行政院所屬各機關因公出國人員報告書

(出國類別：技術協助)

中馬技術協助合作計畫

馬來西亞家具設計及製造技術輔導報告

服務機關：國立屏東科技大學木材工業系
國立雲林科技大學工業設計系
出國人職 稱：教授兼系主任、副教授兼系主任
姓 名：林正榮、陳啓雄

出國地點：馬來西亞
出國期間：**92.12.8-92.12.14**
報告日期：**92.12.22**

系統識別號:C09205398

公 務 出 國 報 告 提 要

頁數: 8　含附件: 是

報告名稱:

中馬技術協助合作計畫—馬來西亞家具設計及製造技術輔導

主辦機關:

國立屏東科技大學

聯絡人／電話:

曾薇之／7703202-6109

出國人員:

林正榮　國立屏東科技大學　木材工業系　教授
陳啓雄　國立雲林科技大學　工業設計系　副教授

出國類別: 其他

出國地區: 馬來西亞

出國期間: 民國 92 年 12 月 08 日 -民國 92 年 12 月 14 日

報告日期: 民國 92 年 12 月 23 日

分類號/目: F8／林業　F8／林業

關鍵詞: 家具設計,家具加工技術,家具塗裝,木材工業局,馬來西亞,木材工業技術發展中心,

內容摘要: 本次馬來西亞家具設計及製造技術協助計畫，乃是執行第五屆台馬部長級經貿諮商會議，由我國派遣兩位專家前往馬國指導及提供技術協助之決議，安排於馬國木材工業局木材工業技術發展中心（Malaysia Timber Industry Board，Wood Industry Skills Development Center）講授家具風格及市場、設計人因工程、與加工有關之木材性質、木材膠合劑及膠合、木質家具塗裝等課程，爲期三天。研習會前並安排參訪工廠了解加工技術現況，研習會後亦安排工廠輔導。

本文電子檔已上傳至出國報告資訊網

摘要

本次馬來西亞家具設計及製造技術協助計畫，乃是執行第五屆台馬部長級經貿諮商會議，由我國派遣兩位專家前往馬國指導及提供技術協助之決議，安排於馬國木材工業局木材工業技術發展中心（Malaysia Timber Industry Board，Wood Industry Skills Development Center）講授家具風格及市場、設計人因工程、與加工有關之木材性質、木材膠合劑及膠合、木質家具塗裝等課程，爲期三天。研習會前並安排參訪工廠了解加工技術現況，研習會後亦安排工廠輔導。

目錄

頁次

一、前言

此報告乃是執行第五屆台馬（馬來西亞）部長級經貿諮商會議，我國派遣技術專家前往馬國指導或提供技術協助之決議中的項目之一。對馬國家具工業發展提供技術協助，輔導重點在於協助提昇馬國家具業者之設計能力、生產技術及塗裝技術等，爲期一週。目的在協助馬國政府及人民提昇家具整體品質及國際競爭力之目標。

二、行程安排及工作概況

此次馬來西亞家具設計、生產製造技術及塗裝技術等行程之安排非常緊湊，由 92 年 12 月 8 日至 92 年 12 月 14 日止共計七天。第一天午後抵達吉隆坡，先於木材工業局木材工業技術發展中心（Malaysia Timber Industry Board【MTIB】，Wood Industry Skills Development Center【WISDEC】）聽取馬國家具工業發展現況簡報後，隨即展開工廠參訪（兩家）。第二天上午繼續安排參訪另外兩家工廠，中午則赴馬國木材工業局總部（Headquarter of MTIB）參加木材工業局之新春餐會；下午繼續參訪兩家家具製造廠商。第三天至第五天則連續三天在 WISDEC 授課。第六天則至蔴波（Muar）輔導一家工廠，

並舉辦一場木材加工性質的演講，回程順訪馬六甲市（Malacca），夜宿吉隆坡。第七天搭機返國。

三、工廠參訪觀感

所參訪的幾家家具製造工廠之規模並不算大，與台灣早期經營者相當；但加工層次普遍較低，加工技術明顯不足。因而，加工缺點很多，故而影響產品品質，進而影響價格，這亦是其競爭力不足原因之一。

古人云：「家有弊掃，享之千金。」馬國家具業者的保守心態導致故步自封，缺乏技術交流，故阻礙整個家具工業之進步。

管理技術普遍缺乏，許多廠房中物料凌亂，動線不明，影響整個生產流程；因而，木製零組件常需另外耗用防潮措施，增加生產成本。由於管理階層加工專業知識不足，聽信耗材經銷商之宣傳，用了許多可省或不必要之耗材，亦增加生產成本，減弱競爭力。

切端材及鋸屑等廢料不知回收利用，均以燃燒處理且無熱能回收，浪費可利用資源。工廠環安衛之觀念並未建立或薄弱，員工往往暴露於有機溶劑、粉塵及噪音等不良環境中，長期發展不利員工健康，且亦使員工易於倦怠，使工廠生產力降低，若有人員更迭，員工之重新訓練等開銷都是工廠損失。

另外馬國工廠普遍聘用印尼、印度、孟加拉及越南等等外勞，亦現勞力不足之問題。又所使用之原物料幾乎均爲橡膠木，現在已有許多由印尼或泰國進口，慢慢物料短缺之現象會愈來愈嚴重；馬國政府雖然有橡膠木再植林政策，但緩不濟急，可預見最近之未來，木材價格會水帳船高。如何增加家具工業之競爭力，除了加工技術有系統引進外，同時亦發展家具設計課程是明智之抉擇；由 OEM 轉換成 ODM 也是未來馬國發展的一個理想方向。但各國都往此方向進行時，馬國整體家具產業之發展，仍有許多變數，值得觀察。

四、對馬國政府之建議

發展家具工業並非一蹴可及，必須配合膠合劑、塗料、五金、玻璃、加工機械等等基本工業，及完善的教育制度等硬體及軟體之配合始可競其功，短期的訓練或可訓練基本加工技術人員，但管理階層則必須有完善的教育，以訓練各階層之技術管理人材。

由 WISDEC 之圖書室資料中，可見曾有來自德國、義大利、紐西蘭及澳洲等各國專家歷年技術協助授課之講義，但馬國相關部門似乎未完全擴大其價值，善加利用推廣。以此次任務爲例，兩位專家影響所及，僅限於參訪之七家廠商及四十五位學員，馬國政府並未開放

給大眾或業者自由報名參加。建議應該是多少人報名參加而決定授課空間，而不是多大空間來決定參加人數，以收最大效益。

五、對我國政府之建議

技術援外等不外乎是國與國之間的利益交換，但如何增加我國在國際舞台之知名度應該也是目的之一，駐外單位應可主動發布新聞稿週知有興趣之業者，尤其是台商之參與，不但利他，同時也是利己。此次深深覺得太低調。

利用此次機會，會見由國立屏東科技大學木材工業系畢業，共包括前後三期之十一位同學，得知個個都已獨當一面，位居工廠管理高層，且就業率幾乎是百分之百，甚感欣慰。僑委會舉辦類似訓練班別，已獲得僑胞深深肯定。建議宜寬籌經費，擴大招生，以增強華僑對我國之向心力。在大陸廣設獎學金招攬之下，我政府似乎也應該有相對之因應措施。

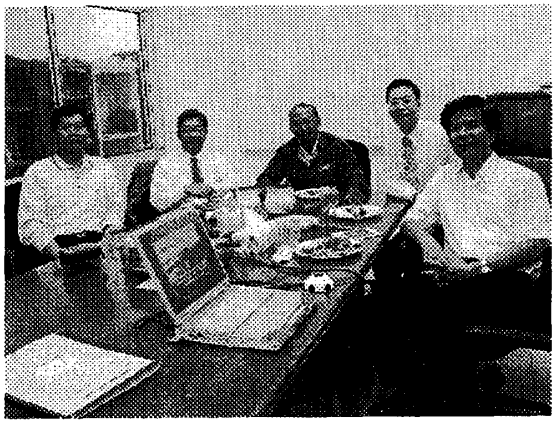
六、結論

以此次任務而言，除了課堂講授之外，課堂上學員及工廠參訪之

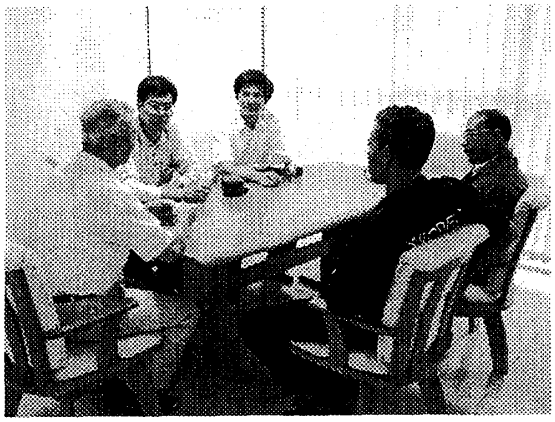
業者所提出之實務問題，都能得到實用且滿意之解答，準備之教材也與各國協助理論式者不同，因而深獲肯定；馬國政府並力邀陳專家明年擔任該國舉辦家具展中家具設計競賽之評審；並言明經費許可，將自辦訓練班並再邀兩位專家再度光臨指導，故此次任務應算是成功圓滿。

馬國家具工業製造技術，由於許多台商之投資，基本加工技術尚稱成熟，只是資訊之交換不足及固步自封之心態阻滯了進步。但因未來原料之短缺及人工外聘等問題，家具工業之發展勢必面臨一些問題。由接單生產的 OEM 方式轉爲接單設計生產的 ODM 方式，爲一理想之構思，就向我政府目前發展文化創意產業一樣，但馬國各種軟硬體之配合能到何種程度，值得觀察。

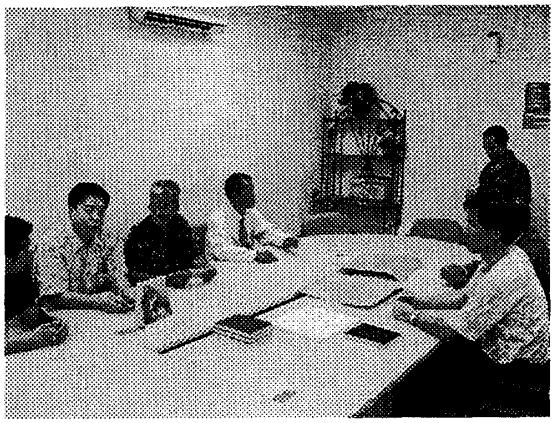
12月8日抵MTIB WISDEC由駐馬經濟文化辦事處經濟組范組長(左二)及陳秘書(右二)陪同聽取馬國家具工業發展簡報



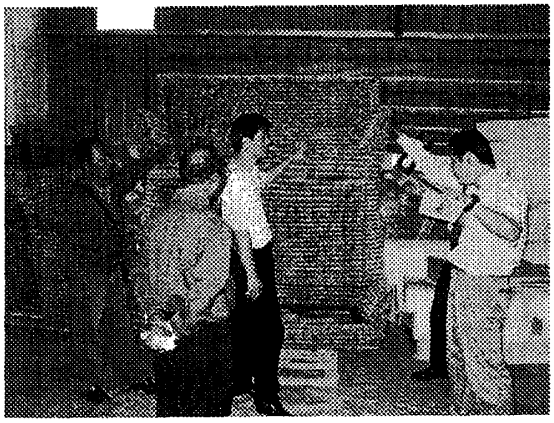
Multi Nation Furniture Sdn. Bhd.工廠參訪輔導(12月8日)



Kurogane Sdn. Bhd.工廠參訪輔導(12月8日)

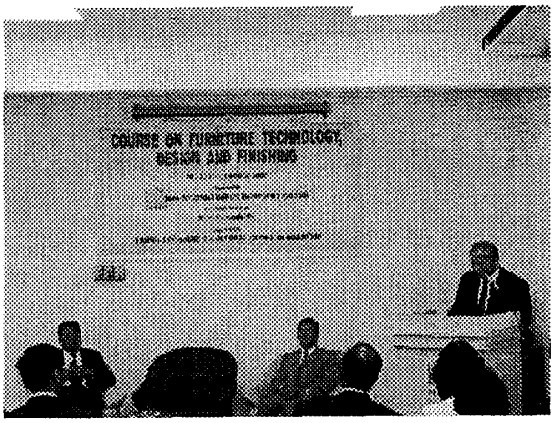


Yew Hoong Sofa Products（M）Sdn. Bhd.工廠參訪輔導(12月9日

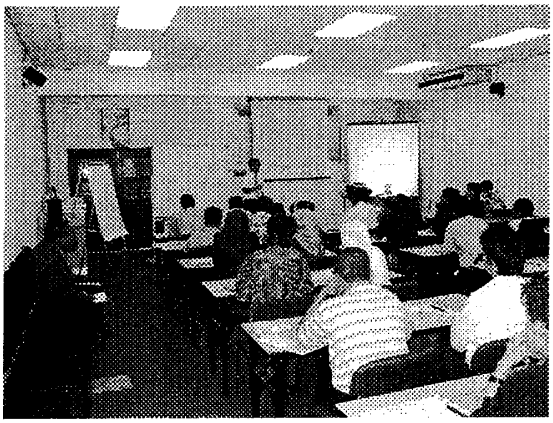


12月9日中午在Headquarter of MTIB舉行新春聚餐之表演

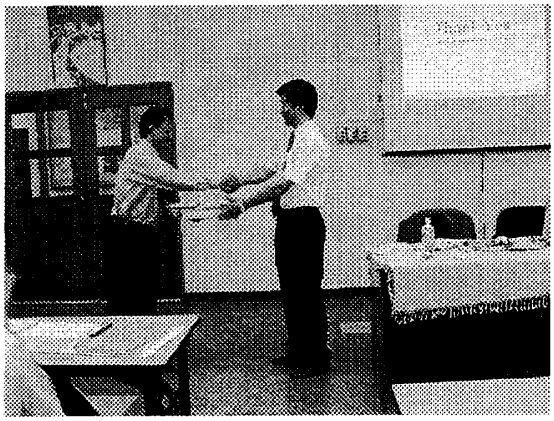
12月10日研習會開幕由馬國Ministry of Primary Industries之Deputy Secretary General主持



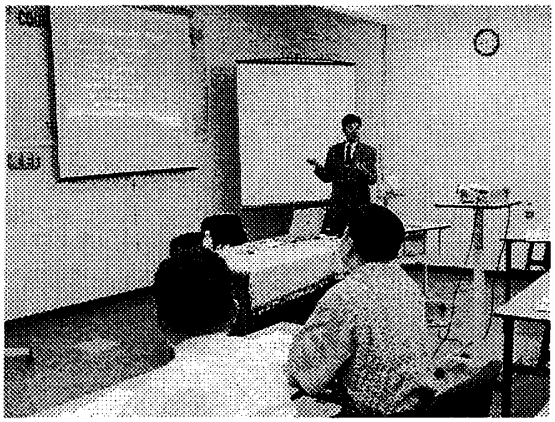
研習會講授家具設計風格



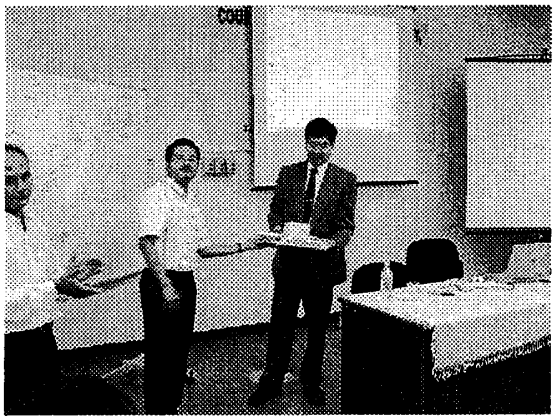
MTIB的WISDEC主任贈紀念品



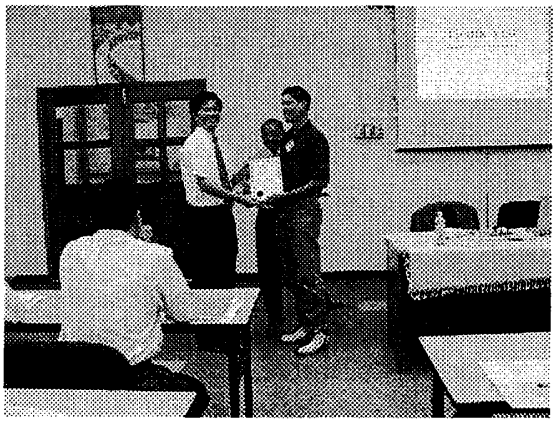
研習會講授家具塗裝技術



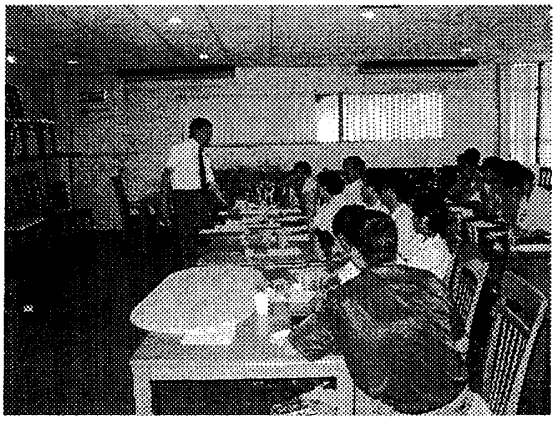
MTIB的WISDEC主任贈紀念品



12月12日結訓頒發證書



Yeu Hong Enterprise Sdn. Bhd. 工廠輔導(12月13日)



