THE USE OF PLASTICS IN WOOD FURNITURE

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ABSTRACT

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By

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This study tries to analyze the acceptance of plastics in the furniture industry in the United States and tries to find possibilities for similar developments acceptable to the Taiwanese furniture industry.

Analyses on the furniture industries of these two countries shows that there exists similarity and difference; rising labor costs, rising purchasing power and sophisticated domestic markets are the similar characteristics, but the size of the factory, the mechanization of the furniture industry and the customer's taste are the differences. The study also reveals that the Taiwanese furniture industry can not only strengthen its aggressive exportation but also can improve its position in the domestic market.

The basic chemistry of plastics is discussed with particular emphasis on: (1) molding plastics: polystyrenes, (2) casting plastics: polyurethanes and polyesters, (3) mold-making plastics: silicones, and (4) laminating plastics: polyvinyls, phenolics and melamines.

The processes of manufacturing decorative or structural items for furniture are presented in such a way that detailed discussions are limited to the most frequently used methods and materials; injection

molding of polystyrenes and flexible RTV silicone rubber mold casting of polyurethanes and polyesters. Various laminating processes are also discussed.

The manufacture of intricate, ornate, whole wood furniture for export markets, the use of wood-grained cast plastic parts, wood-grained, laminated furniture panels on particleboard core stock for domestic markets are recommended to the furniture industry in Taiwan.

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1. INTRODUCTION (4) (7)

Plastics is the name of a family of synthetic materials which have large molecules made up of chains of atoms. The official definition of plastics accepted by the Society of Plastic Engineers (SPE) and the Society of the Plastics Industry (SPI) is "a large and varied group of materials which consist of or contain as an essential ingredient a substance of high molecular weight which, while solid in the finished state, at some stage of its manufacture is soft enough to be formed into various shapes --- most usually through the application (either singly or together) of heat and pressure."

Natural rubber was one of the first materials to be considered moldable plastic. In 1839, Charles Goodyear mixed the masticated raw rubber with sulphur and found that he could vulcanize the rubber into its final shape by heating it in the mold.

In 1846, Dr. Friedrich Schönbein found that he could convert the cellulose in wood and other plant products into a clear tough, horny material by treating it with nitric acid. Schönbein's nitrocellulose became the basis of our modern plastics industry.

In 1862, Alexander Parkes found that he could dissolve nitrocellulose in molten camphor. As the solution cooled, it passed through a putty-like plastic stage during which it could be molded. Then it set a flexible horny material.

In 1897, W. Krische and Adolf Spittler discovered that casein could be waterproofed and hardened by treating it with formaldehyde. With this discovery they had laid the foundation to the casein plastics industry.

In 1909, Dr. Leo Henrik Baekeland had found that the product formed from phenol and formaldehyde was a resinous substance. It was the first synthetic plastic. Rubber was a natural resinous substance obtained from a tree; celluloid had been based on cellulose, a plant product. Casein was an animal material obtained from milk. But Bakelite, named after Baekeland, was different. This time, the chemist had made his plastic from the simplest of raw materials in the form of coal tar chemicals.

With the discovery of Bakelite, plastics became a part of organic chemistry and the possibility of making other materials with this property of plasticity, thus, had been stimulated. Within a short time, the study of plastic materials was to become a complex and specialized branch of scientific research.

Although its foundations were laid in the 1920's, rapid growth in plastics was brought about, in part, by the shortages of materials during the Second World War. This permitted the evaluation of plastics in a wide variety of applications and markets. Plastics offered a unique combination of availability, properties, economics, style, and ease of processing. Building construction, packaging, electronics, agriculture, automobile, housewares, and toys are examples of major markets.

Low cost, durability, and insulating properties, lightweight, resistance to chemicals and ease of fabrication make plastics competitive with metals, glass, wood, and other materials.

Versatility in fabrication is a major advantage especially with respect to economics.

Another major advantage of using plastics is that large quantities of intricate parts can be duplicated rapidly with a relatively high degree of dimensional accuracy. From one mold thousands of identical parts can be made. Furthermore, parts require little or no work after they come from the mold.

An extremely important consideration in practically all applications of plastics is their light weight. In making parts, the primary concern is with volume, and the low specific gravity of plastics, compared to metals, gives them an advantage in terms of economics and applicability. Other advantages include corrosion resistance, fire control characterisitcs, weatherability and aesthelic appeal.

According to most economic industry indicators the plastics industry is rapidly approaching the number one position as a producer of basic materials and fabricated products. It is calculated that by the year 2000 plastics will constitute three-quarters of all engineering materials in terms of volume.

At first, plastics penetrated the conventional wood furniture industry in the form of resin adhesives. By 1935, phenol and urea formaldehyde were used owing to their superior properties, such as extreme durability and ease of application.

After the Second World War the decorative high-pressure laminates were introduced into this field. Ten years later, in 1965 injection polystyrene parts appeared in the furniture industry. Cast polyurethane and cast polyester successively showed up in 1966 and 1967 respectively. The revolution with plastics in furniture, then, spread.

The technical revolution in the furniture industry with plastics started with the introduction of highly styled Mediterranean and Spanish designs which required intricate replicas and ornate carvings and decorations. Plastics made it possible to produce these styles within the price range of the mass market by eliminating expensive labor in carving and machining operations. Rising labor costs, a shortage of skilled and semi-skilled labor and shortages of conventional raw material have been the factors contributing to the use of plastics. Furthermore with plastics, the designers have been given a greater freedom of expression without having to resort to more expensive production techniques. To date, plastics appear in the furniture world in the form of total plastic furniture as well as solid furniture parts.

The entrance of plastics into the furniture industry is following the course of what took place earlier in other industries where plastics replaced conventional materials. Costs began to rise and labor became expensive. However, wood is cheaper than plastic on a pound for pound basis and wood is difficult to displace because of its natural texture and superior properties. Even though it was overwhelmed in some areas, plastics still cannot compete when wood is used to produce a flat or fairly simple nonornate piece of furniture. In addition, the soaring prices of plastic raw materials derived from oil and its petrochemicals due to energy shortage leads to an uncertain circumstance for the plastics development in the wood furniture industry.

The furniture industry in Taiwan is very different from that of the United States in size, mechanization, furniture styles and customers' taste. Relatively small capital investment has limited the size and the degree of mechanization of the typical furniture factory. Inadequate and inaccurate equipment in Taiwan has produced low quality furniture in small quantities to provide the local necessities. The majority of the local consumers have been satisfied with low quality products at a low price for a long time.

However, Taiwan also faces rising labor costs, rising purchasing power and more sophisticated local markets which will lead into improved techniques and innovation in the furniture industry. Besides, increased exports also prove that the men, materials, and methods revolution is extremely necessary to meet the quality and quantity requirement.

By observing the innovation with plastics in the United States, we realize that the possibility of using plastics in furniture might become attractive today or sometime in the future in Taiwan.

This study will try to analyze the use of plastics in the United States and will try to explore the possibility for similar developments in Taiwan.

2. PROFILE OF THE FURNITURE INDUSTRY AND INNOVATION WITH PLASTICS IN THE UNITED STATES

1) The Characteristics of the Furniture Industry

It may be said that furniture manufacture is more of an art than a science or a technology, even though significant advances have been made in the more recent past.

The furniture industry has existed as long as human civilization and has developed certain distinguishable characteristics. First, the industry is largely composed of small and medium-size family controlled and long established manufacturing units. 1) Almost 65% of the wood furniture plants employ less than 20 people, (Table 1) and 2) the number of establishments has remained at a figure of some 5300 without significant change during the last decade; they were 5211 in 1958 and 5365 and 5302 for 1973 and 1974 (Table 2) respectively. Secondly, the industry is monopolized by a few large companies. A tendancy shows that the profitability rates seem to increase in accordance with the size of the company (49). The top 50 factories produce almost half of the furniture products (49). It further appears that the industry is becoming more densely concentrated as a result of consolidation. Thirdly, furniture has been traditionally a low paying industry. The problem gets more serious because the labor constitutes a large percentage of the total cost. Fourth, the skillful craftsmen become scarcer year after year owing to the absorption by other more

TABLE 1. Household Furniture - U.S. General Statistics, By Employment Size of Establishment: 1972 (55).
(Selected Data)

ITEM	ESTABLISH-MENTS	ALL EMPLOYEES		PRODUCTION WORKERS		
		Number	Payroll	Number	Man-hours	Wages
	(number)	(1,000)	(million dollars)	(1,000)	(millions)	(million dollars)
WOOD HOUSEHOLD FURNITURE ESTABLISHMENTS, TOTAL.	2,348	133.8	806.8	118.8	240.9	642.3
ESTABLISHMENTS WITH AN AVERAGE OF-						
1 to 4 Employees	825	1.5	8.6	1.5	2.7	6.7
5 to 9 Employees	372	2.5	14.6	2.2	4.3	11.3
10 to 19 Employees	324	4.4	25.6	3.8	7.4	19.3
20 to 49 Employees	333	10.7	61.2	9.2	17.4	46.5
50 to 99 Employees	190	13.4	77.9	11.6	22.2	60.0
100 to 249 Employees	171	27.0	165.7	23.6	47.2	127.6
250 to 499 Employees	83	29.5	173.2	26.6	54.8	144.0
500 to 999 Employees	39	25.5	157.1	23.0	49.2	131.9
1,000 to 2,499 Employees . . .	9	19.5	123.0	17.1	35.8	95.0
2,500 Employees or More. . . .	2					
ESTABS, COVERED BY ADMIN. RECORD	965	3.8	20.5	3.6	6.6	15.8
UPHOLSTERED HOUSEHOLD FURNITURE ESTABLISHMENTS, TOTAL.	1,308	92.0	605.3	78.3	150.2	454.7
ESTABLISHMENTS WITH AN AVERAGE OF-						
1 to 4 Employees	216	.4	2.6	.4	.7	2.0
5 to 9 Employees	158	1.1	6.8	1.0	1.7	5.2
10 to 19 Employees	164	2.3	14.5	2.0	3.7	11.5
20 to 49 Employees	316	10.3	65.8	8.9	16.4	50.0
50 to 99 Employees	211	14.4	89.8	12.3	23.5	68.0
100 to 249 Employees	165	25.7	168.0	21.7	41.1	126.2
250 to 499 Employees	53	18.6	127.2	15.8	30.7	94.4
500 to 999 Employees	21	13.7	94.4	11.5	22.2	70.3
1,000 to 2,499 Employees . . .	4	5.4	36.4	4.7	10.2	27.3
ESTABS, COVERED BY ADMIN. RECORD	282	1.2	7.3	1.1	2.0	5.5

TABLE 2. 1974 Profile, Household Furniture (54).

SIC CODES	2511, 2512, 2514, 2515, 2517, 2519	
Value of Industry Shipments	8,973	(millions)
Number of Establishments	5,302	
Total Employment	342	(thousands)
Exports as a percent of product shipments (%)	0.8	
Imports as a percent of apparent consumption (%)	4.2	
Compound annual average rate of growth 1967-74 (%)		
Value of Shipments (current dollars)	7.7	
Value of Exports (current dollars)	16.6	
Value of Imports (current dollars)	27.9	
Employment	2.0	

sophisticated industries and to the fact that the young generation is reluctant to undergo long periods of training (9). In addition, the shortage of wood, increases costs of the material and the slow productivity associated with the machining of wood also increases the cost. Lastly, it is clear that the conventionally managed furniture plant will be forced to employ labor at higher wages as the size of the traditional furniture work force decreases.

To sum up, the furniture industry is on the verge of making significant changes with regard to employment, materials and methods to run the business effectively not only with regard to good quality but large quantity also.

2) Innovation With Plastics

The plastics used in the United States are so developed that more than two thousand synthetic products from about forty distinct plastic raw material families are being produced by about twenty different processes, and the products can fit almost any purposes besides furniture (4).

A survey conducted by Furniture Methods and Materials showed that plastics really made large in-roads into the furniture industry. It also showed that 86 percent of the furniture plants use plastics almost totally in the form of decorative parts. Of the companies using plastics, 16 percent do their own molding. Concerning the material used, almost 57 percent of the plastic-using plants have used polyurethanes, polystyrene 49 percent, and polyesters 43 percent (18). Table 3 gives more information.

TABLE 3. FMM Survey Showing Use of Plastics in Furniture (18).

PLANTS USING PLASTICS	PLANTS NOT USING PLASTICS	PLANTS USING PLASTICS FOR DECORATIVE PARTS	PLANTS USING PLASTICS FOR STRUCTURAL PARTS	SOURCES CAPTIVE MOLDING	SOURCES CUSTOM MOLDING
86.1%	13.9%	82%	43.2%	16.2%	83.8%
		PLANTS USING CUSTOM MOLDING SOURCES:		ENTIRELY	IN PART
				75%	25%

TYPE OF PLASTICS USED (represents % of plants using this plastics)

Polyurethane	56.8%
Polystyrene	48.6%
Polyester	43.2%
Polypropylene	5.4%
Other Plastics	8.0%

PLANTS HAVING CAPTIVE MOLDING OPERATIONS:	PLANTS WITH PLANS FOR FUTURE CAPTIVE MOLDING OPERATIONS
7.3%	14.6%

Another survey (Table 4) conducted by the Monsanto Company in late 1968 investigated the relationship between plant size and consumption characteristics. The larger the company, the greater their use of plastic components.

