HERCULES (Solenis)

MARKET, COMPANY, TECHNOLOGY & JOB

by *John Smith*

JobDeck

HERCULES & Wood Adhesives

MARKET
1. Summary

The current annual global demand for phenol formaldehyde (PF), urea formaldehyde (UF), and isocyanate (MDI) adhesives is 18.822 billion lbs valued at $6.588 billion[1]. Adhesives and sealants are classified as SIC code 2891 and NCAIS Code 325520. Plastic materials and resins are classified as SIC Code 2821 and NCAIS Code 325211. The plywood and composite panel industry is classified as SIC Codes 2435/5031 and NCAIS Codes 321211/423310. The reconstituted wood products is classified as SIC Code 2493 and NCAIS Code 321219.

MARKET
2. Associations

- Adhesive and Sealant Council (ASC) http://www.ascouncil.org
- Composite Panel Association (CPA) http://www.pbmdf.com/
- Hardwood Plywood and Veneer Association (HPVA) http://www.hpva.org/
- The American Home Furnishings Alliance (AHFA) http://www.ahfa.us/index.asp
- Wood Products Manufacturers Association (WPMA) http://www.wpma.org/
- Kitchen Cabinet Manufacturer's Association (KCMA) http://www.kcma.org/
- Business and Institutional Furniture Manufacturers Association http://www.bifma.com/

- International Wood Products Association (IWPA) http://www.iwpawood.org/
- Canadian Plywood (CANPLY) http://www.canply.ca/english/
- Western Wood Products Association (WWPA) http://www.wwpa.org/members.asp

MARKET
3. Trade Shows

- International Woodworking Machinery & Furniture Supply Fair (IWF) – One of the world's largest trade shows for the furniture manufacturing, architectural woodwork, custom and general woodworking. http://www.iwf2006.com/
- Association of Woodworking & Furnishings Suppliers Fair (AWFS®) - The largest exhibition of woodworking hardware and machinery, board and panel products, upholstery material, wood components, supplies, services and new technologies in North America. http://www.awfsfair.org/awfsfair/home/index.asp

TECHNOLOGY
4. Adhesion

Adhesion[2] is the state in which two surfaces are held together by interfacial forces, which may be valence forces, interlocking action, or both. Valence forces are forces of attraction produced by the interactions of atoms, ions, and molecules that exist within and at the surfaces of both adhesive and adherend. Interlocking action, also called mechanical bonding, means surfaces are held together by an adhesive that has penetrated the porous surface while it is liquid, then anchored itself during solidification.

Mechanical interlocking is probably the primary mechanism by which adhesives adhere to porous structures, such as wood. Effective mechanical interlocking takes place when adhesives penetrate beyond the surface debris and damaged fibers into sound wood two to six cells deep.

For two wood adherends to be held together with maximum strength, a liquid adhesive must wet and spread freely to make intimate contact with both surfaces. Wetting of a surface occurs when the contact angle approaches zero. The contact angle approaches zero when the surface has high attractive energy, the adhesive has an affinity for the adherend, and the surface tension of the adhesive is low.

TECHNOLOGY
5. Wood Adhesives

- Adhesives used to bond wood may be separated in two distinct groups[3].
    1. Materials of natural origin (e.g. animal, vegetable, casein, and blood glues)
    2. Products of the petrochemical and related industries (e.g. synthetic resins derived from petroleum, natural gas, and coal)
- Synthetic[4] resin adhesives may be separated into two distinct categories - thermosetting adhesives and thermoplastic adhesives:
    1. Thermosetting adhesives depend upon a condensation type of polymerization reaction in which water is eliminated. During this cross linking reaction, the adhesive undergoes an irreversible chemical and physical change which renders it insoluble. The reaction itself may be initiated by means of chemicals or heat or a combination of both. Urea-formaldehyde, melamine formaldehyde, phenol-formaldehyde, and resorcinol-formaldehyde along with

phenol-resorcinol formaldehyde are included in this group of adhesives. All of these resins utilize formaldehyde as a common raw material. Thermosets are used for plywood and particle board adhesives, laminates and moulding[5].

2. Thermoplastic resins are pre-polymerized and set by loss of dispersing solvent. They do not undergo a chemical cross linking reaction while curing but remain in a reversible state and can readily be softened by heating. Polyvinyl acetate emulsions (white glue) and hot melt glues belong to this group of adhesives.

TECHNOLOGY
6. Chemistry of Wood Adhesives

Tables 1 and 2 show the class, resin type and typical system for wood adhesives.

Table 1. Classification of wood adhesives[6]

Class	Resin	Typical
Synthetic		
Thermosetting	Amino	Urea formaldehyde **(UF)** Melamine-formaldehyde **(MF)** Melamine-urea-formaldehyde **(UMF)**
	Phenolic	Phenol-formaldehyde **(PF)** Resorcinol-formaldehyde **(RF)** Phenol-resorcinol-formaldehyde **(PRF)**
	Isocyanate	Dyphenylmethane-4-4'-disocyanate **(MDI)**
	Epoxy	Bisphenol A-based epoxy resins
	Elastomeric	Styrene butadiene rubber **(SBR)**
Thermoplastic	Vynil	Polyvinyl acetate **(PVAc)**
	Hot-melts	Ethylene vinyl acetate **(EVA)**
Natural	Protein	Casein / Soybean / Blood / Animal

Table 2. Wood adhesives and structural performance

Structural Integrity	Service Environment	Typical adhesive system
Structural	Fully exterior (withstands long-term water soaking and drying)	PF RF PRF Emulsion polymer/isocyanate MF
	Limited exterior (withstands short-term water soaking) Interior (withstands short term high humidity)	MUF Isocyanate UF Casein Blood
Semistructural	Limited exterior	Cross-linked PVAc Polyurethane
Nonstructural	Interior	PVAc Animal Soybean Elastomeric construction or contact Hot-melt Starch

TECHNOLOGY
7. UREA-FORMALDEHYDE Adhesives

Urea-formaldehyde resins[7] are the most prominent examples of the class of thermosetting resins usually referred to as amino resins. They are widely used for the manufacture of interior grade plywood and also for the manufacture of particleboard. They are extensively used in producing hardwood plywood for furniture and interior paneling and for furniture assembly. They are available in both liquid and powder forms and may be mixed with hardeners, fillers, and extenders to obtain formulations which cure at temperatures ranging from

room temperature to nearly 400 °F. Fillers and extenders are added to the resin to control flow, viscosity, resin penetration into the wood, and to lower glue line costs. Unmodified urea formaldehyde resins are light colored and form joints which have high moisture resistance. Extension of these resins with various flours significantly reduces their moisture resistance. Urea-formaldehyde resins may also be fortified with melamine resins to improve both their moisture and temperature resistance[8].