TENTATIVE VISIT PROGRAM FOR THE TAIWANESE EXPERT PRIOR TO THE COURSE HELD BY WISDEC ON FURNITURE TECHNOLOGY, DESIGN AND FINISHING

8.12.2003 Monday	3.00 pm	Wood Industry Skills Development Center (WISDEC) Lot 167, Jalan 3 Kompleks Perabot Olak Lempit Tel: 03-31492924
	4.00 pm	Multi Nation Furniture Sdn Bhd Lot 134 & 135 Jalan 4, Kompleks Perabot Olak Lempit 42700 Banting. Tel: 03-31494961 (Mr. Ng Kok Chan)
	5.00 pm	Kurogane (Malaysia) Sdn Bhd Lot 128, Jalan 8 Kompleks Perabot Olak Lempit 42700 Banting. Tel: 03-31492826 (Mr. Sakor) 016-3289064
9.12.2003	9.00 am	Hentz Wood Resources Sdn Bhd Lot 1956, Batu 1 ½ Jalan Bangi 43500 Semenyih Tel: 03-87241552 (Mr. Helen Foo)
	9.30 am	Yew Hong Sofa Manufacturer Sdn Bhd Lot 807, Batu 1 ½, Jln. Bangi 43500 Semenyih Tel: 03-87231888
	10.30 am	Wyser Furniture Sdn Bhd Lot 808, Bt. 1 ½, Jalan Bangi 43500 Semenyih Tel: 03-87237848 (Mr. Ah Tee)
	12.00 pm	To Head Quarter MTIB In Kuala Lumpur
	3.00 pm	Step Furniture Manufacturer Sdn Bhd Lot 102 & 103, Jln. Perusahaan Lima Tmn. Perindustrian Mahkota 43700 Beranang. Tel: 03-87660000 (Ms. Hong Ooi Lan)
	4.00 pm	Woodlandor Furniture Sdn Bhd Lot 442, Batu 22 ½, Jalan Sg. Lalang 43500 Semenyih, Selangor Tel: 03-87237743 Fax: 03-87236311 (Chin)

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MJA/jh

LAMPIRAN I

Tentative Programme
Course On Furniture Technology, Design And Finishing

Date :
10 – 12 December 2003

Venue :
Wood Industry Skills Development Centre (WISDEC)
Lot 167, Jalan 3, Kompleks Perabot Olak Lempit, 42700 Banting, Selangor

Organised by :
Malaysian Timber Industry Board (MTIB)

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10 December 2003 (Wednesday)

08.00 - 09.30 am	Registration and arrival of guests
09.30 - 09.45 am	Opening Ceremony Speech by Deputy Secretary General II, Ministry of Primary Industries cum MTIB's Chairman Y. Bhg. Dato' Hj. Suboh Mohd Yassin
09.45 - 10.00 am	Coffee and tea break
10.00 - 12.00 pm	Furniture design history & styling (I) by Prof. Dr. Chi-Hsiung Chen
12.00 - 14.00 pm	Break/Lunch
14.00 - 17.00 pm	Wood properties relating to processing by Prof. Dr. Cheang-Jung Lin

11 December 2003 (Thursday)

09.00 - 12.30 pm	Furniture design history & styling (II) by Prof. Dr. Chi-Hsiung Chen
12.30 - 14.00 pm	Break/Lunch
14.00 - 17.00 pm	Wood adhesion and adhesives by Prof. Dr. Cheang-Jung Lin

12 December 2003 (Friday)

09.00 - 12.30 pm	Economics and design by Prof. Dr. Chi-Hsiung Chen
12.30 - 14.00 pm	Break/Lunch
14.00 - 17.00 pm	Furniture finishing by Prof. Dr. Cheang-Jung Lin

WELCOME

To

Prof. Dr. Cheng - Jung Lin

(Dept. Of Wood Industry, National Pingtung University)

&

Prof. Dr. Chi – Hsiung Chen

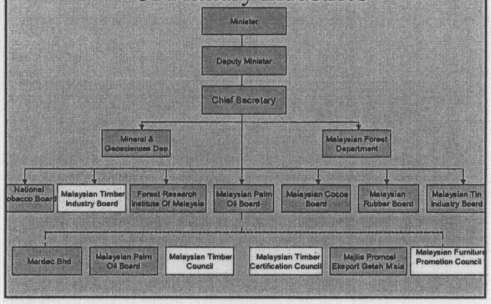
(National Yunlin University Of Science And Technology)

For Coming To

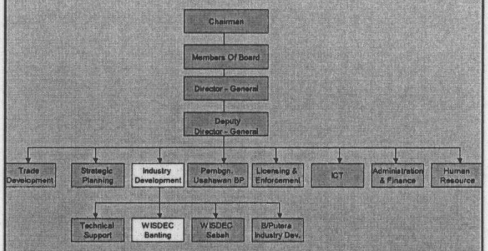
Wood Industry Skills Development Center

(WISDEC)

Organisation Structure Of Ministry Of Primary Industries



Organisation Structure Of MTIB



Presentation outline;-

1) Forestry and sustainable resource

2) Wood-based industry in Malaysia

3) Furniture industry

4) Issues and challenges

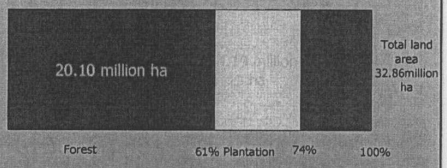
5) Future directions

Policy Statement

The Government will continue to emphasist on the development of the value-added sector , whilst ensuring that the primary sector continue to produce raw materials for the downstream sector, and for export.

1) Forestry and sustainable resource

a) Malaysia resources base



Consumption Patterns

Estimated installed capacity:

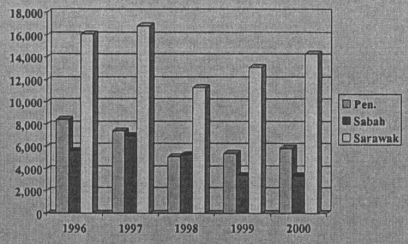
P.Malaysia	14 mil.m3
Sabah	8 mil.m3
Sarawak	10 mil.m3
Total	32 mil.m3

b) Forest area in Malaysia

	(million ha.)
• Penansular of M'sia	5.97
• Sabah	4.25
• Sarawak	9.84
Total	20.06

100 years in forest management (1901-2002)

c) Production of Logs 1996-2000 ('000 m³)



Rubberwood & Forest Plantation logs

- Projected that log production from forest plantation will increase
- Rubberwood production will drop to level of 2 million m3 in year 2006 onwards

Rubberwood - consumed by the furniture sector, MDF, particleboard, flooring, plywood and BCJ.

The Wood-based Industry Policy

1. **To attain a developed and innovative industry capable of producing value-added products of high quality and good designs geared towards the medium- to high-end markets.**

2. **To improve productivity and efficiency of the industry to enhance competitiveness.**

3. To enhance R&D in manufacturing technology improvement, product development, design and marketing.

4. To intensify HRD in line with K-based economy to produce skilled and creative manpower for the industry.

5. To promote participation of private sector in forest plantation and agro-forestry.

6. To promote investments in downstream sector to generate growth.

7. To provide assistance to smes to improve their performance in domestic and international markets.

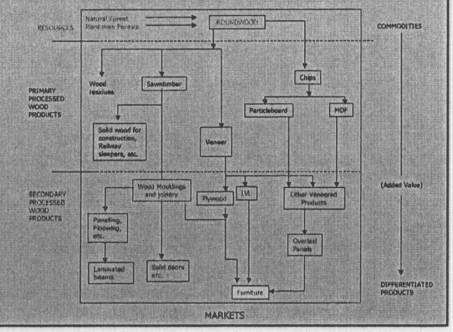
8. To further enhance the consumption of timber and timber products in both the domestic and global markets.

2) Wood-based industry in Malaysia

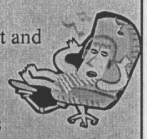
a) Number of mills

	Malaysia	Peninsular
• Furniture	3,298	2763
• Sawmill	1,132	672
• Plywood mill	183	50
• Moulding & joinery	344	150
• Panel (MDF. PB)	13	11
• Others	557	>300
• Total	5,527	

b) DIAGRAM : INTER-INDUSTRY LINKAGES WITHIN TIMBER SECTOR PRODUCERS



- Furniture - fragmented industry
  - low rate of capital investment and productivity growth
  - labour cost per employee at 9.3% indicate industry is less competitive



Exports

- Exports of primary products declining
- Taking over are the value-added products
- Furniture - OEM - should diversify and create distinct Malaysian design/brand
- Diversify markets
- primary products should go for value-added.

Contribution to economy (2001)

Market size:

Export	:	RM 14 Billion
Local	:	RM 5 Billion
Total	:	RM 19 Billion

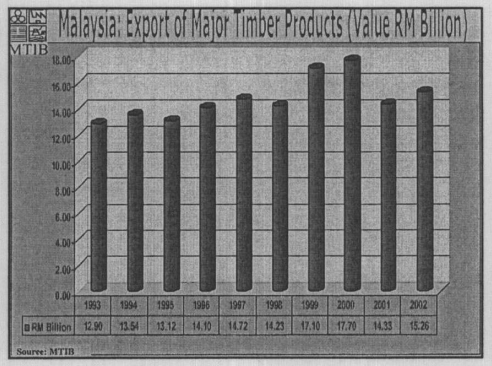
Employment:

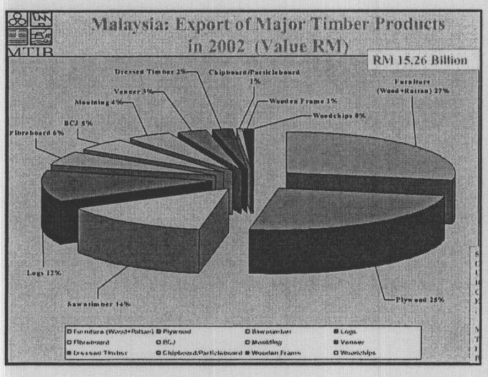
Total	:>	265,000

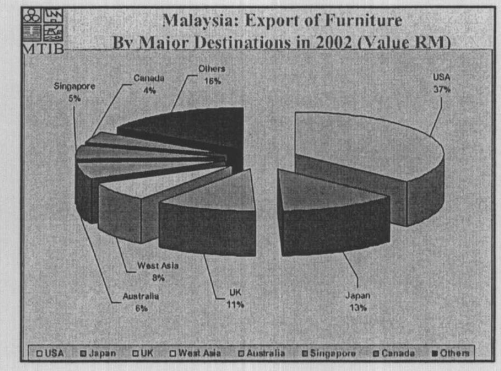
Contribution to Exports Earning: 5%

Major timber products

Sawn timber
Plywood
Furniture
Logs
Panel products
Moulding components
etc







Issues & Challenges

1) Sustaining resource advantage – log supplies declining. Need to increase:
- commercial plantations
- efficiency of forest management
- recovery rates
- Efficiency in supply and distribution to d-s sectors
- Procurement from other sources
- Agro-forestry activities

2) Shortage of skilled labour
- **Heavily dependent on foreign labour**
- **Turnover of workers high**
- **Maximum foreign worker can stay is 7 years**

3) Fragmented industry
- **Each sector has own aspirations and interests**
- **Regional basis**

4) Automation & Technology
- Level is quite low
- Dependent on manual labour
- High cost deters installation of modern machinery

Remedy:
- ✓ Rapidly changing trends
- ✓ Upgrade new technology R&D
- ✓ Upgrade innovative capabilities and inventions
- ✓ Commercialise homegrown technology

5) Knowledge and trained workers
- **Lack of indigenous designs and creativity in locally-made furniture**
- **According to a study – industrial training is unsuccessful**

Therefore, need to
- **Upgrade HRD**
- **Attract knowledge workers**
- **Organise courses tailored to industry's requirements**

6) Competition
- From other producing countries
- Substitutes

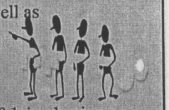
- Need to enhance market intelligence and networking
- Proper planning in promotion activities
- Agencies should collaborate

7) Non tariff barriers
- Increased demand for certified timber
  - certification an important marketing tool

- Health & safety motivated measures
  - phytosanitary
  - building codes
  - formaldehyde emission levels

8) Trade liberalisation & globalisation

- WTO, AFTA, APEC.....
  - compete in trade in services as well as investment



Industry's competitiveness

need to be enhanced - reduce cost of doing business

Private sector cooperate with Government

Public sector must become stronger, more efficient and effective and more productive

9) Competitiveness enhancement

Manufacturers have to base competitiveness in value-added products either on

- low cost inputs
- high total productivity
- superior quality of products including design; or preferably
- all these factors

10) Certification

Europe is major market (UK, Germany,Netherlands, Belgium)

Local consumers are alert on environmental issues

Demand increase for timber products from sustainable forest managed

National timber certification efforts

11) Competitive market environment

Competitive from softwood, temperate & other timber producer

Economics cycles

Discriminatory trade measures and protectionism

Substitutes material (steel, plastic, aluminium, concrete)

12) Price fluctuations

Cheaper logs price from Russia

Plywood prices unstable

Panel products experienced severe downward pressure

Future directions

a) **R & D**
b) **Technology upgrading**
c) **Market access and trade promotion**
d) **International cooperation**
e) **Plantation timber**
f) **Certification scheme**


THANK YOU
Wood Industry Development Center (WISDEC)
Malaysian Timber Industry Board (MTIB)
(Ministry Of Primary Industries)

COURSE ON FURNITURE TECHNOLOGY, DESIGN AND FINISHING
10 – 12 DECEMBER 2003
WISDEC, BANTING

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FDS- for Furniture Class Presenting at Malaysia

Furniture Design Styling I&II

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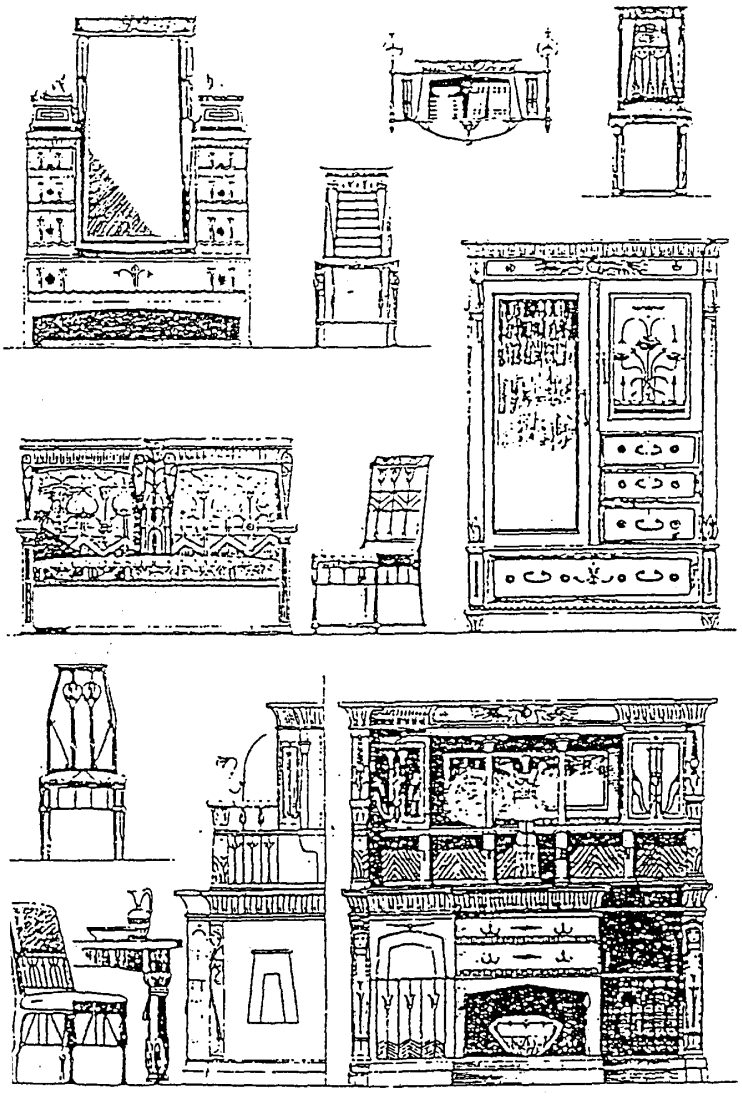
Dec. 09, 2003; from Taiwan

EGYPTIAN (4000 B.C.—300 A.D.)