TABLE 4. Plastic Consumption Characteristics by Furniture Manufacturers Based on Plant Size (18).

Size (in annual sales)	Plastic Used million lb/yr	Using Plastic Components	Using Custom Molder
Under $1 million	Less than 10	26%	92%
Over $25 million	10 to 100	100%	59%

The data in Table 5 depict the consumption of plastics in furniture. They indicate the sharp rise in the use of plastics of all categories. Both 1975 and 1980 figures are estimated by Modern Plastics (37).

Since plastics are so commonly used by the furniture industry, it is necessary to understand what makes plastics popular.

a) Product Performance

Plastic products can be made to substitute wood products and can have similar looks and functions. People usually are unable to distinguish between the two. In addition to the above similarity, the plastic products exhibit some advantages. For example, finish and grain effects

TABLE 5. Plastics In Furniture (37). Unit: 1965-70, million pounds; 1971-80, 1,000 metric tons.

MATERIALS	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1980
A B S				2	3	5	4.6	5.9	6.5	5.0	18.2	45.5
Melamines	8	9	11	13	15	16	7.7	8.4	8.6	8.1	13.7	27.3
Nylons											4.6	45.5
Phenolics	34	38	44	52	60	64	40.9	35.3	37.0	34.0	54.6	109.2
Polyesters	3	4	5	22	20	23	11.4	13.7	15.2	15.1	22.8	45.5
Polystyrene	10	15	26	52	75	85	45.5	56.6	68.2	58.0	91.0	182.0
Polyolefins				5	12	13	9.1	16.8	23.3	24.2	22.8	91.0
Polyurethanes												
Flexible Foam	136	155	185	140	245	240	134.1	150.2	168.0	175.0	136.5	273.0
Fabric Coating									6.2	7.0		
Rigid Foam			1	15	25	28	15.9	18.1	20.0	19.5	91.0	182.0
Polyvinyl Chloride		189	202	240	260	255	114.0	145.0	145.0	144.0	182.0	273.0
Miscellaneous	3	5	8	5	5	6	2.7	3.2	4.7	4.0	9.1	91.0
Total	364	415	482	546	720	735	384.0	453.2	502.7	493.9	646.1	1,365.0

Source: Modern Plastics and industry estimates. Miscellaneous includes Acrylics, Butyrates, Expoxies, Acetates, Polycarbonates, etc., and new material developments. Materials exclude fillers and reinforcements.

in the plastic products are more uniform than those of wood pieces. Furthermore, the plastic product performs better in terms of physical and thermal properties and its greater resistance to chemical and environmental damage as compared to the conventional raw material (Table 6).

b) Product Processing

It is possible to design plastic parts in a way which is impossible, uneconomic, or impractical with wood parts. For example, radical designs can be duplicated in great quantities. Assembling problems encountered in wood products do not exist in plastics, since the plastics are molded with tolerances between ± 0.005 and ± 0.010 inches. Furthermore, there are almost no limitations to the size of plastics that are usually found in the wood industry, and this will reduce assembling operation and labor cost.

c) Product Cost

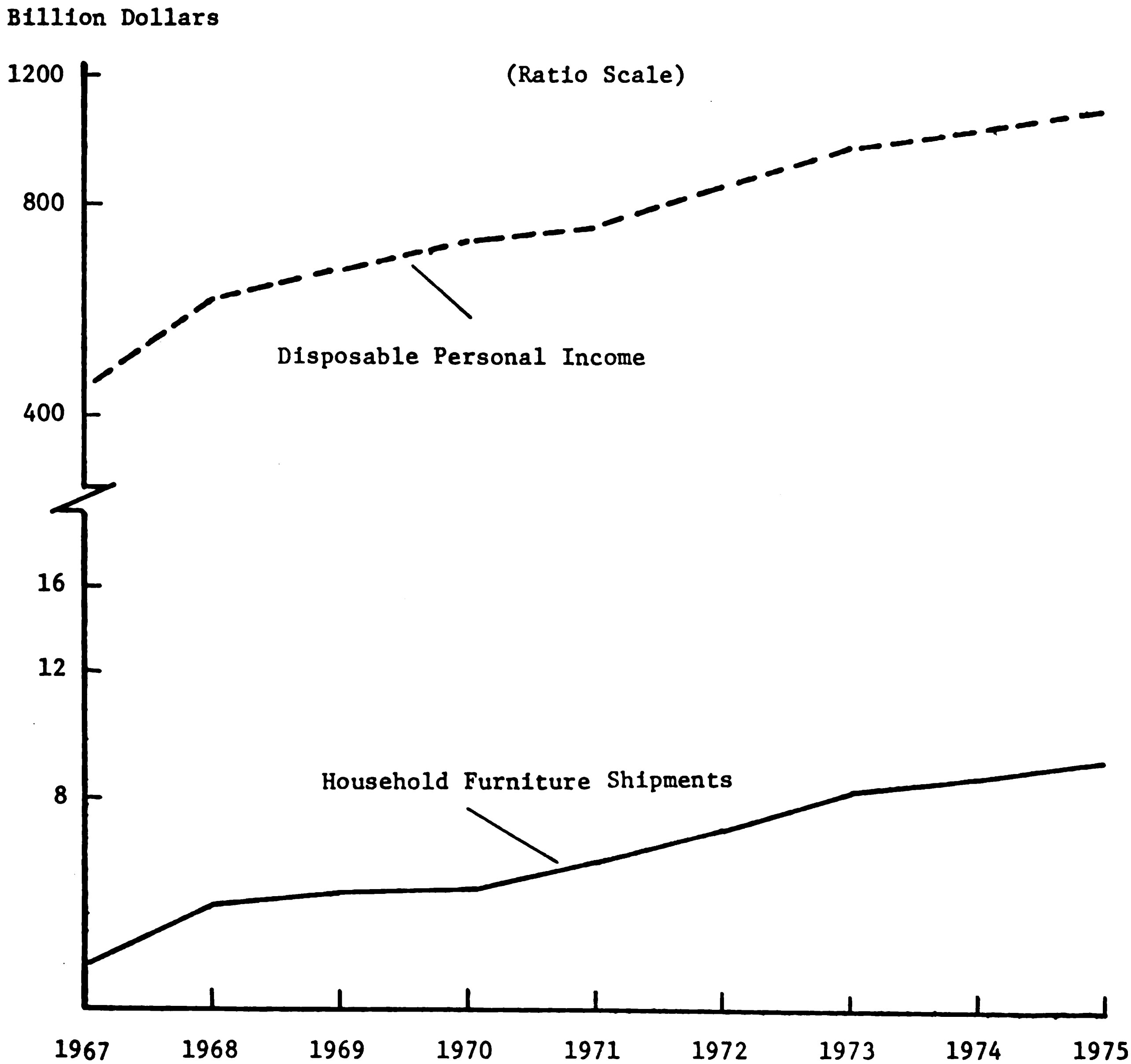
Basically speaking, pound for pound, plastics are more expensive than wood. But they are inexpensive on the basis of unit price due to the greater productivity and the one step molding process. Moreover, taking advantage of custom molders, furniture manufacturers can benefit from their high volume and low cost without increasing their investment.

3) <u>The Bright Future (19)</u>

The furniture industry grows steadily in proportion to the trend of disposable personal income, (Figure 1) (54). The two are closely related. The annual average growth rate of household furniture,

TABLE 6. Properties of Wood and Plastics (4).

	WOOD		CAST PLASTICS			
	Along Grain	*Across Grain*	*Poly-esters*	*Urethane Foam*	*Injection Molded Plastics Polystyrene, ABS, Polyolefins*	*Decorative Laminates*
Specific gravity, g/ml	0.3–0.66		0.7–1.3	0.1–0.6	0.98–1.25	1.4–1.5
(Wood) Working Qualities	Very Good–Excellent		F–VG	VG–E	Poor–Fair	Very Good
Nailability	Excellent		F–VG	VG	Fair–Good	Good–Very Good
Screw-holding power	Very Good–Excellent		G–E	G–VG	Very Good	Very Good
Effect of Chemicals						
Water absorption (24 hrs. in water) %	Over 15%		0.1–3.5	0.2–0.7	0.005–0.4	0.3–0.8
Resistance to polar solvents	Poor–Very Good		VG	VG	Poor–Good	Very Good
Resistance to dilute acids	Good		VG	VG	Very Good	Very Good
Resistance to dilute alkali	Good		VG	VG	Very Good	Very Good
Thermal Properties						
Thermal expansion per °C (10^{-5})	10–15	70–120	3–9	3–5	6–23	3–4.5
Resistance to long term exposure above 170°	Poor		E	E	Excellent	Excellent
Physical Properties						
Tensile strength, psi	——	200–1200	500–50,000	100–8,000	800–9,000	10,000–15,000
Fatigue resistance	Excellent		G–E	VG	Good–Very Good	V. Good–Excellent
Compression strength, psi	2000–6000	200–2000	13,000–37,000	——	3,000–11,000	20,000–40,000
Scratch and wear resistance	Fair–Good		VG	G–VG	Poor–Fair	Very Good
Impact resistance	Fair–Very Good		G–E	F–G	Good–Very Good	Very Good
CREEP (resistance to long-term load)	Excellent		E (if reinforced)	VG	Good–Very Good	Very Good
Electrical Properties						
Volume resistivity, Ohm–cm	10^{17}–10^{18}		10^{12}–10^{14}		10^{14}–10^{16}	10^{12}–10^{14}
Other Properties						
Decay resistance	Poor		Excellent		Excellent	Excellent
Resistance to insects	Fair–Poor		Excellent		Excellent	Excellent



Source: Bureau of the Census, Bureau of Economic Analysis, and BDC.

FIGURE 1. Growth of Furniture Shipments Parallels Disposable Income (54).

1967-1974, was 7.7 percent. Tables 2 and 7 depict some more detail. Manufacturer's shipments of household furniture in 1975 are expected to show an increase of 7 percent over that of 1974, despite the economic depression. A survey, conducted by the Bureau of Census, revealed that besides disposable personal income, the age of household head played an important role regarding household expenditures on household durables. Households headed by persons under 35 years of age spent the most on furniture and appliances. In addition, the survey also pointed out that more and more families will be headed by persons under 35 years of age.

According to William J. Hodge, Consumer Goods and Services Division, "A continuing high level of consumer expenditures for durables and increased formation of new households are expected to have a favorable effect on sales of house furniture during the reminder of the decade." (54).

However, the soaring prices of plastic raw materials because of the energy crisis may lead to an uncertain circumstance for the development of plastics in the wood furniture industry.

TABLE 7. Household Furniture: Trends and Projections 1967-75 (54).

[in millions of dollars except as noted]

	1967	1968	1969	1970	1971	1972	1973 [1]	1974 [1]	Percent increase 1973–74	1975 [1]	Percent increase 1974–75
Industry:[2]											
Value of shipments, total	5,107	5,663	6,047	5,932	6,623	7,636	8,451	8,973	6	9,652	8
Wood [3]	2,439	2,660	2,868	2,641	3,030	3,127	3,530	8,780	7	4,080	8
Upholstered [3]	1,242	1,440	1,555	1,675	1,809	2,104	2,350	2,490	6	2,690	8
Metal	618	664	697	714	764	882	970	1,020	5	1,090	7
Bedding	743	834	869	848	969	1,031	1,072	1,125	5	1,200	7
Wood TV/Radio Cabinets [3]	n.a.	n.a.	n.a.	n.a.	n.a.	321	334	340	2	347	2
Household furniture, n.e.c.[4]	65	65	58	54	51	171	195	218	12	245	12
Total employment (000)	297.8	306.0	314.5	299.7	308.5	322.0	342.0	342	--	--	--
Production workers (000)	257.3	264.4	271.3	255.8	262.8	272.2	289.1	287	−1	--	--
Value added by manufacture	2,650	2,962	3,180	3,093	3,434	3,959	n.a.	n.a.	--	--	--
Value added per production worker man-hour ($)	5.16	5.58	5.88	6.14	6.60	7.29	n.a.	n.a.	--	--	--
Product:[5]											
Value of shipments, total	4,893	5,418	5,791	5,807	6,445	7,005	7,735	8,205	6	8,815	7
Wood [3]	2,300	2,502	2,677	2,587	2,919	2,660	3.010	3,220	7	3,470	8
Upholstered [3]	1,216	1,398	1,506	1,671	1,821	1,974	2,210	2,340	6	2,520	8
Metal	588	644	690	666	702	843	925	970	5	1,030	6
Bedding	710	793	832	806	924	1,062	1,100	1,155	5	1,240	7
Wood TV/Radio Cabinets[3]	n.a.	n.a.	n.a.	n.a.	n.a.	281	280	285	2	290	2
Household furniture, n.e.c.[4]	79	81	86	77	79	185	210	235	12	265	13
Value of exports	22.2	24.7	25.4	23.0	23.3	31.8	47.2	65	38	--	--
Value of imports	61.6	82.2	113.6	140.3	147.1	203.5	277.3	345	24	--	--
Wholesale price index (1967 = 100)	100.0	104.2	108.9	111.7	114.8	117.3	123.0	134.0	--	--	--

[1] Estimated by Bureau of Domestic Commerce (BDC).