The use of urea-formaldehyde resins as a major adhesive by the forest products industry has the following advantages: 1) Low cost, 2) ease of use under a wide variety of curing conditions, 3) low cure temperatures, 4) water solubility, 5) resistance to microorganisms and to abrasion, 6) hardness, 7) excellent thermal properties, and 8) lack of color, especially of the cured resin. The major disadvantage associated with urea formaldehyde adhesives as compared with other thermosetting wood adhesives, such as phenol-formaldehyde and polymeric diisocyanates, is its lack of resistance to moist conditions, especially in combination with heat (temperature in excess of 120 °F). These conditions lead to a reversal of the bond-forming reactions and the release of formaldehyde. For this reason, urea formaldehyde resins are usually used for the manufacture of products intended for interior use only. However, even when used for interior purposes, the slow release of formaldehyde (a suspected carcinogen) from products bonded with urea formaldehyde adhesives is a major concern that has come under close scrutiny by state and Federal regulatory agencies.

TECHNOLOGIE
8. SOY Adhesives

The principal protein-based vegetable glue is manufactured from either soybean meal or the vegetable protein isolated from it[8]. Proteins have a complex three-dimensional structure of highly coiled chains[9]. The three-dimensional structure is dependent on the types of amino acid in the polypeptide chain and their sequence and the hydrogen bonding and disulfide cross-links between individual amino acid side groups. For the protein to function as an adhesive the internal cross-links must be broken and the highly polar side groups on the amino acids made available for interaction with a polar adherent such as wood. The disruption of the internal cross-links is accomplished by dissolving (dispersing) the protein, usually in alkaline media.

Bulk soybean flour, which is usually used as the source of wood adhesives, typically contains about 44-50% protein. The flour is formulated into wet mixed adhesives usually using a combination of slaked lime, caustic soda, and sodium silicate. A number of formulations are possible, and a variety of additives are used to help improve properties. Soybean glue has properties and characteristics which are similar to those of casein glue, but lacks its water resistance. Soybean glue may be hot-pressed.

The major disadvantages of the proteinaceous adhesives compared with the thermosetting adhesives are: 1) They are subject to attack by microorganisms. Preservative materials can be added that inhibit microbial degradation to some extent and 2) They are much less resistant to moisture. Various cross-linking agents have been tried that increase water resistance to some extent. Table 3 shows a comparison of Urea and Soy based adhesives.

Table 3. Strength properties and typical uses of soy and urea adhesives[10]

Type	Form & color	Preparation	Strength	Typical uses
Urea	Powder and liquid forms; may be blended with melamine or other more durable resins; white to tan resin with colorless bond line	Powder mixed with water, hardener, filler, and extender by user; some formulations cure at room temperatures, others require hot pressing at 120 C (250 F); curable with high-frequency heating	High dry and wet strength; moderately durable under damp atmospheres; moderate to low resistance to temperatures in excess of 50 C (122 F)	Hardwood plywood; furniture; fiberboard; particleboard; underlayment; flush doors; furniture cores
Soybean protein	Powder with added chemicals; white to tan, similar color in bond line	Mixed with cold water, lime, caustic soda, and other chemicals; applied and pressed at room temperatures, but more frequently hot pressed when blended with blood adhesive	Moderate to low dry strength; moderate to low resistance to water and damp atmospheres; moderate resistance to intermediate temperatures	Softwood plywood for interior use.

TECHNOLOGY
9. Wood Adhesives Raw Materials

Phenol and urea wood adhesive pricing and availability are both subject to the vagaries of the petrochemical industry[11]. Phenol demand is driven by bisphenol (used for polycarbonate plastics) and caprolactum (for nylon 6 used in carpeting).

Phenol capacity is expected to become very tight as demand in these areas grows. UF is derived from natural gas, with only about 5 percent of capacity going into adhesives. Agricultural uses for fertilizer and feed additives utilize more than 90 percent of U.S. urea capacity. Urea prices fluctuate significantly with agricultural demand, and supplies are seasonally tight. Formaldehyde pricing is dependent on methanol supply and demand. The United States is a net methanol importer.

Soy adhesives, in contrast, are based on a renewable resource. Soy prices fluctuate with world supplies of feed grains and oilseeds. The US is the world's leading producer and exporter of soy, with annual production approaching 3 billion bushels.

TECHNOLOGY
10. SOY Varieties

- **Soy protein isolate (used to make Hercules adhesive)**
  Soy protein isolate is a highly refined or purified form of soy protein with a minimum protein content of 90% on a moisture-free basis. It is made from defatted soy flour which has had most of the non-protein components, fats and carbohydrates removed.
- **Soy protein concentrate**
  Soy protein concentrate is about 70% soy protein and is basically soybean without the water soluble carbohydrates. It is made by removing part of the

carbohydrates (sugars) from dehulled (removal of beans, seeds, etc.) and defatted soybeans.

- **Soy flour**
  Soy flour is made by grinding soybeans into a fine powder. It comes in three forms: 1) natural or full-fat (contains natural oils), 2) defatted (oils removed) with 50% protein content and with either high water solubility or low water solubility; and 3) lecithinated (lecithin added).

TECHNOLOGY

11. Issued Patent & Patent Applications

The following recent patent and patent applications govern the use of soy for Hercules:

1. Modified protein adhesives and lignocellulosic composites made from the adhesives
   7,060,798
   Li; Kaichang (Corvallis, OR), Liu; Yuan (Corvallis, OR)
   Abstract: An adhesive composition made by reacting a soy protein with at least one compound under conditions sufficient for introducing additional phenolic hydroxyl functional groups, amine functional groups, and/or thiol functional groups into the soy protein structure.
2. Modified protein adhesives and lignocellulosic composites made from the adhesives
   20040037906
   Li, Kaichang; (Corvallis, OR); Liu, Yuan; (Corvallis, OR)
3. Formaldehyde-free lignocellulosic adhesives and composites made from the adhesives
   20040089418
   Li, Kaichang; (Corvallis, OR)

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Abstract: Method for making lignocellulosic composites by adhering lignocellulosic substrates together. A first variant of the method involves using an adhesive composition that comprises a reaction product of (i) first ingredient selected from a soy protein or lignin and (ii) at least one substantially formaldehyde-free curing agent that includes at least one amine, amide, imine, imide, or nitrogen-containing heterocyclic functional group that can react with at least one functional group of the soy protein. A second variant of the method involves using an adhesive composition that comprises a reaction product of (i) a protein or lignin, (ii) a first compound that includes at least one amine, amide, imine, imide or nitrogen-containing heterocyclic functional group that can react with at least one functional group of the protein and (iii) a curing agent.