THE Egyptian style had a great influence on later craftsmen and it is primarily important because of this. Great craftsmen themselves, Egyptians not only were adept at furniture making, but were known for their weaving skills.

Egyptian weaving is the most ancient known industry. Egyptian linens are famous, being embroidered with gold, silver and purple. The moment we leave the age of savagery and man clothed himself, we reach the age of weaving—as clothing was one of the first necessities of mankind. Tombs of Egypt, 2800 B.C., illustrate weavers at work and at least one depicts a man weaving a checkered rug. Monuments of ancient Egypt and Syria show the manufacture of rugs and fabrics in 2400 B.C.. In 908 B.C., fine embroidered Egyptian canopy cloths were made that had a patch character. The history of lace begins in 900 B.C., but drawn work and nettings are of prehistoric origin.



As early as 2100 B.C., Egypt was highly civilized. In buildings, moldings were seldom used and chambers were decorated with illustrations representing industries.

Carvings, instead of standing out in relief, were sunken and the ground stood out, a system exactly opposite to the Assyrian system, where the ground was depressed and the subject stood out in relief. Decoration was full of gold and brilliant colors, the triad form being popular (black, yellow and red), (red, blue and white), (dark blue, light blue and white), cream color, blue and black), (dark red, medium yellow and hue). Ornaments were frequently in hieroglyphics.

Among motifs and designs were the sun, the beetle, the cobra or serpent, feathers, papyrus buds and reeds, lotus, date-palms, the lily, zigzags for water ways, herbs, animals, fan-shaped ornaments, nude figures, winged human figures, human faces, the ram, sparrow, hawk and sacred tree.

Late Egyptian furniture had rope or rush covered seats. Egyptian wall treatments were confined to frieze decorations against plain walls.

Couches were made low with no foot-boards and had small rests at the head to fit under the neck. Stools often had wooden bottoms, but couches were always plaited. In 600 B.C., seats were of narrow strips of plaited leather and furniture was often wood inlaid with metal. Seats were curved to fit the figure.

GRECIAN (1200—B.C.)

THE ancient Greeks' contribution to furniture design is substantial. Primarily, we are indebted to them for the three classic orders of Greek capitals or column tops: Doric, Ionic, and Corinthian.

Exceptional simplicity is the chief characteristic of Doric while the Ionic is noted for its volutes or spiral scrolls.

The Corinthian, like the celebrated city of Corinth for which it is named, is noted for its richness of design in the same manner as the city was renowned for its luxurious living.

Although the Greeks developed an untold variety of decorative motifs, the anthemion and the acanthus are the two which have exerted the most influence on furniture styles. These two important motifs can be traced through subsequent centuries in various forms.

While both of these ornamental styles were derived from foliage, the acanthus is the most popular and has been used in many other styles. Its popularity is due to the many ornamental possibilities of its beautiful leaves which the Greeks depicted as sharp-edged and narrow.

One of the most interesting contributions of Greek art to furniture styles is the ornamental fret of interlacing design. The simple square fret is purely geometric in line while the raking fret with its bent line is the origin of all other interlacing ornaments in styles following the Greek.

The wooden furniture of the Greeks was often decorated with glass, ivory and metal inlays. Wooden beds were sometimes ornamented in tortoiseshell and veneers of fine woods. Chests had already made their appearance as a household utility, and were used for the purpose of storing clothes and linens.

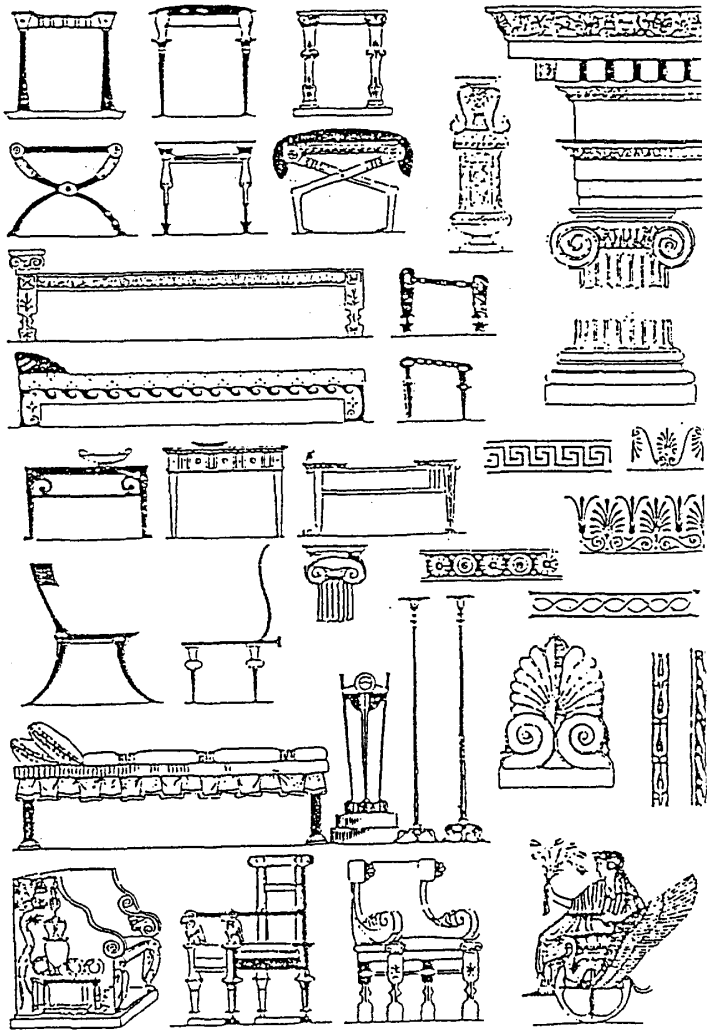
Smaller chests formed containers for jewels, toilet articles, papers and other small articles. Painting, carving, turning, inlaying, incrusting with metal, ivory and other precious stones were favorite methods of decoration.

Greek chairs had upright backs with the frame of the seat sometimes mortised to the legs. These designs played an important part in the work of Duncan Phyfe.

Couches were designed to seat three people and were much in evidence. Because the Greeks reclined when eating, tables were naturally built low and the tops did not project from the bases.

The Greek harp-like lyre infl enced the furniture designing Adar brothers.

Greek architectural and furnitur designs influenced the later Lou XVI, Sheraton, Hepplewhite, Adan Empire and Federal (especially th late federal styles of Duncan Phyf



ROMAN (600 B.C.—400 A.D.)

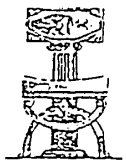
HE Romans who followed the Greeks as leaders of the ancient world created nothing w in the realm of the arts, but cop- and elaborated on the Greek signs.

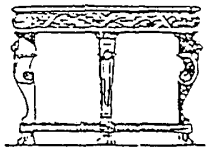
To the three classic orders of col- n tops the Romans added the ssic Roman Composite and the scan.

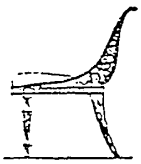
The Roman Composite is a combi- ion of the Greek Ionic and Corin- an while the Tuscan is very similar to the simplicity of the Greek Doric.

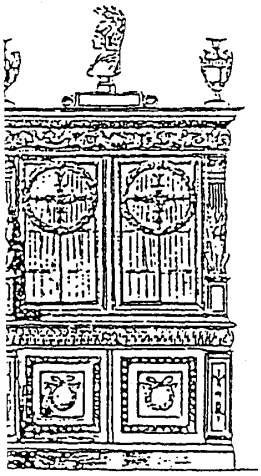
One of the favorite motifs of Roman decoration was the acanthus leaf. It is characterized by gracefulness and naturalness with the leaf veins carefully chiselled.

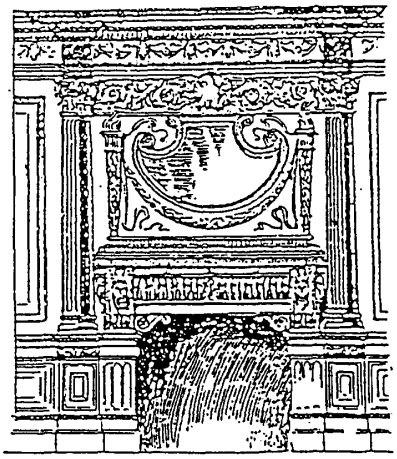
The Romans also ornamented their furniture with scrollwork which is evident in the latter day designs of the Adam Brothers of England. It was also this type of ornamentation that northern European countries borrowed.











Probably because early Roman furniture was constru cted by Greeks, it shared the rigid construction and rectangular forms.

An improvement which the romans pioneered was the concave backed chair which f it the contour of the body and gave some semblance of comfort.

During the Roman period bronze work was developed to a high degree and many pieces we re made entirely of this metal. Others were constructed of bronze and marble.

The pleasure loving Romans had their furniture richly upholstered in vivid Oriental colors and the coverings for cushions, chairs and couches were made of silks, linens and velvets.

The Romans were noted for four major types of chairs: *curule*, *bisellium*, *solium* and *cathedra*.

The *curule* was characterized by a square seat and le gs crossed into an X-shape. The *bisellium* were couches or settees and varied in length from five to six feet.

The *solium* was a chair which was reserved for the hea d of the household, and the *cathedra* was a chair exclusively for women and children.

The beds of the period had headboards, footboards, and pillow rests. The dining couch was built lower than the sleeping bed and a ledge on which the occupant might rest his left arm was fastened to the piece. A general storage chest was also developed that resembled a cupboard but which served as repository for warrior's weapons.

Roman furniture was elaborately embellished with carvings, paintings, gildings and fancy wood veneering. Also used were precious and semi-precious stones.

Most of the Roman furniture that has survived until this day is bronze or some type of stone.

Modern day furniture based on the Roman period is usually found in club rooms, hotel lobbies and other public places and rarely found in homes.

GOTHIC (1100-1500 A.D.)

THE Gothic period which followed the Byzantine and Romanesque age was greatly influenced by the spread of Christianity throughout Europe.

It was at first crude and heavy, but later became highly decorative as people put a greater emphasis on worldly living. The Crusaders helped to introduce Byzantine influences in the period's furniture.

The general lines of the style were heavy and cumbersome with an accent on church motif. It sometimes featured a profuse use of tall arches.

Little furniture appeared during this period other than in the monasteries and church edifices. Strictness of church discipline decreed that furniture be formal rather than comfortable. Consequently, the chairs were rigid and the chests and coffers were massive and almost immovable.

The chest or hutch was probably the most popular piece of furniture. These were used for seats and benches by day and beds and couches by night. Household articles also were stored in the hutches and they were used as trunks when the family moved, which in those times was quite often.

The hutches were roughly constructed with the tops nearly always opening on pin-hinges. The front was a solid board of oak of great widths.

Late Gothic furniture took on a little more structural refinement when chests and dressers became more common. It was at this time that the trestle table came into being, some even having drawers.

Decorated chairs with arms were used only in churches as seats for the clergy or as choir stalls. The X-shaped chair was in use as were triangular seats brought from Byzantium.

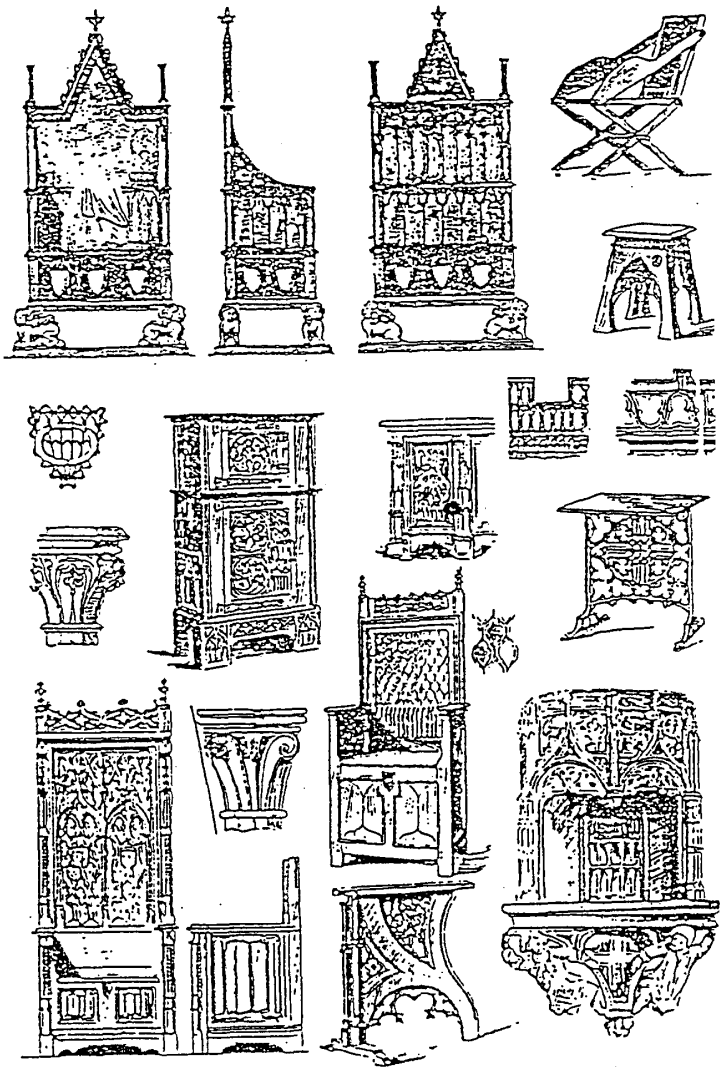
Decorative motifs took their inspiration chiefly from church ceremonies and the linen-fold type was principally used. It was derived from Catholic ritual which utilized a folded napkin.

Also popular motifs of the period were tracery patterns and the pointed arch.

Decorations were reproductions of the local foliage, and flutings with foliage ornament. Probably the most notable floral pattern developed was the royal fleur-de-lis.

Oak was the principal wood used at this time but in the late part of the Gothic period softwoods we introduced.

Because of its church influen and design the furniture of the Goth period is chiefly used in church although the English type is use in paneled dining rooms, huntir lodges, summer homes and wherev a primitive atmosphe res is wante



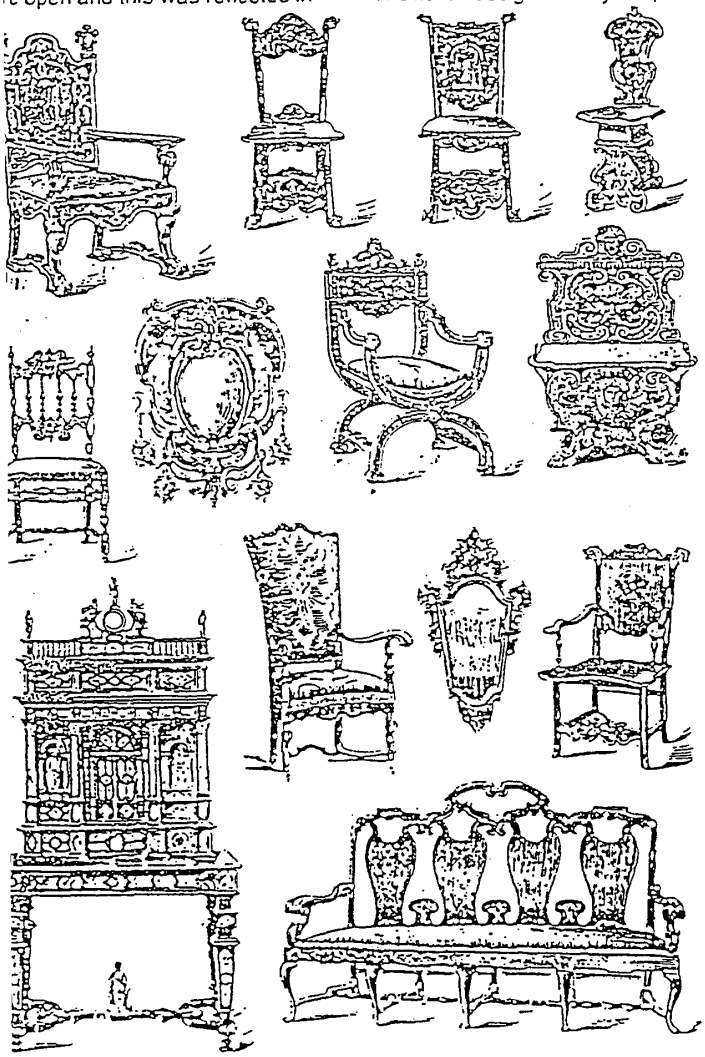
ITALIAN RENAISSANCE (1443--1564)

THE Renaissance or rebirth of interest in the highly original and creative Greek and Roman arts began in Italy.