[2] Value of all products and services sold by household furniture industries (SIC 2511, 2512, 2514, 2515, 2517, 2519).

[3] Effective 1972, due to revisions in the Standard Industrial Classification (SIC), wood kitchen cabinets are now in industry 2434; wood TV, radio, and sewing machine cabinets are in industry 2517; frames for upholstered furniture are in industry 2426.

[4] 1972 data for industry 2519, as reported by Census Bureau, are not comparable with years 1968–71.

[5] Value of shipments of household furniture made by all industries.

n.e.c. = Not elsewhere classified.

n.a. = Not available.

Source: Bureau of the Census, Bureau of Labor Statistics, BDC.

3. BASIC CHEMISTRY OF PLASTICS

Plastics are made from simple molecular monomers by a mechanism known as polymerization. In recent years the highly sophisticated understanding of structure-property relationships and the introduction of new monomers have resulted in the capability to "tailor make" plastics.

1) Polymerization Reactions

There are three methods to synthesize larger molecules. First, the reacting molecules simply add together end to end; this is known as addition polymerization. Second, the reacting molecules are joined together through the elimination of a small molecule, usually water or alcohol; this is known as condensation polymerization. And lastly, the reaction involves the rearrangement of atoms and bonds between adjacent molecules; this is known as rearrangement polymerization (27).

a) Addition Polymerization

The great bulk of commercially produced polymers is made by the addition method. For instance, ethylene is the monomer for polyethylene. Its formula can be written as $CH_2 = CH_2$. The existence of the double bond in the monomer is necessary in all addition polymerization processes (27).

(1) Initiation

Under certain conditions the two unshared valences present in the double bond can become available for reactions.

$$CH_2 = CH_2 \rightarrow -CH_2-CH_2-$$

Some high evergy sources such as radiation and thermal energy, or an ionic type of catalyst such as peroxides are employed to do this job. Heat is usually used because it is relatively inexpensive (20) (51).

$$CH_2 = CH_2 - R^{\bullet} \rightarrow R-CH_2-CH_2-$$

Where $R^{\bullet}$ is called a free radical.

(2) Propagation

The ethylene molecule becomes active and tends to react with neighboring molecules.

$$R-CH_2-CH_2- + -CH_2-CH_2- \rightarrow R-CH_2-CH_2-CH_2-CH_2-$$

Then, the reaction continues, 6, 10, ... more and more carbon molecules are linked to each other. It occurs very quickly, and many hundreds of ethylene molecules join the chain within a second. There is a remaining active end (20) (51).

(3) Termination

When the active ends meet each other, they will deactivate each other. Therefore some of the molecular chains might be very long but some shorter (27).

R ~~~~~~~~ $^{\bullet}$ + $^{\bullet}$ ~~~~~~~~~~~~ R → R ~~~~~~~~~~~~~~~ R or

R ~~~ $^{\bullet}$ + $^{\bullet}$ ~~~~ R → R ~~~~~~~~~~ R

(4) Molecular Weight

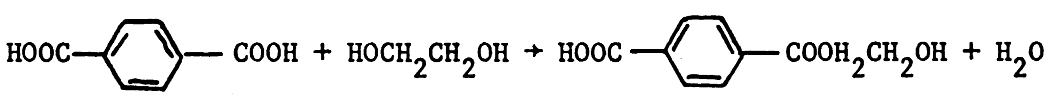
The moment of termination of any chain is quite random. The mass of polymer therefore consists of many chains of different lengths. The average molecular weight and the molecular weight distribution thus are used to identify a particular polymer instead of a unique molecular weight as used in inorganic compounds. The average molecular weight and the molecular weight distribution are of great technological importance, because the chemical, mechanical and aging properties of a polymer depend to a considerable extent on them (27).

b) Condensation Polymerization

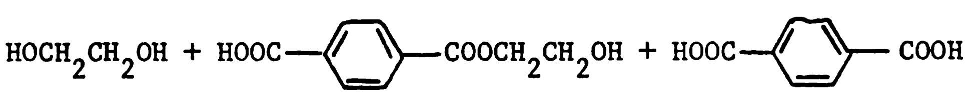
This type of reaction does not involve double bonds. For example,

$$C_2H_5OH + HOOCCH_3 \rightarrow C_2H_5OOCCH_3 + H_2O$$

The product of this reaction is ethyle acetate (ester). However the monobasic acids and alcohols cannot react any further, because there is only one functional group (OH- or COOH-) on each molecule available. Terephthalic acid which has two carboxyle groups, and ethylene glycol which has two hydroxyl groups can produce a polymer by condensation polymerization. The polyesterification involves condensation of hydroxyl and carboxyl groups. For example, (38)



Terephthalic acid Ethylene glycol



Ethylene glycol Terephthalic acid

and so on ...

These molecules often increase to a molecular weight of 10 or 20 thousand and are known as Dacron.

c) Rearrangement Polymerization (27)

Just like the condensation polymerization, for a rearrangement reaction to occur, the reactants must have two or more functional groups. For example,

$$OCN(CH_2)_6NCO + HO(CH_2)_4OH \rightarrow OCN(CH_2)_6NHCOO(CH_2)_4OH$$

Hexamethylene di-isocyanate   Butane diol

In this reaction some atoms from the isocymate group (-NCO) and the hydroxyl group (-OH) have to rearrange themselves to form the -NHCOO- linkage. The resulting molecule still has functional ends and can react further.

$$HO(CH_2)_4\text{-OOCHN-}(CH_2)_6\text{-NHCOO-}(CH_2)_4\text{-OOCHN-}(CH_2)_6\text{-}$$

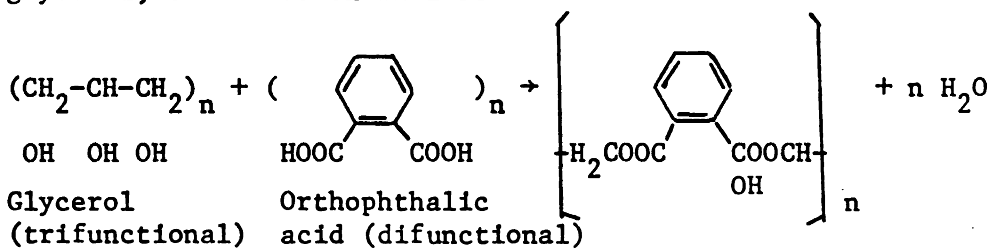
Polyurethane

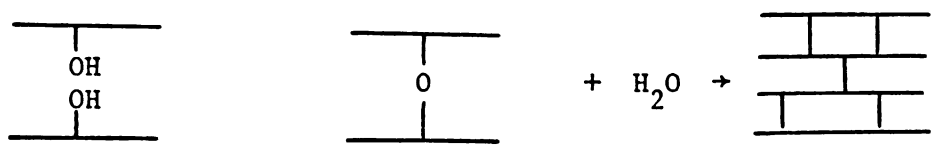
and so on ...

2) Thermoplastics Versus Thermosets (20) (27) (51)

Those polymers that contain repeated units in a linear or chain-like form are referred to as thermoplastic. They become moldable when heated and can be repeatedly heated until soft and remolded. The plastics mentioned so far are all linear or have chain-like forms, therefore, they are all thermoplastics. But polyurethanes for example, form crosslinkages rather than linear chains by further reactions and are thermosetting.

Polyesterification can be made more complex by using tri- or quadri- functional molecules instead of mono- or di- functional molecules. For example, if we use a trihydric alcohol such as glycerol, the reaction will be:





After the linear reaction, they develop further into cross-links. Once the cross-links have formed, the molecules are set and solidified. These are called the thermosets.

3) <u>Copolymers (20)</u>

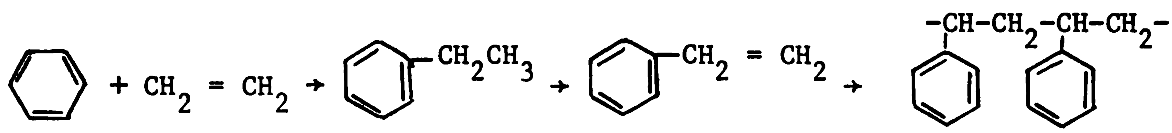
The polymer chain can be made not only from identical monomers but also from non-identical ones. The latter type of polymer is also called copolymer. Their properties are infinitely variable and depend on the proportions of the different compounds used. For example, by polymerizing mixtures of vinyl chloride and vinyl acetate, molecular chains can be built up in which the links consist partly of polyvinyl chloride (PVC) and partly of polyvinyl acetate (PVA). These copolymers combine the properties of the PVA and PVC, the nature of the copolymer depending upon the proportion of the constituents that are present. Another example, ABS plastics used in molding furniture parts, are copolymers which combine styrene with butadiene and acrylonitrile.

4) Common Plastics In Wood Furniture

There is no other family of materials with so many variations in forms like plastics. Plastics can appear as molding compounds, liquid casting resins, solid structural shapes, coatings, adhesives, laminates, fibers, etc.

a) Polystyrenes (20) (30) (48)

Styrene in the common name for vinyl benzene. Commercially, the reaction of benzene with ethylene is universally used to produce the styrene monomer. Styrene, then, polymerizes very fast under heat into polystyrene. The reaction can be visualized as:



styrene　　Polystyrene

Polystyrene homopolymer which is made of styrene identical monomers is noted primarily for excellent balance of characteristics rather than for one or two unique properties. One of polystyrene's defects as a plastic is its brittleness and a tendency to craze on aging. Polymerization with acrylonitrile gives the copolymer better chemical and aging properties than polystyrene alone. ABS copolymer is made with improved impact strength, elongation characteristics and is accepted as one of the best quality materials for molding furniture parts.

Polystyrene is by far the major plastic being used in simulated wood in the furniture industry because of its low price and good properties (Table 8). Polystyrene parts are generally injection molded.

TABLE 8. Properties of Polystyrene and Polyester (6).

QUALITY PARAMETERS	POLYESTERS	POLYSTYRENE
Appearance	Excellent	Very good
Feel	Excellent	Good
Knocking	Excellent	Poor
Acceptance of finishes	Very good	Good
Resistance to solvents	Good	Poor
Nailability	Excellent	Good
Screw-holding power	Excellent	Good
Tensile strength	Excellent if reinforced	Good
Shear strength	Excellent if reinforced	Good
Compression	Excellent if reinforced	Good
Creep	Excellent if reinforced	Fairly good at high loads and long times. Poor at elevated temp.
Impact resistance	Excellent for semi-rigid overlays, flexible molding strips and reinforced parts	Good
Stress cracking	Very good	Good
Use for overlays	Excellent	Good
Use for whole doors and drawers	Fair	Very good
Use for picture frames	Fair	Good
Use for very thin parts (under 1/8")	Good	Excellent
Use for headboards	Very good	Good
Use for very small parts	Fair	Good
Use for structural parts large sofa ends, pedestals, etc.	Excellent if reinforced	Good, if no exposed to long times of high loads and temperatures
Use for flexible parts	Excellent	Not possible
Performance at extreme cold temperatures	Fair	Good
Performance at extreme high temperatures	Very good	Very good
Dimensional Stability	Very good	Excellent

b) Polyurethanes (4) (5) (6) (20) (31)

A polyurethane is made by reacting a polyol (hydroxy compounds) with an isocyanate (l-c rearrangement polymerization). Polyurethanes represent one of the most complex areas of plastics chemistry. There are almost an infinite number of polyurethane materials. Because the ability to use a number of different raw materials makes it possible to produce polymers of different densities. In addition, a gas which is either generated by the reaction or introduced into the reaction creates a foamed material of cellular form. The finished polymer may be flexible or rigid, depending on the degree the reaction is allowed to progress.

As with polystyrene, rigid polyurethanes started out in the decorative areas. Now they are used more and more in the structural areas and in the fabrication of complete furniture units. It is hard to find any area of furniture where rigid polyurethanes are not used.

Casting is generally employed to mold the urethane articles, even though injection molding can also be used. Some outstanding characteristics of polyurethane foam casting parts are:

1. Densities can be varied from 4 to 50 pounds per cubic foot.

The widespread use of rigid polyurethanes is due in large part to the great variety of densities that can be produced. As the density changes so does the strength of the material.

For instance, beams and wall plaques for decorative purposes would run about 3.5 pounds per cubic foot, mirror frames can range from 8 to 27 pounds per cubic foot, and kitchen cabinets would range from 25 to 30 pounds per cubic foot.

2. Equipment cost and mold cost are low.

The casting for rigid polyurethanes is a low pressure process which uses inexpensive molds and constraining frames.

Polyurethane parts can be cast economically when production runs are only a few parts per day up to a few thousand parts per day. In contrast, the injection molding of polystyrene components is economical only when thousands of parts are turned out per day.

3. Styling is virtually unlimited in designing.

Polyurethanes employ elastomeric molds. A more intricate design can be produced without worrying about draft angles. The flexible mold allows under cuts in the design.

4. Molds can be easily and quickly made.

5. Polyurethane parts can be finished and worked like wood and feel and have the sound of wood.

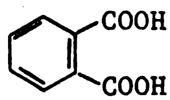
6. Dyes and pigments can be added to give uniform color throughout the foam.

7. A barrier coat is unnecessary.

Polyurethanes as well as polystyrenes show a fast projected growth in their application as furniture parts.

	1968	1970	1974	Unit: million pounds
Polystyrenes	52	85	127	
Polyesters	22	23	33	
Polyurethanes	15	28	42	

c) Polyesters (5) (6) (27) (32)

Polyesters are produced by condensating an acid and an alcohol. Rigid polyesters are usually made from maleic acid $\left(\begin{array}{c}\mathrm{CHCOOH}\\ \|\\ \mathrm{CHCOOH}\end{array}\right)$, Phthalic acid 

and glycols, while flexible polyesters contain adipic ($HOO(CH_2)_4COOH$), and glycols.

The properties and appearance of polyester, and rate of cure can be tailored by means of blending the flexible and the rigid polymers in suitable proportion. For example, a resin consisting of 70 percent flexible type, 30 percent rigid type and combined with an equal quantity of filler would have a density of about 94 pounds per cubic foot. The product would have 2,500 psi tensile strength and 6,500 psi compressive strength. Such a material could be easily stapled, nailed, sanded, and sawed. Furthermore, the filler such as wood flour, not only lowers the price but also provides a receptive surface for stains and it makes polyester components easier to finish than other plastic materials.

The melting point of a polyester is usually an indicator for flexibility of rigidity of the final products. Resins that are liquids or show a low melting point give generally flexible products. Resins that have a higher melting point usually are rigid.

Polyesters are cast in a manner somewhat similar to that of rigid polyurethanes. Both of these polymers are not a single material but rather a range of materials. Polyesters parts can be made to range from very flexible to highly rigid materials.

Like polyurethanes, polyesters also have the advantages of the casting process such as lower mold cost, remarkable time-saving in preparing a mold, perfect reproduction of wood surfaces, etc. Table 8 depicts the outstanding end product properties of polyesters.

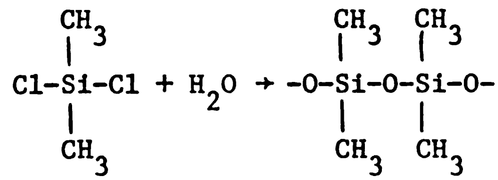
d) Silicones (20) (29) (53)

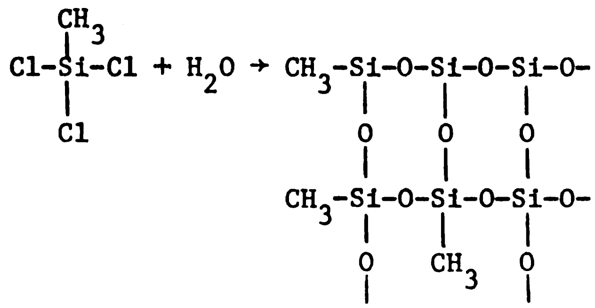
In general, organic chemicals which are compounds of carbon, are inflammable and will decompose when heated. That is what happens when we burn wood or coal. It is inevitable, therefore, that synthetic plastics should suffer defects characteristics of organic compounds. They are subject to chemical change under the effect of heat and atmospheric degradation. They will often dissolve in solvents such as alcohol or benzene, and under suitable conditions they will be decomposed and burnt. These tendencies are inherent in most of the synthetic plastics for they are organic compounds. On the other hand, inorganic compounds are often inert, unchanging materials. Stone, asbestos, clay, or glass are not readily changed to other compounds by combustion or atmospheric attack. They do not lend themselves to such intricate chemical changes as do the compounds of carbon.

Silicone is an element that occurs in inorganic substances such as quartz and glass; relatively inert and resistant to the effects of heat or atmospheric inflences. However, silicone possesses certain properties similar to those of carbon, and the two elements belong to the same chemical group.

Silicone is capable of forming compounds with the same structure as the corresponding carbon compounds. For instance, the hydride silane, SiH_4, is analogous to methane, CH_4.

Thermoplastic polymers and thermosetting polymers can be produced by the hydrolysis of dimethyldichlorosilane and methyltrichlorosilane respectively.





Besides methyl CH_3-, phenyl C_6H_5- or vinyl CH=CH- group can be attached to silicone derivates. These groups impart characteristics, such as solvent resistance, lubricity, compatibility, and reactibility with organic chemicals and polymers.

Silicones, combining organic and inorganic substances, not only look like, but act like organic materials on one hand. On the other hand, they also are like their inorganic ancestor, silica SiO_2, resistant to heat, cold, chemicals and weathering.

Instead of being a molding material for decorative items or structural parts, silicones in the furniture industry play an important role as mold-making materials, which will be discussed in detail later.

e) Polyvinyls (20) (38) (39) (40)

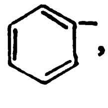
Vinyl polymers and copolymers consist of a large family of thermoplastics. Their general structure can be presented as follows:

$$-\!\!-\left[-CH_2-\underset{\substack{|\\ R}}{CH}- \right]_n-\!\!-$$

When R is Cl-, it is polyvinyl

R is CH_3COO-, it is polyvinyl acetate

R is H-, it is polyethylene

R is , it is polystyrene

and R could be others.

In general, the lower the molecular weight, the poorer the mechanical properties of the polymer will be, and the lower is its thermal stability. Polyvinyls are light in weight, often transparent and glass-like. The solid plastics are tough and strong, and can be cast into films. When they are softened, they are suitable for modern mass-productive techniques employing injection molding.

Polyvinyls can be modified by plasticizers, fillers, and stabilizers to produce rigid or flexible materials as desired. Stabilizers are used to prevent polyvinyls from the effects of oxidation, of heat, and of light. Plasticizers are used to soften polyvinyls, and to make them flexible when the products are cool. The plasticizer molecules machanically rather than chemically penetrate between the vinyl chains and separate them apart on cooling. Therefore the cooled polymers remain soft and flexible.

In the furniture industry, polyvinyls are employed as laminates rather than structural or decorative parts. Polyvinyl sheets, engraved and printed with wood grain, are laminated to solid vertical or horizontal surfaces.

f) Phenolics and Melamines (20) (38) (39) (40)

Phenolic plastics are made by chemical reaction between phenol or cresol, and formaldehyde. The phenol has three non-specific reactive sites instead of two. When phenol and formaldehyde begin to join together into a chain in the presence of heat and a small amount of alkaline catalyst such as ammonia, they join head to tail to give a straightforward thread-like molecule. The product is a thick sticky resin and it is thermoplastic. However, as the heating continues, the molecule tends to branch out here and there from the three non-specific reactive sites of the phenol and the branching chains begin to join up with formaldehyde. The polymer, then, develops a rigid network structure and sets.

Melamines are produced by reacting amino-bearing melamine with formaldehyde at temperatures of 160 to 195°F with pH values exceeding 8.5. Basically, the melamines are similar to phenolics. As in the case of phenolic plastics, the molecule of the melamine polymer is not a simple straightforward chain; it develops branches, as a result of which the molecules can eventually join themselves together to form a three-dimensional network. For adhesive purposes, the material is pre-condensated and cooled to 70°F. For the purposes of impregnating laminated, modifying media are added to enhance the elasticity of the hardened melamine resins and to prevent the films from sticking to the press plates.

Both phenolics and melamines are hard, durable and are highly resistant to heat and scratch. Bearing those excellent properties, they are commonly used in the production of laminated materials from cloth or paper.

4. PROCESSING

There are three ways to produce plastics, namely: by molding, casting, and thermoforming. Molding processes in the furniture industry are custom operations most of the time, while casting processes are captive operation. Injection molding represents a major portion of the plastics production. Here, productivity must be high for economic reasons. In contrast, flexible mold casting gives flexibility in the quantities of production and still has economic advantages. The methods of molding and casting will be discussed in great detail in this part and additional discussion will be given the rotational molding (rotomolding) for its versatile characteristics.

1) Injection Molding (2) (11) (24) (30) (34) (45)

The largest fraction of furniture parts such as decorative articles and structural items, is molded by injection molding. This trend is believed to continue for some time to come. The important factors which make the injection molding so widespread are:

1. Technology is well advanced.
2. Equipment is readily available in all sizes.
3. This method produces uniform parts at high volumes.
4. Good simulation of wood is possible.

There are, however, some shortcomings associated with this process, such as:

1. Machinery and anxiliary equipment are expensive.
2. Processing is complicated.
3. Mass production is required for acceptable unit cost.
4. No undercuts of design are possible.

a) Molds

The molds used in injection molding are of very high quality, machined to close tolerances and thus are very expensive. The mold must be designed to be able to withstand the very high pressures it will be exposed to during the injection process. Since the cycle time depends largely on the cure time of the plasticized material in the mold, the thermal conductivity of the mold for cooling the molten plastic is also one of the critical factors. The shorter the cycle time, the greater the quantitives the machine will produce, and thus the more economic the operation will be.

b) Mold Making

Aluminum, steel, and beryllium-copper, can be employed as mold-making materials. Usually, beryllium-copper is used for the injection mold.

To make a mold, selection of a fine model carefully made with desired grain structure and appearance is most essential. In addition, the mold should be free from undercuts and a draft of two to seven degrees is desirable. Moreover, the model should be about two hundredth of an inch larger than the desired part to allow for shrinkage of the metal mold and the plastic part.

It takes about three weeks or more to make a beryllium-copper mold. A flexible silicone rubber prototype mold is first cast from the model. Then, a ceramic mold is cast from the prototype mold. At last beryllium-copper is cast in the ceramic mold. The plastic products are made in the beryllium-copper mold and the features produced are replicates of the mold. Flexible mold casting will be discussed in the next part.

However, there is a better process - the Shaw process. The Shaw process is recognized as a superior technique for casting a rigid mold by shortening the time needed for the cast sequence described above and without sacrificing faithful duplication. The outstanding characteristics lie in the fact that when a slurry mold, which is made of a compound of refractory powders with an ethyl silicate binder and a jelling agent, from the rubber prototype mold is ignited, a microcrazed structure is formed in the mold. This microcrazed structure mold can be used for the casting of the beryllium-copper mold.

The rigid mold is usually cored with drilled intersecting channels for circulating heat transfer medium, such as water, to cool the incoming molten plastic. In addition to shortening the cycle time of the molding process, the cooling design also plays an important role in influencing physical properties of the end products to some extent, such as uniformity of the plastics.

c) Molding Process

Injection molding is the major method employed for molding thermoplastics, especially for polystyrenes. There are four types of injection machines operating in the United States. The reciprocating screw type (the single-stage screw type) is the most popular (Figure 2). It has some advantages, such as:

1. A better preparation of the plastic material for molding.
2. A higher pressure on the material when it is injected into the mold.
3. A better color dispersion when using dry coloring or color concentrate.
4. A quicker change from one material or color to another.

During the molding cycle, the plastic pellets are forced from the hopper into a heating cyclinder. There, the material is plasticized and screwed forward into the injection chamber (Figure 2). In the second step, when the chamber loaded with sufficient quantity of molten plastic, the screw moves forward, acting as a ram (Figure 3) and forcing the accumulated plasticized material through the nozzle into the sprue bushing through the runs, the gates and then into the cavity of the mold. Then, the cavities are quickly filled and uniformly cooled. Other important factors in the molding operation are:

1. Drying and blending the plastic compound.

Drying reduces the moisture content of the molding pellet to a point where it will not affect the molding process or cause defects in the molded parts.

Blending is used to tailor material properties to desired end products and sufficiently use up the scrap.

FIGURE 2. Single-Stage Screw Type Plastic Injection Molding Machine (2).

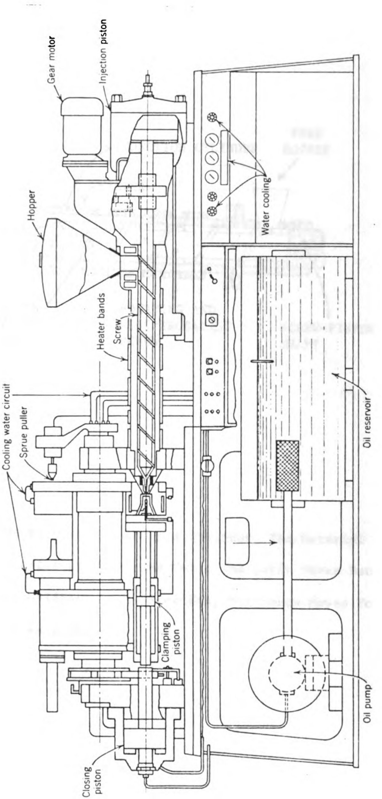

Gear motor
Injection piston
Hopper
Water cooling
Heater bands
Screw
Cooling water circuit
Sprue puller
Oil reservoir
Clamping piston
Oil pump
Closing piston

FIGURE 2.

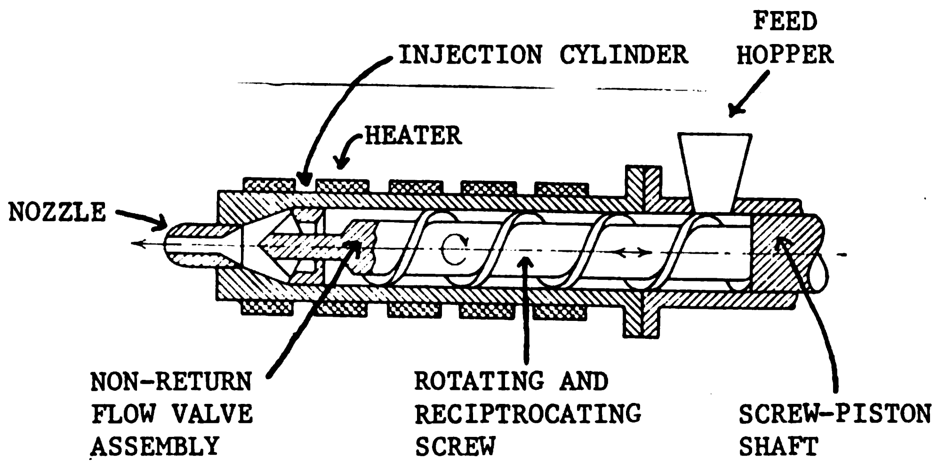


FIGURE 3. In the Reciprocating Screw Cylinder, The Material Is Plasticated by the Screw While The Later Moves Backward in the Cylinder; For Injection, The Screw Moves Forward, Acting as a Ram (2).

2. Feeding the plastic compound.

The plastic material can be fed to the heating cylinder on either a volume or weight basis. Generally speaking, the latter is more precise than the former. Improper feeding, such as caused by inventory fluctuation in the heat cylinder will cause short shots, part shrinkage, etc.

3. Plastication.

To plasticate the molding compound thoroughly and uniformly into a homogenous melt plastic with controlled viscosity is essential for the production of sound parts. In order to obtain an even melt plastic, and to avoid degrading, a balance must be maintained between the need to provide adequate time for proper heat exposure of material in the cylinder and the need to move more material through the cylinder as fast as possible.

2) Casting

Casting is a relatively simpler process for the production of plastic components if compared to the molding systems. In short, the process includes pouring resins into the mold, allowing to cure at room temperature and ejecting the solid item. As a general rule, thermosetting resins are employed in casting and thermoplastics in injection molding, with some exceptions. However, thermoplastics can also be cast, and thermosets can be injection-molded.

a) Advantages and Disadvantages

The investment in casting equipments is not high and production can be carried out economically at just a few parts a day. Mold costs are much lower than in injection molding and molds can be easily made by the furniture maker. In addition, flexible casting molds can be made for highly ornate parts, having a high degree of undercutting which is absolutely impossible in injection molding. In other words, we can get more precise wood grain duplicate than we do in injection molding. The main disadvantage is that the number of parts obtainable from a flexible mold is limited to a range of 80 to 200 due to chemical, mechanical action and slower heat transfer.

b) Mold Making

(1) Materials for Mold Making (23)

Several materials can be employed for the mold-forming. Among those, latex, urethane and silicone elastomers are most commonly used. Latex elastomers are very cheap and are useful for casting all kinds of materials. But its excessive shrinkage and high labor-requirement reduce its attractiveness. Urethane elastomer molds have to be treated with the troublesome wax or silicone type release agents before molding. In addition, the urethane elastomer used for mold-making has a short pot life which makes the fabricating operation difficult. For these reasons, latex elastomers and urethane elastomers, lose their ground to the silicone elastomers, even though they are excellent in resistance to solvents in the coatings and chemicals produced by the molded parts and are very tough.

Silicone room temperature vulcanizing (RTV) rubbers have certain outstanding characteristics, such as:

1. Thermal and oxidation stability from -100°F to 500°F.
2. Chemical inertness.
3. Surface stability to prevent other materials from sticking.
4. Ability to precisely reproduce fine detail figure.
5. Hardness to resist foaming pressures.

RTV rubbers are the best materials for making the flexible mold, though they are expensive.

(2) Model (50)

Caution must be taken in making the mold from a model to account for an average shrinkage of the plastics of 2 percent. The grain pattern should be accentuated to produce a more realistic wood-like part. In the case of a wood model, this grain accentuation can be accomplished by rubbing a soft wire brush over the pattern part in the direction of the grain. A mixture of 5 percent petroleum jelly and 95 percent methylene chloride serves as a release agent. It is sprayed on the model and makes the mold separate easily and cleanly from the pattern.

(3) Mold Fabrication (12) (23) (50)

All of the RTV silicone rubbers used for mold making are two-component systems containing a polymer and a catalyst. The mixture is 91 percent polymer and 9 percent catalyst by weight.

There are four steps to fabricate a mold:

1. Mix the two parts thoroughly by hand or with a power mixer until the color of the catalyst disappears.

2. Deair the mixture in a chamber which has a minimum vacuum of 29-inches of mercury. During the deairation, the mixture will expand as much as four times the original volume, then the mixture will recede after a few minutes. A vibrating table can also be used for the deairation purpose. The entrained air bubbles are forced out by vibrating and can be broken with compressed air.

3. Pour the deaired mixture over a framed model. There are three types of molds generally used nowadays.

   (a) The flatback or open face construction mold.

   This is used to produce five sided furniture parts. After pouring the deaired mixture a lid drilled with 1/16 inch bleed holes and coated with the release agent is fastened on the confining frame. The elastomer, the RTV silicone rubber, should be forced out the holes to make sure there is no entrained air between the lid and the mold back. After curing the silicone rubber at room temperature, the bottom of the frame is removed first and then the model.

   (b) The split mold.

   This is used to produce furniture leg, lamps bases or other similar parts. The frame for this type of mold is split into two parts. The elastomer is poured over the bottom just as in the case of the flatback mold. After the bottom half has cured completely a release agent is sprayed or brushed over the matching surfaces. At least, the top half is fastened in place and the elastomer is poured into the existing cavity.

(c) The six sided construction mold.

This is used to produce cabinet doors or the like. A sheet of about 3/8 inch thickness of RTV silicone rubber with the desired pattern and size of one side of the cabinet door is fastened to the lid. After the elastomer is poured over the flat back mold, the impressed lid is then clamped on. A six sided mold thus is made after the elastomer has cured.

4. Aging the mold.

Generally, the mold should be allowed to cure for 24 hours before removing the model. Furthermore, three more days are needed for aging the mold at room temperature. Before using the mold, it is recommended to allow seven days for developing complete physical properties after pouring.

(4) Extending Mold Life (22) (50)

Mold life primarily depends on the materials cast in the mold and the maintenance of the mold. Usually proper application of a barrier coat will at least double the life of the silicone rubber mold.

In developing a barrier, every part of the mold must be evenly coated every time. For the deep undercuts, a pencil type air brush or extension nozzle is needed to accomplish the coating job. A qualified barrier coat should provide two functions:

1. During the mold cycle, the coating penetrates to the casting parts to make them compatible with the succeeding finishing without further treatment after demolding.
2. When applied to the mold surface, it protects the mold from chemical attack.

Before applying the barrier coat, a release agent is sprayed on the mold which is then laid aside to dry completely. If not completely dried, the heat generated by the thermoplastic and residual solvent will cause a defective part owing to the broken barrier. Soap was used as release agent for a long time, but it does not do the job well. Wax in petroleum solvent generally serves the purpose. The problems of rapid deterioration of the molds such as swelling, hardening of the surface, brittleness, broken surface, and discoloration of the surface stem from either too much release agent or the solvent of the release agent remaining in the mold.

Mold temperature built up during the casting runs due to the exothermic reaction should not exceed 100 to 110°F. Otherwise, the protection of the release agent will be lost and the mold exposed to the chemical such as isocynate of the polyurethanes. Polyesters can also cause trouble, like sticking to the mold after many repeated runs. It is recommended to heat the mold to 550°F for about an hour after every five-or-so coatings to melt polyester residue and improve mold life.

The parts should be ejected from the mold as soon as possible, since mold life is directly proportional to the accumulated contact time.

c) Casting Polyurethanes and Polyesters (12) (23) (28)

Plastic parts of polyurethanes and polyesters not only perform the same functions in the furniture item, but also are cast almost in the same way in many respects. Some of the main differences between these two materials are:

1. Polyester exerts no pressure on molds, therefore no clamping or back-up operations are necessary for the mold.
2. Mold life is longer when polyester is used.
3. Mold release agents, when used, are more readily cleaned from polyester parts.
4. Polyester parts are denser than those of polyurethanes.
5. Polyesters tend to shrink more than polyurethane foams, therefore molds must be built to allow for this shrinkage.

3) Rotational Molding (3) (21) (42) (56)

Getting more and more attention in the furniture industry in recent years is rotational molding, a process in which a fixed quantity of plastic compound, either powder or liquid, is sealed in the mold and rotated in biaxial direction while being heated. The molten plastic is then distributed evenly in the cavities. The mold keeps rotating biaxially during the cooling phase. The plastic item is then cured and ejected (Figure 4). The reasons for favoring the rotational molding lie mainly in the fact that it can mold parts of various shapes and sizes. The more complex the shape is, the more suitable the rotational molding is. The larger the size of the part is, the better the rotational molding operates.

FIGURE 4. A Multiple-Spindle, or Carousel-Type Rotational Molding Machine. Each Spindle Carries a Group of Molds or a Single Large Mold Through Heating and Cooling Enclosures Prior to Loading and Unloading of the Mold (3).

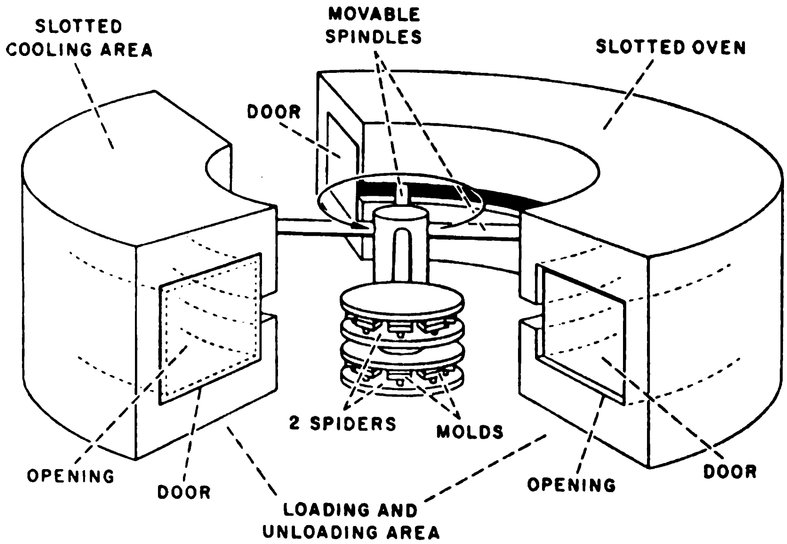

SLOTTED
COOLING AREA
MOVABLE
SPINDLES
SLOTTED OVEN
DOOR
2 SPIDERS
MOLDS
OPENING
DOOR
LOADING AND
UNLOADING AREA
OPENING
DOOR

FIGURE 4.

The following are the advantages of rotational molding for the furniture industry:

1. Products are made seamless and stress free. In addition, there is a tendency to make the wall thicker at the corners where most often extra strength is needed.
2. The wall thickness of the part except for the corner is uniform.
3. Fine appearance can easily be gained.
4. The tooling costs are relatively low.
5. Any shape and size can be molded especially hollow parts or parts of angular shape.

4) Finishing Molded Parts (14) (36) (43)

One of the most essential factors, which help plastics make inroads into the furniture industry is that the developed finishing technology makes the finished wood-grain plastic components indistinguishable in decorative appearance from real wood.

Some plastic articles, such as a mirror frame or a waste basket, can be finished separately. However, the plastics which serve as components of wood furniture should be finished right along with the wood parts. In the latter case, the finishing not only furnishes the wood-grain plastics with satisfactory finishing effects, but also makes the plastics indistinguishable from the other wood components in the piece of furniture. In separate finishing, special topcoats can be developed to give adequate adhesion to the plastic, but in simultaneous finishing the conventional finishing materials for wood are being used step by step along with the wood parts. Unfortunately, the solvents of the finishing materials tend to attack the plastics. Therefore a special treatment, a barrier coat should be applied first, before the plastic parts are attached to the wood base.

a) Barrier Coat (1) (13) (17) (25) (33) (46)

The first and the most important step in finishing the plastic parts is the application of a proper barrier coat (base coat). A barrier coat should:

1. Provide proper color background.

Since the plastic will be assembled with wood after the barrier coat has been applied, it will be treated simultaneously with wood step by step from then on. Therefore, the barrier coat should be formulated in a color as close to the natural wood color as possible. Practically, it should always be somewhat darker than the uncoated wood substrate, since the plastic is much less porous than wood and will not absorb the succeeding stain to the same degree as wood. This must be compensated by adjusting the color of the basecoat.

In most cases, the color is molded into the plastic in such a way as to match the color of the furniture. In case the finished furniture is scratched, the plastic part will not appear so significantly different from the wood part.

2. Provide adhesion not only to the molded plastic but also to the subsequent finishing coats.

Most of the conventional lacquers used in wood finishing have no adhesion to polystyrene. So, a barrier coat should be formulated to bond the plastic and the conventional nitrocellulose lacquers.

3. Provide some absorptivity to hold stains.

This makes it easier to match color with wood parts.

4. Act as a barrier in preventing a solvent attack by lacquer topcoats containing strong solvents.

Polystyrenes are very sensitive to those solvents such as naphthas, ketones, and esters which are the major components of common finishing products. Plastics attacked by the solvent will develop a number of surface irregularities such as wrinkling, cracking, alligatoring, and other unique effects. These are categorically defined as "crazing". Generally speaking, plastic parts tend to craze in stressed areas during the finishing operation. The stresses are usually set up around the sprue area and in certain places where excessive shrinkage occurs in the mold. The cooling cycle and the flow characteristics of the polystyrene are factors influencing the development of shrinkage.

b) Stains and Toners (1) (17)

This adds color to the wood and enhances the grain. The synthetic parts are finished in conjunction with wood after base coating.

Non-grain-raising (NGR) stains or dye stains have little effect on polystyrene because of its non-porous surfaces. The NGR stains or dye stains are therefore not used for polystyrene.

Toner with binder is sometimes used to give additional depth to the basecoated plastic and adjacent wood parts.

c) Filler (1) (17)

The function of fillers is to add color and to close the pores of the wood. Since plastic does not absorb stain and the barrier coat absorbs only slightly, therefore, generally, filler has little effect on the finish of plastics.

d) Sealer (1) (17)

The sealer is applied over stain or filler to seal off the surface and provide a smooth foundation for the topcoats. Between-coat sandings of wood can be accomplished in a normal manner, but plastics require no sanding in order to perfectly match the completed finish.

e) Pigment stains and glaze stains (1) (17)

Pigment glazing gives the furniture piece a highlighted, shaded or antique appearance. Pigment stains or glaze stains contributes more to the realistic woody appearance of plastic furniture components than any other finishing steps.

f) Topcoating (1) (17)

A shellac, varnish, or lacquer topcoat can be applied after sealing. Usually, two or more coats are required.

g) Finishing polyurethane and polyester parts (1)

So far, the discussion has dealt with finishes for polystyrenes which represent the largest quantity of plastics consumed in the furniture industry and which appear to be more difficult to finish.

Polyurethanes and polyesters basically need no basecoat because they are not attacked by the chemicals in the solvents of conventional lacquers or varnishes. Therefore the basecoat is used for the purposes of providing a uniform and consistent color. After basecoating, polyurethanes and polyesters can be finished like polystyrenes. However, because of the porous nature, polyurethanes and polyesters will be more like wood in their ability to receive and absorb the various finishing steps.

5. COATING

Furniture finishing with wood grain can be done in three ways. First, on the plastic molding or cast parts. Second, on an overlay material which will then be applied to the wood-base substrate. Third, on the wood-base substrate directly. These finishing processes involve embossing, printing, coating, overlaying, and laminating. The first method has been discussed previously and the other two will be discussed here.

Basically, no matter what process is employed in finishing flat stock, a series of rolls are used to accomplish the coating, even though some alternatives are available, such as a press plate. A discussion of coating is basic to the understanding of these other finishing processes: embossing, printing, overlaying and laminating. For embossing and printing, the roll surface is engraved with the desired pattern instead of the plain roll used in coating. After printing and embossing usually on the vinyl film or on the phenolic- or melamine-impregnated craft paper, overlaying or laminating is then performed on the flat stock.

1) Roller Coating (7) (26) (35)

The reverse roll coater is one of the prime coaters used in the furniture industry. The three-roll reverse-roll coater (Figure 5), modified from one-roll and two-roll coaters, will be discussed for

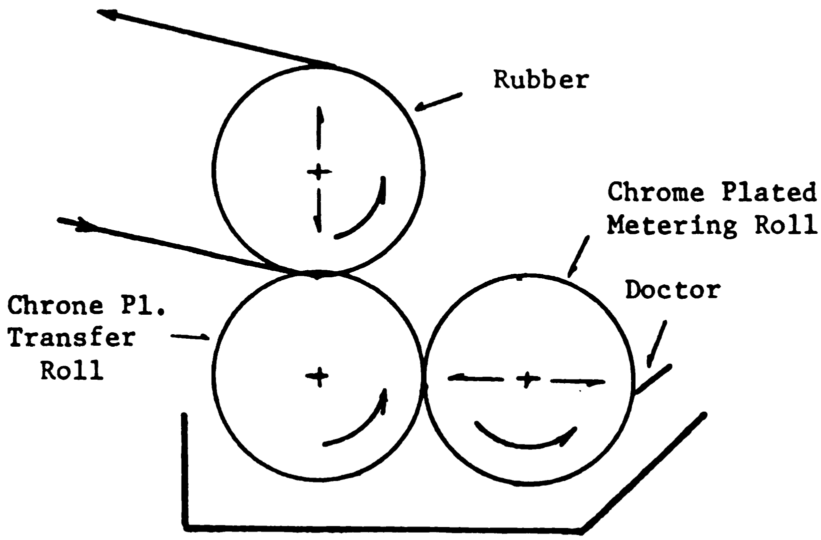


FIGURE 5. The Three-Roll Reverse-Roll Coater

supplying basic technical information. On the basis of operation principle, there is no difference between the more sophisticated coaters and this three-roll coater.

The coating material is supplied from a reservoir. Roll B picks up the coating material which is metered at the nip between the roll B and the roll C by adjusting roll C. A doctor on roll C removes the excess coating material so that the surface of this roll will be clean when it arrives at the nip. The substrate runs between roll A and roll B in a direction opposite to the direction of rotation of roll B. An even coating thus is applied to the substrate.

Most finishing materials contain three ingredients; the solvent, the vehicle, and the pigment. Color and shininess are due to the pigment. The vehicle (resin and oil) in which the pigment is dispersed presents the dry film binding the pigment to the substrate. The solvent regulates the viscosity of the coating material for easy operation.

Synthetic resins are normally used as the vehicle solids in the furniture industry nowadays. But natural resin and nitrocellulose resin are still used in this industry also. Plasticizers such as oxidizing oils and non-drying oils provide the dry film flexibility.

The roll can be a hollow or solid steel cylinder. Surfaces are chrome-plated or covered with synthetic rubber.

During operation, control of proper viscosity of the finishing material is essential. Ropings which are small ridges formed at right angles to the coating roll, are most often caused by high viscosity owing to solvent evaporation before coating operation. There are two other factors contributing to ropings: (1) unevenly worn roll, and (2) bad condition of the roll surface.

2) Embossing and Printing The Film

In the furniture industry, horizontal tops are often overlayed or laminated for prevention of mechanical destruction and chemical attack. The embossed and/or printed film is employed as the material for laminating or for overlaying. Direct printing and embossing of the wood-based substrate are common also.

Embossing is carried out by forcing a metal roll, which carries an engraved pattern raised above the roll surface, against the heated plastic followed by cooling. As for printing operation, a back roll is provided to transfer ink from the engraved roll to the film. If multicolor is needed, a series of three or more engraved rolls should be aligned. The first one carries yellow ink, for example, the second, red and then blue for the third, etc. The rolls are prepared from color separations produced by photographing the subject through color filters.

3) Low Pressure Laminating (15) (16) (44) (47)

The wood-base substrate, most often a particleboard, can be laminated with (1) high pressure laminate, (2) low pressure laminate, and (3) either paper, cloth, or plastic films overlay. Laminating can be accomplished by cold press, hot press, and rotary press for high-volume production, and by manual methods in low volume. Cold press and hot press methods are used for bonding rigid laminate to particleboard, while the rotary press is used for bonding flexible films as well as rigid material. The following will discuss the low pressure laminating.

a) The Paper

Usually, there are three layers of alpha cellulose paper which is decorated with wood grain and/or impregnated with resin on the face of the substrate and a sheet of resin impregnated cellulose paper on the back. The paper should have the right porosity and resin reception and must have a high wet tearing strength as well.

(1) Overlay Paper

This paper, with 2.0 to 4.5 grams per square foot in weight, is made of unfilled alpha cellulose and saturated with melamine resin up to 300 percent, based on dry paper weight. It will be fused and give good transparency and good protection after hot pressing.

(2) Pattern Sheet (Decorative Paper)

This paper, with a basic weight of between 8.0 and 15.0 grams per square foot, is made of filled alpha cellulose and is saturated with the same resin used for overlay paper to a range of 100 to 150 percent related to the basic paper weight.

The wood grain pattern on the paper is printed by rotogravue. The ink used should possess the follow properties:

1. It should be compatible with melamine resin.
2. It should be insoluble in the solvents of the resin.
3. It should be fade-resistant and be able to withstand the laminating process.

(3) Bonding Kraft (Barrier Paper)

This is either a filled alpha cellulose paper impregnated with melamine resin or a natural colored soda kraft paper impregnated with phenolic resin. The basic weight of the paper varies from 8.0 to 15.0 grams per square foot. The saturant which is phenolic or melamine resin ranges between 60 to 100 percent. It is used to provide a smooth surface for the board to laminate.

(4) Balancing Paper

This is filled cellulose paper with a basic weight between 8.0 to 15.0 grams per square foot depending on the weight of the face sheets. Its principal function is to prevent warpage and to equalize the moisture vapor transmission rates during service.

b) Impregnation

The paper unwinds from a roll, then is immersed in and emerges from a watery solution of resin. The absorbed water then is evaporated in an oven. The resin quantity is adjusted by the concentration and the viscosity of the resin solution and by squeezing off the excess resin by way of rolls or wipers. The films should be wet enough for further processing, but it should not be too wet, as this will cause stains.

c) Press

The proper flow of the resin in the paper and the final cure are all depending on a time and temperature-pressure relationship. A workable laminating cycle (Figure 6) is presented in the following description.

The specific pressures for laminating particleboard is about 355 psi and is about 570 psi for hardboard. There are two combinations of time-temperature relationship for the pressing processes; pressing at 275°F with longer curing times of 8 to 10 minutes for a total cycle

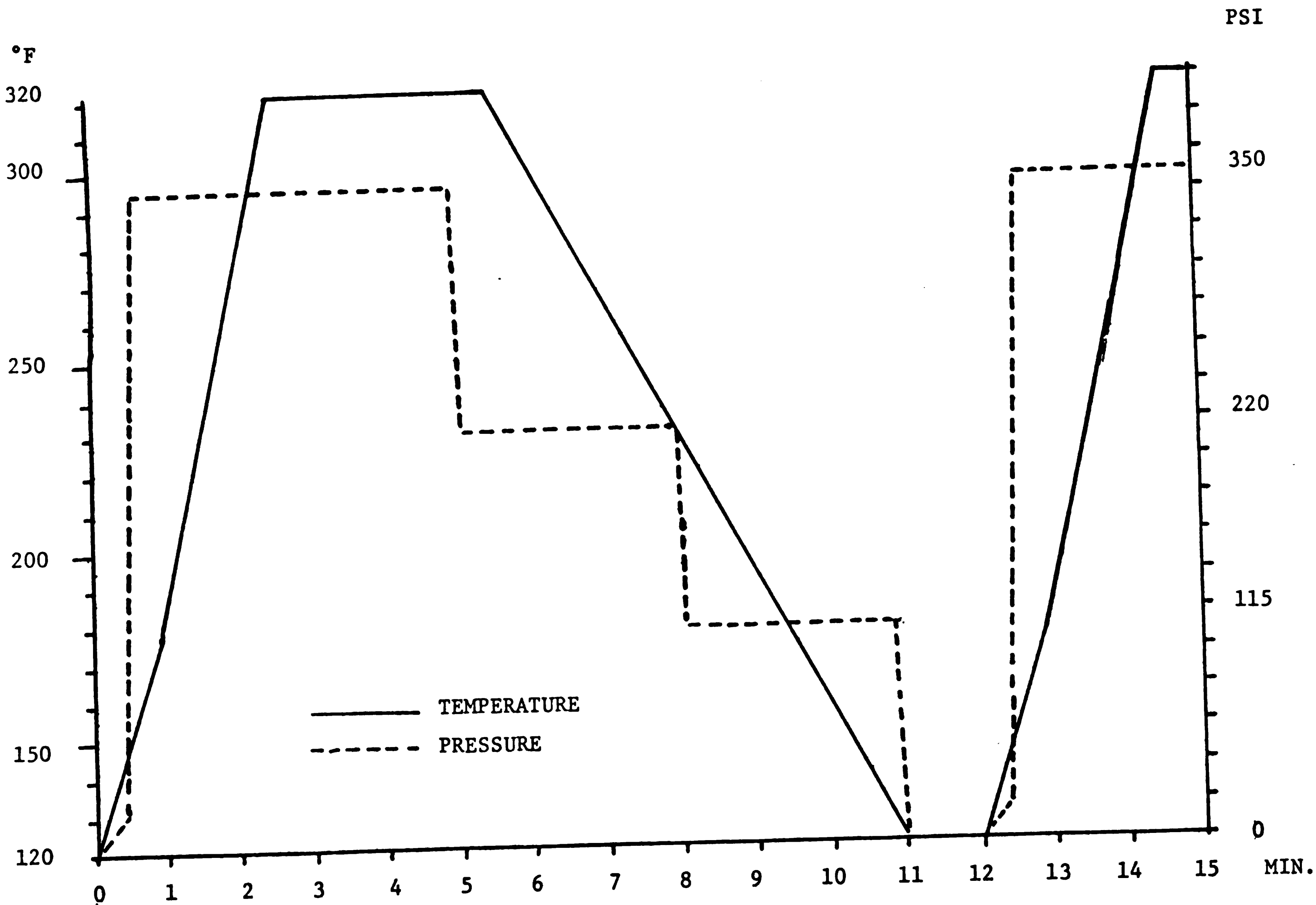


FIGURE 6. Temperature and Pressure Diagram of a 12-Opening Particleboard Laminating Press (16).