4. Adhesive compositions and methods of using and making the same
   20040220368
   Li, Kaichang; (Corvallis, OR); Geng, Xinglian; (Quebec, CA)
5. Formaldehyde-free lignocellulosic adhesives and composites made from the adhesives
   20050282988
   Li, Kaichang; (Corvallis, OR)
6. Modified protein adhesives and lignocellulosic composites made from the adhesives
   20060156954
   Li; Kaichang; (Corvallis, OR); Liu; Yuan; (Corvallis, OR)

TECHNOLOGY
12. Possible Mechanism of SOY Adhesive

The bonding process of Hercules adhesive appears to be a cross-link of soy protein with Kymene such as to organize a large molecule into a mesh-like configuration[12]. This cross-linking occurs after the glue is applied to the wood, during curing (the chemical and physical process by which ingredients are united into a stable form). Mussel protein (the origin of the adhesive idea) contains large amounts of 3,4-dihydroxy-phenylalanine, lysine, and cysteine while soy protein does not. Modification of soy protein with catechol, amino, and mercapto groups blocking acid groups with curing agents made it similar to the mussel adhesive. Kymene provides the polyamidoamine-epichlorohydrin curing agent.

Kymene[13] is a product that consists of polyamide backbones with many reactive side chains. The azetidinium groups can (1) react with residual amines to form cross links and increase the molecular weight of the resin (Figure 1) and (2) react with the carboxyl groups of cellulose surface (Figure 2). Heat is required for this reaction.

Figure 1. Self-Crosslinking of Polyamide Resin

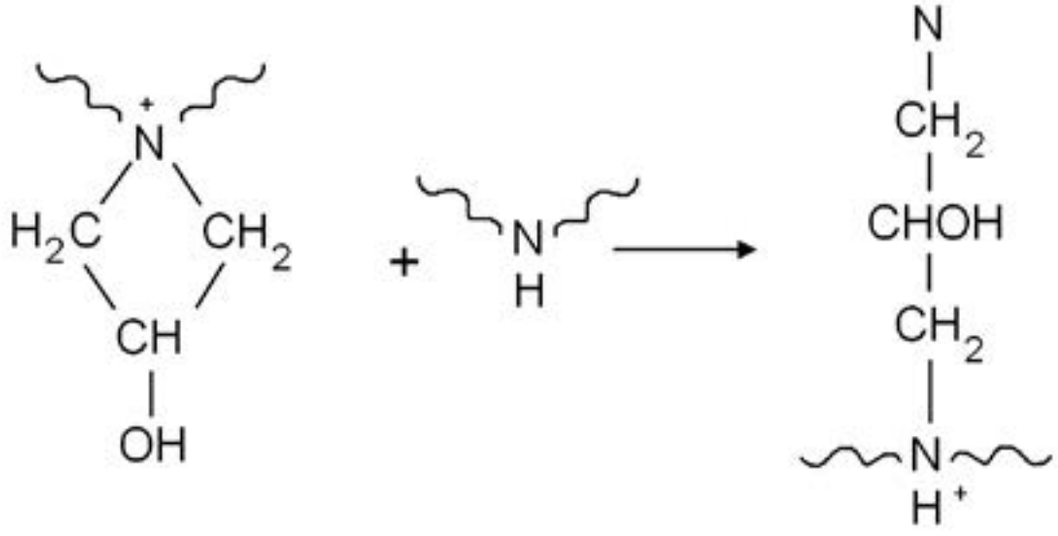
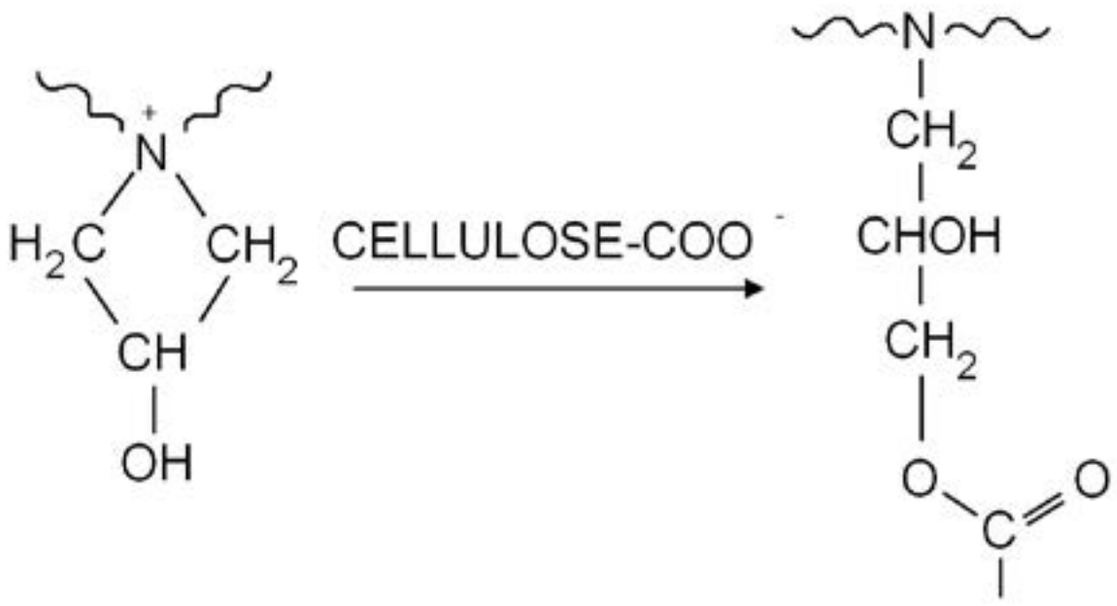


Figure 2. Reaction Of Polyamide Resin With Cellulose Carboxyl



The mechanism of the PAE resin is classified into two categories: (1) the preservation mechanism, which suggests that the cross- linking of the resin with itself occurs within the cellulose or surrounding the fiber-fiber contacts, impeding cellulose fiber swelling and holding the fibers with hydrogen-bonding distance; and (2) the reinforcement mechanism, which suggests that more direct covalent linking of cellulose to cellulose is achieved through a resin molecule or the resin network.