Its influence spread very quickly and it soon came to France. Spain. England and other European countries. Under the influence of the Renaissance. life became freer and more open and this was reflected in the furniture of the period.

The furniture craftsmen used familiar and beautiful things as their inspiration for motifs and decorative designs. Carvings of the human body, flowers, trees, musical instruments such as the lyre and the harp, vines and vases were all applied to furniture decoration.

The Italian designer freely adapted Roman and Greek themes into a composite style that was artistically fine even though some of the motifs were grotesque and imaginary. An example of the grotesque were dragons with men's heads and plant structures with women's bodies.



The Greek acanthus leaf was liberally inspired in naturalistic and romantic styles.

Velvet upholstery of a crimson color, heavily fringed and decorated with tassels and flat brass nails were added decoration to the fine furniture of the Renaissance.

The lines of the Italian furniture were modifications of Greek and Roman predecessors and generally had straight lines, were low, and well proportioned.

While the Italian Renaissance furniture was beautiful it was essentially made to please the eye and not to comfort the body. It was characterized by dignity and restraint, but did not possess charm.

The chairs were rectangular and straight in line while the tables were large and turned with decorative lion paws at their extremes.

Many of the chests, cupboards, dressers, rested on the floor without feet. The arms of the chairs were generally straight from the back, being plain or rounded under at the end. Heavy underbracings were also a characteristic of the period. Mouldings which were used on almost every piece of furniture were delicately executed, and gave a perfect balance to the piece of furniture on which they were placed.

The wood of the Italian Renaissance period was essentially walnut; but oak was also used.

Brilliant colors were used everywhere as was ivory and metal. In the late part of the Renaissance, marble tops were used for cabinets and consoles.

Today, adaptations of Italian furniture are used extensively for home libraries, public parlors, and reception rooms.

FLEMISH RENAISSANCE (1500--1600)

THE peoples of the Netherlands and Flanders (which is now Belgium) were influenced late by the Renaissance that was sweeping Europe, but once it reached them there was rapid progress.

Their furniture was influenced by their own conservatism and by their natural attraction to home life.

The Netherlands was a great seafaring nation and her travelers brought back ideas from foreign countries which were used by the craftsmen of the period.

When the Netherlands became a free country the style of her furniture changed and in turn influenced England and helped develop the late Jacobean and William and Mary periods.

Because they were home-loving countries their furniture showed a solid domesticity characterized by a heaviness and bulk that was more clumsy than graceful.

Although probably not as artful as the Italian and French furniture of the period, its proportions were good and in close harmony with the homes in which it was used.

Carving was the chief decoration since Flanders had many skilled carvers and furniture craftsmen. Foliated ornament and grotesque scrollwork were embellished on the furniture. Seats of chairs were often upholstered with leather, attached to the wood by heavy brass nails.

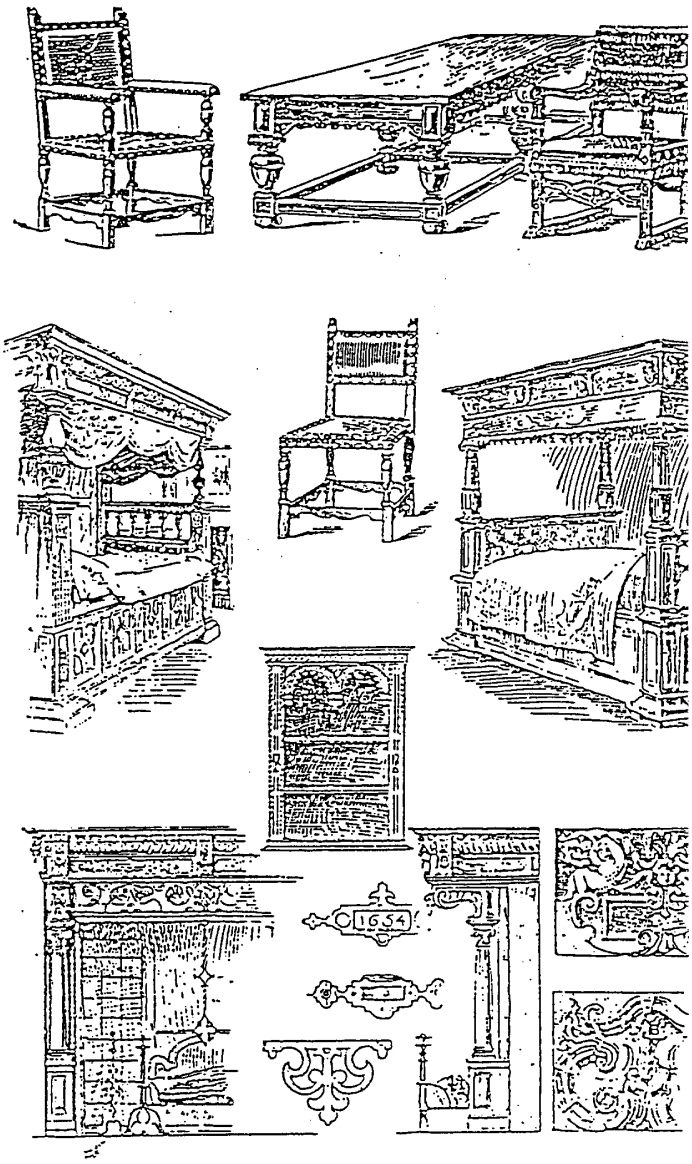
Inlaying was done with black ebony, yacca and other materials.

Cupboards, beds, tables and chairs were ornamented with columns in the Italian style and added scrollwork, mountings and pyramid ornament. The arm chair had legs turned in balusters and cubes, and connected by stretchers.

Cupboards were made with four doors and had bases mounted on bun feet. Chairs usually had straight lines similar to modern chairs. Stretchers connected the four solidly made legs and gave the chair the appearance of solidity and strength.

During the period of the Flemish Renaissance, oak was the predominant wood.

Some of the small tables and consoles of the period still have so favor in homes, while the chairs adapted in public places.



SPANISH RENAISSANCE (1500--1650)

=HE Spanish Renaissance or revival of interest in the arts was influenced from nearby ' and also by the Moors from lhern Africa. These people had oc- ied a large part of Spain for many rs before the Renaissance.
panish furniture was also in- nced by the prior Gothic period therefore possessed a distinct racter that was different from other European style.
ecause Spain was constantly 'ar, its furniture was influenced he military and is masculine in character and line, decorated with Moorish and Italian ornament. Although much of the furniture was made in monasteries the church had little influence.

Spanish furniture was of splendid and honest character and had dignity and richness. Decorations were restrained yet vigorous. It also had great individuality, balance of proportion and refinement with a brilliance of color in relief against severe backgrounds.

Intricate scrolls and arcades, as well as the twisted iron braces on tables, were used, as was Moorish-influenced leather and iron work.

The development of the claw-foot and the hoof-foot came about at this time. The "Spanish Scroll" foot was a copy of a Netherland design and later spread to England and showed up in Colonial American furniture. Other feet commonly made were bun-shaped, pear-shaped, the straight and the rectangular.

Spanish ornament was rich and widely used. Carvings were fine and curves subtle. Metal motifs and intricate open-work designs were used. Gilt nails, bone, brass, silver and tortoise-shell were frequently found in designs.

A distinct Spanish style was the use of leather over wood which was stamped, colored and highlighted.

Furniture craftsmen borrowed arcades of spindles from Spanish architecture and this motif was used generously.

The Spanish also developed the well-known shell ornament which was copied by later designers.

Spanish furniture makers did not produce in great volume and their variety was limited.

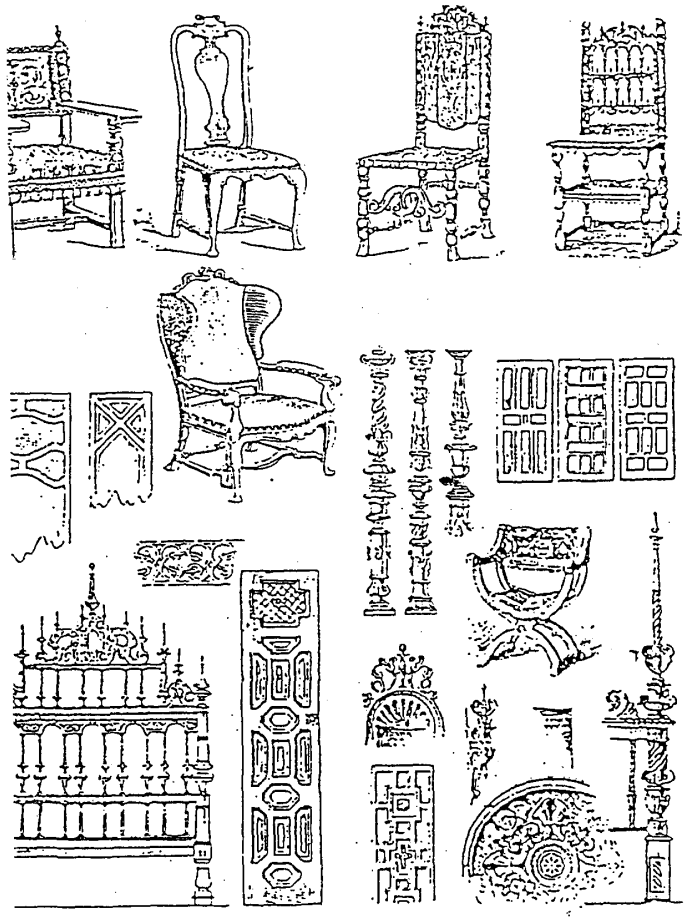
Chairs, upholstered benches, beds, tables and unique writing desks, together with certain chests and screens were the predominant pieces made.

The Spanish Moorish scissor chair was an example of the work of the period. It was decorated with fine geometrical inlay known as "certosina" work.

Only Spain developed the varqueno cabinet secretary which has many of the distinct features of Spanish design. When the writing desk was opened there were many little cabinets and drawers.

Some of the woods used during the era were oak, walnut, cedar, chestnut, cypress and pine.

Spanish Renaissance influence on modern furniture is very limited, but some of the pieces which were in vogue may be seen in club rooms and other public places.



TUDOR-ELIZABETHAN (1509--1603)

THE revival of interest in the arts by the English began when Henry VIII broke with the Church and invited craftsmen from all over Europe to beautify the English Court.

The Tudor period began with him and culminated in the reign of Elizabeth. It was one of the greatest ages of learning in history.

It is also commonly thought of as the begining of the modern English Empire.

The style which predominated was an intermixture of French, Italian, Gothic, and Flemish influences spread over a backround of Tudor tastes.

Because of the influence of the Gothic, the furniture of the period was massive, straight in line, elaborately carved and largely copied from the Italian Renaissance.

It was sturdy, made of oak and had richly carved ornaments. Chair backs were paneled and elaborately carved.

The largeness of the Tudor furniture was due to the vast halls in which it stood and the fact that a man in armor needed a sturdy chair to hold him.

During the Elizabethan period there was a lightening of furniture.

Motifs of the period were carved acanthus leaves, the Tudor arch and rose, carved lozenges, linenfold, fruit and floral carvings, grotesque figures nude to waist, animals, masques and heraldic devices.

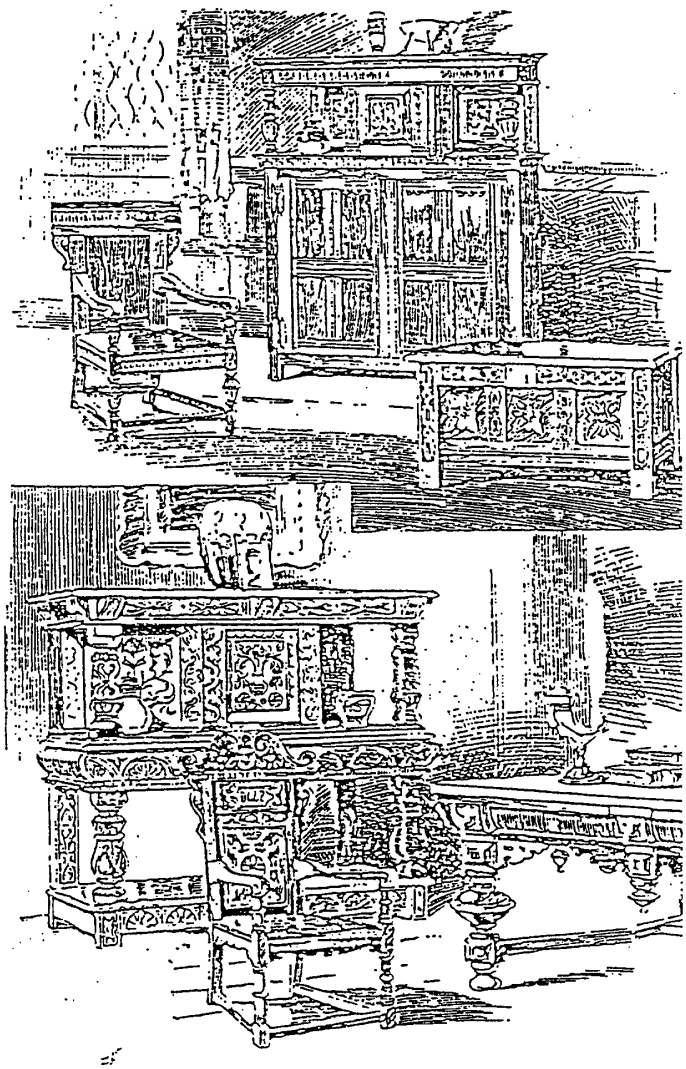
The ornamentation consisted chiefly of carvings, moldings and paneling, very rich in effect. Bulbous ornaments on legs and balusters were often used and carving was spread well over the surfaces.

Sturdy construction was the key feature of the Tudor-Elizabethan period. This has been attributed to the usage of wooden pegs in construction.

Underbracings were used on chairs, tables and stools. The terminals of chair, table, stool, and bed legs were either straight, square or bun shaped. The Gothic arm coming straight from the back of the chair was characteristic during the early part of the period, but during Elizabeth's time, the arm began to slope downward.

Beds were enormous and designed for comfort. The bed posts w frequently built independently of bed itself and decorated with the fuse carvings of the day.

Some of the characteristics Elizabethan design were use modern times. This was true of mellon legs, channeling and Tu rose.



JACOBEAN (1603--1688)

THE Jacobean Period of furniture style includes three periods: Early Jacobean, Cromellian, and Late Jacobean.

Although the periods have variations, they are grouped together because of the political changes that came about at this time.

In the Early and Late Jacobean periods the English were ruled by Lord Protector in the person of Oliver Cromwell, thus the Cromellian era.

Early Jacobean furniture developed from earlier Elizabethan designs.

Ornament was less pronounced, particularly in the curves and curved furnishes of the Elizabethans.-The style was straighter, more practical, simpler, and tended to grace rather than strength.

Legs were straight, and turned in various designs, but the "melon-bulb" was smaller when used. Chair underbracings were tied together and served as foot rests.

Chests were box-like and rested on the floor, often without feet. Tables were but boards set on legs and cupboards were like large boxes.

Early Jacobean features were used in early American styles and show up in modern reproductions.

Because of the religious basis of the Cromwellian period, the furniture departed from the ornate and became severe, austere and simple.

The craftsmen of the period used many mouldings and turnings, with the legs often having bun or ball feet.

It was at this time that upholstery began to find a more general use. Chairs frequently had padded backs as well as padded seats.

The gateleg table found favor and has been popular ever since, as has the Welsh dresser.