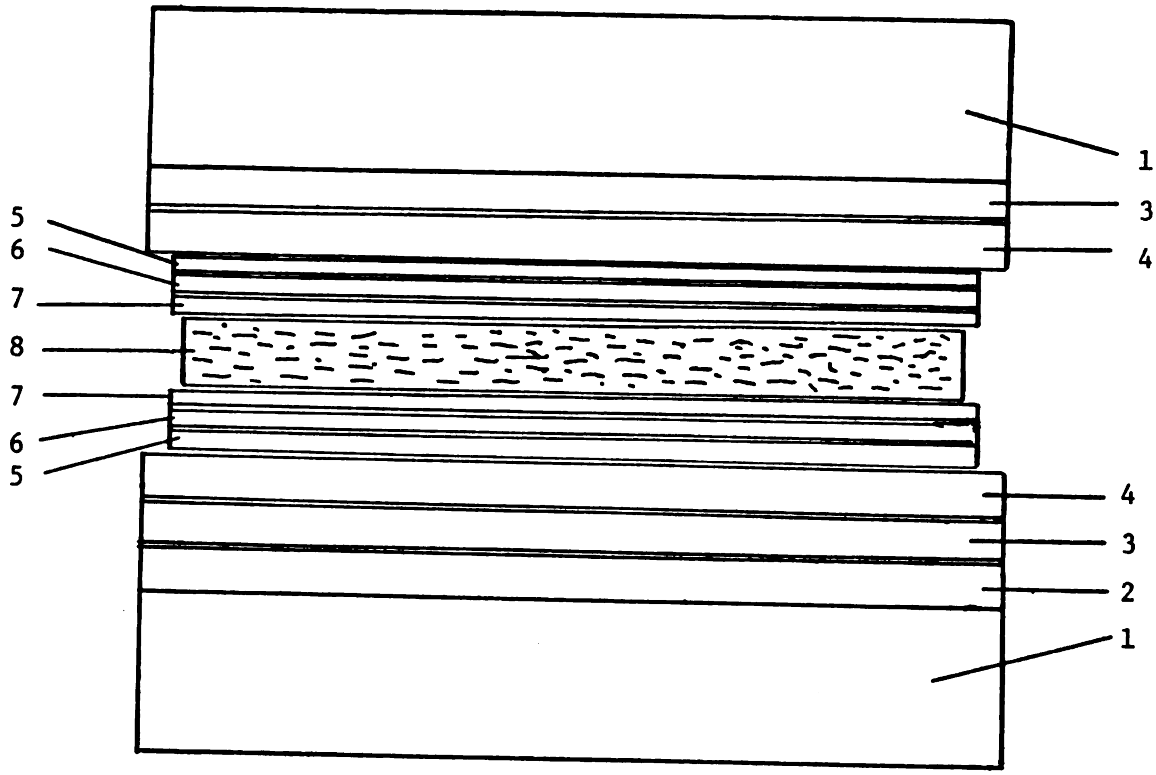
time of about 16 to 18 minutes and pressing at 310°F with a shorter curing time of about 5 minutes for a total cycle time of 10 minutes. The lower temperature decreases the possibility of fracturing later, but has a tendency to increase shrinkage of the particleboard. One press build-up for melamine resin impregnated paper is shown in Figure 7.

The particleboard for conventional laminating should have densities ranging between 45 and 47 pounds per cubic foot and the optimum moisture contant ranges between 6 and 7.5 percent. Furthermore, thickness should be controlled to a tolerance of plus or minus 0.005 inch. Of course, the surfaces must be made of fine chips.

4) Vinyl Laminating (41)

Wood-grained vinyl is widely used in laminating by the direct roll coater. The direct roll coater system for application of vinyl film to particleboard (Figure 8) is a high speed production layout.

At first the particleboard is cleaned by the brush roll, then it goes through the glue spreader and a resin coat is applied and the glue is dried in the succeeding oven. Then, the gluing and curing processes are repeated again. After that, the substrate passes under heaters to make the adhesive sticky. Simultaneously, the vinyl film is unwound from the roll to meet the in-coming particleboard. A heated laminating nip roll applies pressure to bond the substrate and the film together. Then, the laminated particleboard is embossed and cut to size.



1 HEATING PLATEN
2 CARRIER PLATE
3 PAD
4 ONE-SIDED PRESSPLATE
5 DECORATIVE FILM
6 UNDERLAY FILM
7 PHENOLIC FILM
8 PARTICLE BOARD

FIGURE 7. Build-Up of One Board per Opening (16).

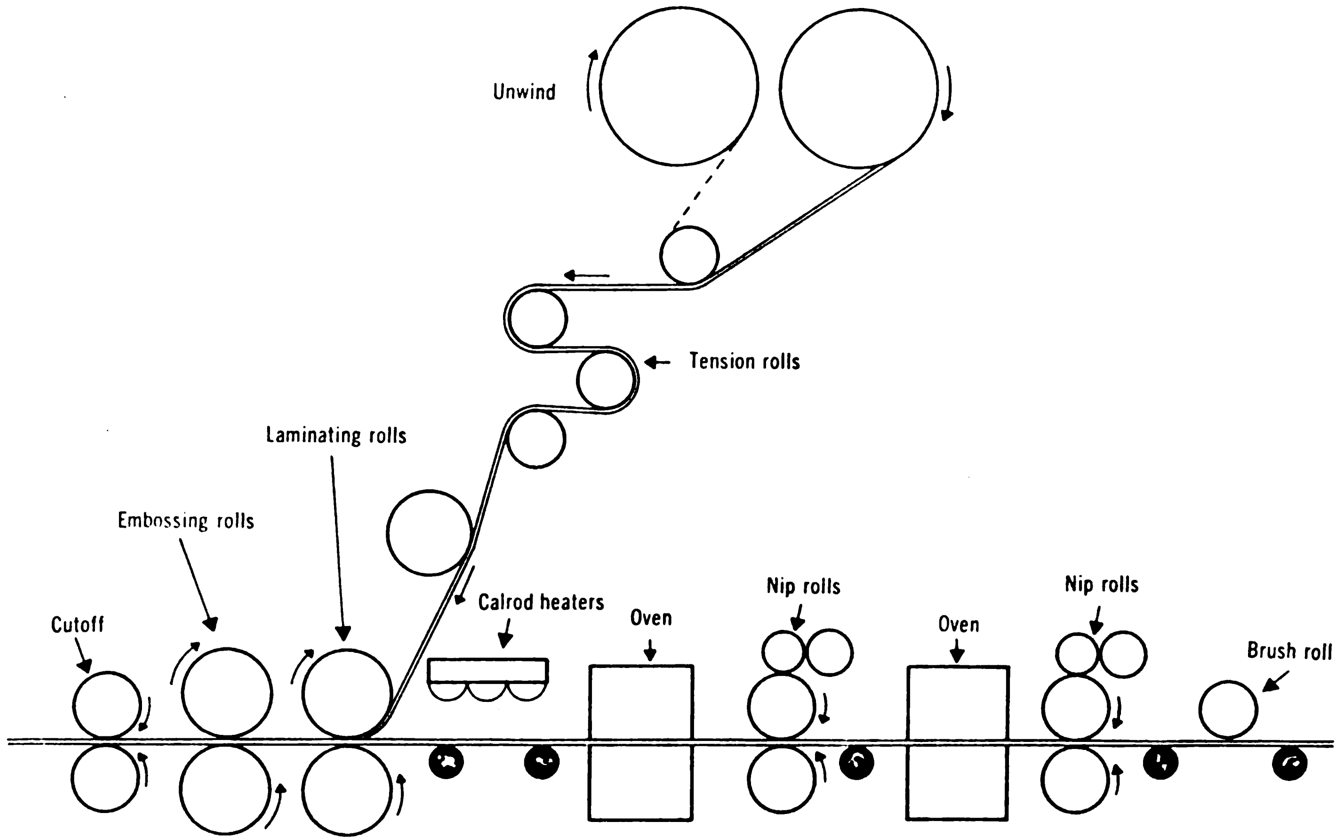


FIGURE 8. Typical Direct Roll Coating System for Application of Vinyl Film to Particleboard (41).

6. FURNITURE INDUSTRY IN TAIWAN

Taiwan is a densely populated country and her manufacturing industries have experienced periods of growth and development. The dense population has contributed to these developments by providing low cost labor. This labor force with at least a seven-year education on the average is basically skillful, intelligent, and industrious in nature. Besides, the ever-green climate of the island provides an ideal environment for running factories by eliminating a lot of auxiliary facilities and equipment.

Taiwan is at a stage between a developing and a developed country. This shows in the prosperity of labor intensive industries which have a relatively low level of technology, such as the textile industry and the wood products industry.

1) Status of Taiwan Furniture Industry

a) The High Growth Rate Industry

Sources from the Industry Bureau of Taiwan, Republic of China, point out that the manufacturing industries will continue to grow steadily and rapidly. A long term estimation (Table 9) depicts an annual growth of 10 percent or more, during the next five years. Wood products industries rank the highest among all industries and will have a high growth potential even after the country will switch its emphasis from light industries to heavy industries. Table 9 shows that

TABLE 9. Estimated Annual Growth of Manufacturing Industries in Taiwan (10).

Unit: Percent

	1974	1975	1976	'76-'80	'81-'84
Heavy Industries	13.5	17.7	15.5	12.3	8.9
1. Petro. and Gas Ind.	6.6	12.5	6.0	4.6	12.6
2. Electric and Electronic Ind.	22.3	18.0	14.7	13.9	9.2
3. Transportation Ind.	15.8	15.0	12.9	12.1	11.0
Light Industries	12.3	15.3	14.1	8.7	6.5
1. Food Ind.	5.8	5.6	5.5	4.5	3.9
2. Textile Ind.	16.2	16.6	15.3	8.6	6.2
3. Wood Products Ind.	15.7	16.3	15.9	15.0	12.0
4. Non-Metalic Mineral Ind.	3.6	12.8	18.5	11.5	7.5

Source: Industry Bureau of Taiwan, Republic of China.

the growth rate of heavy industries will leave light industries behind after 1976.

b) A Further Study on the Furniture Industry Structure in Taiwan

A census conducted by the Ministry of Economy of Taiwan in 1960 revealed that at least 90 percent of the furniture factories employed less than six workers per factory. However, the census of 1970 showed that 68 percent of the establishments employed less than 20 workers each with a total of 12 percent of the labor force in the furniture industry. The census also showed that two big factories were established in that period and absorbed 42 percent of the furniture employees (Table 10).

TABLE 10. Size of Factory Based on Number of Employees in Furniture Industry of Taiwan (1970) (8).

NUMBER OF EMPLOYEES	NUMBER OF ESTABLISHMENTS	PERCENT	TOTAL EMPLOYEES	PERCENT
1 - 19	52	68	379	12
20 - 39	8	10	197	6
40 - 99	12	16	708	23
100-199	2	2.5	295	10
200-499	1	1	203	7
Above 500	2	2.5	1286	42
Total	77	100	3068	100

Sources: Ministry of Economy, Republic of China.

It should be noted that almost two-thirds of the furniture industries are still operated under family controlled, non-efficient condition. On the other hand, large sized, modern plants have operated in this field for the past three years.

In contrast to its population surplus, Taiwan lacks resources. Forests cover almost three-fifths of this tiny island, unfortunately, most of them are unaccessible and uneconomical for wood harvesting. Most of the wood for furniture is imported from South East Asia; teak from Thailand, and lauan, meranti and similar species from the Philippines and Indonesia (Table 11). Almost all the teak logs go into the furniture industry, while 80 percent of lauan logs are processed in plywood factories (8).

TABLE 11. Logs Imported into Taiwan (8). Unit: Cubic Meter.

YEAR	LAUAN	TEAK
1961	168,029	27
1962	275,958	762
1963	446,492	397
1964	562,307	383
1965	625,102	190
1966	691,878	1,204
1967	727,150	1,490
1968	1,090,149	501
1969	1,183,022	1,564
1970	1,489,298	3,776
1971	2,205,287	3,938

Source: Import and Export Statistics of Republic of China.

A production cost analysis conducted by the United Nation's forestry and forest industry development plan in 1968 in Taiwan is shown in Table 12. The analysis revealed the following: First, log cost in furniture-making was about 50 percent or more, depending on what the end products were. Second, direct labor varied over a wide range depending on the degree of mechanization. The lower the degree of mechanization, the higher was the percentage of the direct labor cost. Third, selling expenses, administrative, and profit were relatively low, compared to equivalent figures for the United States furniture industry, because there are few sales-promotion activities such as public exhibits or services after the sale.

In all, the fragmented, raw material lacking and inefficient furniture with rather primitive processing and selling-promotion techniques is backed up inexpensive and high quality labor and offers a very attractive investment environment.

As a rule, the development of an island style economy, dense in population and poor in resources, depends much more on foreign trade than on domestic sales, as Japan has shown. However, some factors favoring domestic consumptions are worthy of consideration.

2) Potential Market In Domestic Consumption

It was mentioned previously that sales of furniture have related significantly to disposable personal income, residential construction and the number of young families. They are the main factors to provide a potential market.

TABLE 12. Product Cost Analysis Of Some Furniture Items Manufactured In Taiwan (8).

PRODUCTS	MATERIAL COST	DIRECT LABOR	FACTORY OVERALL	SELLING EXPENDITURE, ADMINISTRATIVE AND PROFIT	TOTAL
Teak Coffee Table	46.5 %	33.1 %	8.0 %	12.4 %	100 %
Teak Dresser	57.5 %	22.7 %	6.2 %	13.6 %	100 %
Lauan Solid Door	59.6 %	15.3 %	10.7 %	14.4 %	100 %
Lauan Drawer Side	69.0 %	4.0 %	11.6 %	15.4 %	100 %

Source: United Nation's Forestry and Forest Industry Development Plan in 1968.

a) Disposable Annual Income

The annual total income in Taiwan was $192 in 1966, $293 and $329 in 1970 and 1971 respectively (8). A few months ago there was a report in one of the Taiwan newspapers, Economic Daily News, which revealed that the annual total income reached $745 in 1974. And, according to the official estimation that figures will exceed $1200 at the end of 1980.

It is believed that the expenditure for durable furniture will reach 6 percent of the annual total income as a conservative estimate. The figures for 1970 and 1971 are 3.6 percent and 4.2 percent respectively (8). Money spent in purchasing furniture seems quite little, if judged by the living standard of the United States. It should be noted, however, that the price of furniture bought in Taiwan usually ranges between 1/2 and 1/3 that of the exported furniture.

b) Residential Construction

Office space and new housing are desperately needed in Taiwan because of economic and population growth. The building industry, thus, is growing at a very high rate (Table 13). Accordingly, the need for better, less expensive furniture is growing.

c) Number of Newly Married Couples

Table 14 shows the increase in the number of newly married couples. In addition, the traditional big family system has been abandoned gradually due to better transportation facilities and the more industrialized society. On the other hand, the number of smaller family units (5 people) has increased.

TABLE 13. Residential Construction In Taiwan (8).

Unit: Foundation area in m^2.

YEAR	TOTAL	BRICK STRUCTURE	STEEL-CEMENT STRUCTURE	WOODEN STRUCTURE	OTHERS
1961	396,332	328,249	43,412	21,307	3,364
1962	432,641	342,847	75,372	12,327	3,095
1963	498,925	413,864	67,673	15,094	2,294
1964	588,879	475,604	93,868	14,033	2,374
1965	1,795,309	1,039,368	698,326	42,698	14,899
1966	2,866,999	1,771,160	1,017,431	50,820	27,588
1967	3,705,424	2,554,681	1,053,033	45,766	51,948
1968	4,659,564	3,152,269	1,407,819	59,671	39,805
1969	5,810,863	4,076,882	1,582,618	75,205	75,975
1970	5,456,083	3,020,822	2,250,297	68,815	115,849
1971	6,397,320	2,806,073	3,443,679	85,334	2,293

Source: Taiwan Industry Products Statistics.

TABLE 14. Number of Annual Married Couples in Taiwan (8).

	1966	1967	1968	1969	1970	1971
NUMBER	95,897	98,443	102,698	104,336	109,026	106,812
INDEX (1966: 100)	100	102.7	107.1	108.8	113.7	111.4

Source: The Monthly Statistics Report, Executive Yean, Rep. of China.

d) Social Attitude

People have changed their attitudes. Because they have been far away from war and starvation for a long time, they have lost their interest in keeping savings for war time expenses. Especially the younger generation, having no idea of war, expects to have a more comfortable living. People like to spend more money on durable goods, such as appliances, but not on automobiles due to the convenience of public transportation and high taxation on purchasing automobiles.

3) Foreign Market Analysis

a) Growth Of Export Market

The Taiwanese furniture industry has made progress in its exports (Table 15) to a number of countries (Table 16). Among them, the United States and Japan rank first and second respectively. A 50 percent annual sales increase (Table 16) is really impressive. A regression line of annual sales, $Y = 4,720,000 + 1,398,000\ t$, based on the period from 1967 to 1971, predicts that the increase will be 1,398 thousand dollars each year (8). In addition, one may expect that progress made in the last three years would exceed that figure. However, the nation-wide energy crisis has affected the growth of the furniture industry in Taiwan severely.

b) Export Of Labor

The industrial export of furniture is actually an export of labor. The people are paid very little for their labors. The workers are paid twice a month. Table 17 shows average monthly payments. It

TABLE 15. Wood Products Exported From Taiwan (8).

Unit: 1,000 Dollars

CATEGORY	1969 SALES	%	1970 SALES	%	1971 SALES	%	1971(1-7) SALES	%
FURNITURE	3,668	0.33	5,389	0.35	8,467	0.40	8,345	0.52
PLYWOOD	65,671	5.90	83,790	5.37	99,889	4.68	68,541	4.19
OTHER WOOD PRODUCTS	35,960	3.24	46,475	2.97	54,666	2.56	46,679	2.85
TOTAL VALUE OF WOOD PRODUCTS	105,200	9.47	135,654	8.68	163,022	7.64	123,655	7.56
TOTAL VALUE OF EXPORT PRODUCTS	1,110,623	100	1,156,652	100	2,135,546	100	1,676,979	100

Source: Currency Exchange Bureau, Central Bank of Republic of China.

TABLE 16. Export Countries For Taiwanese Furniture (8).

Unit: $1,000

COUNTRY	1969 SALES	%	1970 SALES	%	1971 SALES	%	1972 (1-7) SALES	%
USA	2,782	75.8	3,883	72.1	5,373	63.5	4,780	56.7
Japan	138	3.8	307	5.7	779	9.2	1,164	13.8
Okonawa	74	2.0	302	5.6	471	5.6	589	7.0
Canada	91	2.5	120	2.3	318	3.8	301	3.6
Australia	155	4.2	118	2.2	181	2.1	286	3.4
Honkong	17	0.5	55	1.0	166	2.0	211	2.5
United Kingdom	59	1.6	89	1.6	223	2.6	211	2.5
Holland	92	2.5	189	3.5	202	2.4	201	2.4
Germany	27	0.7	109	2.0	148	1.6	199	2.4
Others	233	6.4	217	4.0	605	7.1	493	5.8
Total	3,668	100	5,389	100	8,466	100	8,435	100
Annual Increase	-----		46.9%		57.1%		-----	

Source: Currency Exchange Bureau, Central Bank of the Republic of China.

TABLE 17. Average Monthly Wages In The Furniture Industry of Taiwan (8).

Unit: One Dollar

YEAR	1968	1969	1970	1971
PAYROLL/MON.	43.55	51.06	60.22	67.58

Source: The Monthly Production Statistics of Taiwan Industry.

illustrates the low cost of labor. However, payments have risen in the last three years. Current payrolls are approximately 50 percent more than those of 1971.

In addition to the low cost labor, one of the characteristic features of the exporting industry is that the great majority of exported items are either furniture parts or other small items, such as drawer sides, salad bowls, shelves, etc. (Table 18). The miscellaneous goods which make up 80 percent of the furniture items exported, vary greatly in unit price and include more than one hundred categories. In general, the goods classed in this category are labor intensive and most often are low in price.

It is true that there is a rapid economic growth in Taiwan based on the ever growing exporting furniture industry. However, continued growth must always be based on low cost labor.

4) Recommendations

Having judged the structure and development of the furniture industry in Taiwan and the United States, the writer is in a position to recommend the use, in Taiwan, of certain raw materials and technology already practiced in the United States. This may improve both local sales and the export business. It must be expected that labor costs in Taiwan will not remain at their present level but will rise in the years to come. The labor available to the furniture industry is decreasing because of the following reasons:

TABLE 18. Furniture Items Exported From Taiwan (8).

Unit: $1,000

CLASSIFIED ITEMS	1969 SALES	%	1970 SALES	%	1971 SALES	%	1972 (1-7) SALES	%
SEATINGS & PARTS	492	13.4	1,094	23.0	1,786	21.1	1,758	20.8
MEDICAL USE FURNITURE	5	----	20	----	4	----	2	----
MATTRESS & PAD	8	----	28	----	25	----	53	----
*MISCELLANEOUS GOODS	3,163	86.2	4,247	78.8	6,652	78.6	6,623	78.5
FURNITURE	3,668	100	5,389	100	8,467	100	8,435	100

Source: Currency Exchange Bureau, Central Bank of Republic of China.

*Miscellaneous goods include shelves, drawer sides, salad bowls, hangers, carvings, etc.

1. Younger generation not interested.

Most of the children in Taiwan are persuaded to take a nine-year primary education. At graduation, they are about 16 years old. This is considered too late to start a three-year apprenticeship to become a skilled worker. Moreover, the wages paid in the furniture industry are lower than the average of all industries. This also discourages the younger generation.

2. Competition.

The residential construction industry keeps pace with the general economic growth. It pays higher wages and competes successfully with the furniture industry for skilled labor. In addition, low wages do not mean low cost of the products at all. This is especially true when the price of the product is low. So one can only take advantages of the relatively low costs in Taiwan when producing high quality but labor intensive products.

a) Products For Foreign Markets

To produce intricate highly ornate, whole wood, conventionally finished furniture is a good idea from the standpoint of serving foreign markets. Internationally traditional styles, like Italian, French, Spanish and Mediterranean designs have gained amazing popularity. The writer believes that the Taiwanese furniture industry is able to furnish those products, if a varnish or lacquer can be properly formulated.

Low labor cost sometimes means low quality product. This is true, most of the time, in case of products consumed by Taiwan's domestic market. Since the taste for better furnishings is developing in connection with the higher living standard, a large domestic market, thus, is waiting for higher quality products. The writer suggests the following will fit the need well.

b) Products For Domestic Markets

(1) Wood-Grained Cast Plastic Parts

Most of the intricate and highly decorative export furniture items in Taiwan are carved by skillful hands or produced by machines. These items are too expensive for the majority of consumers in Taiwan, partly because of the higher prices at foreign markets and partly because of the consumers being unable to pay the 47 percent import duty charged on top of the relatively high price of imported lumber. In addition, the carving cost is high in nature also. Using plastics, the carving cost could be reduced considerably and the price would come down accordingly. Furthermore, lower duty charged on plastics also seems to favor the use of cast plastic parts.

A Woodworking Manufacturers' Directory of Taiwan (52) shows that by the end of 1974 among the 146 establishments, the capital investment to be below $100,000 in 80 percent of them. It is the writer's feeling that these small-sized factories are in a position to employ cast plastic parts to provide the local market with good decorative furniture at moderate prices.

(2) Wood-Grained Laminated Furniture Panels

Finishing practiced in the furniture industry in Taiwan is not high in quality. Lacquer or varnish formulated in Taiwan cannot develop the characteristics necessary for furniture, such as resistance to chemical attack and mechanical wear. The printed paper or plastic film overlays which are being used in the domestic market are dull and do not resist chemicals, heat and mechanical wear at all. Wood-graining techniques would be developed in the near future. The writer thinks that these new developments will be readily accepted by an industry experienced and equipped to manufacture laminated products such as plywood. This type of manufacture would be combined with existing plywood factories and thus require lower additional investments.

(3) Particleboard

The prime wood industry in Taiwan, the plywood industry, has shown a decline in production for a number of years (Table 15). In contrast, the furniture export industry has experienced 50 percent increases each year (Table 16). This means that the industry structure is changing. Apparently, plywood industry, with its relatively low added value, no longer dominates the wood industry. Moreover, veneer logs are getting scarcer because of the limited resource on one hand and the tendency of the timber producing countries to establish their own plywood factories on the other hand. It should be expected that in the future the quality of imported logs will decline. As a result, lower grade logs will be peeled and much more wood scraps will be produced in the plywood factories in Taiwan. The plywood scraps provide the raw materials needed for the particleboard industry. The particleboard industry thus possesses a reliable raw material base. Furthermore, the prosperous furniture industry needs particleboard as its core stocks.

Plastic laminated particleboard is therefore an important substitute for plywood and an important element in a modernizing furniture industry. Its development should be encouraged.

7. CONCLUSION

Based on an analysis of the use of plastics in the manufacture of furniture in the United States and on personal knowledge of the structure and technological level of the furniture industry in Taiwan the following conclusions with regard to potential improvements of the stature of the Taiwanese furniture industry are offered:

1. While the furniture industries of the two countries showed marked differences in the size of the factories, the degree of mechanization and customer taste, they also have significant similarities, namely rising labor costs, rising purchasing power and growing sophistication of the domestic market.
2. Due to its lower labor costs the Taiwanese furniture industry should be in a position to increase exports of furniture particularly highly ornate, labor intensive products.
3. The real potential for the use of plastics exists in the local market. Consumers demanding high quality, stylish furniture cannot afford to buy labor intensive products. Prices of furniture for local consumption would be reduced by introducing cast plastic furniture parts, which can be produced economically even on a small scale.
4. Plastic laminates offer finishes which are superior to conventional finishes. Their introduction would have to follow the introduction of particleboard as substrate for flat panels. The manufacture and

application of particleboard in furniture construction should therefore be encouraged.

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