The commercialization of the new Hercules adhesive affects only a subset of the very large engineered wood market, since Columbia Forest Products produces decorative hardwood plywood exclusively for interior applications. But work is under way to commercialize the patented formaldehyde-free wood adhesive for production of particleboard, medium-density fiberboard, exterior-grade oriented strandboard, and plywood[14]. However, the method of applying adhesives differs

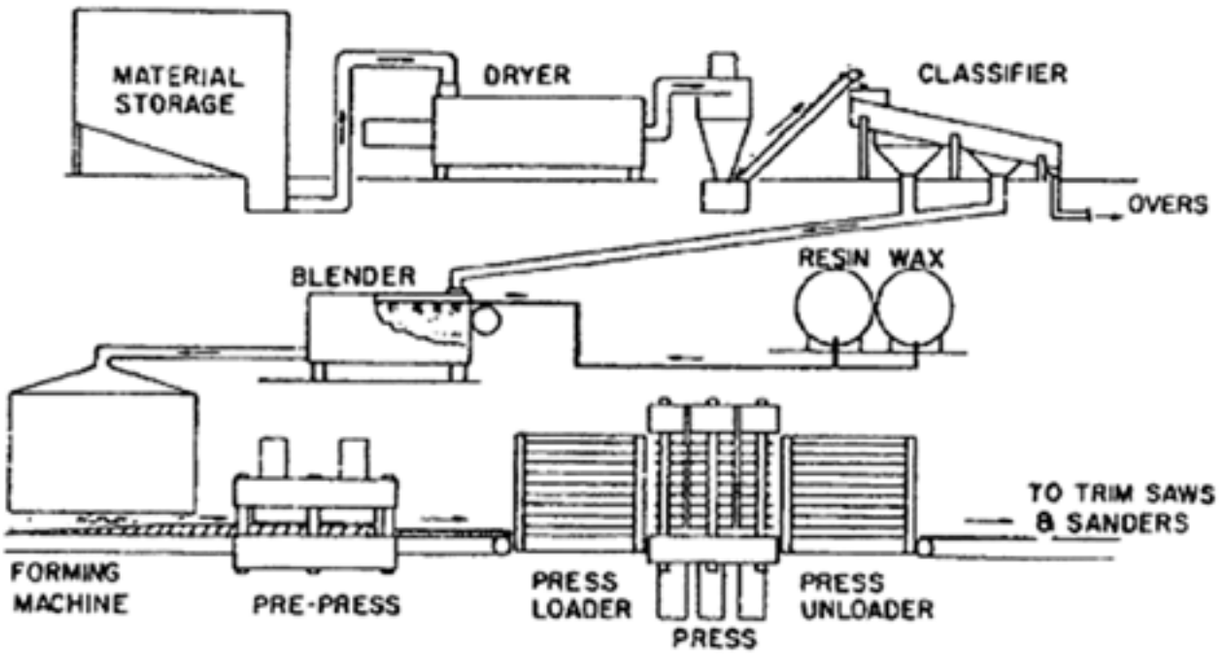
by product type. For plywood, glue can be rolled onto the panels before they are pressed, but to form composite products out of small wood pieces and sawdust, the adhesive must be reformulated to a sprayable consistency. There is less pressure to convert exterior-grade wood products because they use phenol-formaldehyde resins, which offgas formaldehyde at a much lower rate than the urea-formaldehyde resins. Adhesives in exterior wood products must also meet stricter moisture-proofing standards set for certification by industry organizations such as the Engineered Wood Association, says Grabiel[15].

TECHNOLOGY
13. Wood Composites

Particleboard (PB)

Particleboard is a composite panel product consisting of cellulosic particles of various sizes that are bonded together with a synthetic resin or binder under heat and pressure[16]. Manufactured similarly to MDF, with the exception that the wood chips are not further refined into fiber[17]. Once the chips are produced they are milled to a certain size, blended with adhesive, and mat formed prior to hot pressing. The blanks are sawn to the desired sizes and sanded to specific thicknesses. Formaldehyde emission limits are established for particleboard in ANSI A208.1. These include separate emission limits for industrial particleboard (0.30 ppm) and particleboard flooring grades (0.20 ppm).

Figure 3. PB production process[18]



Medium Density Fiberboard[36]

Medium Density Fiberboard (MDF) is widely used in the manufacture of furniture, kitchen cabinets, door parts, mouldings, millwork and laminate flooring. It is produced mostly from softwood logs, although some hardwoods may be included in the process[19]. Logs are reduced to wood shavings and chips by mechanical means. The shavings and chips are then exposed to steam under pressure to break down the lignification of the wood, softening it to the extent that it can be refined into tiny bundles of cellulosic fibers. The fibers are dried, blended with adhesive, and extruded onto a conveyor in a large, thick loose mat form. The mat is divided into manageable sizes, heated and cured under pressure to the desired thickness. The pressed blanks are then cut to size and sanded to very tight tolerances. While MDF is normally produced with

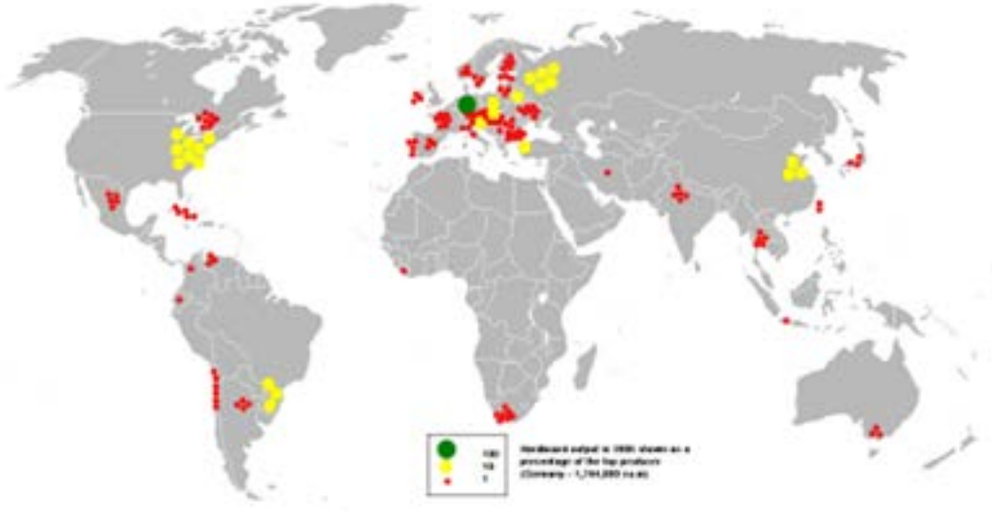
a urea formaldehyde resin for interior applications, it is available with methyl di-ethyl isocyanate (MDI) adhesive for exterior uses. ANSI A208.2 sets the formaldehyde emission limit for MDF at 0.30 parts per million (ppm).

Figure 4. World Production of MDF[20]

Hardboard

Hardboard is a composite panel manufactured primarily from interfelted ligno-cellulosic fibers consolidated under heat and pressure. Hardboard is used in a variety of applications including furniture components, wall paneling, exterior siding and trim, underlayment, interior trim and perforated boards.

Figure 5. World Production of Hardboard[21]



Decorative overlays[22]

Decorative surfaces are broadly separated into two groups – overlays and coatings – and are applied by various techniques to panel products like particleboard, medium density fiberboard (MDF) and hardboard. Overlays include products such as foils, high pressure laminates, papers, TFM, veneers and vinyls. Common applications of decorative surfaces include cabinets, moulding, flooring, furniture and store fixtures.

Veneers can be overlaid either with heat activated resins or cold pressed. The main resin used in hot press systems is a urea based adhesive due to its ability to make the panel more rigid, faster processing parameters and lower cost base. Cold press systems typically use polyvinyl acetates, casein and contact adhesives. These systems are used for smaller production quantities and may be less rigid than heat activated resin systems. Composite panels, like particleboard and MDF, are the preferred substrate for veneers due to their superior surface qualities of being flat, smooth, uniform, dense and free of knots and grain patterns.

MARKET
14. Market Size & Competitors

The adhesives industry in the US was about 8.3 billion dollars in 2004. Market share of wood and wood related products adhesives was about 21% (1.743 billion dollars)[23]. The largest competitors in the forest products resins market are: Hexion, Dynea International, Georgia Pacific and Kronospan.

Tables 4, 5 and 6 summarize the composite wood panels and current as well as future resin systems[24].

Table 4. Commercially available composite wood panels

Trade Name	Manufacturer	Wood Products	Resin System
Medite II, Medex, and Arreis	SierraPine	MDF	MDI
Resincore	Limited exterior (withstands short-term water soaking) Interior (withstands short term high humidity)	PB	PF
Purebond	*Columbia Forest Products*	*HWPW*	*Soy-based*
Multibond	State Industries	HWPW	PVA
Purekor-Particleboard Plus/MDF Plus	Panel Source Int.	PB, MDF	PVA
Purekor-FSC Plywood Plus	Panel Source Int.	HWPW	PF
Skyply	Roseburg	HWPW	PF
Skyblend	Roseburg	PB	PF

Table 5. Commercially available resin systems

Trade Name	Company	Wood Products	Resin System
EcoBind Resin System	Hexion	HWPW, PB, MDF	MUF + co-reactants, PF, Soy/ PVA blend
Kenocatch Catcher System	Akzo Nobel	MDF, PB	MUF + catcher
Rubinate & Suprasec Resin System	Huntsman	PB, MDF	Polyurethane & MDI
ReacTite EP-925	Franklin Chemical	HWPW	PVA
Multibond	States Industries	HWPW	PVA

Table 6. Future resin developments

Resin	Reference
Phenol-UF	Zhao et al. 1999
Phenol-UF-Tannin	Vazquez et al. 2004
Cashew Nutshell Liquid	A. Pizzi 2006
MDI Hybrids (UF, PF, MUF, PMUF)	Lel et al. 2006
Soyad® - PF/ Soy blend	http://www.hearlandresource.com

COMPANY

15. Press Releases

Columbia Forest Products to produce formaldehyde-free particleboard - 12/11/2006

Portland, OR – Columbia Forest Products has announced that it will begin producing formaldehyde-free PureBond™ particleboard in the first quarter of 2007, complementing the company's existing line of PureBond formaldehyde-free hardwood plywood products.

Brad Thompson, president of Columbia's plywood and veneer division, said, "We are extremely excited to roll out PureBond particleboard to meet the growing market demand for formaldehyde-free materials. Since we introduced PureBond adhesive technology for hardwood plywood, our customers have been anxiously awaiting a formaldehyde-free particleboard. We're happy to tell them it's on its way."

Columbia's PureBond formaldehyde-free technology involves a patented, soy-based adhesive cooperatively developed by Columbia, the College of Forestry at Oregon State University and Hercules Incorporated. Hercules has awarded Columbia a license to utilize its patented adhesive system on an exclusive

basis for all of Columbia's North American decorative panel markets.

PureBond particleboard will be manufactured at the company's Hearst, Ontario, facility, which will also turn the board into finished hardwood plywood and other value-added panels.

Columbia is committed to increasing the availability of formaldehyde-free panel products, and is actively seeking arrangements for additional composite panel manufacturers to incorporate the PureBond adhesive system in their processes.

Columbia Commercial to offer formaldehyde-free, FSC-certified hardwood flooring to commercial market in 2007 - 02/22/2007

Danville, VA – Columbia Commercial Flooring today announced plans to roll out formaldehyde-free, FSC-certified engineered hardwood flooring to the commercial segment in 2007.

Available by special order at first, with plans for a wholesale conversion of its engineered hardwood flooring plant in Danville, Columbia Commercial will market its formaldehyde-free flooring as PureBond™, the brand created by parent company Columbia Forest Products for its decorative hardwood plywood. The panel producer converted all of its hardwood plywood plants to formaldehyde-free manufacturing processes in 2005, and PureBond has become a fast-growing brand in the green-building, architecture and design, and environmental health communities.

Columbia Commercial sources veneers and core material from its parent company's veneer and plywood mills, eight of which are FSC-certified, to make its environmentally certified engineered hardwood flooring.

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"Sustainability and environmental health are extremely important issues in the architecture and design world," Columbia Vice President of Sales and Marketing Lance Rooney said. "Being able to offer both formaldehyde-free and FSC-certified hardwood flooring to the commercial market is not only a point of differentiation in the marketplace, it's something we believe is crucial to our future."

Rooney said PureBond hardwood flooring—which will be launched in domestic species of oak, maple and pecan, in 3-inch and 5-inch widths—will be available throughout the company's North America distribution network. Marketing efforts will initially be focused on the western United States and select metropolitan areas where large "green" commercial construction projects are currently underway. Columbia plans to add additional species in the near future.

ACC MEMBER, HERCULES INCORPORATED, WINS EPA PRESIDENTIAL GREEN CHEMISTRY AWARD - June 26, 2007

ARLINGTON, VA (June 26, 2007) – The American Chemistry Council (ACC) is pleased to announce that Hercules Incorporated, in collaboration with Professor Kaichang Li of Oregon State University and Columbia Forest Products, received a 2007 Environmental Protection Agency (EPA) Presidential Green Chemistry Challenge Award. Hercules Incorporated was honored in the Greener Synthetic Pathways category at today's ceremony held at the National Academy of Sciences in Washington, D.C.

Established in 1995, the Presidential Green Chemistry Challenge Awards recognize chemical technologies that incorporate the principles of sustainable chemistry into chemical design, manufacture and use. Award applications are

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judged by an independent panel of technical experts convened by the American Chemical Society.

ACC member companies have long practiced and promoted the principles of sustainable chemistry and effective product stewardship through their ongoing contributions to the nation's economic, energy, health, environmental and social progress. The fourteenth ACC member to be honored by EPA, Hercules Incorporated received this award for its part in developing and commercializing a formaldehyde-free adhesive made from soy flour.

The products of chemistry make our lives healthier, safer and better, while building a solid foundation for the future. Through ACC's Responsible Care® program, ACC members have reduced emissions by 77 percent since 1988 and have reduced greenhouse gas intensity by 30 percent since 1992.

Professor Kaichang Li, Oregon State University
Columbia Forest Products
Hercules Incorporated
Development and Commercial Application of Environmentally Friendly Adhesives for Wood Composites – EPA

Innovation and Benefits: Adhesives used in manufacturing plywood and other wood composites often contain formaldehyde, which is toxic. Professor Kaichang Li of Oregon State University, Columbia Forest Products, and Hercules Incorporated developed an alternate adhesive made from soy flour. Their environmentally friendly adhesive is stronger than and cost-competitive with conventional adhesives. During 2006, Columbia used the new, soy-based adhesive to replace more than 47 million pounds of conventional formaldehyde-based adhesives.

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Since the 1940s, the wood composites industry has been using synthetic adhesive resins to bind wood pieces into composites, such as plywood, particleboard, and fiberboard. The industry has been the predominate user of formaldehyde-based adhesives such as phenol–formaldehyde and urea–formaldehyde (UF) resins. Formaldehyde is a probable human carcinogen. The manufacture and use of wood composite panels bonded with formaldehyde-based resins release formaldehyde into the air, creating hazards for both workers and consumers.

Inspired by the superior properties of the protein that mussels use to adhere to rocks, Professor Li and his group at Oregon State University invented environmentally friendly wood adhesives based on abundant, renewable soy flour. Professor Li modified some of the amino acids in soy protein to resemble those of mussels' adhesive protein. Hercules Incorporated provided a critical curing agent and the expertise to apply it to commercial production of plywood.

Oregon State University, Columbia Forest Products (CFP), and Hercules have jointly commercialized soy-based adhesives to produce cost-competitive plywood and particleboard for interior uses. The soy-based adhesives do not contain formaldehyde or use formaldehyde as a raw material. They are environmentally friendly, cost-competitive with the UF resin in plywood, and superior to the UF resin in strength and water resistance. All CFP plywood plants now use soy-based adhesives, replacing more than 47 million pounds of the toxic UF resin in 2006 and reducing the emission of hazardous air pollutants (HAPs) from each CFP plant by 50 to 90 percent.

This new CFP plywood is sold under the PureBond™ name. During 2007, CFP will replace UF at its particleboard plant; the company is also seeking arrangements with other manufacturers to further the adoption of this technology.

With this technology, those who make and use furniture, kitchen cabinetry, and other wood composite materials have a high-performing formaldehyde-free alternative. As a result, indoor air quality in homes and offices could improve significantly. This technology represents the first cost-competitive, environmentally friendly adhesive that can replace the toxic UF resin. The technology can greatly enhance the global competitiveness of U.S. wood composite companies. In addition, by creating a new market for soy flour, currently in over-supply, this technology provides economic benefits for soybean farmers.

MARKET

16. Porter's Five Forces Industry Analysis

Supplier power

Suppliers exert extraordinary power over industry participants by continuously passing on increasing costs for energy, raw materials, and distribution. This power is further enhanced by the specialty chemical companies' inability to quickly respond to price increases given the contractual nature of the majority of their customer relationships. '...Significant upward raw material pressure plagued the specialty chemical group in 2004 and ... the game of 'catch-up' the group has been playing with regard to cost increase vs. price increases will remain an ongoing concern in 2005'[25].

'Rising oil and energy prices are expected to remain the primary threats'[26] with the rise in oil prices having a cascading effect on the industry (Industry Info: Diversified Chemicals).

The control of the energy suppliers is by the primary input materials provided by commodity chemical companies. Switching costs, such as testing and regulatory approvals, for the specialties run high however, driving supplier power higher in many instances.

Customer power

Customers do not appear to exert a great deal of power over industry participants, as specialty chemical pricing tends to be 'set by their value in use, not by costs'[27]. However, customers have recently '...garnered greater buying power, keeping pressure on pricing'[28] and demanding innovative products that continuously contribute to their own performance. Additionally, as customers consolidate, they are creating larger entities with greater buying power (and exposure).

Similar to industry participants, customers are also subject to many of the same issues identified in the supplier power section: long-term contracts with fixed pricing in place that create the time-lag of cost-increase pass-through to pricing their own products. Many customers are also subject to high switching costs: extensive testing and approvals are typical when making changes. The specialty chemicals industry is not very susceptible to the decline, or cyclicality, of any one industry sector, as their breadth of applications spans many industry sectors. Major end markets include manufacturing, automobile, housing, and agricultural sectors27 which tend to cyclically overlap.

The manufacturing sector is a large customer segment for this industry. As manufacturers continue to shift production capacity overseas27, specialties are experiencing pressure to

acquire/create overseas production capacity of their own due to the nature of their production and distribution processes – smaller facilities, small batches, and less-than-truckload distribution.

International markets, such as Asia/Pacific, are growing and also exerting pressure on industry participants to increase their overseas presence, with '...robust demand from Asia...' (Industry Commentary: Chemical (Specialty), 2005).

Rivalry

Innovation is the primary key to successful competition within this industry: creating new products with specific attributes that help customers meet quality, environmental, or other requirements[27], that in turn, help customers sustain their own competitive advantages. Chemical Week points out that '...there are several, "high performers" who have managed to use innovation to differentiate themselves with new products and services, and ultimately grow profits and revenues'[28]. Recently, Accenture performed a survey of chemical companies, specifically looking for attributes correlated to success, "We found that between 15% and 30% of revenues from [the high-performing specialty companies] came from new products less than five years old"[29].

Tied closely with innovation are the strong customer relationships borne of not only novel products, responsiveness, and flexibility, but the nature of distribution, which tends to '... discourage distant competitors.'[30].

All the above indicates this industry is not driven primarily by low-cost, which is not to say that participants are ignoring cost. Competition is forcing cost reduction efforts, and rivals continue to strengthen their balance sheets- 'Most of the spe-

cialty chemical names spent the last three years cleaning up their balance sheets by paying down debt with the free cash they generated.'[31]. The additional leverage created has been driving strong merger and acquisition (M&A) activity within the industry[32].

Global market demand is shifting as the 'Asia/Pacific, Latin American and Eastern European regions have the potential to see more rapid growth than do those in the US and Europe'[30]. This shift is forcing industry participants to consider M & A activity in these emerging markets as a more rapid, and culturally-appropriate, means of market entry and growth.

All rivals within this industry are subject to the same regulatory issues – anti-dumping, legacy liabilities, etc. However, older companies may have heftier liabilities (i.e. pensions and environmental liabilities) due to the sheer length of time they have been conducting business. Not only do specialty chemicals companies compete in the market to sell their products, but they also compete for human resources. Since product research and development is critical to the success of a specialty chemical company, intellectual capital must be obtained and retained. In this arena, specialties must also compete with organizations outside of its industry, for example pharmaceuticals[33].

Threat of new entrants

Significant barriers to entry – capital, research and development (R & D), and marketing requirements - reduce the threat of new industry entrants, in addition to extraordinary regulatory issues regarding health, safety, and the environment[30]. New entrants are also discouraged as existing customers are often subject to high switching costs.

Commodity chemical companies do pose a threat of entry, however, they are typically deterred by the cultural and production differences and a reluctance to 'bite the hand that feeds them', given that the specialty companies are their customers.

Threat of substitutes

Given the tight nature of the customer relationships, in which products are often created specifically for singular applications, there are few threats of substitution. This is not to discount the threat of disruptive technological breakthroughs, again making it incumbent upon the specialty chemical companies to continuously invest heavily in R & D. This is particularly the case as stricter regulations are put in place in Europe and North America.

MARKET
17. Factors for Succeeding in the Industry

Key factors for success in this forest products adhesives industry are:

- **Service** – Provide on-site value-added technical service with highly skilled technical employees
- **Intellectual Capital** - Patent protection and leverage, trade secrets, and also programs for development & retention of technically-superior employees
- **Innovation** – Create and enhance products, processes, applications and technologies in accord to industry and environmental regulations.
- **Manufacturing Flexibility** - The industry tends to anticipate and respond rapidly to customer needs such as soy-Kymene resins

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- **Capital Flexibility** – The industry responds to opportunities as presented in the marketplace since major players are large corporations
- **Productivity Improvements** – There is a permanent goal of driving down costs in processes
- **Quality** – There is a continuous attention to maintaining high quality in processes. The industry drives in delivering consistent and high quality products
- **Negotiation** – Negotiation capacity with vendors and customers that contain periodic price adjustment mechanisms as well as passing through raw material price changes is key in the industry

The building products business is affected by

1. the level of new housing starts
2. the level of home repairs
3. remodeling and additions
4. industrial and commercial building activity
5. the availability and cost of financing, and
6. changes in industry capacity[34]

The demand for building products tends to be stronger during the second and third quarters when weather conditions favor construction. The European Commission has enacted a new regulatory system, known as Registration, Evaluation and Authorization of Chemicals, or REACH, which requires manufacturers, importers and consumers of certain chemicals to register these chemicals and evaluate their potential impact on human health and the environment. Under REACH, significant market restrictions could be imposed on the current and future uses of chemical products that we use as raw materials or that we sell as finished products in the European Union.

COMPANY
18. Differentiation Strategy

Point of Parity

Hercules adhesive has several similarities to UF adhesives:

1. Equal price
2. Similar application process
3. Technical expertise

Point of Difference

There are several points that differentiate Hercules Building Product Adhesives from UF adhesives:

1. Environmentally friendly
2. Abundant and renewable raw material
3. Better water resistance
4. Favorable state and federal regulations

COMPANY
19. Sales

Table 7. Hercules Building Products Sales and Profits in 2007

Total Building Products	Jan	Feb	Mar	Apr	May	Jun (BP)
Volume - Lbs						
Net Sales						
Gross Profit						
Gross Profit %						
North America						
Volume - Lbs						
Net Sales						
Gross Profit						

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Total Building Products	Jan	Feb	Mar	Apr	May	Jun (BP)
Gross Profit %						
Europe						
Volume - Lbs						
Net Sales						
Gross Profit						
Gross Profit %						

COMPANY
20. Business Strategy

Develop new technologies that save customers time, money, resource consumption and that are environmentally/regulatory favorable for all other composites besides plywood. Expand business at strategic accounts. Create technical expertise in the adhesives application process. Develop market intelligence through industry conferences and associations. Establish relationships with state agencies such as the California Air Resources Board and the Formaldehyde Free Organization.

Interview with Mark Akers (sales) from Russell Plywood Inc.

Most new constructions are requesting formaldehyde free plywood. They include schools, churches, office building particularly in big cities. Formaldehyde free products are being used for wall panels, cabinets, table tops, etc. They have had the product for a year and it is gaining acceptance. It is sold at the same price as their competitors.

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Letter from Elizabeth Whalen
from Columbia Forest Products[35]
April 12, 2007

Senator Joseph Simitian
Chairman
Senate Committee on Environmental Quality
State Capitol, Rm. 2205
Sacramento, California 95814

Dear Senator Simitian:

Thank you for the opportunity to testify on SB 509 on Monday, March 26. You were very gracious to extend the invitation and I was privileged on behalf of Columbia Forest Products to support the legislation with your amendments. It was gratifying to see support from so many other public interest groups and to have majority support from the Committee for the legislation.

Unfortunately, in the course of testimony, one of those who testified against the bill, Gene Livingston, representing the Composite Wood Industry Coalition, made a series of false and defamatory statements concerning my company and its products which cannot be allowed to go without correction. It was shocking to listen to these deeply unprofessional remarks, but unfortunately I had no opportunity to publicly refute them, owing to the ground rules for the hearing. Accordingly, I hope you will convey the contents of this letter to the Committee present.

Mr. Livingston claimed that Columbia has a monopoly on formaldehyde-free products which would be advantaged by the legislation. That is false and Mr. Livingston knows it to be false.

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The market is already served by products produced by members of Mr. Livingston's industry association, including Timber Products (plywood), Roseburg Forest Products (plywood and particleboard), States Industries (plywood) and Sierra Pine (MDF) – which was represented at the hearing by Chris Leffel for opposition testimony. These companies sell their products into domestic and foreign markets that require a higher standard than California. They have ample time under your proposed legislation to increase their production of formaldehyde free products. And, if they choose, Columbia has already publicly committed to licensing our technology at minimal cost if they prefer it to their existing resins.

Most appallingly, Mr. Livingston made a series of unsupported allegations about the quality of products manufactured by Columbia Forest Products using our formaldehyde-free process. These statements are false and, indeed, slanderous and Mr. Livingston knows this.

All of Columbia's products pass the tests and standards for quality that are employed by every manufacturer in the industry. And Columbia's formaldehyde-free resin bond has performed at a superior level every time when compared to UF glue bonds We are the largest producer with a 40% share in the hardwood plywood market in North America, manufacturing over a million panels a month, and all of our manufacturing has been converted to this formaldehyde-free process. In every way, the quality of our products is superior to competing wood products using urea formaldehyde. These facts are well known throughout the industry. We will demand a full retraction and apology from Mr. Livingston for his outrageous comments, which serve only to thoroughly impeach his credibility.

Finally, you will recall that Chris Leffel, representing Sierra Pine, who testified alongside of Mr. Livingston, claimed there was scientific research that humans could safely tolerate formaldehyde emissions of two parts per million. We are unaware of any such valid scientific study. The consensus within the scientific community, as reflected in the ARB staff report and OEHHA's position on this toxic air contaminant, is quite to the contrary.

I look forward to continuing to support your important legislative efforts to protect the health of Californians.

Very sincerely,

Elizabeth Whalen

Director of Corporate Sustainability

cc: Bruce Jennings; ARB Board Members; Catherine Witherspoon; Jim Aguila

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APPENDIX I

	Columbia Forest Products Inc.	Jeld-Wen	Roseburg Forest Products
Business	Manufacturing: Hardwood veneer, plywood and laminated products.	Manufacturing: Doors and windows, building supplies and fixtures. Services: Marketing agency, resort development and operation firms. Real Estate: Real estate developer. Finance: Holding company.	Manufacturing: Hard and soft plywood and particleboard.
Location	222 SW Columbia St., Ste. 1575, Portland, Oregon, 97201-6615	401 Harbor Isles Blvd., Klamath Falls, Oregon, 97601-1283	Old Hwy. 99 S, Dillard, Oregon, 97432-9700
SIC	2435 - Hardwood Veneer & Plywood	2431 - Millwork	2435 - Hardwood Veneer & Plywood
	2426 - Hardwood Dimension & Flooring Mills		2436 - Softwood Veneer and Plywood
			2493 - Reconstituted Wood Products
NAICS	321211 - Hardwood Veneer and Plywood Manufacturing	321918 - Other Millwork (including Flooring)	321211 - Hardwood Veneer and Plywood Manufacturing
	321912 - Cut Stock, Resawing Lumber, and Planing	321999 - All Other Miscellaneous Wood Product Manufacturing	321212 - Softwood Veneer and Plywood Manufacturing
			321219 - Reconstituted Wood Product Manufacturing
Sales	915 M Sales, Estimate	2606 M	688 M

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	Columbia Forest Products Inc.	Jeld-Wen	Roseburg Forest Products
# of employees	4,000	25,000	3500
Year Founded	1957	1960	1936
URL	http://www.columbiaforestproducts.com	http://www.jeld-wen.com	http://www.rfpco.com
Features	Exporter, Importer, Private Company	Private Company	Private Subsidiary
Parent			RLC Industries Co.
CEO	Harry L. Demorest	Roderick C. Wendt	Allyn Ford
Source	Business and Company Resource Center	Business and Company Resource Center	Business and Company Resource Center
Credit Rating	Excellent	Excellent	Excellent
Products	Hardwood Plywood, Hardwood Veneer, Particleboard		Softwood Plywood, Particle Board

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	Flakeboard	States Industries
Business	Manufacturing: Paperboard mill; manufactures building and roofing paper, felts and insulation siding; manufactures laminated building paper from purchased material; wholesales construction materials	Lumber and wood merchant wholesaler
Location	80 Tiverton Crt Ste. 701, Markham, ON, L3R 0G4, Canada	Eugene, Oregon
SIC	5039 - Construction Materials, Not Elsewhere Classified	503104
NAICS	423390 - Other Construction Material Merchant Wholesalers	42331035
Sales	79.5 M	50 to 100 M
# of employees	25	500
Year Founded	2005	
URL	http://www.flakeboard.com/contact.asp	http://www.statesind.com/
Features	International Private company	Private
CEO	Kelly Shotbolt	
Source	Business and Company Resource Center	Reference USA
Credit Rating	Excellent	Excellent
Products	MDF, Particle board, Fibrex (thin MDF)	Appleply (veneer)

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	The Collins Companies	Stimson Lumber
Business	Manufacturing: Lumber mill producing siding, flooring, veneer and particleboard.	
Location	1618 SW 1st Ave., Ste. 500, Portland, Oregon, 97201-5706	Portland, Oregon
SIC	2426 - Hardwood Dimension & Flooring Mills	503109
	2493 - Reconstituted Wood Products	
NAICS	321912 - Cut Stock, Resawing Lumber, and Planing	443177878
	321219 - Reconstituted Wood Product Manufacturing	
Sales	$7.00 M Sales, Estimate or 20 to 70 M from ReferenceUSA	100 to 500 M
# of employees	25, Telephone Interview or more than 30	2100
Year Founded	1855	1860
URL	http://www.collinswood.com	http://www.stimsonlumber.com/
Features	Private Company	Private Company
CEO	Eric L. Schooler	
Source	Business and Company Resource Center	
Credit Rating	Excellent	Excellent
Products		

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North America Composite Panel Industry[36]

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