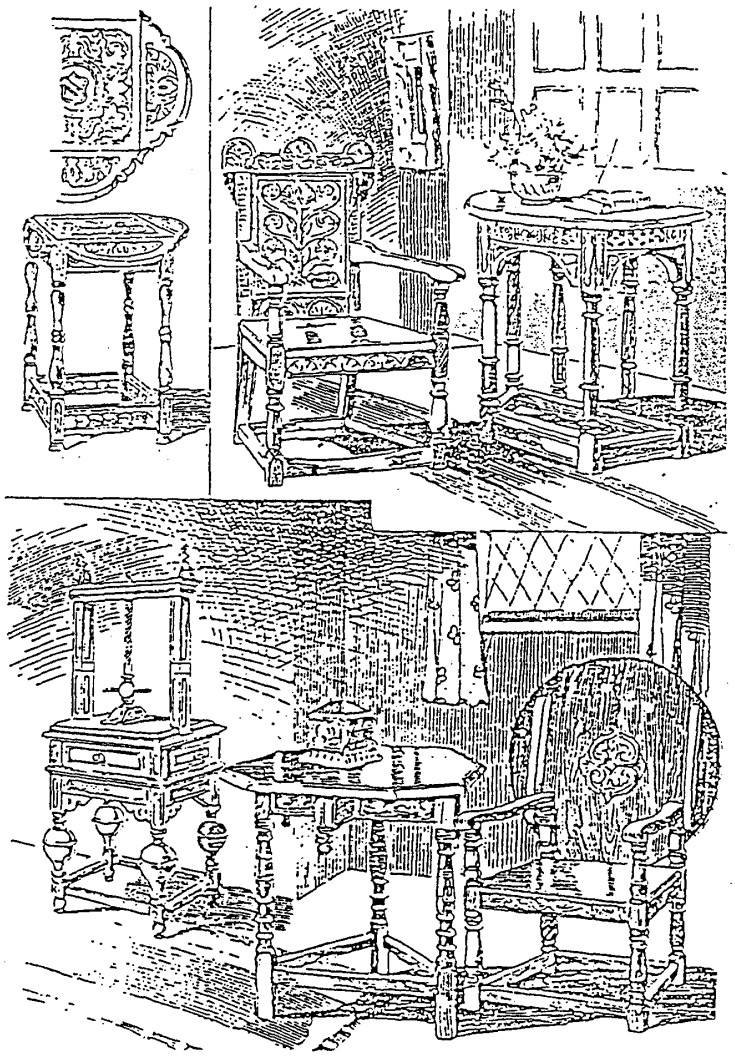
When the English became tired of the strictness of Cromwell, they again turned to a king, and this period is known as the late Jacobean.

It was a period of gaiety and luxury and was influenced by the French, Dutch, Flemish and other Continental countries.

The principal ornaments of the time were the "S" and "C" scrolls which were repeated and reiterated, joined and rejoined until they finally completed a panel. The style is characterized by ornamentation, by its spiral turned legs and geometrical mouldings.

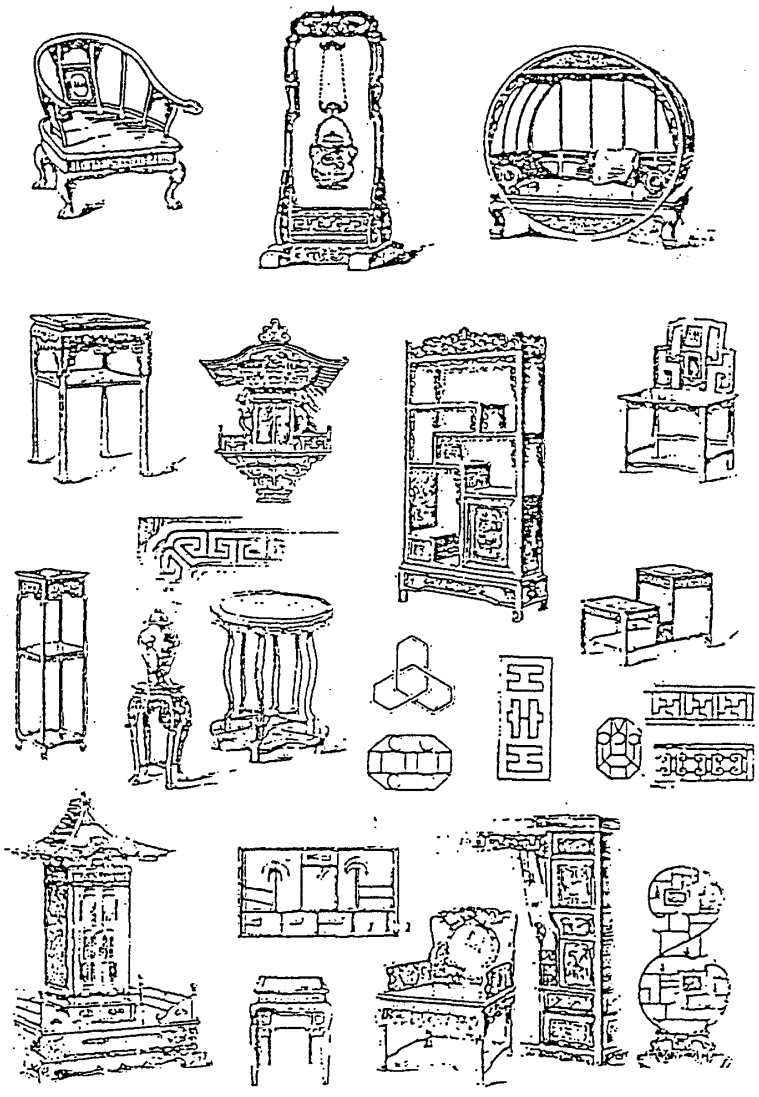
The carved crown is another feature of the period and indicated the return to monarchy.

Today, Late Jacobean furniture is used in public buildings, reception rooms and halls and churches.



CHINESE (1600--1700)

IT is unknown when the Chinese first began to use slate or domestic furniture. Whether, like the ancient Assyrians and Egyptians, there was an early civilization which included the arts of joining, carving and upholstery cannot be determined. Most probably there was. From early plaster casts on the ornamental stone gateways of Sanchi Top in Bhopal, Central India, it appea that in the early part of the Chris an era, Hindu wood carve represented figures of men a animals in the woodwork of sacr buildings or places. The marvelo dexterity in manipulating woc ivory and stone which can be recc nized in the Chinese of today h been passed down from their ea ancestors.

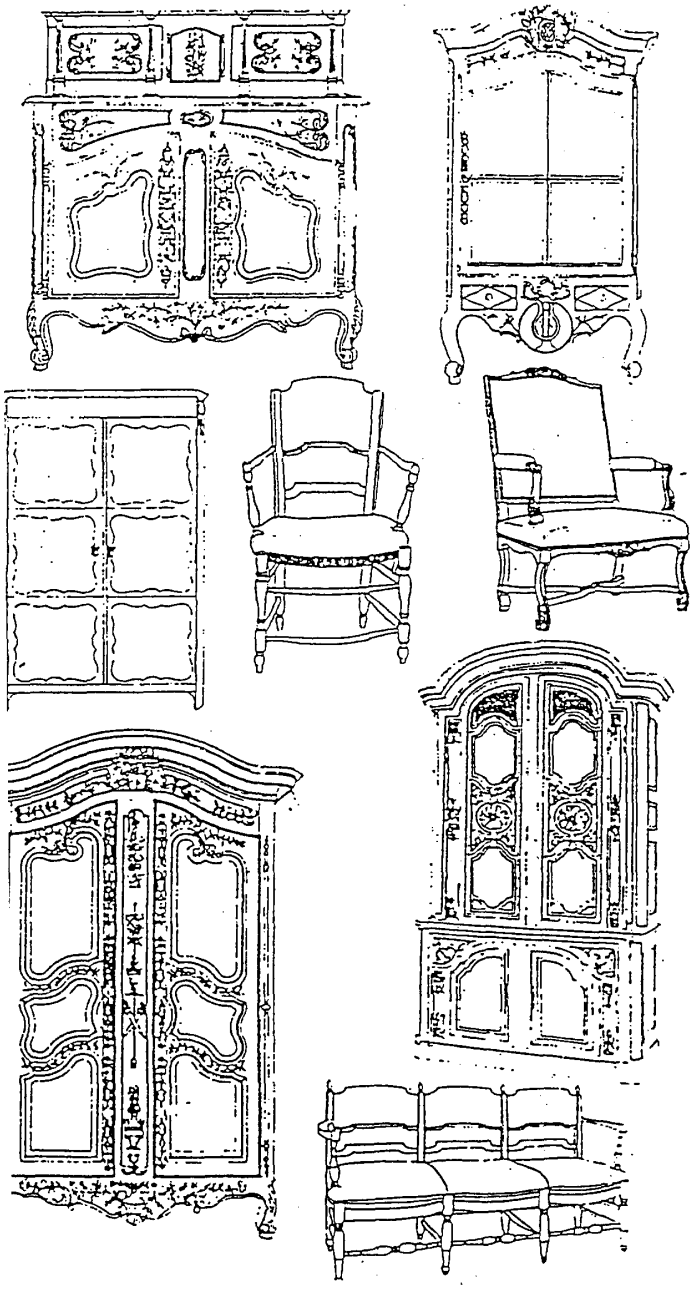


Sir William Chambers travellec China in the early part of the ei teenth century, and it was he w introduced "the Chinese style" i furniture and decoration, which w adapted by Chippendale and otl makers.

Older Chinese furniture seen day often dates from the eighteer century, having been made to o er and imported by the Dutch. T explains the often curious combi tions of Oriental and European fluences in these pieces.

The most highly prized Chine decorative furniture has beaut lacquer work. Smoothly plar wood is covered with a coat made of powdered red sandsto and buffalo's gall. This is allowec dry, is polished and and rubbed w wax, or else washed with g water, holding chalk in solution. T varnish is laid on with a flat bru and the article is placed in a da drying room. It then passes into hands of a workman who polist it with a piece of very fine grair soft clay slate, or with the stalks the horse-tail or shave grass. It th receives a second coat of lacqu When dry it is polished. These op ations are repeated until the surf becomes perfectly smooth and l trous. There are never less th three coatings applied and seld more than eighteen.

FRENCH PROVINCIAL (1610--1800)



ABOUT 1912, collectors and connoisseurs began to show interest in what was known as Rustic or Provincial French furniture. In France, the term Rustic described this style, but in America, Rustic has an entirely different meaning so that Provincial is a better description of this style.

The styles of the French provinces outside of the larger cities are varied; therefore, we have tried to choose a few for illustration that will give a general theme.

The study of French Provincial started with the reign of Louis XIV, 1643. Prior to that time very little furniture was made and that was extremely simple.

With the establishment of peace in France, furniture began to grow in quantity and variety. At the beginning, the styles were greatly influenced by the Italian, being encrusted with precious stones, ivory or mother of pearl or carving.

The bourgeois furniture had a distinct Dutch style from which finally emerged the French Renaissance style.

From the beginning of Louis XIV's reign, all inlays and veneers were dropped and furniture was produced from native solid woods—oak, beech, walnut and fruit woods.

In spite of the fact that the French peasant was usually wealthy, his tastes remained simple.

During the reign of Louis XV a whole series of pieces came into being with drawers, such as chiffoniers, secretaries, and tiny tables for various purposes. At the same time, simple furniture began to develop along the local lines and the once barren peasant cottage assumed a homelike atmosphere. Well styled French Provincial furniture at last came into its own.

It is noted that the style which originated during the reign of Louis XV conformed with the popular manner of French tastes, and it continued into the XVI period.

WILLIAM & MARY (1689--1702)

WILLIAM and Mary introduced to England the styles and workmanship of the Low Country.

Because of this influence the furniture of this period became lighter and more comfortable and therefore better suited to home use. The people readily accepted this change as they were becoming tired of the Jacobean style.

Mary was interested in home furnishings and her influence on styles was great. She was a skilled needleworker and contributed some of her products to be used as chair coverings.

For the first time, England came to know furniture that was subtle and graceful with a harmonious combination of straight and curved lines.

The cabinet work was rectangular and arched; and double-arched backs on cabinets, as well as on the backs of settees and chairs, became a distinguishing feature.

The style is easily identified by the turned legs, with inverted cups; by the serpentine-shaped stretchers, usually crossed, and frequently with a finial at the intersection.

Backs of chairs were high and rounded at the top. Some of them were carved and caned or upholstered. They were slanted somewhat and seats were square. The legs were turned, octagonal or square. Late in the period, the Dutch cabriole leg came into use.

Feet were of the Dutch bun, the Dutch ball-and-claw, and the Spanish scroll. Block-feet were found on low chests of drawers. Arms usually flared outward and were made of wood, or were upholstered and rolled over.

The Dutch cockle-shell motif was popular and was carried over into the Queen Anne period. Also characteristic was the apron-shaped ornamentation with pendants. Marquetry was exceedingly popular, and veneering for the first time was largely used.

The marquetry was quieter than in the preceding Jacobean period and the chairs were less decorated and more dependent upon graceful curves.

Chairs and upholstered stools were generally popular. Beds were exceedingly tall, with slender posts and elaborate hangings. Some of these posts were twice as high as a tall man. Chest of drawers appeared and became known as highboys and lowboys.

China cabinets came into fashic owing to a vogue for collecting chi and ceramics.

Walnut was the principal wo used.

This period established the po that furniture design could be simp and beautiful at the same time, a also be within the reach of the mar

William and Mary period furnitu is not in vogue today.

AMERICAN COLONIAL (1620--1795,1795--1847)

ARLY American furniture design falls into two periods, the first prior to the revolution and second after. In the pre-revolutary period the colonists' des were fashioned after those of ppendale and Louis XIV, while the revolution the young reic looked to France only for inition.

uring its early period, American iture design was primarily a fu- of styles that could be used by colonists. Colonial furniture deincluded almost all of the En- periods, many Dutch forms, some French. Because the of the settlers were hard, their ts were basic and so their furre needs were primarily arian.

olonial styles were plainer and sturdier than the foreign els. There were few complex or iful elements, with a charactic freedom of line, at once ghtfoward, durable and usable. ecorative effects used by the nists were hand wrought nts and drawer-pulls of iron and s.

oods that were popular during period were imported mahogative oak, pine, ash, hickory, , apple, pear, cherry, maple black walnut. Reed and rush s were popular, as were upholed seats in the later portion of period.

ter the Revolution, the citizens e new state disliked British des and turned to France. The of the French Directoire periready was felt in this country, when the Napoleonic regime ated fashion at the beginning of 19th century, Americans also to these forms (Empire).

he motifs of post-Revolutionary iture include acanthus leaves, , pineapples, winged griffin feet lion and bear claws. Furniture carved and some of the carvwas gilded. Metal mounts were popular and scrolls were also used extensively.

Curved and straight lines were employed and proportions were large and the effect massive. The legs were straight or curved outward in the classic curule style.

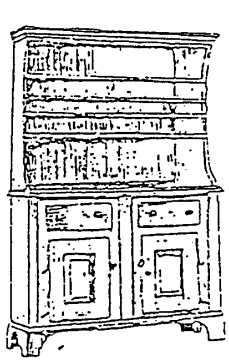
Arms of chairs began well up on the uprights of the back, swept downward in a fairly graceful curve and ended in a scroll. Sofa arms were usually rolled over. The backs of chairs were low and simple in design, while the top rail was usually curved to fit the contour of the body.

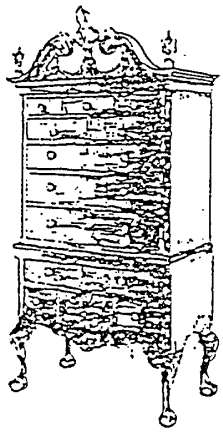
AMERICAN COUNTRY (1620--1875)

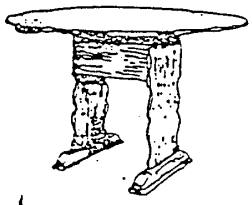
Early American furniture design falls into two periods, the first prior to the revolution (1620-1795) and the second after (1795-1847). In the pre-revolutionary period colonial furniture was fashioned after Georgian, Louis XIV and Louis XV designs. After the revolution the young republic looked to France only for inspiration.

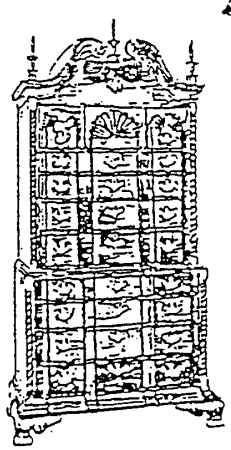
During its early period, American furniture design was primarily a fusion of styles. Almost all the English periods, many Dutch forms, and some French were represented. Because the lives of the settlers were hard, their wants were basic and so their furniture needs were primarily utilitarian.

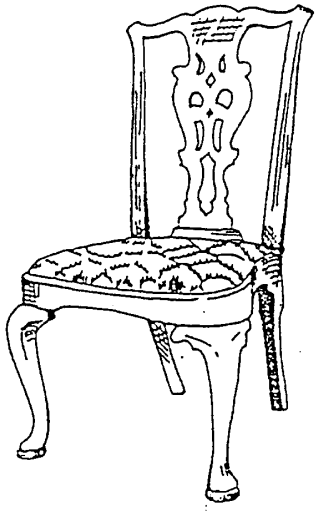
Colonial houses were neat buildings of brick and wood. The rooms were not large, and furniture tended to be narrow and taller than English works. Most of the furniture was practical and seldom luxurious.











'Chippendale' chairs were plentifi as were upholstered settees, car tables, and tea-tables, either of tl round snap-top form with a bir cage, or the rectangular tray top va iety. Beds tended to be simple, wi posts and draped testers. Lc chests or kneehole writing-table which served as dressing-tables bedrooms were also popular.

Decorative effects used by tl Colonists were hand wroug mounts and drawer-pulls of iron ar brass.

Woods that were popular durir the period were imported mahog ny, native oak, pine, ash, hickor gum, apple, pear, cherry, map and black walnut. Reed and ru seats were used, but later uphc stery also was utilized.

Seventeenth-century colonial fu niture showed marked region differences. New York and New Je sey, produced the great Dutch cu board, or 'kas', while the Ne England seaports, Boston and Ne port, produced joined pieces, su as chests of drawers and tallboy of English derivation. Until tl 1700's furniture of Massachuset and Connecticut continued to l made essentially on the Jacobe lines. Only after that did the desig of William and Mary becon popular.

After the Revolution, the citize of the new republic disliked Briti designs and turned to France. Tl style of the French Directoire pe od already was felt in this counti and when the Napoleonic regin dictated the fashions at the begi ning of the 19th century, America also took to these forms.

The motifs of post-Revolutiona furniture include acanthus leave lyres, pineapples; winged grif feet, lion claws and bear claws. Fu niture was carved and some of tl carving was gilded. Metal mour were popular and scrolls also we used extensively.

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AMERICAN COUNTRY (1620--1875)

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Reproductions and adaptations of nerican Colonial designs fall into ′o categories. Simple designs ;aracteristic of "country style", and ore sophisticated designs made r the wealthy. Since the Sheraton, ıippendale and Hepplewhite de-gn schools were immensely popu-r in both England and the nerican colonies, it is often ifficult to tell whether accurate productions of furniture made for ə wealthy were originally made by ıglish or American craftsman.

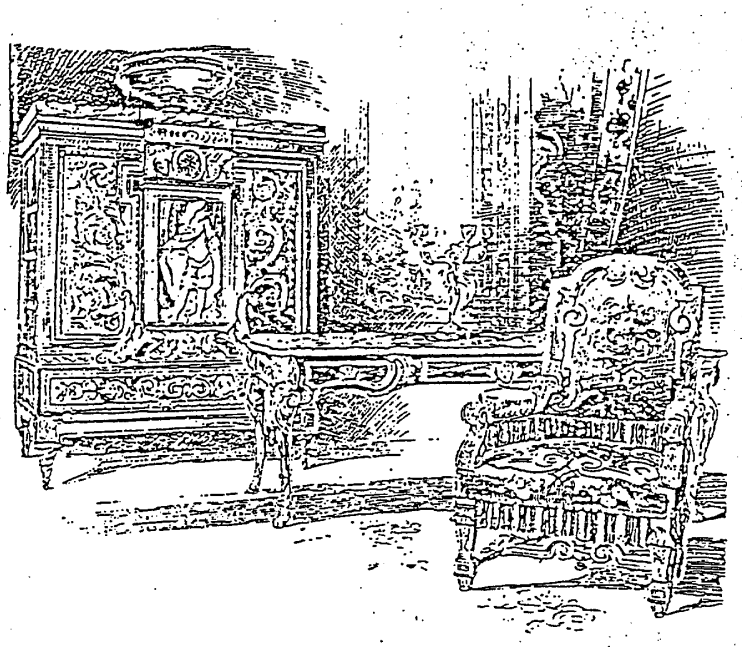
Many chairs known today as nerican Country or Early Ameri-. are Windsor chairs in maple, k or pine. Dining chairs and ta-ːs are often heavy with generous ɔportions. Chairs have saddle or ven rush type seats and comb, ı, hoop, ladder, banister and bow ɜped backs. Chair legs are often ned and connected by H-etchers. Tables may have ıestal bases (single or double), ɜtle type bases or turned legs. ons are plain or shaped. Butter-and gateleg dining tables, cup-ırds, hutches and dry sinks often ′e American Colonial styling.

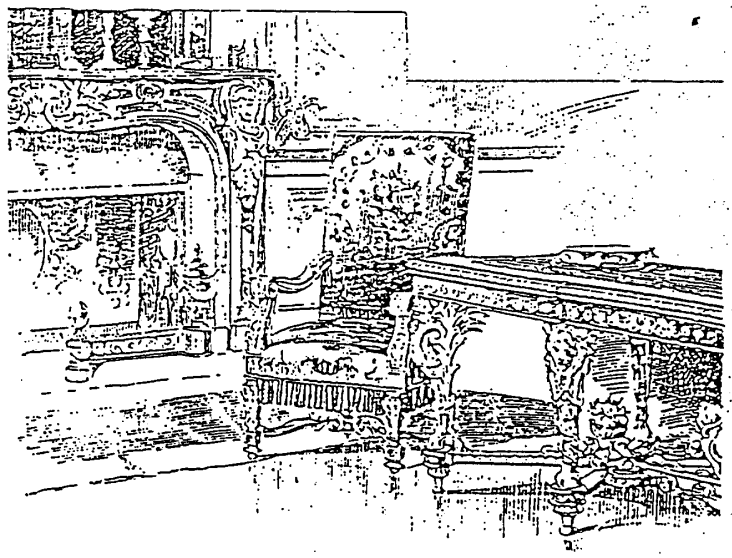
Some American Colonial styled ːasional tables are adaptations of ɟinal butterfly and gateleg styles. ıer occasional tables, dining ta-s and chairs incorporate ele-nts from Queen Anne, ppendale, Adam, Hepplewhite l Sheraton. Occasional furniture ːes that have heavy oak, maple pine turnings and generous ɔortions are often called Early American.

Upholstered Colonial styles which have some of the following characteristics fall into the American Country or Colonial style category: exposed wood trim in an oak or light brown maple finish; pleated or ruffled skirts; wing backs; loose cushion seats; loose or tight cushion backs; ample crowning; distinctive "country styled" covers. Many of these upholstered pieces are not reproductions of original colonial designs. Some have evolved to correlate with colonial styled tables chairs and case pieces or to give a comfortable casual feeling representative of country living. Others are modified 18th century designs.

Country styled bedroom furniture is often massive with head and footboards made from turned members. Split balusters may adorn case pieces which are usually constructed from pine, oak or maple.

LOUIS XIV (1643--1715)





IN France, the Renaissance p
od was followed by the distinc
furniture styles of Louis XIV.
This age was marked by splen
and grandeur. It is considered
most magnificent of the Frer
periods.

The style of Louis XIV was brc
and magnificent, with many strai
lines and very few curves. It w
severe, classical, symmetrical; d
orated beautifully, but not to exce
built for grandeur rather than
comfort.

Two opposite views were
pressed in the furniture. While t
structure was formal and rectan
lar, it was decorated with playfu
informal motifs and the color co
binations favored by the King.

Some of the legs were straig
while others were cabriole in shaf
The four legs of a chair were alwa
alike. The feet were paws, clov
hoofs or carved acanthus leave
Chair backs were generally hi
and straight at the sides, and oft
straight across at the top. X-sha
stretchers were also used.

The ornament was always lar
in scale and alike on both sides.
bilaterally symmetrical. The sh
was often employed.

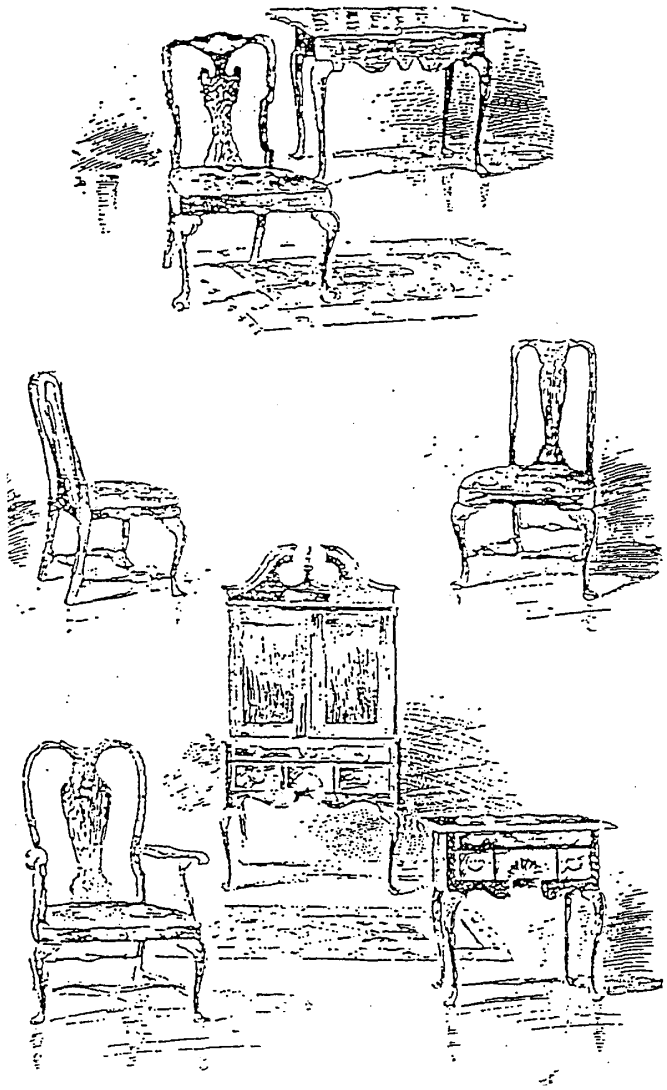
New types of decoration such
carving, painting, gilding, inlayir
lacquer-work and metal mounts we
developed. Oak, walnut, ebony a
chestnut were used extensively, w
various rare woods for inlays. Ma
ble was frequently used for tat
tops. Upholstery was very rich.

Andre Charles Boulle was the mc
successful furniture designer of t
period and was appointed the King
cabinet maker. He was noted for h
ebony furniture and he inlaid th
wood with tortoise shell, brass a
other metals until it resembled a b
liant mosaic. He also decorated h
work with chiseled mounts of gilt

QUEEN ANNE (1702--1714)

ALTHOUGH Queen Anne furniture still shows the influence of Dutch designers as did the ceeding period of William and ary, a freedom was extended to iftsmen and tney developed British designs.

As a result, furniture of Queen Anne's time shows a step forward in refinement, in grace and in comfort. The English home was becoming more modernized, and greater comforts began to appear. Uncomfortable chairs of the earlier period were replaced by upholstered, overstuffed wing chairs. The easy chair was also introduced during the Queen Anne period.



Wide flaring chair seats designed to accommodate the huge skirts worn by women of the time came into fashion. Because of this fact, many of the chairs did not have arms. Backs of chairs, in order to provide comfort, were shaped to fit the body.

The cockle-shell ornamental carving was the most popular and is found on the knees of cabriole legs, on the cresting of chair backs, in the middle of drawers and aprons, and frequently formed the center motif of carved designs. This ornament and the cabriole leg are perhaps the most outstanding features. The cabriole leg is an adaptation of the "S" scroll. It is often found on the apron, chair-backs, mirrors and even table tops.

The cabriole leg was later used in Louis XV furniture and in the designs of Chippendale. Other feet used were the claw-and -ball, the paw and the club.

Furniture surfaces were kept plain, without paneling or molding. Veneering was much used and lacquer work was popular.

Dining tables were of the drop-leaf variety; chest of drawers, highboys and lowboys, and beds with tall slender posts supporting testers were popular. A feature of the chair was the solid fiddleback-shaped splat, with uprights in sweeping contours. These backs were generally narrow. Underbracing was not used.

Queen Anne construction was used by later designers who added their own conceptions to it. This showed up in the Georgian period.

Walnut was the principal wood used and sometimes the age is referred to as the Age of Walnut.

CHIPPENDALE (1705--1779)

THOMAS Chippendale, the son of a woodcarver, was the first cabinetmaker to have his name associated with a furniture style.

Chippendale was a master designer, a peerless carver and a remarkable craftsman. He was particularly able at choosing ideas from other periods and other countries. Critics have charged, and with some validity, that he freely picked up other designs without acknowledgement. But even though this charge is true, he always added his own style and distinction to his works.

Chippendale adapted Oriental motifs, until he evolved what is known as Chinese-Chippendale. Even the Gothic supplied him with inspiration.

In addition to his designing ability, he was also a good business man and a good salesman. In 1754 he wrote and published the first book on furniture designs; and, in so doing, he identified individual designs with the maker's name.

His style is richly carved in mahogany, with a free use of curves gracefully, beautifully and substantially proportioned. It may be more difficult to recognize than the average because of his borrowings, but generally speaking, substantial beauty, with marvelous carving are the signs of Chippendale.

The claw-and-ball foot is one of the most characteristic motifs and was used with cabriole legs. Other feet used with cabriole legs were the club, web, scroll, paw, dolphin, leaf and slipper. The straight leg was used on his Gothic and Chinese styles, while on his other designs he extensively used the cabriole leg.

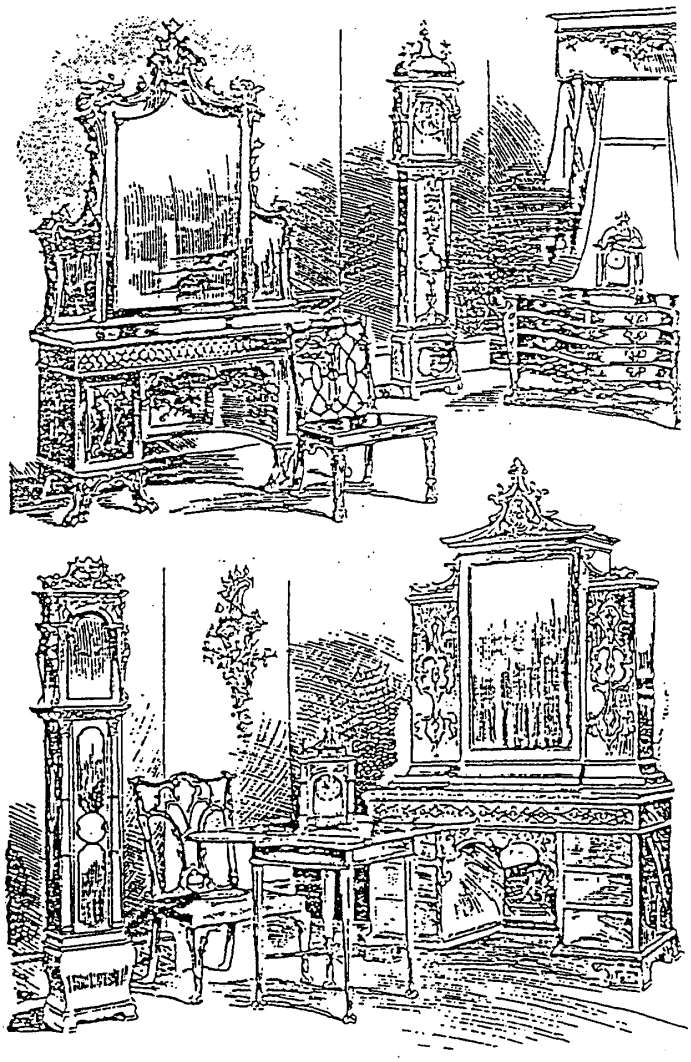
The arms of the chairs were curved and flaring at the end, and usually joined the uprights at an angle, while the supports were shaped forward at the side rails of the seat. This feature is a definite Chippendale characteristic.

The backs were inclined to be square in outline with serpentine shaped tops.

Chippendale was free in his use of motifs and some of his favorites were scrolls, acanthus leaves, knotted ribbons and interlaced straps. He also used rococo shells large curves as well as the "C" scroll, lion heads and masks.

Mahogany was his favorite wood.

although he someti mes usedwa
He made almost all types of f
ture including sideboards and b
cases.



LOUIS XV (1715--1774)

"HE age of Louis XV was marked by vice and immorality, licentiousness and hypocrisy. ıecause they were covered by a ‹ of refinement, art contributed ogress.

ıtil Louis XV came of age France ruled by a Regent and the furni- of this era is referred to as Re- y. Many new objects appeared such as commodes and chiffoniers with many drawers, secretaries that concealed many things under closing panels, and falling flaps on the sides of writing tables. The Regency only lasted eight years.

When Louis XV actively took over as king, furniture continued to be decorative and beautiful. Louis XV was influenced by his two successive mistresses Madame du Barry and Madame de Pompadour. Their influence on furn iture fashions produced a strong feminine trend.

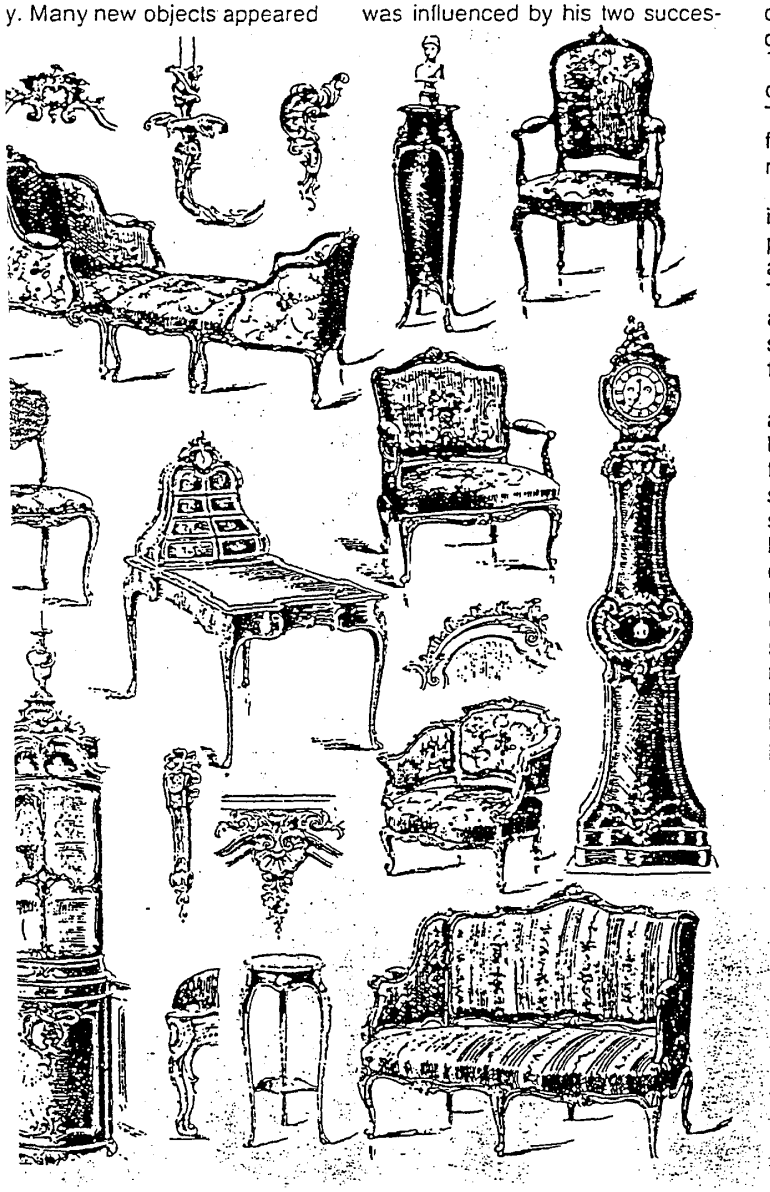
Ladies' writing desks, cabinets, dressing tables, corner commodes and the ever-present mirrors were graceful and dainty in construction, and decorated with charmingly colored silk, tapestry and embroidered covers.

The period developed structures of sinuous curves and contours. There were no straight lines, and the flowing lines became delicate and refined. No classic motifs were used.

Characteristics of the later style influenced by Madame de Pompadour were a combination of rock and shell motifs known as rococo. The endive leaf, the shell ornament and twisted forms lent a large and sumptuous effect and were beautiful to the eye.

Louis XV furniture invariably had a cabriole leg. The feet were scroll-leaf while the dolphin-head sometimes was used. Arms of chairs and settees were short and flaring, with sharply curved support; while the backs were broad with the framing ornately carved. They were usually upholstered, as were the seats. Under-bracing, which had been X-shaped in the time of Louis XIV was not used. Ornamentation was dominant and plain surfaces were avoided; moldings were lighter in effect and panels were longer and not square.

The types of decoration used were carving, inlaying, painting gilding and elaborate metal mounts. Wreaths, flowers, lozenges, human figures and shells comprised the major motifs. Mahogany, walnut and ebony were popular woods but other woods also were used for inlay work. The colors were very light and gay, the more fashionable being white and gold, pearl, silver, rose, light greens and delicate blues.



SHERATON (1750--1806)

THOMAS Sheraton, the first great designer of the 18th century, was a master of cabinet making and inlay.

Following classic lines, Sheraton frankly adapted many of the Louis XVI styles but added his own conceptions and artistic knowledge. The result, which is a prominent characteristic of all Sheraton furniture, was a subtle gracefulness, a remarkable appreciation of form and correct geometrical proportions. His work at all times shows classic dignity, refinement and restraint.

Sheraton leaned heavily on perpendicular lines giving his designs purity and beauty. He never designed short curves, and whenever he used the curve it was as a graceful sweep.

Sheraton used the oval to a great extent while the lyre, slender urns and latticework were characteristic. Reeding and flutings also marked the style. He used swags, the cockshell, the star, fan shapes and small ornamental disks. Inlay was a favorite decoration and he used many beautiful woods. Turning, veneering and painting were used. The carving was delicate and light.

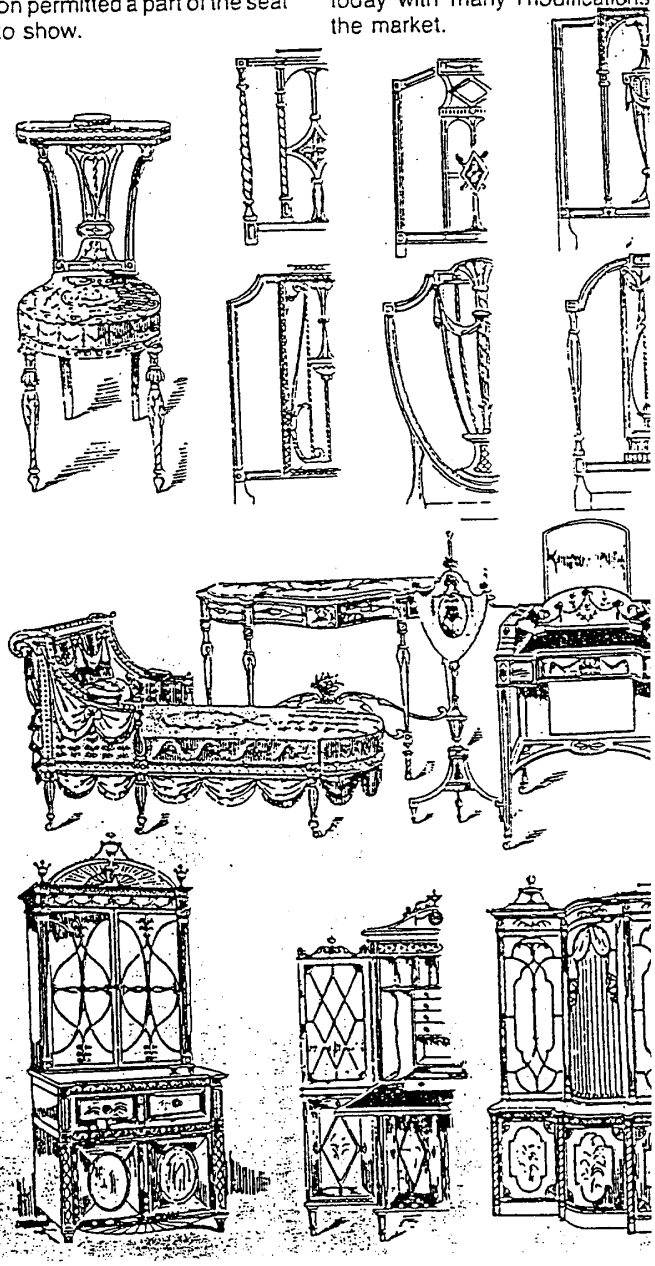
Sheraton knew construction and although his furniture was light it was structurally sound. The legs were very slender and were usually round, tapered and reeded. Another type was square and tapered with acanthus leaf decoration. During the latter part of his career some of the table legs were spiral-turned. The feet are not conspicuous. He used the spade-foot, as did Hepplewhite, the block foot and occasionally the French foot, which curved slightly outward.

The typical Sheraton chair-back was square, with a central panel rising slightly above the top rail. The lower rail usually kept the back well up from the seat. The arms started high on the uprights of the chair and swept downward in a very extended "S" shape to the supports, which frequently were a continuation of the front-legs.

Although there is a similarity between the Hepplewhite and Sheraton designs, Sheraton used more underbracing and often the X-shape stretcher. Hepplewhite pulled his seat-cover well over the apron; while Sheraton permitted a part of the seat frame to show.

Sheraton was a master at asse bling various woods even tho mahogany was favored. For inl he used satinwood tulipwood, sy more, and rosewood.

Sheraton design is still pop today with many modifications the market.

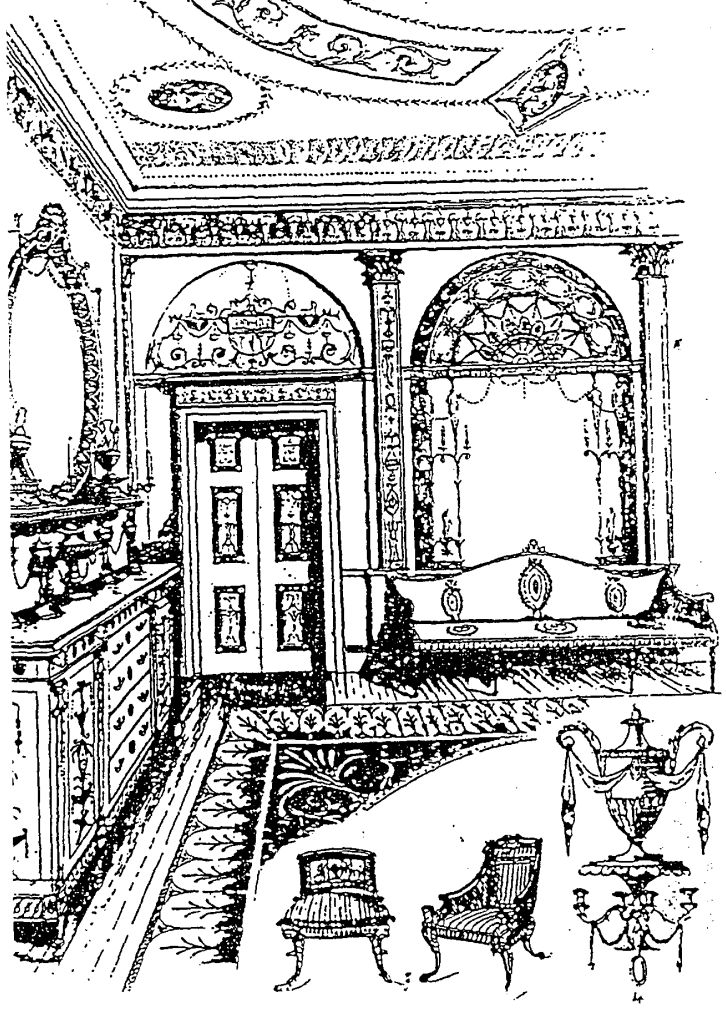


ADAM BROTHERS (1765--1790)

HE Adams brothers were not urniture makers, but architects, decorators and designmploying Angelica Kauffman er husband. Antonio Zucchi, i, Pergolesi and a host of othhey built palaces for the nouses for the middle classes, es, bridges, even streets and es, and in almost every in- their work was classic.

Chinese craze cropped out id then but its popularity waned ie inception of this epoch. Their reflecting the spirit of Pompeii lerculaneum in a purer type than was expressed in the late Louis XVI adaptations, left its deepest impression on ceilings, side-walls and mantelpieces produced under the architects' directions. They were tinted usually in jasper or the palest gray colors. Circles and ovals were used as frames for pictures.

They utilized mythological ornament, the hexagon, circle, octagon and lozenge-shaped, panel, wreath, fan medallion, draped or with figures, the sphinx, griffin, sea horse, goat, faun, ram's head, the caryatid and innumerable other classic motifs found in Roman, Pompeiian and Etruscan work. They designed walls, ceilings, mantelpieces, even door knobs, escutcheons, locks—everything that went into a room, including table tops and furniture panels.



While they were by no means furniture-makers the Brothers Adam always designed furniture to fit their rooms. Many sideboards with urn-shaped knife-boxes and classic brackets, pedestals, clock cases and mirrors were designed by them. They even designed the carriages, the plate and the sedan chair for Queen Charlotte.

Their style was a complete departure from the massive and ponderous compartment ceiling of the Jacobean. Instead they adopted light moldings, delicate stucco frames and painted ornaments. They advanced the theory that dining rooms, being so often utilized for extended conversation, should be finished with stucco, adorned with statues and paintings and never hung with tapestry or damask, "which retain the smell of the victuals." As a result, many of their rooms so largely depended on the work of the painter and sculptor that they lacked coziness. They were often circular or semi-circular or with circular recesses.

The gesso work of Italy was adapted and their ceilings were part in relief and part painted, the plaster being put on cameo-like, with great delicacy. Italian artisans were needed for this work, which preceded the use of plaques and friezes furnished for late Adam work by Wedgewood, who caught the Adam craze and commercialized it.

The brothers were so earnest in imparting their spirit to the entire room that they insisted upon even the carpets being in unison with the surroundings. Even the table clothes corresponded in patterns, and the unity scheme was carried out in the silver plate, the tabletops, and even the snuff-boxes.

HEPPLEWHITE (1770--1790)

THE influence of the London cabinetmaker and designer George Hepplewhite is widespread because of his individual style which emphasized lightness, gracefulness and elegance with a pure beauty of line.

Hepplewhite's work was refined, free from bizarre motifs, and showed a great deal of the Louis XVI influence, a type he copied frequently. In spite of the slender characteristics of the style, he achieved sturdy English qualities.

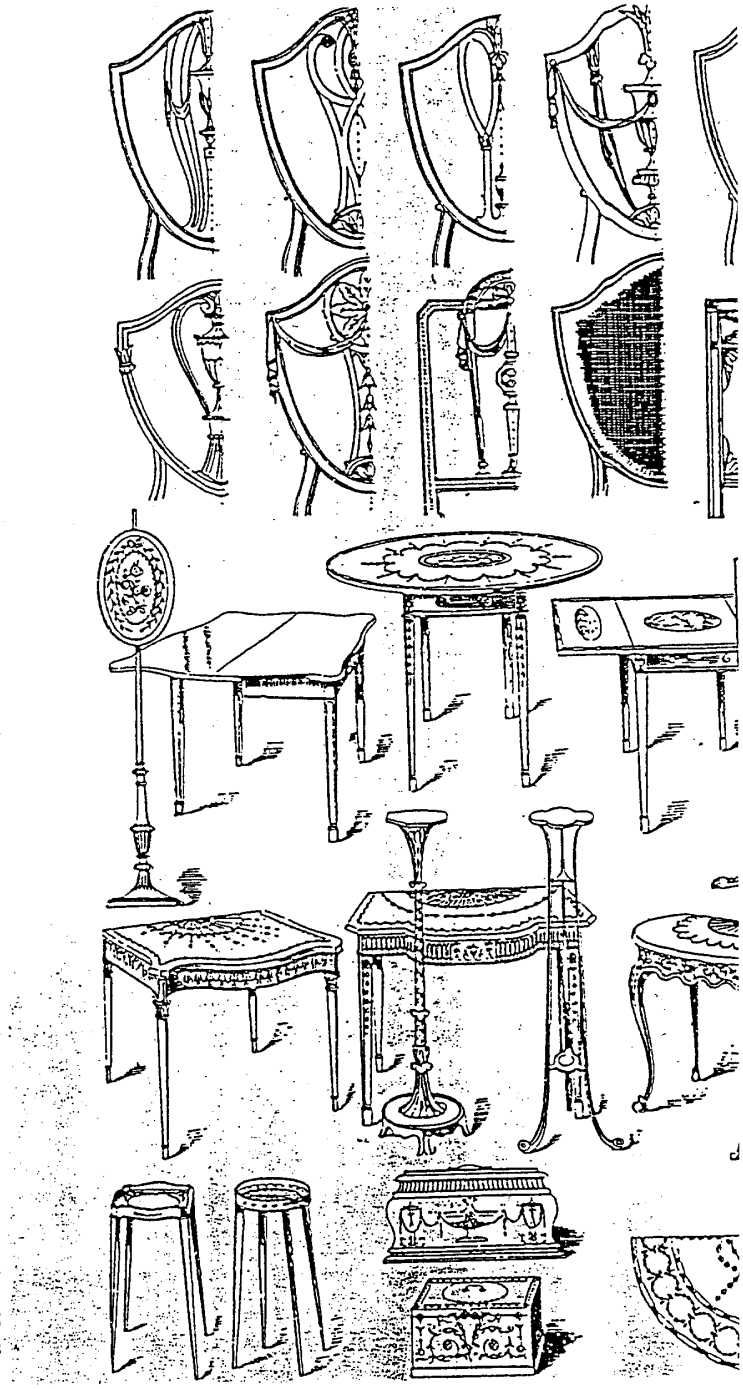
Hepplewhite is distinguished by the graceful straight leg forms, the serpentine fronts, and concave, cut-in corners. Wheat-ears, Prince of Wales feathers and bell-flower husks were used in ornamentation. On the chairs he usually used shield-shaped backs, and unusual short, curved arms. Although Hepplewhite employed curves, they were always refined.

Legs were usually straight, square, tapered and terminated in a spade-foot. The tapered, round leg also was used. Often it was reeded or grooved, and sometimes carved with an intertwining spiral band.

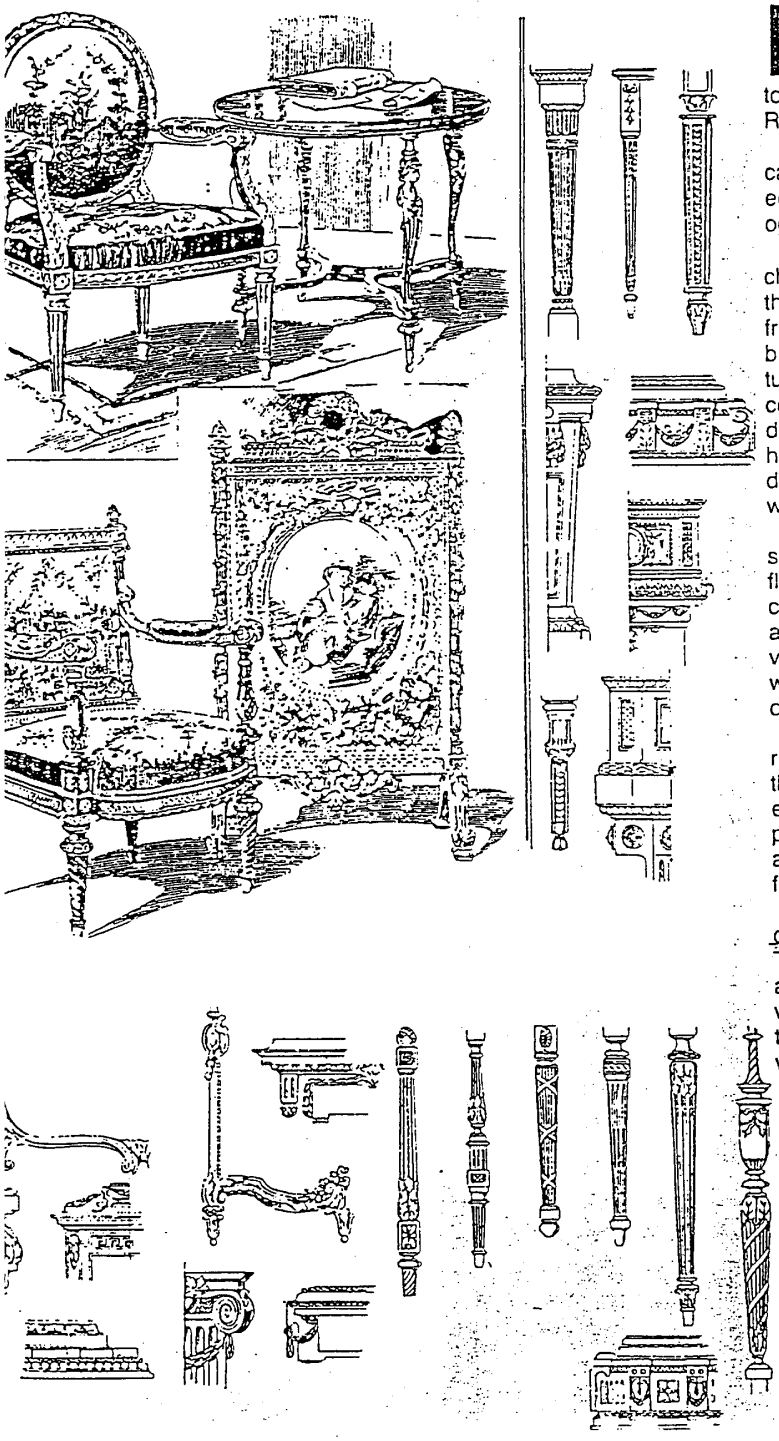
Chairs were the most famous of the Hepplewhite productions with the shield-shaped chair-back the most distinctive. This also was modified by the hoop back, the interlacing heart back and the oval back. The backs of Hepplewhite chairs were supported by a rail above the seat, which joined the slender curved continuations of the back legs.

The designs popular with Hepplewhite were the lyre, the honeysuckle, the urn and "S" curves. The seats were frequently rounded at the back; but others were square and tapering. Usually they were upholstered, and upholstering generally was brought down over the frame.

Although mahogany was a favorite wood, he also used rosewood, satinwood, tulipwood, harewood and other rare selections. Painting was the favorite decoration.



LOUIS XVI (1774--1793)



DURING the reign of Louis XVI and his queen, Marie Antoinette, there was a return to the classic designs of Greece and Rome.

This change first came about, because Marie Antoinette had a classic education, and because archaeologists were digging up ancient ruins.

Structure of the period's furniture changed from the curved line and the cabriole leg to the straight line; from unbalanced ornamentation to balanced ornamentation. Architectural details such as the classic Greek column tops of Ionic, and Corinthian design returned. The style was more home-like and the general effect was dainty, graceful and elegant. Curves, when used, were long and slender.

The sofas were longer and were supported by a number of straight fluted legs. Beds no longer had the curved outlines of the previous style and the wood was almost always visible. Posts were usually crowned with a pineapple, a plume of feathers, or other ornament.

Carving in the design of a twisted rope was a common motif. Acanthus leaves, bows and rosettes, staffs entwined with laurel leaves, oval plaques, mahogany veneers were all used, as were flaming torches, fluted columns, lyres and urns.

Bound arrows formed the corners of many bureaus and commodes. The woods, when not gilded or enameled, were left natural. Favorite woods were mahogany, amboyna, tulip, rosewood, walnut and stainwood.

DUNCAN PHYFE (1795--1854)

DUNCAN Phyfe working in the United States during the 19th Century was materially influenced by Hepplewhite and Sheraton, but all of his furniture was basically a new creation. Although it resembled the furniture of the English masters, it has characteristics which can be easily identified as belonging to Duncan Phyfe.

The early Phyfe pieces are equal in beauty and line to Hepplewhite and Sheraton. The severe simplicity was not a sudden break from the simple and dignified furniture. Chippendale in origin, it was popular in the Post-Revolutionary years.

From the influence of the English masters, Phyfe turned to the styles of the French Empire in response to the demands of his clients and his work along these lines is considered inferior to his early work.

In his last work, Phyfe produced furniture which he himself described as "butcher furniture" due to its heaviness, lack of beauty and grace of his early pieces.

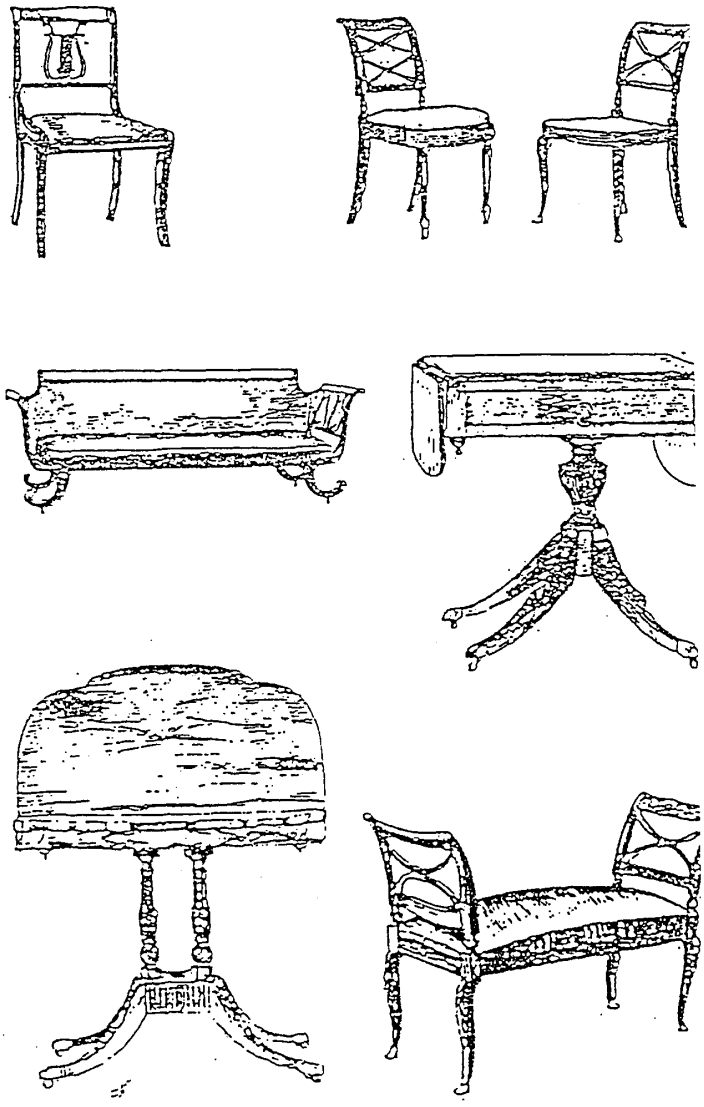
The legs of Phyfe tables, chairs and settees, were straight, reeded and fluted. Chairs often had concavely curved legs and some tables were supported at each end with lyre-shaped bases. The backs of chairs had the lyre motif, X-shaped pieces, either straight or curved, and shaped bars between uprights.

He made several types of dining tables, both extension and sectional, with the lyre often appearing in the pedestals. This motif appears on smaller tables, but the most recognizable feature is the lack of straight lines in both tops and legs.

Table leaves are nearly always slightly rounded, with a clover leaf pattern sometimes at the corners. Pedestals are sometimes either crossed lyres or finely curved pillars. He seldom made a table with four vertical legs.

Phyfe relied heavily on decorations such as acanthus leaves, ovals, lumes, lyres. He also used carving, turning, veneering, reeding and inlay. In his early work he only occasionally used brass while in his later periods he used this metal liberally.

Duncan Phyfe preferred mal any in most of his designs anc creations are still used in conten rary rooms.



EMPIRE (1799--1814)

THE Empire style was a return to classic lines of Grecian, Roman and Egyptian design. :hairs of Greek outline and the de-ail of Roman decoration are promi-ent in this period. Typical Empire ornaments include winged figures of various forms (emblematic of lib-erty), Greek vases, laurel wreaths, lyres, the warrior's helmet and the dove.

Mahogany was the wood chiefly employed in making the furniture of this period, and with the heavy bronze and gilt mountings usually coupled with this style, the pieces present a most handsome ap pearance. Stateliness and dignity a re features of the Empire style. Con trasted with the dainty Louis Seize designs, the transition is very marke d. It is as though one stepped out of a beautiful and cozy boudoir in the castle of Marie Antoinette into the imperial dignity of a great Roman hall.

Perhaps the great Napoleon himself, a kind of 19th century Caesar, favored more the styles of antiquity than the effeminate furnishings that preceded his time of authority. The result is artistic, if at times a little stiff, and some of th e Empire pieces are justly to be described as things of beauty and a joy forever.

Between some styles it is at times difficult to draw a distinguishing line. However, it is never difficult to determine what is Empire. The sudden return to the lines of Egypt, Rome and Greece is plainly in evidence everywhere: as plainly as if they all bore the plain Roman N, surmounted by a royal wreath, or the imperial eagle which so often led the French legions to victory.

There was never a style less in harmony with French temperament than the Empire style. Heaviness, solidity and stately dignity are not characteristic of the Frenchman, and the lines of the Napleonic furniture, though gracefully artistic, seems to be, to a large extent, the expression of an artificial constraint. This view is strengthened by the fact that after the fall of Napoleon the Empire style fell quickly into disrepute, and even as all reactions led more or less to excesses, so we have in the French furniture of the 19th century the "Baroque" or a "debased rococo" in which all the worst features of Louis Quinze ornament and design were revived, without the talent of the great designers whose genius was the redeeming feature of the 18th Century furniture.

VICTORIAN (1840--1900)

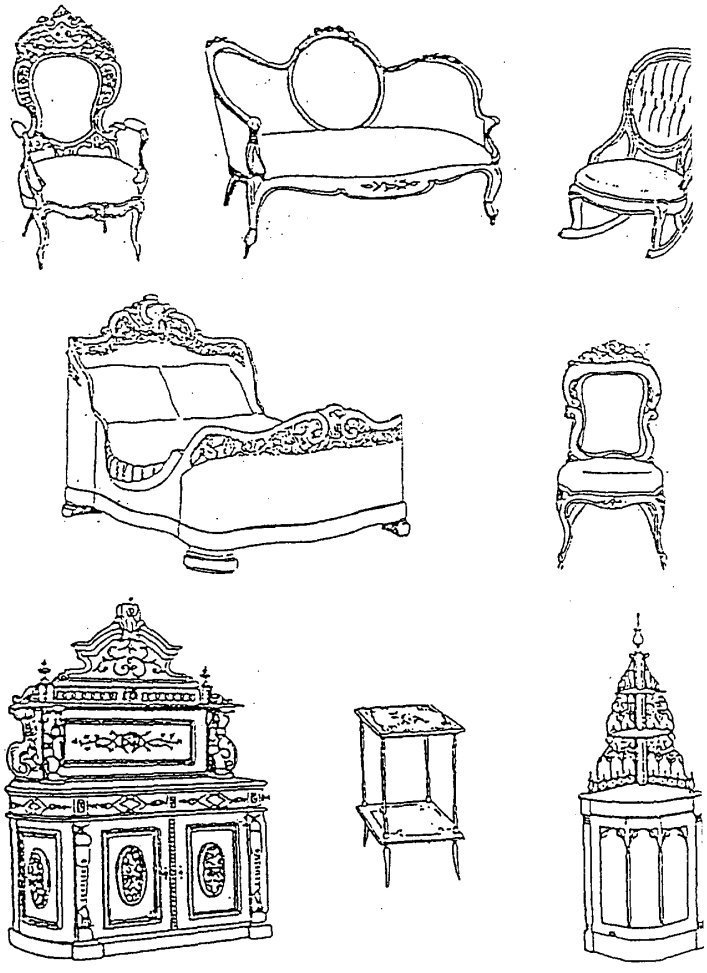
VICTORIAN furniture is essentially a combination of historical designs which have been interpreted, adapted, combined or borrowed. Developed largely from American and English Empire designs, the period is characterized by large, heavy substantial styles with characteristically sombre finishes. Black walnut and rosewood were favored while carving, turning, brass inlays and mother-of-pearl are typical. Favorite motifs are scrolls, flowers, leaves, classical figures and such nautical emblems as dolphins, anchors and tridents.

Comfort and usefulness are the dominating characteristics of Victorian chairs. There are more than forty different types ranging from light side chairs to fringed Turkish upholstered chairs. Oval or horseshoe shaped backs are common and if upholstered, can feature button tufting in a regular design pattern. Round or oval upholstered seats are generally crowned in the center. Typical dining chairs have rounded open backs with one horizontal splat; feet are simple scroll curves. Spool turned and Gothic chairs are also included in the period.

The era cultivated the extension dining table with a split pedestal base. All extension tables have a telescoping bed (the framework beneath the top to which the legs or pedestals are attached) with two parallel units placed 14-18 inches apart. A fifth leg generally provides support for when the table is extended.

Mid Victorian consistently showed a Rococo-Louis XV basis, exaggerated scale and curvature, heavy carving of fruit and flowers principally in walnut with some rosewood and mahogany and new shapes like those of the French Second Empire. Machine work appeared in fancy shaping, molding, turning, veneering and carving applied heavily and often meaninglessly. