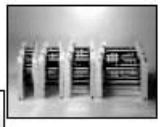
- Commercial Panel (24"x48"x2.0")
- Standard Panel (16"x48"x2.5")





ECO-Block® ICF System

High density plastic latching connectors
Allow wall widths of 4" to 40"
Versatile Panel Connectors
Create 45° and 90 ° angles



Simpler. Faster. Better.

Housing Market Risks

Housing Market Risks

ICF Market - Entry Costs

- Development of Molds:
  - $100K min for limited localized market
  - Full product range one facility ± $400K
  - Major Players have minimum 4 facilities ± $1M
- Locate Manufacturing – Contract vs. Purchase
- Inventory Management
- Testing and Code Compliance
- ICF Industry growth 4.0% 2003
- 80+ Different Systems = ICF Market Saturation

Housing Market Risks

ICF Market - Entry Costs

- Government Regulations & Restrictions on EPS Molding Facilities
- Government Regulations & Restrictions on Cement
- Interest Rate Forecast – Currently at 1.75%
  - Nov. 10 2.00%
  - Dec. 14 2.00%
  - March 22 2.25%

HEADLINES

- US Layoffs at 8 Month High
- Record Oil Prices

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Product Liability Risks

Product Liability Risks

Forming Capacity

- Inadequate manufacturing
- 80+ Systems, Maybe 20 have a Quality Control Program
- Inadequate Installation & Bracing
  - Florida Blow-out Kills 1 Injures 1
    - At least four construction workers in South Florida have been killed on the job in the past few weeks as the state comes under increasing OSHA scrutiny for being among the worst in the country for worker deaths.
    - PBS News September 3, 2004

Product Liability Risks

Inadequate Concrete Consolidation Practices

A large 8' long by 2' tall void is discovered in a newly poured "Insulated Concrete Form Wall".

Simpler. Faster. Better.

Designers Liability & Risks

Designers Liability & Risks

EIFS vs ICF's

- Leaky Condo Stigma (ongoing)
- One Bitten, Twice Bankrupt!!!
- Exposed wood cell structure makes it easier for bacteria to foster
  - Tree
  - 2x
  - Plywood
  - OSB
  - Paper

Designers Liability & Risks

Engineering & Design

- Residential = Wood Construction
- Commercial & Industrial = Concrete & Steel
- Education Limitations
- Complex Designs
- Refusal to Specify
- HVAC Specifications

Designers Liability & Risks

Architects

- Reluctance to Spec: ICF + Stucco ≠ EIFS
- Perceived Higher Overall Costs
- Limited Number of Builders
- Code Compliance & Testing
- Poor design, limited overhangs in high rain load areas (NW)

Designers Liability & Risks

Contractors & Builders

- Available Labor
  - Hands on Perception
  - Glamour
- Education at Institutional Level
- Fear Factor!!
- Insurance – XYZ 2004 Ltd.
- All contractor lose $$$
- Specialized Equipment Required

Designers Liability & Risks

Building Officials & Evaluations

- Required Code Approvals
- Liability
- Code Consolidation
- Long, Slow & Painful

US Code Evaluations

» Fire Rated Assembly ECO/WA 240-01
- Certified by Intertek/Warnock Hersey See Directory of Listed Products for Conformance to ASTM E119

» ICC ES Legacy Reports 5498, 9845A, 2238
- IBC, IRC, UBC, SBC, BNBC, Int'l 1&2 Fam Dwelling, SBCCI Hurricane Resistant

» Dade County NOA 00-1024.02

» Florida Certificate of Product Approval #FL2253

» Wisconsin State Code #200012-I

» City of Los Angeles RR#25446

» Non-Combustible Evaluation - Hughes Associates

ECO-Block® Testing

Compliance Testing Required By Evaluation Reports for Each Facility

- ASTM C203 - Flexural Strength
- ASTM D1622 - Density
- ASTM D1621 - Compressive Resistance
- ASTM E84 - Flame Spread & Smoke Development
- ASTM C518 - Thermal Resistance
  - Type II EPS 1.35 pcf - R = 4.0/inch @ 75°F
  - Type IX EPS 1.80 pcf - R = 4.2/inch @ 75°F

ECO-Block® Testing

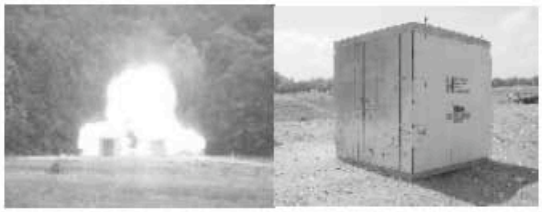
ICF System Testing – Not Required By Evaluation Reports

- Crawl Space Test to SwRI Test Procedure 99-02
- Corner Room Test UBC 26-3 (a.k.a. UL1715)
  - 15 Minute Thermal Barrier Stay-in-Place
- ASTM E119, UL263 – Full Scale Fire Resistance Rating
- ASTM E90 – Sound Transmission Classification (STC)
- ASTM E283 - Air Infiltration
- ASTM E331 - Water Penetration

ECO-Block® Testing

ICF System Testing

» Blast Resistance



ECO-Block® Testing

ICF System Testing

- » Fire Performance

ECO-Block® Testing

ICF System Testing

» Severe Weather

Simpler. Faster. Better.

Consumers Risks

Consumers Risks

New Product = New Problems

- Buyer Beware! – Not All ICF's Are Created Equally
- Convincing the Contractor
- Improper Installations
- HVAC Sizing
- Air Exchanger Required

New Product ≈ Less Problems

- Insurance is Lower
- Energy Efficiency
- Air Quality
- Low Noise

Simpler. Faster. Better.

ECO-Block® ICF Benefits and Features

ECO-Block® ICF Benefits and Features

Ease of Design

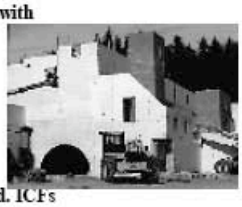
- Flat wall forming system
- Versatile steel placement
- Radius walls
- Arches
- Shapes
- Pilasters
- Welded Rebar
- Structural steel in the wall
- Can adapt to any design criteria

ECO-Block® ICF Benefits and Features

Ease of Construction

ECO-Block is easy to integrate into the building process, works seamlessly with standard construction

- Electrical & Plumbing
- Waterproofing
- Siding & Finishes
- Roof Structure
- Windows
- HVAC



Labor hours are drastically reduced. ICFs are lightweight, requiring less effort to lift, move, place or cut.

ECO-Block® ICF Benefits and Features

Affordable Construction

- Competitive first cost
  - An integrated design approach enables synergies between disciplines and between technologies, allowing a project to stay within budget.
- Reduced Lifecycle Costs (ROI)
- Higher resale value - the NAHB reports green buildings have a competitive edge in the marketplace.
- Lower operating costs
  - Lower utility costs by 40-60%
  - Lower maintenance costs

ECO-Block® ICF Benefits and Features

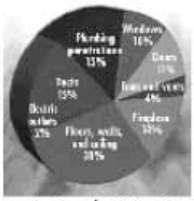
Saving America's Energy™

Superior insulation qualities
- Tested R Value of R22 for EPS Only

Effective R is much higher due to:
- Zero Air Infiltration thru ICF & the Concrete
- Reduced thermal bridging

Reduced size of HVAC equipment

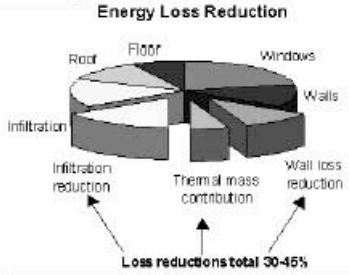
Savings in monthly utility use



How Does the Air Escape?

ECO-Block® ICF Benefits and Features

Optimize Energy Performance



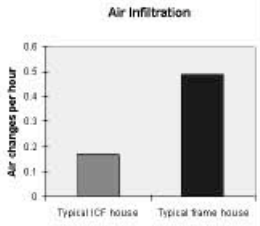
ECO-Block® ICF Benefits and Features

Reduce Air Infiltration

Reduced air infiltration
Wood > .5 ACH
ICF < .01 ACH

Better control of replacement air quality

Less "outdoor" air to heat/ cool



ECO-Block® ICF Benefits and Features

Healthy Indoor Air Quality

No VOCs

No mold issues

Superior Thermal Quality

No drafty spots

No temperature swings

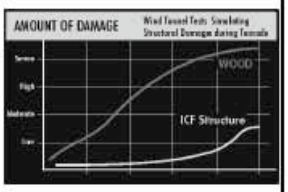
1 in 3 people have an allergy severe enough to seek medical attention on a routine basis - American Lung Association

ECO-Block® ICF Benefits and Features

Withstands Severe Weather

Research has shown ICF structures are more resistant to severe weather conditions than wood construction.

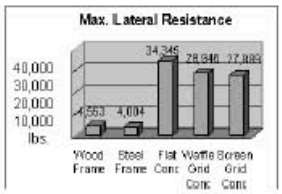
An ICF structure can be engineered to withstand 150 mph+ winds.



ECO-Block® ICF Benefits and Features

Earthquake Resistance

ICF structures can be engineered to withstand seismic zone 4 earthquakes.



ECO-Block® ICF Benefits and Features

Fire Resistance

Flame Spread Index (FSI) is 0 – Max. per Code is 75
Smoke Development Index (SDI0 is 300 – Max. per Code is 450

Fire Resistance Ratings (FRR)

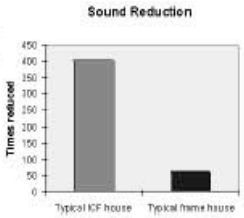
- 4" Concrete Core has a 2 hour FRR
- 6" and Greater Concrete Core has a 4 hour FRR

ECO-Block® ICF Benefits and Features

Superior Sound Suppression

Sound Transmission Classification 6" concrete wall with ½ " Gypsum provides an STC 51

Note a 2x4 wall, insulated w/gypsum both sides provides an STC 38



Ideal Design Solution for theaters, offices, hotels, buildings next to busy streets or airports and schools.

ECO-Block® ICF Benefits and Features

Resistant to Mold & Pest Infestation

EPS and concrete are inorganic, meaning they do not provide a host food needed for mold growth, so regardless of the temperature and humidity, mold will not be able to sustain growth in the ICF wall components.

Resistant to insects such as termites and carpenter ants

Bugs don't eat concrete!

ECO-Block® ICF Benefits and Features

ECO-Block is ECO-Logical

No CFC's in manufacturing

Efficient use of raw materials

Long life expectancy

Local manufacturing

Uses 40% by weight of 100% recycled post industrial material

Contributes to several credits in US Green Building Council LEED™ certification

ECO-Block® ICF Benefits and Features

Contributions to LEED™

ECO-Block Credit Areas

Sustainable Sites = Credit 5 Reduced Site Disturbance
Energy & Atmosphere = Credit 1 Optimize Energy Performance
Materials & Resources
- **Credit 2 Construction Waste Management**
- **Credit 4 Recycled Content**
- **Credit 5 Local / Regional Materials**

Indoor Environmental Quality
- **Credit 2 Increased Ventilation Effectiveness**
- **Credit 7 Thermal Comfort**

Innovation & Design Process
- **Exceeds LEED performance credit in IAQ, Construction Waste, LCA**

ECO-Block® ICF Benefits and Features

Experienced Management Team - with extensive knowledge of the ICF industry.

Knowledgeable, respectful, honest and ethical associates.

Technical Director/Structural Engineer on Staff – providing a quick response to any code compliance or design issues that may arise.

'Green' Construction Specialist on Staff – providing efficient guidance on building a 'LEED' Certified Structure.

Less Waste – ECO-Block® ICF's can have less than 1% waste.

Vapor barrier and Air barrier are not required on ECO-Block® ICF's.

ECO-Block® ICF Benefits and Features

Thermal mass – with R11 each side and zero air infiltration the ECO-Block® ICF's outperform an equivalent wood framed wall of R40

Energy savings up to 60%.

Sound Transmission Classification – the ECO-Block® ICF's obtain an STC of 51 with a 6" concrete core which means the environment produced is comfortable and quiet.

Less on site construction space required for staging of materials.

Stable Prices – unlike the volatility of the steel and wood industry.

Versatility – ECO-Block® ICF's can be cut at any height and in any shape while maintaining structural integrity.

Versatile connector heights – allows for horizontal rebar in increments other than 16" spacings.

ECO-Block® ICF Benefits and Features

Unsurpassed Quality Control – the most stringent quality Control program in the ICF Industry.

Education – On site training is available by our team of construction professionals to yours ensuring you have a positive experience with the ICF Industry.

Product packaging provides UV protection against harmful UV Rays.

Engineered Plastics and Connectors – the limited internal obstructions within the form ensures easier flow and consolidation of the concrete.

Production Capacity – Additional mold capacity is available on short notice and manufacturing facilities maintain inventories.

Abuse resistant drywall is not necessary due to the full support of the gypsum by the EPS.

ECO-Block® ICF Benefits and Features

Professional Design Details – over 300 design details available to the design professional to simplify the incorporation of ECO-Block® ICF's into your structure.

Reduced costs for shipping – the panelized system means more blocks can be shipped on a truck.

Handling damage is reduced as a broken panel from handling can be replaced saving 50% of the block.

Panels and webs can easily be cut in situ or on a table saw, and routed for with new horizontal interlock when necessary.

Full height webs and higher flexural strength of the EPS means no bulging between courses or webs giving you a straight smooth wall for application of interior and exterior finishes.

ECO-Block®

Insulating Concrete Forms

Simpler! Faster! Better!

Appendix C: Innovation Presentations
Preference Panel, DuPont Housewrap Flashing

Flashing Systems

DuPont Flashing Systems: The development of unique self-adhered flashing products

Preferences As A Barrier To Innovation In The Housing Industry – HUD/PATH Expert Panel Presentation
Hilton Embassy Row, Washington D.C.
October 27-28, 2004

James D Katsaros
DuPont Flashing Systems Development Leader

Outline

- Define Market Need for Self-Adhered Flashing Products
- DuPont Flashing Systems Developments
  - Self-Adhered Flashing Products
    - Define, Develop, Test, Validate & Retest
  - Installation Method Parallel Effort
    - Upgrade of existing 'Standards', test 'variations'
- Preference Barriers Hypothesis:
  - cultural values,
  - attitudes to change in general,
  - perceived or real economic advantage,
  - influence of piers and others, or
  - any combination of these.

Flashing Systems DuPont Confidential

What is Flashing?

Illustration from the EEBA Water Management Guide, 2002

"Configuration of materials that are arranged to direct water to the exterior. These materials could be metal, asphalt-impregnated building paper, or adhesive backed bituminous tape."
Fine Homebuilding April/May 1998

Deflects Moisture Away from a building / structure

Flashing Systems DuPont Confidential

Flashing Helps Prevent Damaging Moisture Intrusion.

APA photo

If installed correctly

Flashing Systems DuPont Confidential

Market Risk Mitigation:
Understanding Market Needs & Habits

Focus Groups
Current Situation

Focus Groups
Value Proposition for Development Candidates

• Circle-top windows & sills are problem areas

Flashing Systems DuPont Confidential

Traditional Flashing Products for Windows & Doors

- Asphalt coated / reinforced paper
- Polymeric Film
- Housewraps

Deflect moisture, but don't seal

Flashing Systems DuPont Confidential

Challenges with Traditional Flashing Products & Methods

Can be worse than nothing if installed Incorrectly – acts as a "funnel"

Challenges with Traditional Flashing Products & Methods

Can be worse than nothing if installed Incorrectly – acts as a "funnel"

Flashing Systems DuPont Confidential

Market Wants Easy-to-Use, Forgiving System: Advantages Self-Adhered Flashings....

When installed and used properly, Self-Adhered Flashings:

- Provide a broad moisture seal at the window-wall interface (extension of the sealant)
- Are easy to install (peel and stick)
- Are versatile for many different installation methods and openings (shapes / sizes / etc)
- Maintain their seal through joint movement between dissimilar materials (durable topsheet)
- Provide a much more durable seal than a caulk joint (which is the basis for non-SAF methods)

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But there are Concerns with the Performance of Self-Adhered Flashings....

- "It doesn't always stick" (many examples of SAFs falling off the wall)
- How do I know SAFs are still working effectively behind the siding after many years of thermal cycles & environmental exposure?
- Self-Adhered Flashings can ooze and result in staining cladding surfaces & interactions with caulk
- Lack of a standard for material properties – anything can be a SAF
- Lack of a standard for installation conditions to ensure performance

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Some concerns with Self-Adhered Flashings...

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Some concerns with Self-Adhered Flashings...

Flashing Systems DuPont Confidential

Market Opportunity For Improved Flashing?

- Water intrusion at windows and doors is a serious issue
  - Major source of litigation / new legislation
  - Majority of problems related to improper installation
- Strong fit with Tyvek® Weatherization Systems offering and core focus
- Requested by our customers.
- Large Market Space w/ no clear market leader

Flashing Systems

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DuPont Self-Adhered Flashing via Systematic Product Development Process

Focus Groups	Builder/Installer Opinions on Current Products
Diagnostic Wall Test	Analysis of Current Products/ Installation Methods
R&D	Development Candidates
Focus Groups	Value Proposition, Likes/Dislikes
Performance Wall Test	Performance of New Product vs. Current Products

Flashing Systems

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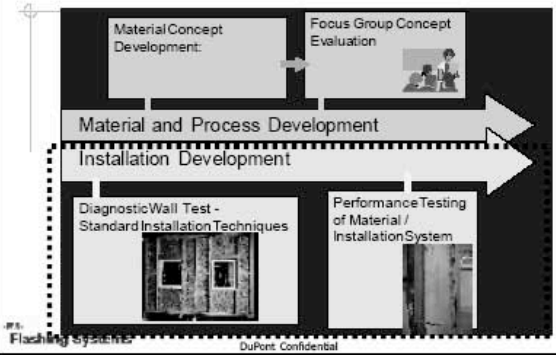
Concurrent Development of Flashing Material and Installation Method



Flashing Systems

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Enhanced Performance Offering:
Keys to Successful Use of Self-Adhered Flashing Products

- Continuity of window-wall interface
- Shingling / lapped correctly
- Moisture Management: Provide a Drainage Path for leaks
- Installed Systems Testing: window-wall installation as a complete system
- Installation conditions (real life) that promote adhesion
- Material choice - durability & robustness
- Education: Provide hands-on training & support on site

Flashing Systems

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Enhanced Performance Offering:
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Flashing Systems

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Continuity of the Window-wall interface

5.1 ***Continuity*** —Continuity shall be maintained between elements in the fenestration product and the weather resistant barrier that provides weather protection, air leakage control, and resistance to heat flow and vapor diffusion....

A continuous integration at the window-wall interface that provides a *durable* seal to air, thermal, and moisture intrusion...

..."caulks and sealants are generally not a suitable substitute for flashing." Durability by Design guideline published by the Partnership of Advancing Technology in Housing (PATH)

Flashing Systems

DuPont Confidential

Enhanced Performance Offering:
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Flashing Systems

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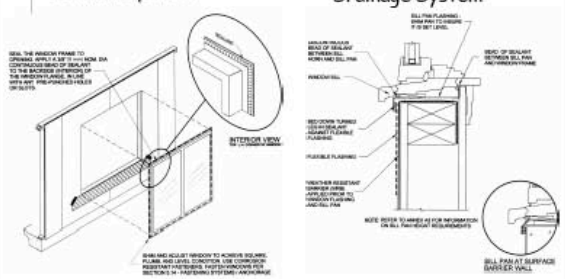
Flashing Installation Method Comparison:

Barrier System

Drainage System



Drawings taken from ASTM E2112, "Standard Practice for Installation of Exterior Windows, Doors and Skylights", Figures 11 & 15

Flashing Systems

DuPont Confidential

Moisture Leakage Associated with Windows Widely Reported

- "35% to 48% of newly installed windows were found to leak through the window unit itself, through joints between the window and the rough opening, or both."
  (Journal of Light Construction, November 2003, based on CMHC / HPO study)
- "100% of installed residential windows examined after years in service were found to leak either through the window unit itself or at points of attachment to the building."
  (Journal of Light Construction, November 2003, based on CMHC / HPO study)

Flashing Systems

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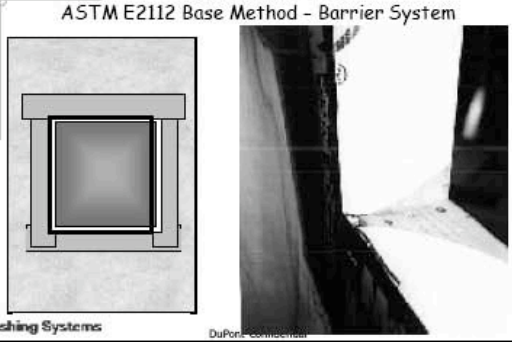
Traditional Window Flashing Methods

ASTM E2112 Base Method - Barrier System



Flashing Systems

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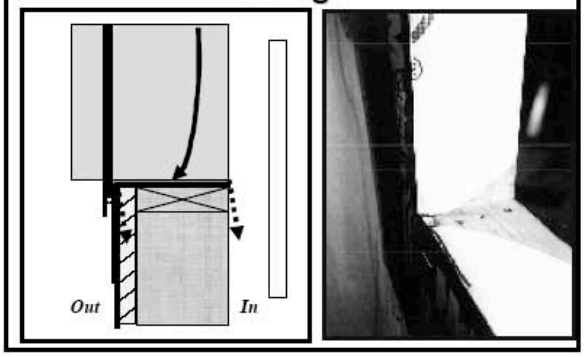
2-D Flashing / Caulked Bottom Flange



Barrier System Caulking and Flashing does not "forgive" leaks at the window and window-wall interface

Observations on Base ASTM E2112 Barrier Installation Method

Advantages:

Ease & Cost of Installation

Concerns:

Unforgiving to leaks in Window or Window-wall interface

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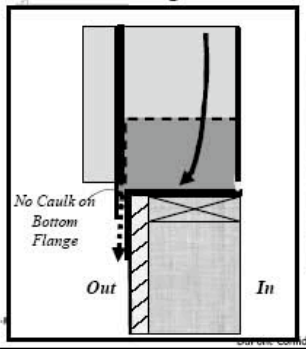
The Drainage Method: 3-D Flashing / Bottom Flange Not Caulked



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DuPont Flashing Systems

- DuPont FlexWrap™ was commercialized in Feb of 2001
  - Primary application is for sills, round top and custom shapes
- DuPont StraightFlash™ commercialized June 2002
  - Designed to complement FlexWrap™ and be used where conformability is not required
  - 4" product designed to flash the jambs and heads of rectangular window

Flashing Systems

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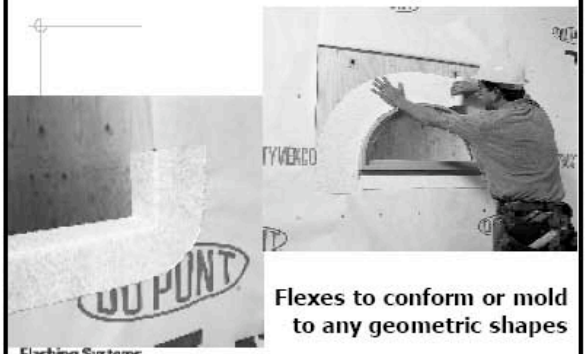
DuPont FlexWrap™



Flexes to conform or mold to any geometric shapes

Flashing Systems

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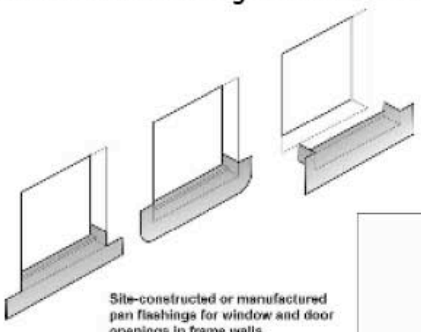
Various Sill Pan Designs – Revised ASTM E2112



Site-constructed or manufactured pan flashings for window and door openings in frame walls

Detail from the EEBA Water Management Guide 2012

Flashing Systems

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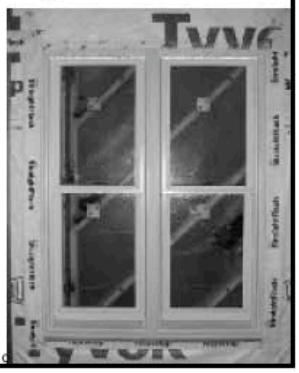
DuPont StraightFlash™

- Complementary product to complete system
- Designed for straight runs where conformability is not required
- Consists of non-elastic laminate and butyl adhesive



Flashing Systems

DuPont C

Detailed Installation Techniques

Example: Flanged window / wood frame after the weather resistive barrier has been installed.

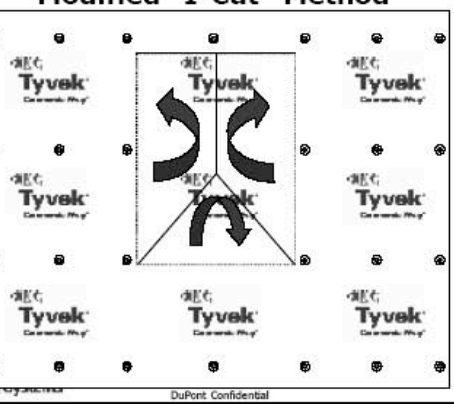
Flashing Systems

Installation Method / Material Development

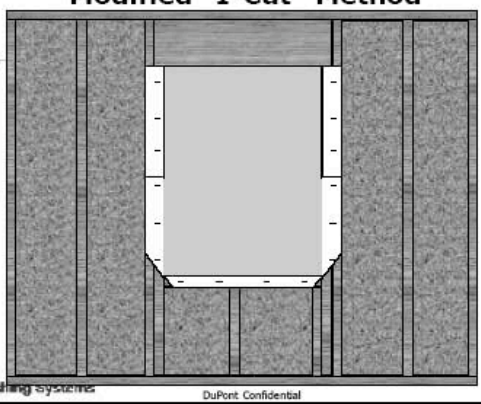
- Protect bottom corners into the rough opening
- "Moldable" Self-adhesive flashing (SAF)
  - seamless 3-dimensional flashing on sill and 6" up either side rough opening
  - single piece continuous head flashing for round-top window applications.
- Creation of a weep system by not applying caulk on bottom flange
- Self-adhesive flashing applied over jamb and head flanges.
- Air seal and back dam by interior caulk joint

Flashing Systems

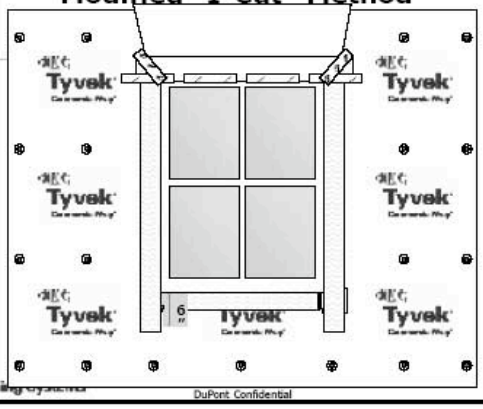
Modified "I-Cut" Method



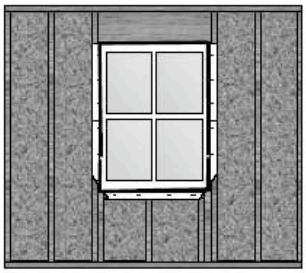
Modified "I-Cut" Method



Modified "I-Cut" Method

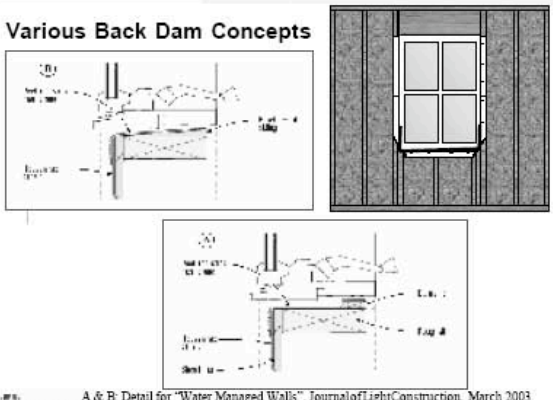


Back Dam and Air Seal



Flashing Systems

Various Back Dam Concepts



A & B: Detail for "Water Managed Walls", Journal of Light Construction, March 2003

Flashing Systems

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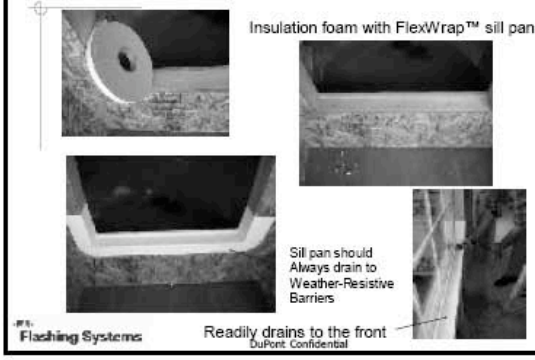
Flexible Sill Pan With Back Dam – Not Yet Required, But A Good Idea



Flashing Systems

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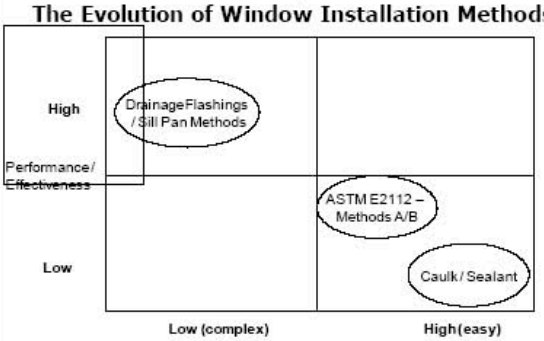
Market Adoption Risk:

The Evolution of Window Installation Methods



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Enhanced Performance Offering:

Keys to Successful Use of Self-Adhered Flashing Products

- Continuity of window-wall interface
- Shingling / lapped correctly
- Moisture Management: Provide a Drainage Path for leaks
- Installed Systems Testing: window-wall installation as a complete system
- Installation conditions (real life) that promote adhesion
- Material choice - durability & robustness
- Education: Provide hands-on training & support on site

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Detailed Testing & Development

Flashing Systems

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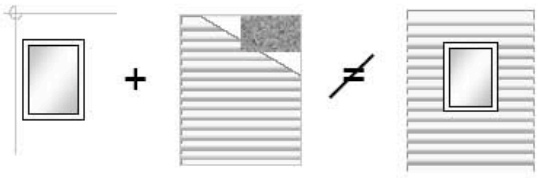
Tested Systems



- Windows and Walls are usually tested separately
- They should be tested as installed units

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Performance Assessment: Exposure

During Construction

During Service

- UV
- Rain
- Wind
- Temperature
- Humidity

- Temperature/Humidity Cycling
- Liquid Water
- Wind / differential pressures
- Compatibility with adjacent materials

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Wall System Testing Goals

- **Phase I** : Installation Method and Performance Specification
- **Phase II**: Durability of Installed Product
- **Phase III**: Installation Variants

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Phase I : Installation Method and Performance Specification

Install Window

Flashing Product
- FlexWrap™ prototypes
- Competitive products

Installation Methods

Window installation
- before WRB
- after WRB

Window type
- flanged
- non-flanged

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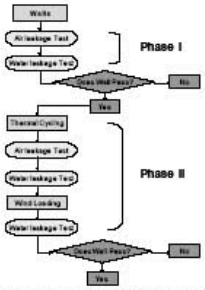
Installed Window – Wall Testing Protocol



REF: Weston T. A., et al.,"Performance Testing of Window Installation and Flashing Details" 2002 Symposium on Improving Building Systems in Hot & Humid Climates, May

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Phase I : Installation Method and Performance Specification

Air Infiltration/ Exfiltration Test (ASTM E283)
Measure infiltration and exfiltration at
.1" H_2O (25 Pa) (15 mph)
.3" H_2O (75 Pa) (25 mph)
1.2" H_2O (300 Pa) (50 mph)

Water Infiltration (ASTM E331)

- Standard water flow rate
- Infiltration pressure of .1" H_2O (15 mph) for 15 min
- Infiltration pressure of .3" H_2O (25 mph) for 15 min
- Moisture sensors will be installed and monitored during spraying along with visual observations.

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Phase I Results

FlexWrap™ / installation performed well- no leaks

Water leaks occurred at mull joint

Caulk positioning provided "forgiveness" for window leak

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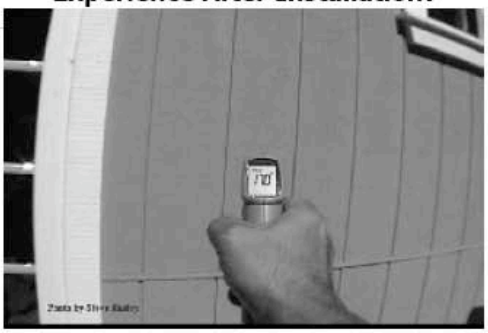
What Temperature Exposures Do SAFs Experience After Installation?



Measured on wood siding on 80°F day in Northern California

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Phase II - Durability

- Repeat Air Infiltration / Exfiltration
- Repeat Water Infiltration
- ASTM E 330 – Wind Loading
  - Infiltration load at 2" H_2O (65 mph) for 1 hour
  - Exfiltration load at 2" H_2O (65 mph) for 1 hour
- Repeat Water Infiltration

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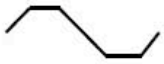
Phase II: Durability

Thermal Cycling
0'F -- 160 'F, seven days cycling

6 hour cycles



Accelerated aging +
ASTM E1677 evaluation

Retest walls for water and air infiltration

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Phase II - Durability

Thermal Cycling

- 0° F to 160° F for 7 days at 4 cycles per day
- 6 hour cycles

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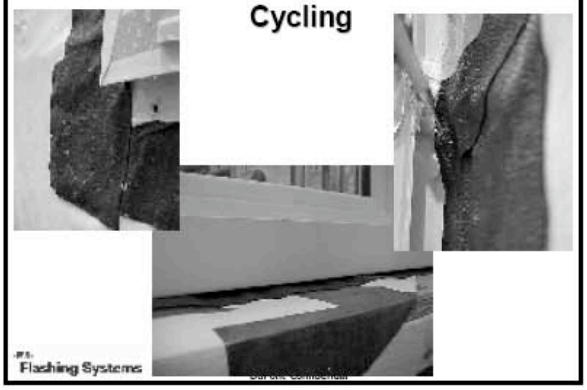
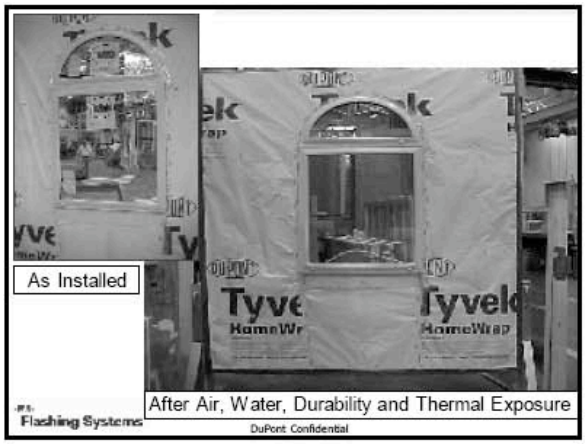
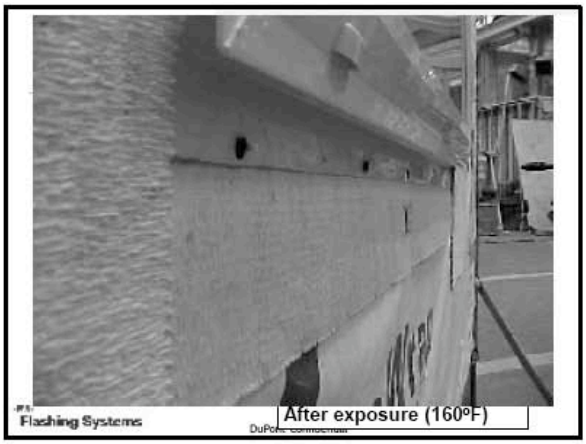
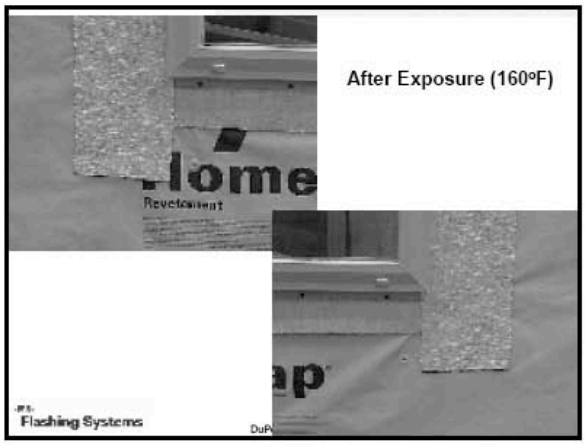
Traditional Peel 'n Stick after Thermal Cycling



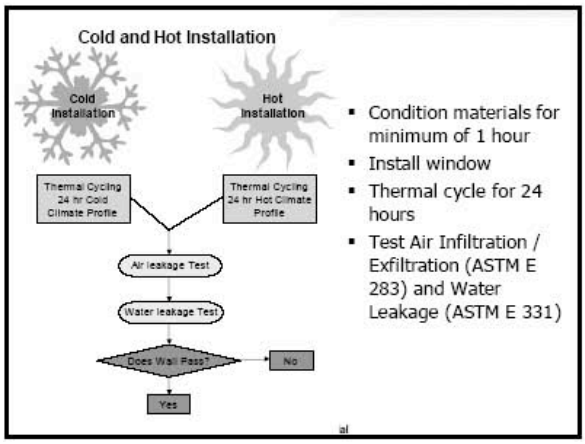
Flashing Systems


As Installed
After Air, Water, Durability and Thermal Exposure
Flashing Systems
DuPont Confidential


After exposure (160ºF)
Flashing Systems


After Exposure (160ºF)
Flashing Systems


Phase II - No leakage in DuPont System
After Thermal Cycling
Flashing Systems


Cold and Hot Installation
Cold Installation
Hot Installation
Thermal Cycling 24 hr Cold Climate Profile
Thermal Cycling 24 hr Hot Climate Profile
Air leakage Test
Water leakage Test
Does Wall Pass?
No
Yes
Condition materials for minimum of 1 hour
Install window
Thermal cycle for 24 hours
Test Air Infiltration / Exfiltration (ASTM E 283) and Water Leakage (ASTM E 331)


Phase III- "Faulty" Installations
Reverse laps
Butt and lap joints
Bubbles and wrinkles
Fastener penetrations
Stretched materials
No caulking
No taping
Test walls for water & air infiltration and durability
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HomeWrap
Revêtement
DuPont Confidential


HomeWrap


HomeWrap
Revêtement


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Tyvek
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Enhanced Performance Offering:
Keys to Successful Use of Self-Adhered Flashing Products

- Continuity of window-wall interface
- Shingling / lapped correctly
- Moisture Management: Provide a Drainage Path for leaks
- Installed Systems Testing: window-wall installation as a complete system
- Installation conditions (real life) that promote adhesion
- Material choice - durability & robustness
- Education: Provide hands-on training & support on site

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Primary "Types" of Self-Adhered Flashings: Bitumen & Butyl Adhesive

ASTM E2112:

X1.2 FlexibleFlashing—Self-AdhesiveType

X1.2.2 *Bitumen Type Flashing*—Bitumen flashing typically has a rubberized bitumen material applied to a sheet of polyethylene, polypropylene, or in some cases a foil. In the majority of these products, the release sheet is pulled off, exposing the rubberized bitumen adhesive, which is then put down on the flange or the frame, depending on the installation method being used.
X1.2.3 *Butyl Type Flashing*—Butyl flashing typically has a butyl adhesive applied to a sheet of polyethylene, polypropylene, or in some cases a foil. In the majority of these products, the release sheet is pulled off, exposing the butyl adhesive, which is then put down on the flange or the frame, depending on the installation method being used. *Some butyl type flashings are formable so they can cover 3-dimensional and non-linear shapes such as the heads of round top windows.* Some other types of butyl flashings have less than 100% adhesive coverage integrated n the film or carrier that can be used in sill applications covering the bottom flange.

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Asphalt (Bitumen) Basics

- Natural products
  - Has been in use since 625 B.C.!
  - From asphalt lakes/deposits or heavy oil of petroleum
  - Complex mixture of organic compounds with high unsaturation
  - Relative low molecular weight
  - May contain nitrogen, sulfur, heavy metals in additional to carbon, hydrogen and oxygen
  - Inherent unpleasant odor

- Key applications
  - Road building materials
  - Roofing felt
  - Sealants

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Asphalt-based Adhesives

- Key advantages:
  - Cheap!
- Key issues:
  - Narrow operating temperature range
    - Brittle/poor adhesion at low temperature
    - Ooze/flows at high temperature
  - Poor chemical stability
    - Sensitive to UV radiation
    - Sensitive to thermal aging
  - Stains easily
  - Adhesives may become brittle overtime due to loss of VOC
  - Questionable seal overtime
  - Unpleasant odor

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Butyl Rubber Basics

- Synthetic elastomers
  - First commercialized in 1942
  - Monomers: isobutylene (>95%) and isoprene (<5%)
  - Low/no unsaturation, little by-products
  - Many grades available to cover a broad molecular weight range (both cured and uncured)
- Key applications
  - Inner tubes for tires
  - Sealants (windows)
  - Automotive suspension bumpers
  - Electrical insulation
  - Rubber sheeting for external use
  - Elastomeric seal for hydraulic systems

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Butyl Rubber-based Adhesives

- Key advantages
  - Broad operating temperature window
    - Flexible/good adhesion at low temperature
    - Resists oozing/flowing at high temperature
  - Excellent chemical/physical adhesion to substrates
    - Adhesion grows with time -- repositionability!
  - Excellent weather resistance
  - Excellent chemical/moisture resistance
  - Excellent stretchability
  - No solvents/VOCs
  - No odor
- Key disadvantages
  - More expensive

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Performance Comparisons

	Butyl Adhesives	Modified Asphalt Adhesives*
1) Use Temperature Range		
Low temperature flexibility	good to excellent	poor to good
High temperature flow-resistance	stable to 180+ F	oozes above 120-140 F
2) Chemical stability		
UV-stability	stable	causes degratation
Thermal Aging	stable above 200 F	causes degratation
Compatibility with sealants / substrates	generally inert	poor with solvents & elastomers
3) Adhesive performance		
Repositionability	generally yes	no
Product stains	not likely	yes
4) Sealability performance	stable over time	time dependent - can become brittle
5) Product ingredients	synthetic - easy to control	natural - hard to control (often waste stream)
6) Product odor	no	strong

* Note: Depending on specific formulation, the performance of polymer-modified asphalt could be better than described here in general.

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Durability Considerations of Self-Adhered Flashings

Must withstand UV exposure until covered by siding (per manufacturer's recommendation)

Must be able to maintain adequate adhesion and moisture seal through environmental cycles (temperature and moisture exposure)

Must maintain integrity (adhesive & topsheet) through thermal cycles and resulting joint movement / settling of building

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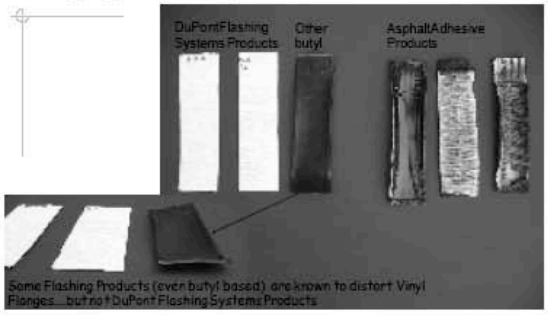
Competitive Products after Accelerated UV Aging for 14 days in Atlas Weatherometer



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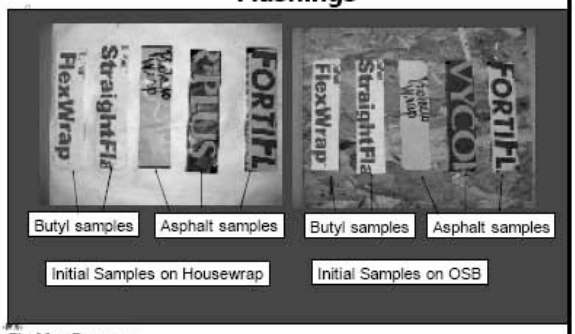
Heat Durability of Self-Adhered Flashings



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Heat Durability of Self-Adhered Flashings – Aged 10 days at 160° F

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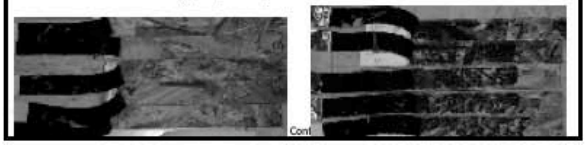
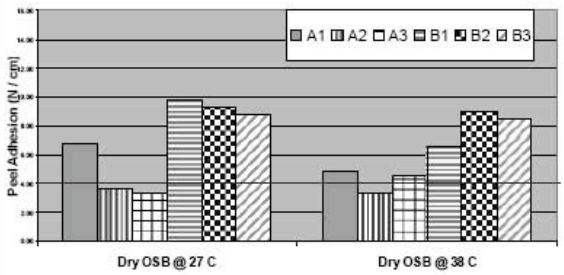
What is an Acceptable Adhesion Level?

- End use requirement: Does the SAF adequately stick to the wall and maintain its moisture seal?
- No performance based measurement exists
- Examined several substrates at a range of temperatures and surface conditions (moist, dusty)
- Full Study reported at ASTM Symposium on the Performance and Durability of the Window-Wall Interface, Salt Lake City, April 18, 2004



Adhesion Test Results: Dry OSB at 27°C & 38°C (77°F & 100°F)



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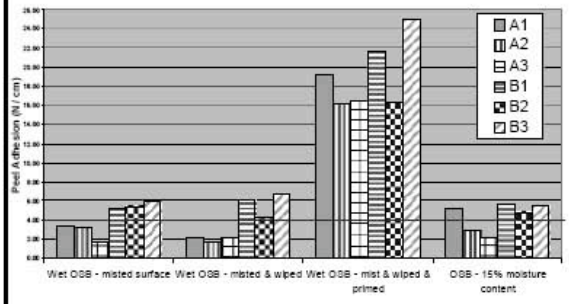
Adhesion Test Results: Wet OSB at 27°C



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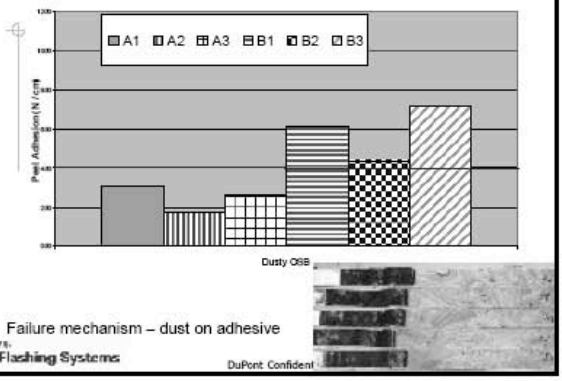
Adhesion Test Results: Dusty OSB at 27° C



Failure mechanism – dust on adhesive

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Enhanced Performance Offering:

Keys to Successful Use of Self-Adhered Flashing Products

- Continuity of window-wall interface
- Shingling / lapped correctly
- Moisture Management: Provide a Drainage Path for leaks
- Installed Systems Testing: window-wall installation as a complete system
- Installation conditions (real life) that promote adhesion
- Material choice - durability & robustness
- Education: Provide hands-on training & support on site

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Tyvek® Specialists Network

- **150 full time individuals located throughout NA**
- **Multi year training & certification program**
  - **University styled curriculum focused on building science fundamentals and product marketing**
- **Address needs of entire value chain:**
  - Consumers
  - Builders & Architects
  - Dealers
  - Building Code Officials
- **Services Performed include:**
  - Building Science training for builders
  - Code education
  - Field installation training
  - Energy Analysis
  - Coordinate Local/Regional Advertising/Promotional Campaigns

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Future Flashings Market

- Trend towards recommending pan flashings
  - ASTM E 2112, EEBA Water Management Guide
- Performance standards under development
  - AAMA
- Requirements increasingly shifting toward window manufacturer specifications
  - California SB800 and "right-to-correct laws"
  - ASTM E 2112
  - IRC

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Need Clear Standards To Support The Codes

- More uniformly applied – standard installation
- Connection to real world performance
- Separate construction phase from in service phase
- Combine different types of environmental exposures

Lack of Performance Based Codes And Standards Are A Hurdle to Innovation

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Preference Barriers Hypothesis:

- Cultural Values
- Attitudes to change in general
- Perceived or real economic advantage
- Influence of piers and others, or
- Any combination of these.

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Preference Barriers Hypothesis:

- Cultural Values –
  - driven (forced) by codes,
  - ASTM / AAMA standards (based on non-adhered system)
  - realization of liability – defects often hidden in wall
  - problems often occur after expiration of builder's warranty
  - responsibility of window-wall interface?
- Attitudes to change in general
- Perceived or real economic advantage
- Influence of piers and others, or
- Any combination of these.

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Preference Barriers Hypothesis:

- Cultural Values
- Attitudes to change in general –
  - risk aversion is typical
  - methods handed down through generations – confident that current system "works"
- Perceived or real economic advantage
- Influence of piers and others, or
- Any combination of these.

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Preference Barriers Hypothesis:

- Cultural Values
- Attitudes to change in general
- Perceived or real economic advantage –
  - Non-adhered or barrier system are lower cost options
  - For drainage system, DuPont Flashing Systems material cost ~$15/window vs other self-adhered systems ~$5-10/window (installed cost difference will be less),
  - Rigid sill pans can be >$25 each
  - Cost of installation defects is substantial!
  - Trust in performance closely linked to brand / image
- Influence of peers and others, or
- Any combination of these.

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Preference Barriers Hypothesis:

- Cultural Values
- Attitudes to change in general
- Perceived or real economic advantage
- Influence of peers and others, -
  - leverage of Tyvek® brand image,
  - hands on support, through Tyvek® Specialist network
  - knowledge intensity / education
- Any combination of these.

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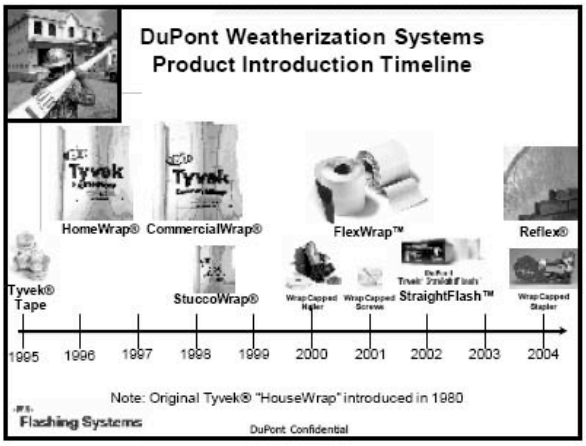
DuPont Weatherization Systems
Product Introduction Timeline
HomeWrap®
CommercialWrap®
FlexWrap™
Reflex®
Tyvek® Tape
StuccoWrap®
StraightFlash™
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
Note: Original Tyvek® "HouseWrap" introduced in 1980
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A Trusted
Brand Image
Proudly introducing the DuPont
Tyvek Weatherization Systems Family.
Tyvek
Flashing Systems

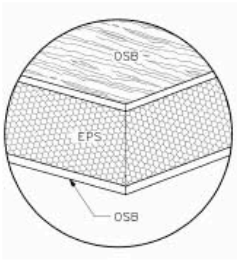
Appendix C: Innovation Presentations
Preference Panel, Fischer SIPs

Building with SIPS

Barriers to Innovation in Housing
Damian Pataluna

What Is a SIP?

- 7/16" OSB
- 1 lb. EPS
- Flame Retardant Bead
- No out – gassing
- Structural Adhesive
- 3rd party tested
- Fully engineered

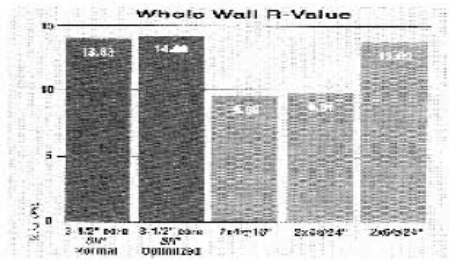


SIP General Info

- First used in 1952. Foam in 1978.
- Are currently 1% of new construction.
- 28 member companies around the U.S.
- Structural Insulated Panel Assoc. (SIPA)
- Mostly used in wall & roof application
- Replaces 2x stud framing & fiberglass.
- Used in 70% Residential. 30% Commercial

Advantages

- Energy Efficiency – Save up to 50%



Advantages

- Save Labor – Faster build Times

Advantages

- 3x stronger than stick construction.

Advantages

- Less Waste/Theft on site.

Advantages

- Pre-Cut Packages

Advantages

- Vaulted Ceilings.

Barriers to Entry

- Increase cost of house 5-7%
- Lack of knowledge by sellers of product.
- No standards have been set.
- Lack of builders & designers.
- Consumer awareness.
- Regional Barriers.

Homeowners Response

- Willing to pay 5%-7% more.
- Look at upfront cost only.
- Would rather spend $$ on windows or visible items then on the hidden walls.

Cost Comparison-Homeowner

Stick Home - $150,000		SIP Home – $158,000	
Monthly Mortgage at 6.5%	$950.00	Monthly Mortgage at 6.5%	$1,000.00
Ultilies	$200.00	Utilities	$ 100.00
Total	$1,150	Total SIP	$ 1,100 Save $50/mo.

Overcoming Barriers

Builders Response to Cost

- SIP package is 50% higher than lumber.
- Don't feel they can charge more.
- Don't care about building better home.
- Want SIPS for the same price as sticks.
- Rarely look at the whole picture (product costs + installation + time savings + waste savings + theft + quality)

Architect & Designer

- Will look at overall cost.
- More open to spending more up front.
- Must be justifiable.

Wholeseller/Retail

- Work on small margins, want cheap price.
- Manuf's can't meet low margin due to low volume.

Barriers to Entry

- Increase cost of house 5-7%
- Lack of knowledge by sellers of product.
- No standards have been set.
- Lack of builders & designers.
- Consumer awareness.
- Regional Barriers.

Homeowners

- Usually know more than the builder.
- Only a few books written on the topic.
- Find info on the internet – how much is good info???
- Women make the buying decision.
- Exterior walls not "interesting to them"

Builders

- Don't keep up with new innovations.
- Reluctance to change to a new product.
- Don't read half the info we send them on our product.
- Many not computer literate. (to surf the net)

Overcoming Barriers

Realtors

- Know that customers will pay more for energy efficiency.
- Often cannot explain what a SIP is to a customer.
- Don't understand R-Values. (more than just a number).
- Would rather push the "sizzle" items.
- Don't know how appraisers look at it.

Architects/Designers

- Can find info on the net.
- Often unsure of connection details.
- Generally understand the product the best.

Wholesalers/Retail

- Have no idea what they're selling.
- Don't know when to suggest it's use.
- Cannot answer technical questions.
- Want simple, easy products that move.

Barriers to Entry

- Increase cost of house 5-7%
- Lack of knowledge by sellers of product.
- No standards have been set.
- Lack of builders & designers.
- Consumer awareness.
- Regional Barriers.

Homeowners

- Generally OK.
- Willing to work with what-ever manufacturer Suggests.

Builders/Wholesalers

- Can cause problems. Like standards
- Different companies have different methods
- Sometimes get confused.
- Sometimes combine methods.
- Leads to frustrations on job site.

Overcoming Barriers

Architects/Designers

- Creates the most problems.
- 28 Companies, 28 systems.
- Who's is best?
- Combine systems in spec's.
- Get frustrated and resort back to comfort.
- Leave out details which creates work on down the line for the builder.

Barriers to Entry

- Increase cost of house 5-7%
- Lack of knowledge by sellers of product.
- No standards have been set.
- Lack of builders & designers.
- Consumer awareness.
- Regional Barriers.

Homeowners

- Cannot find someone to use SIPS so they stick build.
- Rely on SIP companies to suggest builder.
- Some SIP companies have installation crews.
- Many have a small builder network to recommend.

Builders

- Many are not interested in building with any method different than stick.
- Can't find training.
- Manu's need to send a SIP rep to site.
- Annual meetings are geared toward builders.
- Manu's afraid to share their lists (comp)

Designers

- Many are not comfortable dealing with SIPS (not enough standard details)
- Very few places they can get training/info.
- Design CD's would be helpful.
- SIPA working on program.

Barriers to Entry

- Increase cost of house 5-7%
- Lack of knowledge by sellers of product.
- No standards have been set.
- Lack of builders & designers.
- Consumer awareness.
- Regional Barriers.

Overcoming Barriers

Homeowners

- May see SIPS at a home show.
- Companies advertise in trade magazines.
- Rarely does a builder suggest them.
- Count on builders to make them aware of new products.
- No National TV advertising.
- May have seen on "This Old House"

Builders/Designers

- SIPA has booth at the IBShow annually.
- SIPA has internet site. www.sips.org
- Advertising by companies in trade magazines.
- Articles have been written. "This Old House."
- Seminars are held by companies.
- SIPA has a builder & designer program.

SIPA

- Working on fundraising. Needs $1-$2 Million annually.
- Will work on National TV ads.
- Promote in Newspapers & Trade Mag.
- Hold more publicity stunts (Habitat for Humanity homes).
- Need to hire a Marketing Agency to lead.

Barriers to Entry

- Increase cost of house 5-7%
- Lack of knowledge by sellers of product.
- No standards have been set.
- Lack of builders & designers.
- Consumer awareness.
- Regional/Cultural Barriers.

Homeowners/Builders

- Product can be used in any region with benefits.
- Banks/Appraisers/Insurance companies do NOT give added value to a SIP structure.
- Mostly middle to upper income users. More informed clients.
- Should be used more often in low-income housing.
- No incentive to builders to use the product.
- Energy Star Builders should be all over SIPS.

Architects/Designers

- Some areas more inclined to use EE products than others.
- Most designers don't have standard plans with SIPs or even SIP options.
- Average homebuyer doesn't hire an architect to design their home. (plan book)
- PATH recommends our product.
- Energy Star Rating.

Other comments

- Younger/affluent buyers are more common than older and less educated buyers.
- Men are more interested vs. women in Structure. But women do like EE.
- Many people just don't believe the foam is strong enough…
- Many don't believe the energy savings claims.
- Shipping & Freight can be an issue.
- Our product is great for Vaulted ceilings.

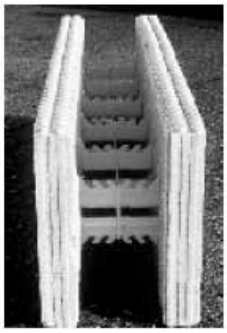
Appendix C: Innovation Presentations
Preference Panel, ICFA

Preferences as a Barrier to Innovation in the Housing Industry

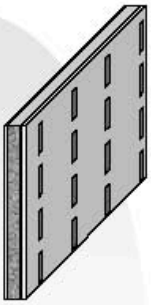
Insulating Concrete Form Association

Wall Functions

Structure
Insulation
Finish Attachment
Chase for utilities



Typical ICF Wall



100% insulation (R- 18 to 22)
100% monolithic structure
Integral furring
Fully insulated chase cavity

End Result

Exterior shell with:
Superior strength
Thermal performance
- High R-value
- Thermal mass
- Virtually no thru wall infiltration

Acoustical attenuation
Disaster resistance
Low Maintenance

Residential

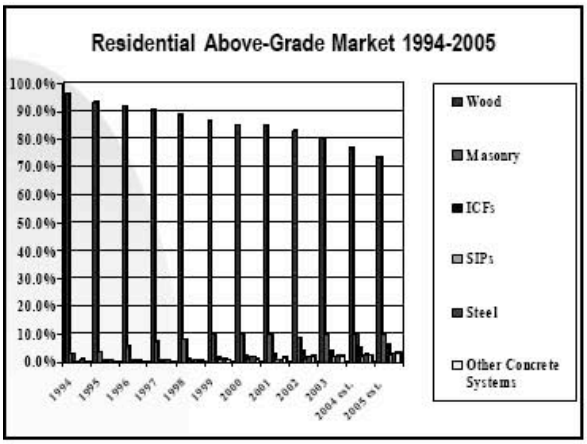
ICF History

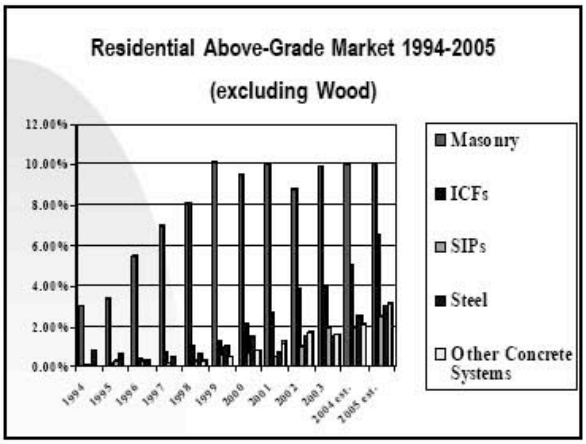
• EPS was created by the German chemical company BASF in 1940s

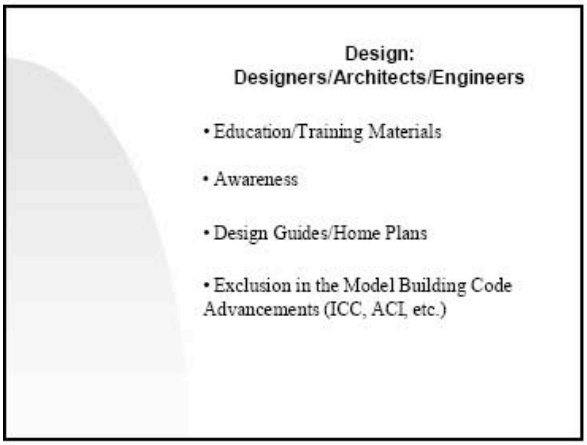
• Werner Gregori created the foam ICF concept in the mid 1960's as a foundation material, and submitted patents in 1966.

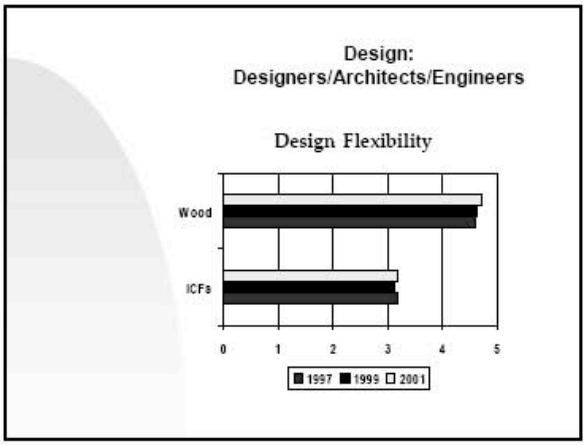
• ICFs amount to 0.1% of total above-grade residential market share in 1994

• ICFs reach 4.0% of total above-grade residential market share in 2003

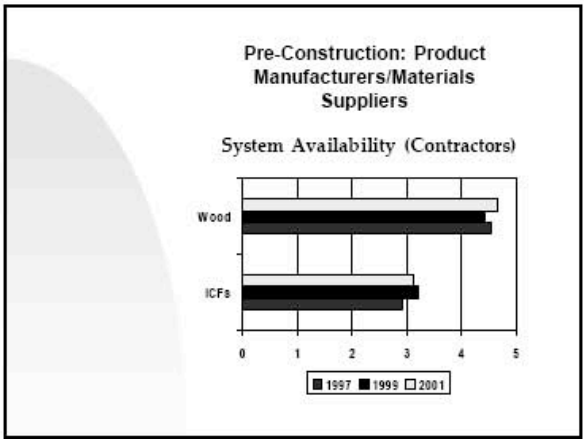

Residential Above-Grade Market 1994-2005
100.0%
90.0%
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004 est.
2005 est.
Wood
Masonry
ICFs
SIPs
Steel
Other Concrete Systems


Residential Above-Grade Market 1994-2005
(excluding Wood)
12.00%
10.00%
8.00%
6.00%
4.00%
2.00%
0.00%
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004 est.
2005 est.
Masonry
ICFs
SIPs
Steel
Other Concrete Systems


Design:
Designers/Architects/Engineers
• Education/Training Materials
• Awareness
• Design Guides/Home Plans
• Exclusion in the Model Building Code Advancements (ICC, ACI, etc.)

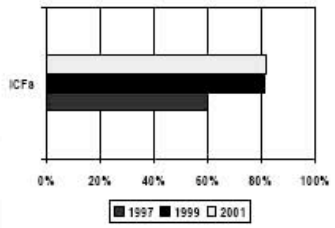

Design:
Designers/Architects/Engineers
Design Flexibility
Wood
ICFs
0
1
2
3
4
5
1997
1999
2001


Pre-Construction: Product Manufacturers/Materials Suppliers
• Training
• Location of Manufacturer/Shipping Costs
• Capital Investment/Capital Improvements
• Lack of Standards for Products
• Size and Resources of Firms
• Price of Raw Materials


Pre-Construction: Product Manufacturers/Materials Suppliers
System Availability (Contractors)
Wood
ICFs
0
1
2
3
4
5
1997
1999
2001

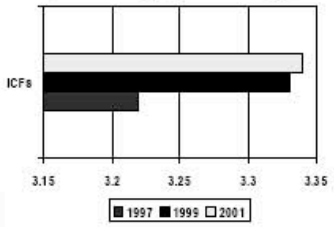
Construction:
Homebuilders/Subcontractors/Labor

Awareness of ICFs



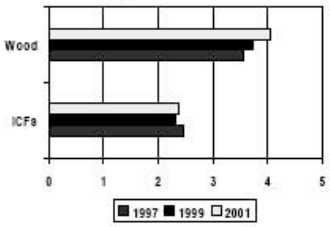
Construction:
Homebuilders/Subcontractors/Labor

How Building Codes Affect the Use of ICFs
(1 discourages; 5 encourages)



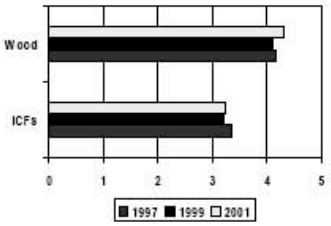
Construction:
Homebuilders/Subcontractors/Labor

Low Initial Cost of ICFs
Compared With Wood



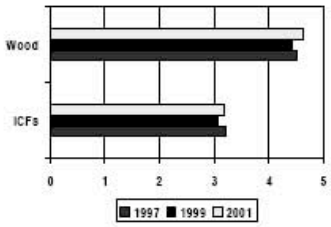
Construction:
Homebuilders/Subcontractors/Labor

Construction Time Compared with Wood



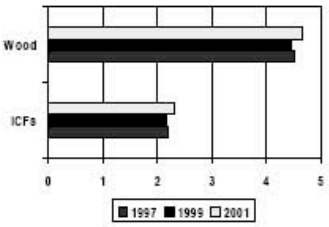
Construction:
Homebuilders/Subcontractors/Labor

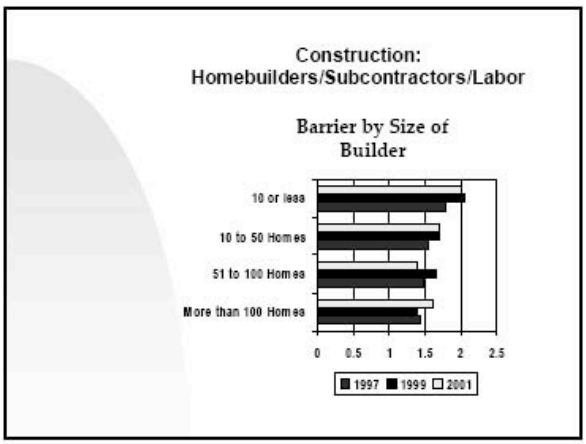
Ease of Construction of ICFs
Compared with Wood

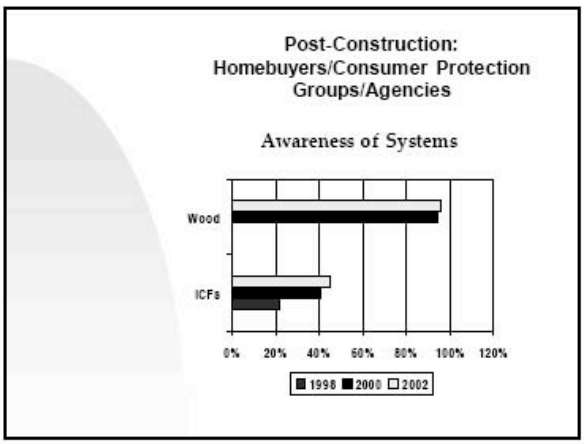


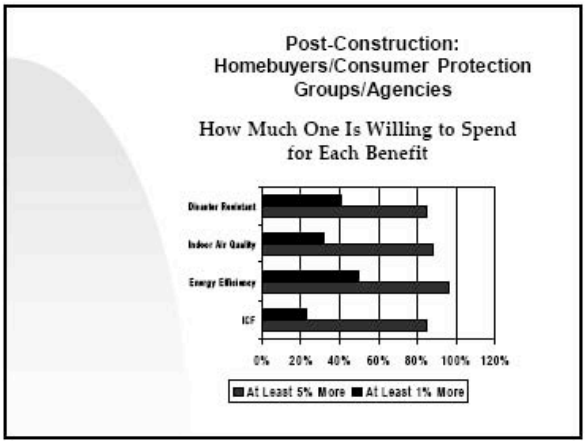
Construction:
Homebuilders/Subcontractors/Labor

Availability of ICF Subcontractor
Compared With Wood




Construction:
Homebuilders/Subcontractors/Labor
Barrier by Size of Builder
10 or less
10 to 50 Homes
51 to 100 Homes
More than 100 Homes
0
0.5
1
1.5
2
2.5
1997
1999
2001


Post-Construction:
Homebuyers/Consumer Protection Groups/Agencies
Awareness of Systems
Wood
ICFs
0%
20%
40%
60%
80%
100%
120%
1998
2000
2002


Post-Construction:
Homebuyers/Consumer Protection Groups/Agencies
How Much One Is Willing to Spend for Each Benefit
Disaster Resistant
Indoor Air Quality
Energy Efficiency
ICF
0%
20%
40%
60%
80%
100%
120%
At Least 5% More
At Least 1% More

Appendix C: Innovation Presentations
Education/Communication Panel, DuPont Housewrap Flashing

Flashing Systems

DuPont Flashing Systems: The development of unique self-adhered flashing products

EDUCATION/COMMUNICATION As A Barrier To Innovation In The Housing Industry – HUD/PATH Expert Panel Presentation
Hilton Embassy Row, Washington D.C.
November 3-4, 2004

G. Kimball Hart, Hart, McMurphy & Parks, Inc.
Based on an adaptation of a presentation by James D. Katsaros, DuPont Flashing Systems Development Leader

Outline

- Define Market Need for Self-Adhered Flashing Products
- DuPont Flashing Systems Developments
  - Self-Adhered Flashing Products
    - Define, Develop, Test, Validate & Retest
  - Installation Method Parallel Effort
    - Upgrade of existing 'Standards', test 'variations'
- Education Barriers Hypotheses:
  - Limited decision-maker attention and requirement for sufficiency
  - Language skills and non-English materials
  - Limitations of existing education channels and need for face-to-face communication to clinch transaction
  - Sufficient firm scale/resources and boom-related resistance

Flashing Systems DuPont Confidential

What is Flashing?

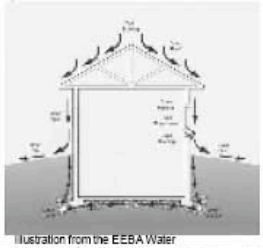


Illustration from the EEBA Water Management Guide, 2002

"Configuration of materials that are arranged to direct water to the exterior. These materials could be metal, asphalt-impregnated building paper, or adhesive backed bituminous tape."
Fine Homebuilding April/May 1998

Deflects Moisture Away from a building / structure

Flashing Systems DuPont Confidential

Flashing Helps Prevent Damaging Moisture Intrusion.

APA photo

If installed correctly

Flashing Systems DuPont Confidential

Market Risk Mitigation:
Understanding Market Needs & Habits

Focus Groups
Current Situation

Focus Groups
Value Proposition for Development Candidates

• Circle-top windows &
& sills are problem areas

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Traditional Flashing Products for Windows & Doors

- Asphalt coated / reinforced paper
- Polymeric Film
- Housewraps

Deflect moisture, but don't seal

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Challenges with Traditional Flashing Products & Methods

Can be worse than nothing if installed Incorrectly – acts as a "funnel"

Challenges with Traditional Flashing Products & Methods

Can be worse than nothing if installed Incorrectly – acts as a "funnel"

Flashing Systems DuPont Confidential

Market Wants Easy-to-Use, Forgiving System: Advantages Self-Adhered Flashings....

When installed and used properly, Self-Adhered Flashings:

- Provide a broad moisture seal at the window-wall interface (extension of the sealant)
- Are easy to install (peel and stick)
- Are versatile for many different installation methods and openings (shapes / sizes / etc)
- Maintain their seal through joint movement between dissimilar materials (durable topsheet)
- Provide a much more durable seal than a caulk joint (which is the basis for non-SAF methods)

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But there are Concerns with the Performance of Self-Adhered Flashings....

- "It doesn't always stick" (many examples of SAFs falling off the wall)
- How do I know SAFs are still working effectively behind the siding after many years of thermal cycles & environmental exposure?
- Self-Adhered Flashings can ooze and result in staining cladding surfaces & interactions with caulk
- Lack of a standard for material properties – anything can be a SAF
- Lack of a standard for installation conditions to ensure performance

Flashing Systems DuPont Confidential

Some concerns with Self-Adhered Flashings...

DuPont Confidential

Some concerns with Self-Adhered Flashings...

Flashing Systems DuPont Confidential

Market Opportunity For Improved Flashing?

- Water intrusion at windows and doors is a serious issue
  - Major source of litigation / new legislation
  - Majority of problems related to improper installation
- Strong fit with Tyvek® Weatherization Systems offering and core focus
- Requested by our customers.
- Large Market Space w/ no clear market leader

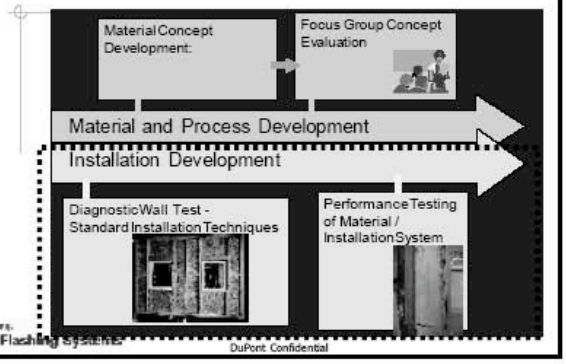
Flashing Systems

DuPont Self-Adhered Flashing via Systematic Product Development Process

Focus Groups	⇨ Builder/Installer Opinions on Current Products
Diagnostic Wall Test	⇨ Analysis of Current Products/ Installation Methods
R&D	⇨ Development Candidates
Focus Groups	⇨ Value Proposition, Likes/Dislikes
Performance Wall Test	⇨ Performance of New Product vs. Current Products

Flashing Systems

Concurrent Development of Flashing Material and Installation Method



Flashing Systems

Enhanced Performance Offering:
Keys to Successful Use of Self-Adhered Flashing Products

- Continuity of window-wall interface
- Shingling / lapped correctly
- Moisture Management: Provide a Drainage Path for leaks
- Installed Systems Testing: window-wall installation as a complete system
- Installation conditions (real life) that promote adhesion
- Material choice - durability & robustness
- Education: Provide hands-on training & support on site

Flashing Systems

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Flashing Systems

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Continuity of the Window-wall interface

5.1 ***Continuity*** —Continuity shall be maintained between elements in the fenestration product and the weather resistant barrier that provides weather protection, air leakage control, and resistance to heat flow and vapor diffusion.....

A continuous integration at the window-wall interface that provides a *durable* seal to air, thermal, and moisture intrusion...

..."caulks and sealants are generally not a suitable substitute for flashing." Durability by Design guideline published by the Partnership of Advancing Technology in Housing (PATH)

Flashing Systems

Enhanced Performance Offering:
Keys to Successful Use of Self-Adhered Flashing Products

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Flashing Systems

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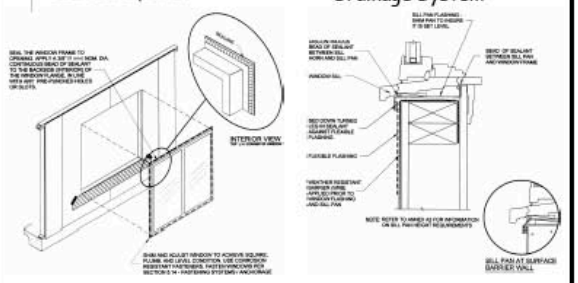
Flashing Installation Method Comparison:

Barrier System

Drainage System



Drawings taken from ASTM E2112, "Standard Practice for Installation of Exterior Windows, Doors and Skylights", Figures 11 & 15

Flashing Systems

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Moisture Leakage Associated with Windows Widely Reported

- "35% to 48% of newly installed windows were found to leak through the window unit itself, through joints between the window and the rough opening, or both."
  (Journal of Light Construction, November 2003, based on CMHC / HPO study)
- "100% of installed residential windows examined after years in service were found to leak either through the window unit itself or at points of attachment to the building."
  (Journal of Light Construction, November 2003, based on CMHC / HPO study)

Flashing Systems

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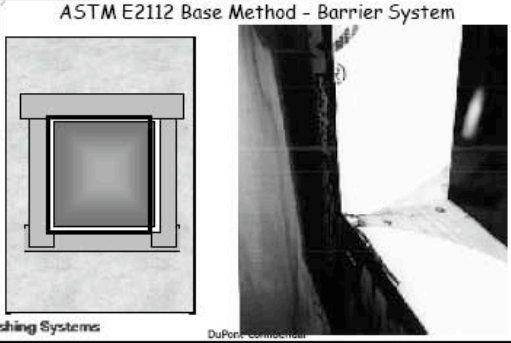
Traditional Window Flashing Methods

ASTM E2112 Base Method - Barrier System



Flashing Systems

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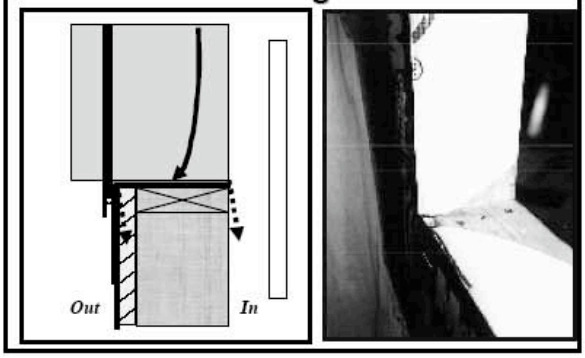
2-D Flashing / Caulked Bottom Flange



Barrier System Caulking and Flashing does not "forgive" leaks at the window and window-wall interface

Observations on Base ASTM E2112 Barrier Installation Method

Advantages:

Ease & Cost of Installation

Concerns:

Unforgiving to leaks in Window or Window-wall interface

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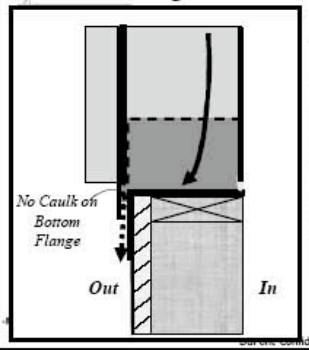
The Drainage Method: 3-D Flashing / Bottom Flange Not Caulked



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DuPont Flashing Systems

- DuPont FlexWrap™ was commercialized in Feb of 2001
  - Primary application is for sills, round top and custom shapes
- DuPont StraightFlash™ commercialized June 2002
  - Designed to complement FlexWrap™ and be used where conformability is not required
  - 4" product designed to flash the jambs and heads of rectangular window

Flashing Systems

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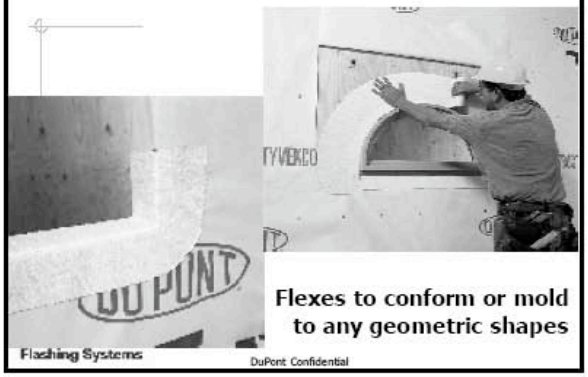
DuPont FlexWrap™



Flexes to conform or mold to any geometric shapes

Flashing Systems

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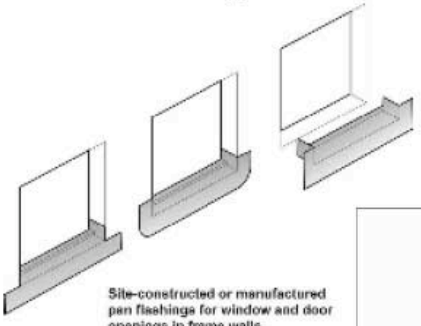
Various Sill Pan Designs – Revised ASTM E2112



Site-constructed or manufactured pan flashings for window and door openings in frame walls

Detail from the EEBA Water Management Guide, 2012

Flashing Systems

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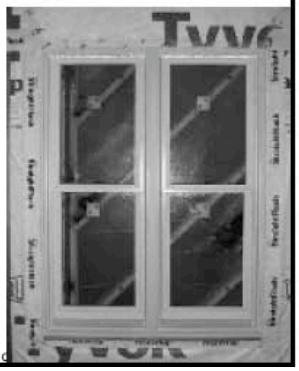
DuPont StraightFlash™

- Complementary product to complete system
- Designed for straight runs where conformability is not required
- Consists of non-elastic laminate and butyl adhesive



Flashing Systems

Detailed Installation Techniques

Example: Flanged window / wood frame after the weather resistive barrier has been installed.

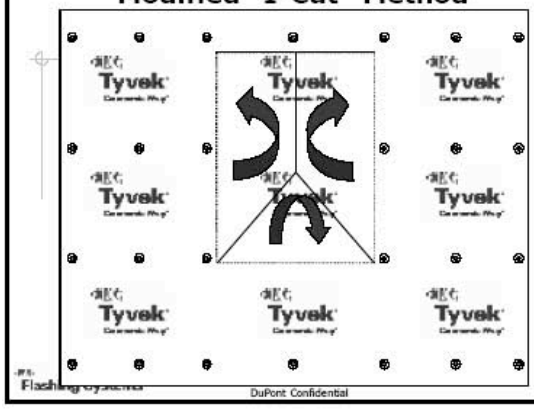
Flashing Systems

Installation Method / Material Development

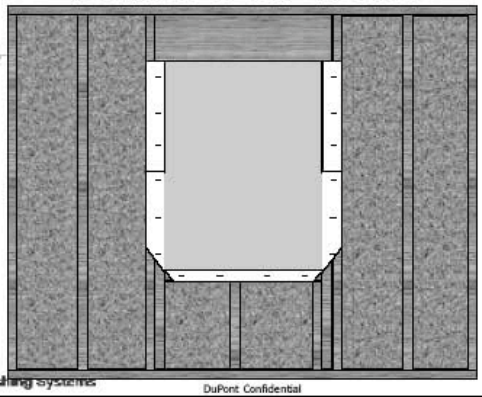
- Protect bottom corners into the rough opening
- "Moldable" Self-adhesive flashing (SAF)
  - seamless 3-dimensional flashing on sill and 6" up either side rough opening
  - single piece continuous head flashing for round-top window applications.
- Creation of a weep system by not applying caulk on bottom flange
- Self-adhesive flashing applied over jamb and head flanges.
- Air seal and back dam by interior caulk joint

Flashing Systems

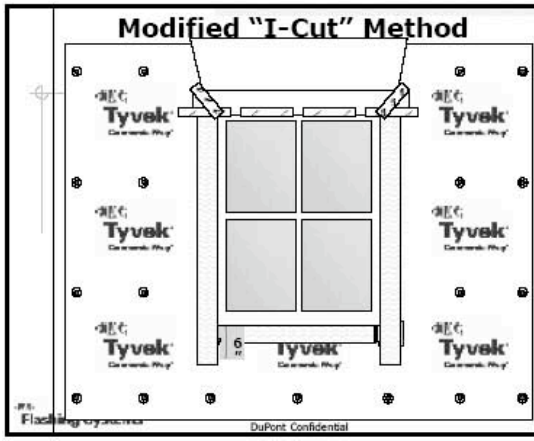
Modified "I-Cut" Method



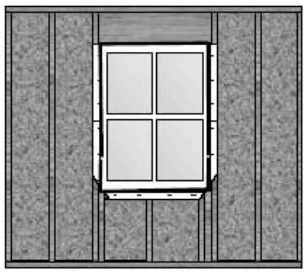
Modified "I-Cut" Method



Modified "I-Cut" Method

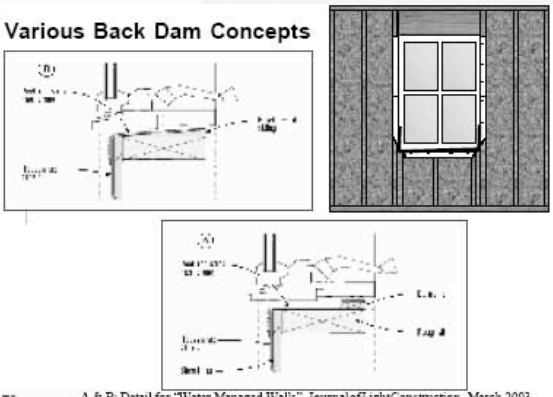


Back Dam and Air Seal



Flashing Systems

Various Back Dam Concepts



A & B: Detail for "Water Managed Walls", Journal of Light Construction, March 2003

Flashing Systems

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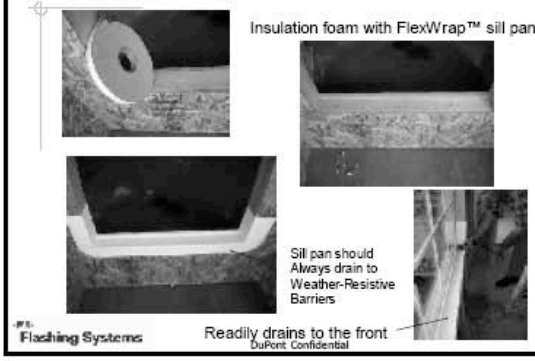
Flexible Sill Pan With Back Dam – Not Yet Required, But A Good Idea



Flashing Systems

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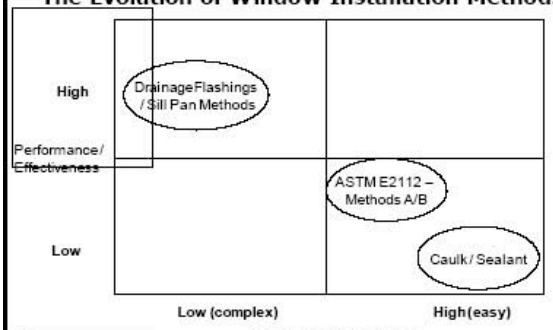
Market Adoption Risk:

The Evolution of Window Installation Methods



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Enhanced Performance Offering:

Keys to Successful Use of Self-Adhered Flashing Products

- Continuity of window-wall interface
- Shingling / lapped correctly
- Moisture Management: Provide a Drainage Path for leaks
- Installed Systems Testing: window-wall installation as a complete system
- Installation conditions (real life) that promote adhesion
- Material choice - durability & robustness
- Education: Provide hands-on training & support on site

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Detailed Testing & Development

Flashing Systems

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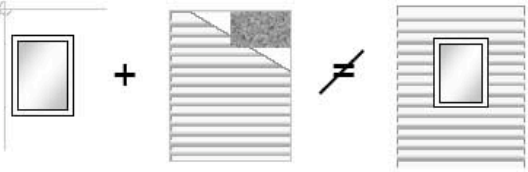
Tested Systems



- Windows and Walls are usually tested separately
- They should be tested as installed units

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Performance Assessment: Exposure

During Construction

During Service

- UV
- Rain
- Wind
- Temperature
- Humidity

- Temperature/Humidity Cycling
- Liquid Water
- Wind / differential pressures
- Compatibility with adjacent materials

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Wall System Testing Goals

- **Phase I** : Installation Method and Performance Specification
- **Phase II**: Durability of Installed Product
- **Phase III**: Installation Variants

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Phase I : Installation Method and Performance Specification

Install Window

Flashing Product
- FlexWrap™ prototypes
- Competitive products

Installation Methods

Window installation
- before WRB
- after WRB

Window type
- flanged
- non-flanged

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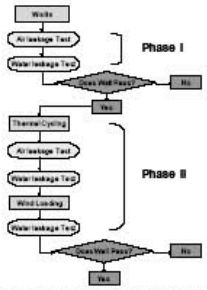
Installed Window – Wall Testing Protocol



REF: Weston T. A., et al., "Performance Testing of Window Installation and Flashing Details" 2002 Symposium on Improving Building Systems In Hot & Humid Climates, May

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Phase I : Installation Method and Performance Specification

Air Infiltration / Exfiltration Test (ASTM E283)

Measure infiltration and exfiltration at
.1" H_2O (25 Pa) (15 mph)
.3" H_2O (75 Pa) (25 mph)
1.2" H_2O (300 Pa) (50 mph)

Water Infiltration (ASTM E331)

- Standard water flow rate
- Infiltration pressure of .1" H_2O (15 mph) for 15 min
- Infiltration pressure of .3" H_2O (25 mph) for 15 min
- Moisture sensors will be installed and monitored during spraying along with visual observations.

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Phase I Results

FlexWrap™ / installation performed well- no leaks

Water leaks occurred at mull joint

Caulk positioning provided "forgiveness" for window leak

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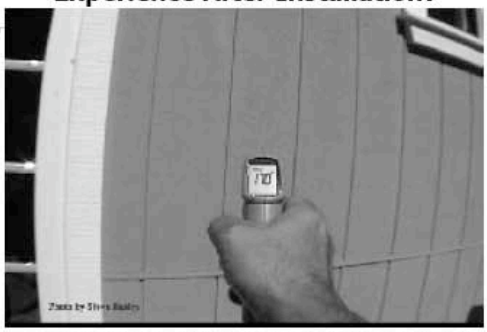
What Temperature Exposures Do SAFs Experience After Installation?



Measured on wood siding on 80°F day in Northern California

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Phase II - Durability

- Repeat Air Infiltration / Exfiltration
- Repeat Water Infiltration
- ASTM E 330 – Wind Loading
  - Infiltration load at 2" H_2O (65 mph) for 1 hour
  - Exfiltration load at 2" H_2O (65 mph) for 1 hour
- Repeat Water Infiltration

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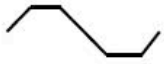
Phase II: Durability

Thermal Cycling
0'F -- 160 'F, seven days cycling

6 hour cycles



Accelerated aging +
ASTM E1677 evaluation

Retest walls for water and air infiltration

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Phase II - Durability

Thermal Cycling

- 0° F to 160° F for 7 days at 4 cycles per day
- 6 hour cycles

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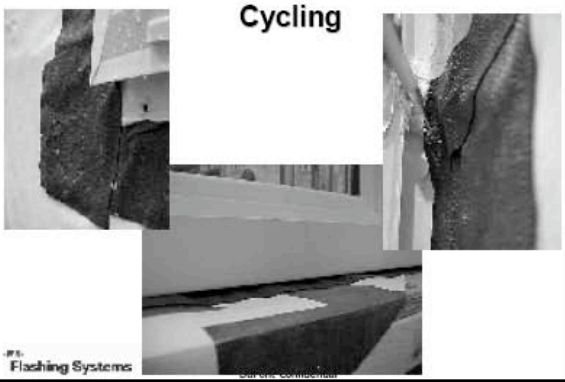
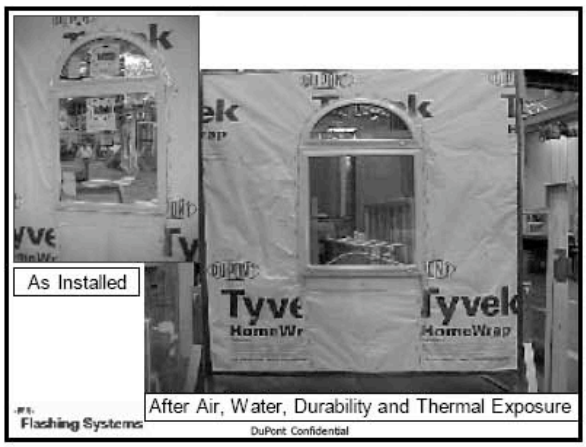
Traditional Peel 'n Stick after Thermal Cycling



Flashing Systems


As Installed
After Air, Water, Durability and Thermal Exposure
Flashing Systems
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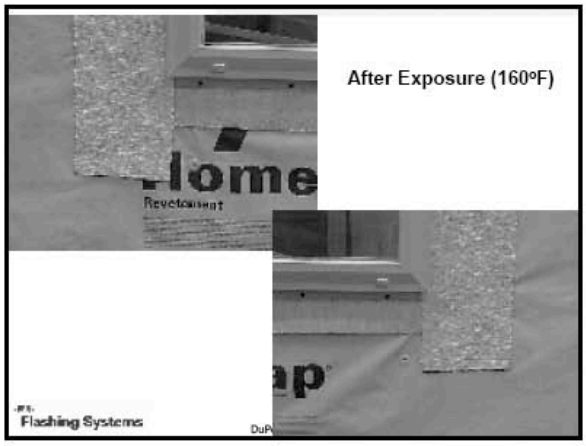
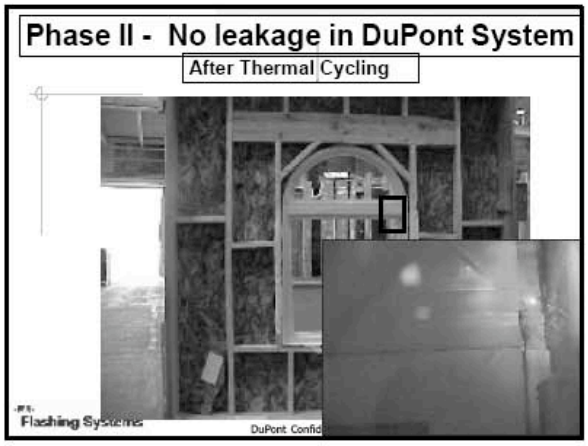
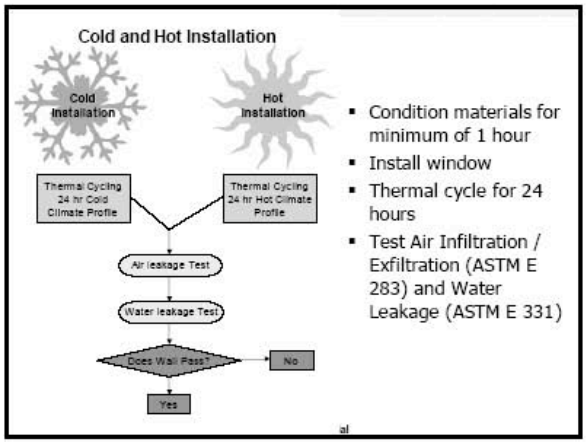
After exposure (160ºF)
Flashing Systems


After Exposure (160ºF)
Flashing Systems


Phase II - No leakage in DuPont System
After Thermal Cycling
Flashing Systems


Cold and Hot Installation
Cold Installation
Hot Installation
Thermal Cycling 24 hr Cold Climate Profile
Thermal Cycling 24 hr Hot Climate Profile
Air leakage Test
Water leakage Test
Does Wall Pass?
No
Yes
Condition materials for minimum of 1 hour
Install window
Thermal cycle for 24 hours
Test Air Infiltration / Exfiltration (ASTM E 283) and Water Leakage (ASTM E 331)


Phase III- "Faulty" Installations
Reverse laps
Butt and lap joints
Bubbles and wrinkles
Fastener penetrations
Stretched materials
No caulking
No taping
Test walls for water & air infiltration and durability
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HomeWrap
Revêtement
DuPont Confidential


HomeWrap


HomeWrap
Revêtement


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Tyvek
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Enhanced Performance Offering:
Keys to Successful Use of Self-Adhered Flashing Products

- Continuity of window-wall interface
- Shingling / lapped correctly
- Moisture Management: Provide a Drainage Path for leaks
- Installed Systems Testing: window-wall installation as a complete system
- Installation conditions (real life) that promote adhesion
- Material choice - durability & robustness
- Education: Provide hands-on training & support on site

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Primary "Types" of Self-Adhered Flashings: Bitumen & Butyl Adhesive

ASTM E2112:

X1.2 Flexible Flashing—Self-Adhesive Type

X1.2.2 *Bitumen Type Flashing*—Bitumen flashing typically has a rubberized bitumen material applied to a sheet of polyethylene, polypropylene, or in some cases a foil. In the majority of these products, the release sheet is pulled off, exposing the rubberized bitumen adhesive, which is then put down on the flange or the frame, depending on the installation method being used.
X1.2.3 *Butyl Type Flashing*—Butyl flashing typically has a butyl adhesive applied to a sheet of polyethylene, polypropylene, or in some cases a foil. In the majority of these products, the release sheet is pulled off, exposing the butyl adhesive, which is then put down on the flange or the frame, depending on the installation method being used. *Some butyl type flashings are formable so they can cover 3-dimensional and non-linear shapes such as the heads of round top windows.* Some other types of butyl flashings have less than 100% adhesive coverage integrated n the film or carrier that can be used in sill applications covering the bottom flange.

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Asphalt (Bitumen) Basics

- Natural products
  - Has been in use since 625 B.C.!
  - From asphalt lakes/deposits or heavy oil of petroleum
  - Complex mixture of organic compounds with high unsaturation
  - Relative low molecular weight
  - May contain nitrogen, sulfur, heavy metals in additional to carbon, hydrogen and oxygen
  - Inherent unpleasant odor

- Key applications
  - Road building materials
  - Roofing felt
  - Sealants

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Asphalt-based Adhesives

- Key advantages:
  - Cheap!
- Key issues:
  - Narrow operating temperature range
    - Brittle/poor adhesion at low temperature
    - Ooze/flows at high temperature
  - Poor chemical stability
    - Sensitive to UV radiation
    - Sensitive to thermal aging
  - Stains easily
  - Adhesives may become brittle overtime due to loss of VOC
  - Questionable seal overtime
  - Unpleasant odor

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Butyl Rubber Basics

- Synthetic elastomers
  - First commercialized in 1942
  - Monomers: isobutylene (>95%) and isoprene (<5%)
  - Low/no unsaturation, little by-products
  - Many grades available to cover a broad molecular weight range (both cured and uncured)
- Key applications
  - Inner tubes for tires
  - Sealants (windows)
  - Automotive suspension bumpers
  - Electrical insulation
  - Rubber sheeting for external use
  - Elastomeric seal for hydraulic systems

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Butyl Rubber-based Adhesives

- Key advantages
  - Broad operating temperature window
    - Flexible/good adhesion at low temperature
    - Resists oozing/flowing at high temperature
  - Excellent chemical/physical adhesion to substrates
    - Adhesion grows with time -- repositionability!
  - Excellent weather resistance
  - Excellent chemical/moisture resistance
  - Excellent stretchability
  - No solvents/VOCs
  - No odor
- Key disadvantages
  - More expensive

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Performance Comparisons

	Butyl Adhesives	Modified Asphalt Adhesives*
1) Use Temperature Range		
Low temperature flexibility	good to excellent	poor to good
High temperature flow-resistance	stable to 180+ F	oozes above 120-140 F
2) Chemical stability		
UV-stability	stable	causes degratation
Thermal Aging	stable above 200 F	causes degratation
Compatibility with sealants / substrates	generally inert	poor with solvents & elastomers
3) Adhesive performance		
Repositionability	generally yes	no
Product stains	not likely	yes
4) Sealability performance	stable over time	time dependent - can become brittle
5) Product ingredients	synthetic - easy to control	natural - hard to control (often waste stream)
6) Product odor	no	strong

* Note: Depending on specific formulation, the performance of polymer-modified asphalt could be better than described here in general.

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Durability Considerations of Self-Adhered Flashings

Must withstand UV exposure until covered by siding (per manufacturer's recommendation)

Must be able to maintain adequate adhesion and moisture seal through environmental cycles (temperature and moisture exposure)

Must maintain integrity (adhesive & topsheet) through thermal cycles and resulting joint movement / settling of building

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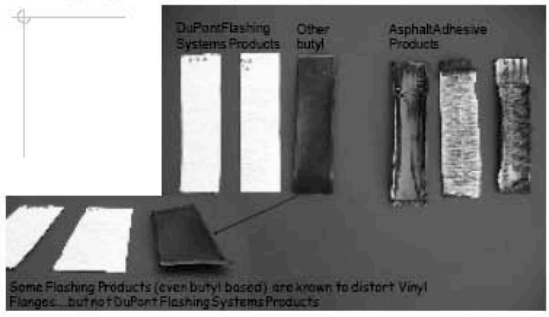
Competitive Products after Accelerated UV Aging for 14 days in Atlas Weatherometer



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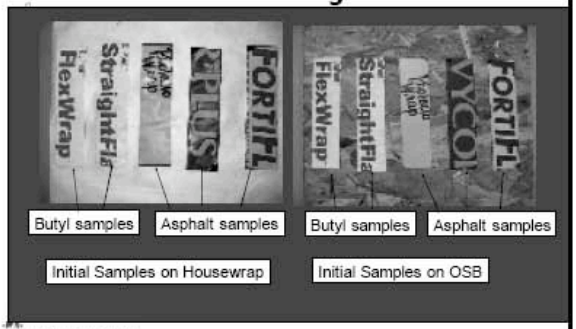
Heat Durability of Self-Adhered Flashings



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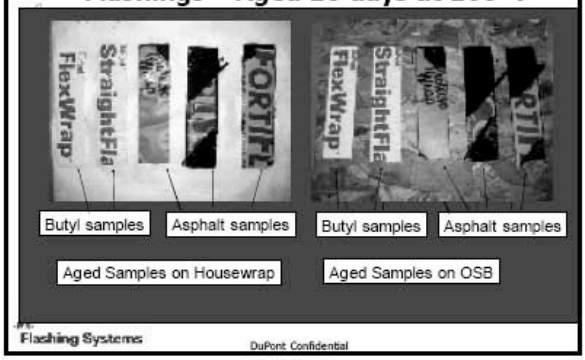
Heat Durability of Self-Adhered Flashings – Aged 10 days at 160° F



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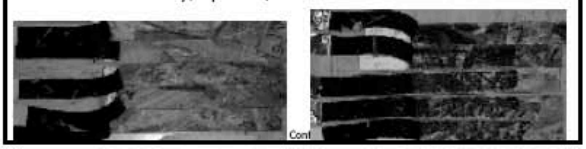
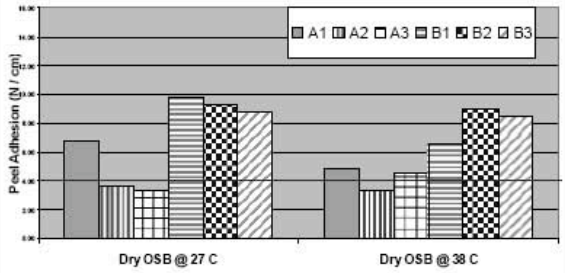
What is an Acceptable Adhesion Level?

- End use requirement: Does the SAF adequately stick to the wall and maintain its moisture seal?
- No performance based measurement exists
- Examined several substrates at a range of temperatures and surface conditions (moist, dusty)
- Full Study reported at ASTM Symposium on the Performance and Durability of the Window-Wall Interface, Salt Lake City, April 18, 2004



Adhesion Test Results: Dry OSB at 27°C & 38°C (77°F & 100°F)



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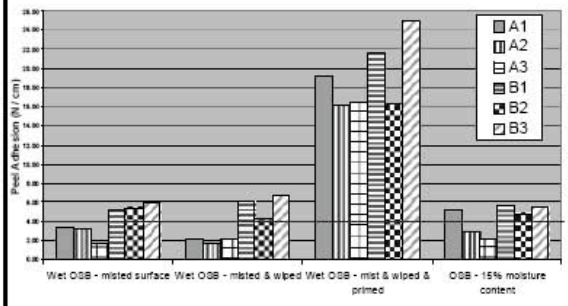
Adhesion Test Results: Wet OSB at 27°C



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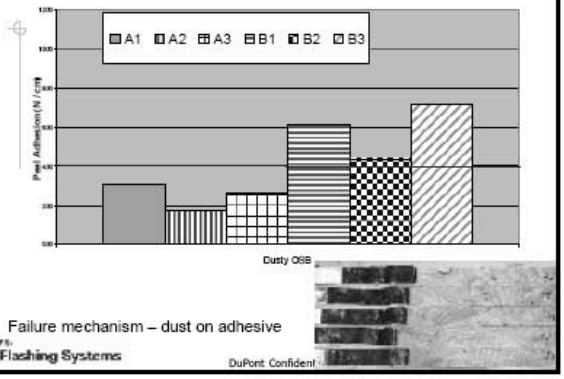
Adhesion Test Results: Dusty OSB at 27° C



Failure mechanism – dust on adhesive

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Enhanced Performance Offering:

Keys to Successful Use of Self-Adhered Flashing Products

- Continuity of window-wall interface
- Shingling / lapped correctly
- Moisture Management: Provide a Drainage Path for leaks
- Installed Systems Testing: window-wall installation as a complete system
- Installation conditions (real life) that promote adhesion
- Material choice - durability & robustness
- Education: Provide hands-on training & support on site

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Tyvek® Specialists Network

- **150 full time individuals located throughout NA**
- **Multi year training & certification program**
  - **University styled curriculum focused on building science fundamentals and product marketing**
- **Address needs of entire value chain:**
  - Consumers
  - Builders & Architects
  - Dealers
  - Building Code Officials
- **Services Performed include:**
  - Building Science training for builders
  - Code education
  - Field installation training
  - Energy Analysis
  - Coordinate Local/Regional Advertising/Promotional Campaigns

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Future Flashings Market

- Trend towards recommending pan flashings
  - ASTM E 2112, EEBA Water Management Guide
- Performance standards under development
  - AAMA
- Requirements increasingly shifting toward window manufacturer specifications
  - California SB800 and "right-to-correct laws"
  - ASTM E 2112
  - IRC

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Need Clear Standards To Support The Codes

- More uniformly applied – standard installation
- Connection to real world performance
- Separate construction phase from in service phase
- Combine different types of environmental exposures

Lack of Performance Based Codes And Standards Are A Hurdle to Innovation

Flashing Systems

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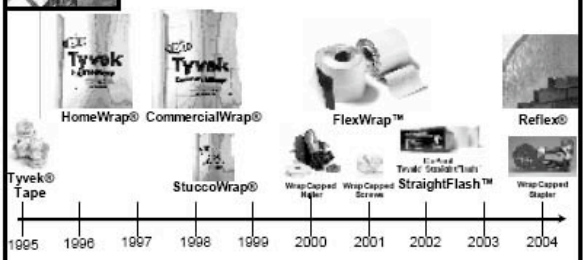
DuPont Weatherization Systems Product Introduction Timeline



Note: Original Tyvek® "HouseWrap" introduced in 1980

Flashing Systems

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A Trusted Brand Image

Flashing Systems

Appendix C: Innovation Presentations
Education/Communication Panel, SIPA

SIPA
Structural Insulated Panel Association

Structural Insulated Panels

HUD/PATH Barriers Research

Introductions

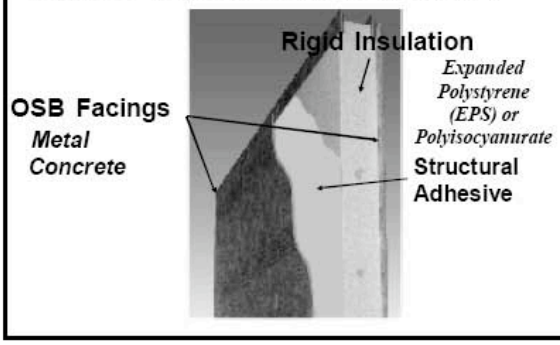
Ken Hawkins
General Manager
Premier Industries

Al Cobb
President
Panelwrights, LLC

Agenda

- SIPs - definition
- Types of construction
- Market applications
- Communications
- Training
- Barriers
- Q and A

What are Structural Insulated Panels ?



Where are we now?

Better measurements still needed but our best estimate shows....

- *51 Million sq. ft. in 2003*
- *10-15% increase annually*
- *70% residential*
- *30% commercial*
- *12,000 – 14,000 single family units*
- *2,300 – 2,500 nonresidential buildings*

Wall Systems

A Superior Building Product for Walls:

- *Fast*
- *The more complicated the design, the easier it is to build*
- *Control over materials and labor*
- *Solves problems prior to construction*
- *Straighter and truer walls*
- *Tighter construction*

Roof Systems

A Superior Building Product for Roofs

- Cathedral and vaulted ceilings
- Much faster dry-in
- Shed roof designs
- Open vaulted hip roofs
- Greater spans
- Pre-insulated
- Engineered

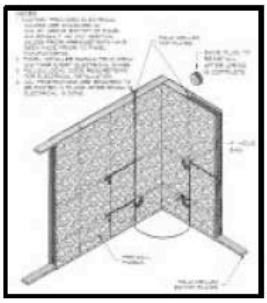
SIP Floor Systems

A Superior Building Product for Floors

- Clean crawl spaces
- Floors that are pre-insulated
- Simple, easy, and fast
- Efficient over unconditioned garages
- Floors that will not squeak

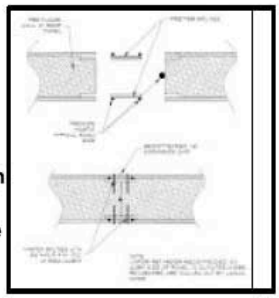
Connections

Electrical Chases



Spline Types

- Type S or Surface spline (OSB).
- This is preferred because it is a thermally broken spline.
- No heat loss through conduction.
- Not all SIP mfg. have this type spline.

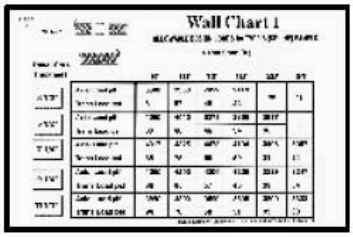


ICBO NES Compliant

Code Recognized

Load Charts

Wall load design chart for combined axial & bending.
Load charts are broken out by spline type.

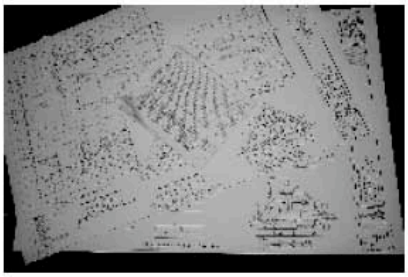


Continuous Processing
CAD/CAM

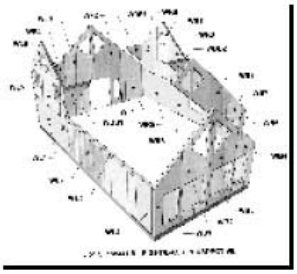
1. Starts with any CAD drawing.

Continuous Processing
CAD/CAM

2. SIP Software converts elevations into SIP shop drawings and material lists.



Continuous Processing
CAD/CAM
Two or Three dimensional

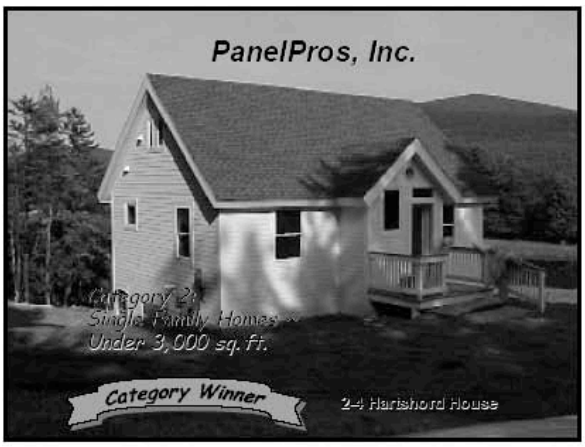


Continuous Processing
Computer Developed Design and Computer directed manufacturing

CAD/CAM

Custom Home Market

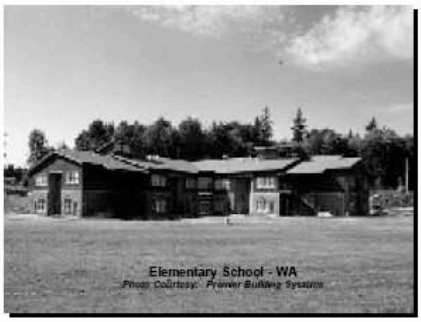
Fenner Residence
Sun Builders, Nevada City, CA



Production Home Market

Pulte Homes

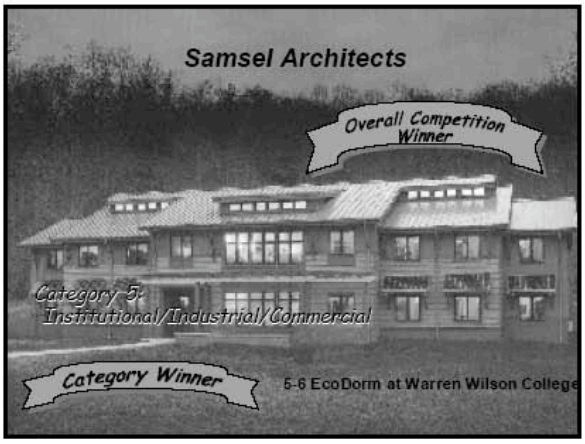
Nonresidential Market



Nonresidential Market

Nonresidential Market

Nonresidential Market



Value Proposition

Builders

SIPs provide design flexibility, durability, and high thermal performance, making it easier to meet energy code requirements. SIPs can improve profitability and efficiency by speeding up dry-in and cycle time, and reducing on-site labor, material waste, and callbacks

Value Proposition

Homebuyers

A SIP home is extremely energy efficient, quiet, safe and sound. SIPs are environmentally friendly (green), enhance indoor air quality, and provide built in quality, comfort, protection for your loved ones, and guaranteed lower monthly energy bills making long-term ownership more affordable

Web Site

www.sips.org

Publicity

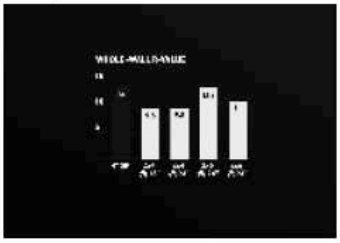
- Building Systems Magazine
- Architect Residential
- Builder Magazine
- Forbes
- Fine Home Building
- Pro Builder

Promotional Literature/Ads

Promotional Literature/Ads

Oak Ridge National Laboratory Studies

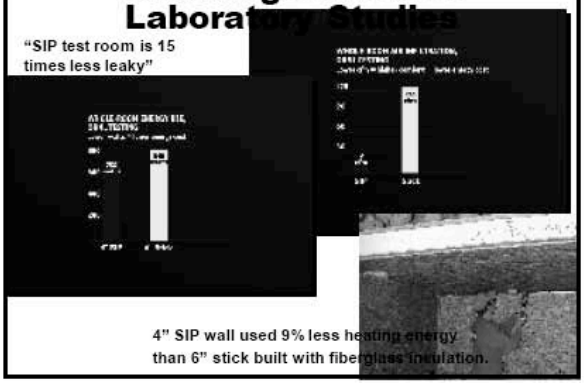
4" SIP wall out performs 6" stud wall with R-19 fiberglass



* 2X6 @ ... compression around ...

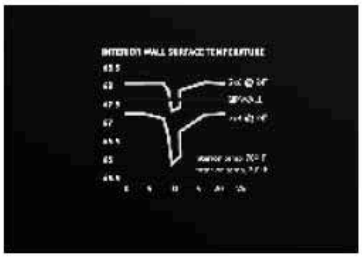
Oak Ridge National Laboratory Studies

"SIP test room is 15 times less leaky"



4" SIP wall used 9% less heating energy than 6" stick built with fiberglass insulation.

Oak Ridge National Laboratory Studies



More even temperature and comfort

3 Simple-Affordable SIP Near Net Zero Energy Houses built and occupied

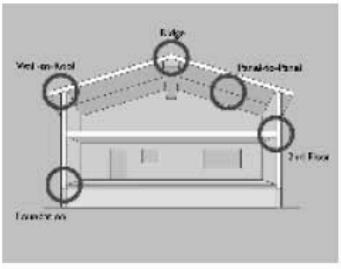
- SIPA / TVA / DOE / Habitat for Humanity
- Annual heating cost $92, cooling $74
- 45 cents per day
- 82 cents per day for total energy with plug loads

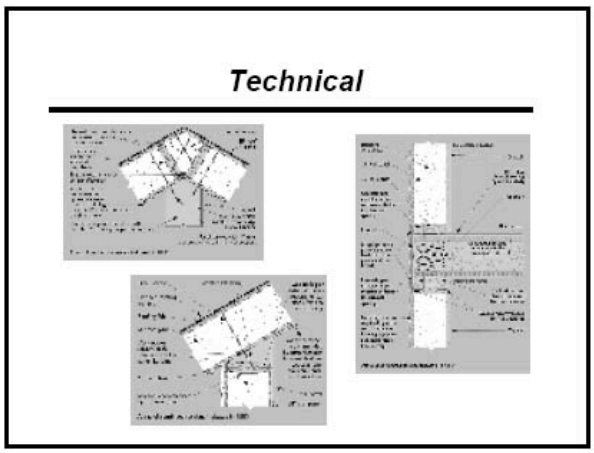
International Builders Show

Demonstration Houses

Next Gen House

Training




Technical

Appendix C: Innovation Presentations
Education/Communication Panel, Premier SIPs

Education / Communication

As a Barrier to Innovation in the Housing Industry

SIP Industry

- Selling as a DIY component ?
  - Lack training
  - www.sipsweb
- Recognized / Approved training
  - Liability
  - Standardization
  - Cost
  - location

Supplier/Retail Market

- Understanding panels
  - 84 lumber sells trusses
  - Wicks Lumber test market
- Industry standards nonexistent

Specification Writer

- Proper application
- Guidelines & Specifications
  - Example: Appalachian Mtn Club

Architectural Community

- Standard Specifications
- Connection details
- Load-Design Data
- Conformity to Code
- AIA continuing education
  - Strong demand

Engineering community

- "Screaming for Information"
  - Standards
  - Technical data
  - Test Data
- Safety Factors
- Example: Boonsboro Md. 4 kip post

Sales

- System vs. component
- Educate the consumer
  - Proficiency in the entire system and its relation to the rest of the structure
    - Shingles
    - HVAC
    - Jamb extensions

Trades / Union

- Approved Training
- Field Certification
- Timber Framers Guild & Log Home Builders Assc.
  - Established apprentice training

Evaluation / Testing / Codes

- Adoption/acceptance by code community
- Engineering review
  - Weyerhauser
  - Mitek
  - Keymark & HSB

Builder

- Owner/Builder
  - Internet educated
- Small builder
  - Niche market
- Medium Builder
  - Established procedure
- Production Builder
  - Fiscally committed

Academic / Operations Research

- Universities
- Solar Decathlon
- Oak Ridge Laboratories
- Building Sciences Corporation
  - Supporting data
  - Validation of system

Media: Real Estate

- Resale Value
- Appraisals
  - Value on energy efficiency?

Learning and Education Specialist

- Job Corp Training
  - Curriculum development
- Community College (North Carolina)
  - Training Program (installers)

Appendix C: Innovation Presentations
Education/Communication Panel, PolySteel ICFs

PolySteel®
WE'RE BUILDING A BETTER WORLD

HUD/PATH
Barriers to Innovation Panel
Education & Training

PolySteel®
Insulating Concrete Forms

PolySteel
Insulating Concrete Forms

- Building System Overview
- American PolySteel History
- Education and Communication
- Barriers Encountered
- Successes Achieved
- Goals for the Future

PolySteel Building System Overview

PolySteel and other Insulating Concrete Forms (ICFs) use permanent insulation material as a temporary concrete form to construct reinforced concrete walls.

PolySteel Building System Overview

The resulting structure provides:

- Superior Comfort
- Superior Safety, Security, and Protection
- Superior Energy Efficiency
- Extraordinary Durability
- Reduced Maintenance
- Environmental Sustainability

PolySteel Building System Overview

PS•3000
Waffle Grid
Forms

PolySteel Building System Overview

Basic Form

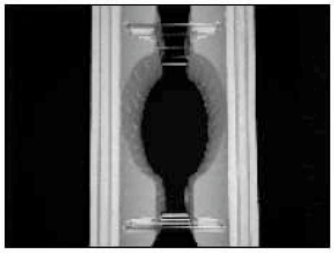
PolySteel Building System Overview

Steel Tie

Tongue & Groove Design

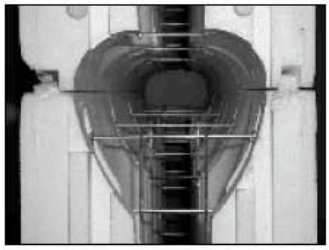
PolySteel Building System Overview

Vertical Posts



PolySteel Building System Overview

Horizontal Beams



PolySteel Building System Overview

Solid Concrete Wall

PolySteel Building System Overview

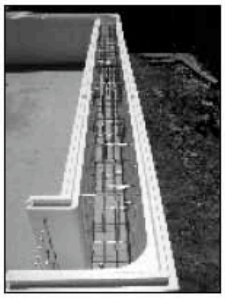
PS•4000 Flat Wall Forms

PolySteel Building System Overview

Basic Form

PolySteel Building System Overview

Solid Uniform Concrete Wall



PolySteel Building System Overview

Setting Forms

PolySteel Building System Overview

Setting Forms

PolySteel Building System Overview

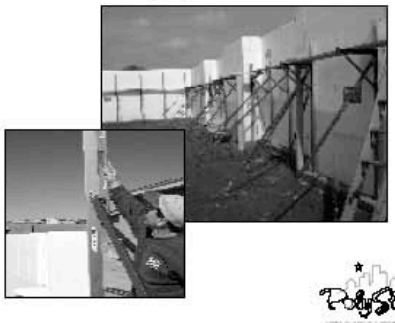
Setting Forms

PolySteel Building System Overview

Stacking Forms

PolySteel Building System Overview

Bracing & Aligning Walls



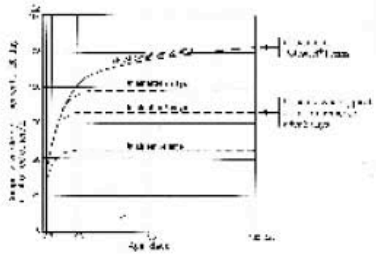
PolySteel Building System Overview

Bracing Openings

PolySteel Building System Overview

Placing Concrete

PolySteel Building System Overview



Stronger Concrete

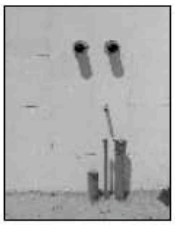
PolySteel Building System Overview

Attachments

PolySteel Building System Overview

Gable

PolySteel Building System Overview



Utilities

PolySteel Building System Overview

Interior Finishes

PolySteel Building System Overview

Exterior Finishes

PolySteel Building System Overview

Exterior Finishes

PolySteel Building System Overview

Residential

PolySteel Building System Overview

Residential

PolySteel Building System Overview

Residential

PolySteel Building System Overview

Residential

PolySteel Building System Overview

Multi-Family

PolySteel Building System Overview

Multi-Story

PolySteel Building System Overview

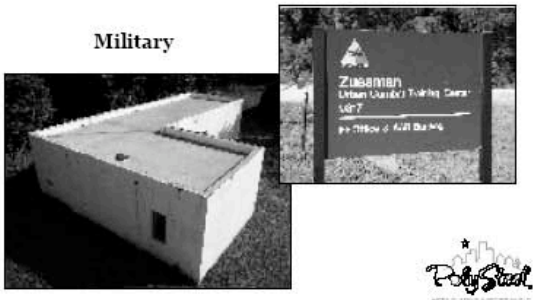
Commercial

PolySteel Building System Overview

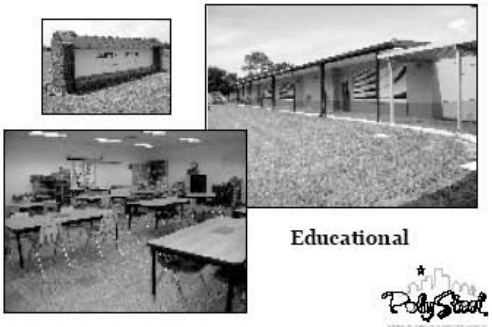
Retail

PolySteel Building System Overview

Military



PolySteel Building System Overview



Educational

American PolySteel History

- Conceived in 1966
- Founded in 1978
- Manufacturing & Sales
- Branded PolySteel in 1989
- National Distribution
- National Media
- ICFA Charter Member
- Energy Star Partner

American PolySteel History

- Perform Guard Addition
- Product Redesign and Expansion
- Eliminated Manufacturing
- Ongoing R&D

Education and Communication

- Product Testing
- Design Engineering
- Installation Training
- Code Evaluation & Approval
- Trade Associations & Alliances
- Media Promotion
- Educational Institutions (UBC, AIA, VoTec)

Education and Communication

- **Product Testing**
  - Acoustic
  - Fire
  - Ballistics
  - Thermal Performance
  - Whole-Wall R-Value
  - Flying Debris
  - Blast
  - Field Studies
    - Thermal
    - Cost
    - Appraisal

Education and Communication

- **Design Engineering**
  - Structural Design Guidelines
  - Structural Design Manuals
  - Structural Design Computer Program
  - Full-Time Staff Engineer
  - FEMA Guidelines
  - ACI, ASTM, PCA , & ICFA Committee Leadership & Participation

Education and Communication

- **Installation Training**
  - Installation Manuals
  - Installation Videos (Proprietary and Industry)
  - Training Classes/Seminars
  - Field Training and Support
  - Industry Initiatives (UBC, JLC, NAHB, WOC)

Education and Communication

- **Code Evaluation and Approval**
  - ICBO, SBCCI, BOCA, NER, ICC
  - Canada
  - NY City and State
  - Wisconsin
  - Dade County
  - LA City

Education and Communication

ICC ES Legacy Report NER-515 for PolySteel Insulating Concrete Forms

Education and Communication

- **Trade Associations & Alliances**
  - ICFA
  - NAHB
  - USGBC
  - PCA
  - UBC
  - HUD (CDBG, PATH)
  - Energy Star
  - AIA
  - DBIA
  - EEBA
  - FEMA
  - Habitat for Humanity

Education and Communication

- **Media Promotion**
  - **National**
    - Television (Hometime, This Old House, Dream Builder, etc.)
    - News (CNN, Today)
    - Print (BH&G, Builder & Trades, Popular Science)
    - Trade Shows (NAHB, WOC, AIA, DBIA, etc.)
  - **Regional & Local**
    - Television Shows and News
    - Magazines & Newspapers
    - Trade Shows & Featured Projects

Education and Communication

- **Internet**
  - Bob Vila DotCOM Dream Home
  - Industry Web Sites
  - All of the Previous Outlets Multiplied

Education and Communication

- **Educational Institutions**
  - Curriculum Development
    - PCA, CAC, UBC
  - UBC Implementation
  - Continuing Education (AIA, Contractors)
  - Vocational Schools (Midland, etc.)
  - On-Line Access

Education and Communication

There now exists sufficient design, testing, installation, code compliance, and field performance information available to support the wide use of this technology and demonstrate its value **quickly and easily** to a prospective user.

What is getting in the way?

Education Barriers Encountered

- **Record Demand for Housing**
  - **Home Ownership vs. Home Performance**
- **Adoption and UNDERSTANDING of Latest Codes and Evaluation Process (No incentive for change, e.g., Perform Guard)**
- **Fundamental Nature of Structural Product**
- **Limited Financial Resources of Fragmented Industry**
- **Consumer Education**
- **Technology Discrimination – How to Decide**
- **Understandable Testing and Performance Standards**
- **Political Will to Change Performance Expectations**

Successes Achieved

- **Builder Recognition**
- **Prescriptive Method**
- **Industry Standards (CSI, ACI, PCA)**
- **UBC Acceptance**
- **NAHB Concrete HB Council**
- **Production Builder Interest**
- **Increased Educational Interest**
- **Consistent Media Interest**

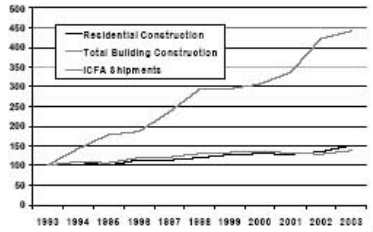
Successes Achieved

- **Market Penetration**
  - Distribution
  - Commercial and Residential
  - Public Awareness
  - Affordable Housing (Wood Not an Option)

Successes Achieved

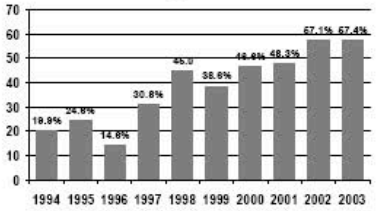
ICF INDEX

ICF Shipment Growth Compared to Total Construction



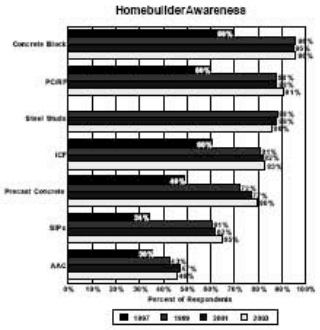
Successes Achieved

ICF Shipments for Above-Grade Applications



Successes Achieved

Homebuilder Awareness



Goals for the Future

- ICF Industry Standards
- Industry Consolidation
- Expansion of Distribution & Training Outlets
- Expansion of Subcontracting Trades
- Spanish Language Training Materials
- Training on Line (Interactive?)
- Consumer Education
- Raising U.S. Construction Standards
- Global Market Penetration

American PolySteel's Mission

American Polysteel is committed to working with our fellow citizens, in reverence to all of creation, to improve our quality of life by improving the quality of the shelters we build, the lives of those involved in the process, and the environment in which we all live, work, and play as we strive to become better human beings. We are committed to leaving the world a little better than we found it so that future generations have an unfettered opportunity to do the same.

Appendix D: Current ToolBase Innovations Database and Statistics

ToolBase Innovations	Diffusion	Affordability	Quality/Durability	Safety/Disaster Mitigation	Energy Efficiency	Environmental Performance	Building Element: mechanical/electrical; structural; envelope; partitions; foundation; floors; fasteners/treatments; site	slaughter scale: incremental, modular, architectural, system, radical	Retrofit Capability/Potential	Technical development/maturity (hi/med/lo)	Diffusion/adoption estimate, %	Field Eval/Demo
Combination Ventilation and Drip Edge System	B-Emerging	Afford			EnEffic		Env	Mod				
Grid-Marked Sheathing	B-Emerging	Afford	Qual/Dur				Env	Inc	Cap			
Insulation Alternatives: Sprayed Fiber Insulation	B-Emerging	Afford					Env	Arch	Pot			
Mortarless Brick Veneer	B-Emerging	Afford	Qual/Dur				Env	Mod	Cap			
Straw-Based Building Products	B-Emerging	Afford	Qual/Dur			EnvPerf	Env	NA				
Strawboard Panels	B-Emerging	Afford				EnvPerf	Env	Inc	Cap			
Energy-Efficient Interior Storm Windows	C-Mature	Afford	Qual/Dur		EnEffic		Env	Mod	Cap			
Insulation Alternatives: Non-Fiberglass Batts	C-Mature	Afford			EnEffic		Env	Inc	Pot			
Spray-Applied Concrete Walls - 1/9/2004	C-Mature	Afford	Qual/Dur				Env	Rad	Pot			
Tubular Skylights	C-Mature	Afford	Qual/Dur		EnEffic		Env	Arch	Cap			Field Demo
Fiber-Cement Siding	D-Graduate	Afford	Qual/Dur			EnvPerf	Env	Inc	Cap			Field Demo
Blower Door	D-Graduate	Afford	Qual/Dur		EnEffic		Env	Inc	Cap			
Tilt-up Roofs for Manufactured and Modular Homes	D-Graduate	Afford					Env	Inc				
Plastic Composite Nails	A-On the horizon	Afford	Qual/Dur	Saf/Dis			Fast	Inc	Cap			
Drywall Clips and Stops	C-Mature	Afford			EnEffic		Fast	Inc				
Concrete Admixtures - 1/9/2004	C-Mature	Afford	Qual/Dur				Fast	Inc	Cap			
Fly Ash Concrete	C-Mature	Afford	Qual/Dur			EnvPerf	Fast	Inc	Cap			
Crystalline Concrete Waterproofing	C-Mature	Afford	Qual/Dur				Fast	Inc	Cap			
Fibrous Concrete Reinforcement	C-Mature	Afford	Qual/Dur	Saf/Dis			Fast	Inc	Cap			
Decorative Concrete Floor Finishes	C-Mature	Afford	Qual/Dur				Floor	Inc	Cap			Field Demo
Trim-able Open Web Floor Truss - 5/2/2003	C-Mature	Afford	Qual/Dur				Floor	Inc				
New Generation OSB Sub-flooring	D-Graduate	Afford	Qual/Dur				Floor	Inc	Cap			
Concrete Footing and Pier Forms - 8/13/2003	C-Mature	Afford					Foun	Inc	Cap			
Frost Protected Shallow Foundations	C-Mature	Afford			EnEffic	EnvPerf	Foun	Mod				Field Demo
Pre-Cast Concrete Foundation Panels	C-Mature	Afford	Qual/Dur				Foun	Mod				
Wood Foundations	D-Graduate	Afford			EnEffic		Foun	Mod				
Natural Gas Refueling Station	A-On the horizon	Afford			EnEffic	EnvPerf	M/E	na				
Aluminum-Plastic Composite Water Piping	B-Emerging	Afford	Qual/Dur				M/E	Inc	Cap			
Modular Air Handler Hot Water Coil	B-Emerging	Afford			EnEffic		M/E	Inc	Cap			
Air Admittance Vents	C-Mature	Afford	Qual/Dur	Saf/Dis			M/E	Mod				Field Demo
Corrugated Stainless Steel Tubing (CSST) for Gas Distribution	C-Mature	Afford	Qual/Dur	Saf/Dis			M/E	Inc	Cap			Field Demo
Electrical Raceways	C-Mature	Afford	Qual/Dur	Saf/Dis			M/E	Mod	Pot			
HVAC Sizing Practice	C-Mature	Afford	Qual/Dur		EnEffic		M/E	Inc	Cap			
Plastic Plumbing Manifold -	C-Mature	Afford	Qual/Dur	Saf/Dis			M/E	Arch				Field Demo
Radiant Floor Heating - Dry System Hydronic	C-Mature	Afford			EnEffic		M/E	Arch				Field Demo
Wireless Thermostats - 5/2/2003	C-Mature	Afford			EnEffic		M/E	Inc	Cap			
Duct Leakage Testing	D-Graduate	Afford			EnEffic		M/E	Inc	Cap			
Evaporative Coolers	D-Graduate	Afford			EnEffic	EnvPerf	M/E	Inc	Cap			
Programmable Thermostats - 10/23/2002	D-Graduate	Afford			EnEffic	EnvPerf	M/E	Inc	Cap			
Drywall Finishing Accessories	C-Mature	Afford	Qual/Dur				Part	Inc	Cap			Field Demo
Wood Interior Wall Paneling System - 6/6/2002	C-Mature	Afford	Qual/Dur				Part	Inc	Cap			
Constructed Wetlands for Wastewater Treatment	B-Emerging	Afford				EnvPerf	Site	Sys				
Permeable Pavement	B-Emerging	Afford	Qual/Dur			EnvPerf	Site	Mod	Pot			
Low Impact Development (LID) Practices for Stormwater Management	C-Mature	Afford				EnvPerf	Site	Mod				
Plastic Chamber Leach Fields	C-Mature	Afford					Site	Mod				
Prefabricated Exterior Stairs	C-Mature	Afford					Site	Inc	Pot			
Shared Wastewater Treatment Systems	C-Mature	Afford				EnvPerf	Site	Mod				
Xeriscaping	C-Mature	Afford				EnvPerf	Site	Mod	Pot			Field Demo
Modular Block Retaining Wall Systems	D-Graduate	Afford					Site	Inc	Cap			
Rammed Earth Construction -	A-On the horizon	Afford			EnEffic		Struc	Sys				
Cob and Adobe Construction	B-Emerging	Afford			EnEffic	EnvPerf	Struc	Rad				
Combination Steel/Wood Framing -	B-Emerging	Afford					Struc	Arch	Pot			
Fastenerless Steel Framing-Clinching	B-Emerging	Afford	Qual/Dur				Struc	Inc				
Flexible Framing Track - 3/5/2002	B-Emerging	Afford	Qual/Dur				Struc	Inc	Cap			
Modular Multiple Dwellings - (20kb)	B-Emerging	Afford					Struc	Sys				
On-Site House Factory	B-Emerging	Afford					Struc	Rad				
Prefabricated Storm Shelter	B-Emerging	Afford					Struc	Mod	Cap			
Reduced Thickness Wall Studs	B-Emerging	Afford				EnvPerf	Struc	Inc	Cap			
Shear Wall Panels	B-Emerging	Afford					Struc	Mod				
Straw-Bale Construction	B-Emerging	Afford			EnEffic		Struc	Rad				
Two-Story Manufactured (HUD-Code) Homes -	B-Emerging	Afford				EnvPerf	Struc	Arch				
Concrete Formed Homes	C-Mature	Afford	Qual/Dur		EnEffic		Struc	Rad				
ICF Walls - Wood Fiber Composite Forms	C-Mature	Afford	Qual/Dur		EnEffic	EnvPerf	Struc	Sys				
Advanced Framing Techniques: Optimum Value Engineering (OVE)	D-Graduate	Afford			EnEffic	EnvPerf	Struc	Arch				

ToolBase Innovations	Diffusion	Affordability	Quality/Durability	Safety/Disaster Mitigation	Energy Efficiency	Environmental Performance	Building Element: mechanical/electrical; structural; envelope; partitions; foundation; floors; fasteners/treatments; site	slaughter scale: incremental, modular, architectural, system, radical	Retrofit Capability/Potential	Technical development/maturity (hi/med/lo)	Diffusion/adoption estimate, %	Field Eval/Demo
Plastic Composite Siding	A-On the horizon		Qual/Dur				Env	Inc	Cap			
Insulative Vinyl Siding	B-Emerging		Qual/Dur		EnEffic		Env	Inc	Cap			
Composite Window Frames	C-Mature		Qual/Dur	Saf/Dis	EnEffic		Env	Inc	Cap			
EIFS-Drainable Systems	C-Mature		Qual/Dur		EnEffic		Env	Arch				
High Wind- and Impact-Resistant Asphalt Roofing Shingles - 3/8/2004	C-Mature		Qual/Dur	Saf/Dis			Env	Inc	Cap			
Panelized Wall and Roof Systems	C-Mature		Qual/Dur	Saf/Dis	EnEffic		Env	Arch				Field Demo
Plastic Exterior Trim	C-Mature		Qual/Dur	Saf/Dis			Env	Inc	Cap			
Rain Screen Exterior Walls - (21kb)	C-Mature		Qual/Dur	Saf/Dis			Env	Arch				
Smart Vapor Retarders - 6/14/2004	C-Mature		Qual/Dur			EnvPerf	Env	Inc				
Latex Foam Sealant	C-Mature		Qual/Dur				Env	Inc	Cap			Field Demo
Wide Span Metal Roofing -	C-Mature		Qual/Dur				Env	Arch				
Impact Resistant Glazing	D-Graduate		Qual/Dur	Saf/Dis			Env	Inc	Cap			
Split-Face Concrete Block	D-Graduate		Qual/Dur				Env	Inc	Cap			
Cement Substitutes	B-Emerging		Qual/Dur			EnvPerf	Fast	Inc	Cap			
Flexible Framing Anchor Straps	B-Emerging		Qual/Dur	Saf/Dis			Fast	Inc	Cap			
Manufactured Housing Ground Anchor Systems	B-Emerging		Qual/Dur	Saf/Dis			Fast	Mod				
Concrete Aggregate Substitutes - 1/9/2004	C-Mature		Qual/Dur			EnvPerf	Fast	Inc	Cap			
Two-Part Universal Sealant Cartridge - 7/1/2003	C-Mature		Qual/Dur				Fast	Inc	Cap			
Wood Preservative - Low Toxicity	C-Mature		Qual/Dur			EnvPerf	Fast	Inc	Cap			
Crawl Space Foundation Systems - 3/21/2002	B-Emerging		Qual/Dur	Saf/Dis			Foun	Mod	Cap			
Manufactured Housing Disaster-Resistant Pier Systems	B-Emerging		Qual/Dur	Saf/Dis			Foun	Arch				
Foundation Drainage Panels	D-Graduate		Qual/Dur				Foun	Inc				
Hot Water Recirculation System	B-Emerging		Qual/Dur		EnEffic	EnvPerf	M/E	Mod	Pot			
Hydronic Radiant Cooling	B-Emerging		Qual/Dur		EnEffic		M/E	Sys				
Structured Wiring Systems	B-Emerging		Qual/Dur	Saf/Dis			M/E	Inc	Cap			
Water Cooled Evaporative Air Conditioning - 4/3/2003	B-Emerging		Qual/Dur		EnEffic		M/E	Inc	Cap			
White LED Lighting	B-Emerging		Qual/Dur		EnEffic		M/E	Inc	Cap			Field Demo
Central Air Purification/Ventilation/Dehumidification Systems	C-Mature		Qual/Dur	Saf/Dis			M/E	Inc	Cap			
Full Spectrum Fluorescent Lamps	C-Mature		Qual/Dur	Saf/Dis			M/E	Mod	Cap			
Humidity-Sensing Control Device	C-Mature		Qual/Dur		EnEffic	EnvPerf	M/E	Mod	Cap			
HVAC "Smart" Zoning Controls	C-Mature		Qual/Dur		EnEffic		M/E	Mod	Cap			
HVAC Equipment and Duct Installation within Conditioned Space	C-Mature		Qual/Dur		EnEffic		M/E	Arch	Pot			Field Demo
Mini-Duct Air Distribution System	C-Mature		Qual/Dur		EnEffic		M/E	Arch	Cap			
Modulating Furnace	C-Mature		Qual/Dur		EnEffic		M/E	Mod	Pot			
Ray-Core Panels	C-Mature		Qual/Dur		EnEffic	EnvPerf	M/E	Sys				
Reverse Cycle Chiller - 6/13/2002	C-Mature		Qual/Dur		EnEffic	EnvPerf	M/E	Mod	Pot			
Electric Moisture Meters	D-Graduate		Qual/Dur	Saf/Dis			M/E	Inc	Cap			
Universal Design Bathtubs and Showers	D-Graduate		Qual/Dur	Saf/Dis			M/E	Inc	Cap			
Guide Marked Gypsum - 6/26/2003	C-Mature		Qual/Dur				Part	Inc	Cap			
Universal Design Kitchen Cabinet	C-Mature		Qual/Dur				Part	Inc	Cap			
Fiberglass Reinforced Plastic Exterior Decks	C-Mature		Qual/Dur	Saf/Dis			Site	Inc	Cap			
Recirculating Sand Filters	C-Mature		Qual/Dur			EnvPerf	Site	Mod				
Cellular PVC Lumber	B-Emerging		Qual/Dur				Struc	Inc	Cap			
Engineered Wood Wall Framing	B-Emerging		Qual/Dur			EnvPerf	Struc	Inc	Cap			
Hybrid Modular/Panelized Housing -	B-Emerging		Qual/Dur				Struc	Arch				
Pre-Cast Concrete Passive Solar Home	B-Emerging		Qual/Dur		EnEffic	EnvPerf	Struc	Sys				
Steel L-Headers	B-Emerging		Qual/Dur		EnEffic		Struc	Inc	Pot			
Steel-Framed Modular Housing -	B-Emerging		Qual/Dur				Struc	Sys				
Recycled Wood/Plastic Composite Lumber	C-Mature		Qual/Dur				Struc	Inc	Cap			Field Demo
Insulating Concrete Forms	C-Mature			Saf/Dis	EnEffic	EnvPerf	Env	Sys				Field Demo
Foundation Flood Vents - 1/6/2004	C-Mature			Saf/Dis			Foun	Mod	Cap			.
Basement Escape System - 4/20/2004	C-Mature			Saf/Dis			M/E	Inc	Cap			.
Emergency Power Backup Systems	C-Mature			Saf/Dis			M/E	Inc	Cap			
Laminar Flow Fixtures	C-Mature			Saf/Dis	EnEffic	EnvPerf	M/E	Inc	Cap			
Tankless Water Heaters	C-Mature			Saf/Dis	EnEffic	EnvPerf	M/E	Arch	Pot			Field Demo
Autoclaved Aerated Concrete	B-Emerging			Saf/Dis	EnEffic	EnvPerf	Struc	Inc	Cap			Field Demo
Residential Light Gauge Steel	C-Mature			Saf/Dis	EnEffic	EnvPerf	Struc	Rad	Pot			Field Demo
Electrochromic Windows	A-On the horizon				EnEffic	EnvPerf	Env	Inc	Cap			
Vacuum Insulation Panel (VIP)	B-Emerging				EnEffic	EnvPerf	Env	Inc	Cap			
Window Film	B-Emerging				EnEffic		Env	Inc	Cap			
Radiant Barriers -	B-Emerging				EnEffic		Env	Inc	Cap			Field Demo
Insulated Headers	C-Mature				EnEffic		Env	Inc				
Insulation Alternatives: Blown or Foamed Through a Membrane - 8/28/2003	C-Mature				EnEffic		Env	Inc	Pot			
Insulation Alternatives: Sprayed Foam Insulation	C-Mature				EnEffic		Env	Inc	Pot			
Low-E Glass and Spectrally Selective Glazing - 6/17/2002	C-Mature				EnEffic	EnvPerf	Env	Inc	Cap			

ToolBase Innovations	Diffusion	Affordability	Quality/Durability	Safety/Disaster Mitigation	Energy Efficiency	Environmental Performance	Building Element: mechanical/electrical; structural; envelope; partitions; foundation; floors; fasteners/treatments; site	slaughter scale: incremental, modular, architectural, system, radical	Retrofit Capability/Potential	Technical development/maturity (hi/med/lo)	Diffusion/adoption estimate, %	Field Eval/Demo
Pumice-Crete	B-Emerging				EnEffic	EnvPerf	Fast	Mod	Cap			
Electric Vehicle ReCharging Station	A-On the horizon				EnEffic	EnvPerf	M/E	na				
Flywheel Energy Storage	A-On the horizon				EnEffic		M/E	Sys	Cap			
Phase Change Materials	A-On the horizon				EnEffic		M/E	Arch	Cap			
Solar Cooling	A-On the horizon				EnEffic	EnvPerf	M/E	Sys	Pot			
Aerosol Duct Sealing	B-Emerging				EnEffic		M/E	Inc	Cap			
Desiccant Cooling	B-Emerging				EnEffic	EnvPerf	M/E	Inc	Cap			
Drainwater Heat Recovery	B-Emerging				EnEffic		M/E	Inc	Cap			
Fuel Cell Electrical Generation	B-Emerging				EnEffic	EnvPerf	M/E	Sys	Cap			
Heat Pump Water Heaters	B-Emerging				EnEffic	EnvPerf	M/E	Mod	Cap			
Information-Age Wiring for Home Automation Systems -	B-Emerging				EnEffic		M/E	Sys	Pot			
Passive Solar Ventilation Air Pre-heater	B-Emerging				EnEffic	EnvPerf	M/E	Arch	Pot			
Photovoltaic (PV) Roofing	B-Emerging				EnEffic		M/E	Sys	Pot			Field Demo
Self-Contained Heat Pump/Air Handler	B-Emerging				EnEffic	EnvPerf	M/E	Mod	Cap			
Two-Stage Evaporative Cooler	B-Emerging				EnEffic		M/E	Inc	Cap			
Ductless (Mini-Split) Heat Pumps	C-Mature				EnEffic	EnvPerf	M/E	Mod	Cap			
Electric Radiant Ceiling Panel	C-Mature				EnEffic		M/E	Arch	Pot			
Geothermal Heat Pumps	C-Mature				EnEffic		M/E	Mod	Pot			Field Demo
Heat/Energy Recovery Ventilators (HRV/ERV)	C-Mature				EnEffic	EnvPerf	M/E	Mod	Cap			Field Demo
High-Efficiency Refrigerators	C-Mature				EnEffic		M/E	Inc	Cap			Field Demo
Horizontal Axis (Front-Loading) Clothes Washers	C-Mature				EnEffic		M/E	Inc	Cap			Field Demo
Horizontal Axis Washer-Dryer Combination Unit	C-Mature				EnEffic	EnvPerf	M/E	Inc	Cap			
Solar Water Heaters	C-Mature				EnEffic	EnvPerf	M/E	Arch	Cap			Field Demo
Vertical Axis (Top-Loading) Energy-Saving Clothes Washers	C-Mature				EnEffic	EnvPerf	M/E	Inc	Cap			Field Demo
Water Heaters With Space Heating Capability	C-Mature				EnEffic		M/E	Mod	Pot			
SIP Modular Housing	B-Emerging				EnEffic		Struc	Sys				
Structural Insulated Panels	C-Mature				EnEffic		Struc	Arch	Pot			Field Demo
Low- or No-VOC Paints	C-Mature					EnvPerf	Fast	Inc	Cap			Field Demo
Bamboo Flooring	B-Emerging					EnvPerf	Floor	Inc	Cap			
Recycled Content Carpet -	C-Mature					EnvPerf	Floor	Inc	Cap			
Recycled Wood Flooring	C-Mature					EnvPerf	Floor	Inc	Cap			
Greywater Reuse	B-Emerging					EnvPerf	M/E	Mod	Cap			Field Demo
High Efficiency Air Conditioners without HCFC	B-Emerging					EnvPerf	M/E	Inc	Cap			Field Demo
In-Line Fans	C-Mature					EnvPerf	M/E	Mod	Cap			
Ventilation Control Systems	C-Mature					EnvPerf	M/E	Inc	Cap			Field Demo
Kitchen Recycling Center	D-Graduate					EnvPerf	M/E	Inc	Cap			Field Demo
Low-Flow Plumbing Fixtures	D-Graduate					EnvPerf	M/E	Inc	Cap			
Termite Baiting	B-Emerging					EnvPerf	Site	Inc	Cap			
Aerobic Wastewater Treatment Units	C-Mature					EnvPerf	Site	Mod	Cap			Field Demo
Drip Irrigation Leach Field - 11/13/2003	C-Mature					EnvPerf	Site	Inc				
Gravel-Less Pipe Leach Fields - 11/13/2003	C-Mature					EnvPerf	Site	Mod	Cap			
On-Site Sewage Disposal Systems - Overview - 11/13/2003 (32kb)	C-Mature					EnvPerf	Site	Mod				
Pressurized Leach Field Dosing - 11/13/2003	C-Mature					EnvPerf	Site	Mod	Cap			
Rainwater Harvesting	C-Mature					EnvPerf	Site	Arch				Field Demo
Substitute Aggregate Leach Field	C-Mature					EnvPerf	Site	Mod				Field Demo

Current ToolBase Innovation Database Statistics:

"On the horizon" Innovations (<10% diffusion?)	9
"Emerging" Innovations (10% to 30% diffusion?)	58
"Mature" Innovations (30% to 50% diffusion?)	90
"Graduate" Innovations (>50% diffusion?)	17
Total Innovations	174
Innovations offering "Affordability" benefits	64
Innovations offering "Quality/Durability" benefits	79
Innovations offering "Safety/Disaster Mitigation" benefits	30
Innovations offering "Energy Efficiency" benefits	79
Innovations offering "Environmental Performance" benefits	68
Total number of benefits	320
"Incremental-scale" Innovations	89
"Modular-scale" Innovations	39
"Architectural-scale" Innovations	22
"System-scale" Innovations	15
"Radical-scale" Innovations	6
Innovations with Existing Stock Retrofit "Capability"	100
Innovations with Existing Stock Retrofit "Potential"	25
Innovations related to "Site" Building Elements	18
Innovations related to "Foundation" Building Elements	8
Innovations related to "Structural" Building Elements	26
Innovations related to "Envelope" Building Elements	35
Innovations related to "Partition" Building Elements	4
Innovations related to "Floor" Building Elements	6
Innovations related to "Fastener/Treatment" Building Elements	14
Innovations related to "Mechanical/Electrical" Building Elements	63
"High" Technical Maturity Innovations	?
"Medium" Technical Maturity Innovations	?
"Low" Technical Maturity Innovations	?
Innovations involved in HUD "Field Demonstration"	34

Appendix E: Informal Panel Recommendations Related to PATH Operations

The following informal recommendations all address the removal of a communication barrier to innovation and relate to PATH internal operations. The premise is that clearer, more targeted, and potentially less misleading PATH communications will focus more attention on innovations with a higher likelihood of acceptance.

1) PATH could stimulate housing innovation by rewarding it.
   - PATH could convene a panel of industry experts to review nominated innovations.
   - The best innovations, based on established judging criteria, could receive a major award from PATH, including major press coverage.

2) PATH should pick only a few innovation "winners" for promotion.
   - PATH resources are scarce.
   - Because housing delivery system system-wide change is so difficult, PATH should allocate more resources to supporting innovations proposing incremental change.
   - Builders have a very high resistance to the risks inherent to system-wide changes. To be accepted, any innovation must clearly offset both the risks and the costs of system-wide changes.
   - From the education/communication panel, PATH needs to establish at least five criteria for determining if an innovation is ready for their support:
     - Does the innovation provide an increased level of safety? (This can be assessed by the Evaluation Service).
     - Are there clear construction cost savings? Will these be passed on to the consumer (home buyer)?
     - Is there a clear potential to reduce construction time?
     - Does the innovation offer significant energy savings? How much and can these projections be confirmed?
     - Will the innovation improve the performance of the building or provide for better long-term maintenance.

3) PATH needs to clarify the role of its Website and its List of Innovations.
   - Simply listing innovations, as is currently done, confuses users. There should be some technical review and some threshold of performance to be met before an innovation is even listed. At the moment, all listings are inferred to be "recommended" in spite of disclaimers to the contrary.
   - Builders are seeking recommendations but will settle for some basic "vetting" of innovations based upon some level of proven performance.
   - Innovations are often so under funded that they cannot do full testing and reporting on their own. Any testing completed should be reported on the website. PATH should support testing and reporting for those who cannot.
   - All of the above recommendations are in line with the concept that PATH, including the website, should be a clearinghouse for all relevant information on an innovation.
   - It would help to have a "better" or more organized "library" of work done to date, including:

  - Testing or evaluations done and sources of this data.
  - Buildings that have incorporated the innovation.
  - Demonstrations completed to date
  - Available Evaluation Service (ES) Reports.
  - Add a question to the Dodge/JD Powers Surveys to collect this data.
- Efforts to get market penetration data in order to establish stages of adoption should be abandoned. An individual product's place in the life cycle is not important.
- The current site is not particularly user-friendly, especially for a builder wanting to get to basic questions answered quickly:
  - Does it lower costs?
  - Does it save construction time?
  - Does it reduce time to sell the house?
  - Does it Work? Has it worked for others?
  - Is it code approved or certified?
  - How to I find a manufacturer or supplier?
- Innovations should be grouped by both type and potential application.
- The website, especially "tool base" is not particularly easy to navigate, especially deep.
- PATH needs to raise awareness of its website. Most builders and consumers would not think of going to HUD first to find out about housing related innovations. They would likely go to "This Old House" or "Ask Jeeves" first.

4) <u>PATH should promote only those innovations that have a relatively complete set of "parts"—and could have an important role in assisting innovators in developing needed capabilities</u>
- Everything is available to facilitate installation.
- "Fail Safe" installations are "in the can."
- Quality processes have been designed and, if possible, proven by testing.

5) <u>Path needs to do more to display the innovations they choose to support.</u>
- Both consumers and builders choose from what they see.
- To encourage acceptance of innovations, PATH needs to find more ways to display these innovations so they can be seen and appreciated.
- Comment from the Education/Communication panel: Unfortunately, about 80% of builders are smaller local and regional builders who really don't have time to stop and retrain in order to accept an innovation. The question is how best to drill down critical information to them so they will take action. I am open to any idea that can jump the "cost savings/time savings" hurdle. But, frankly, few ideas are coming at me right now. My typical sources for new ideas are:
  - Builder shows
  - Salesmen
  - Trade magazines, and Subcontractors.

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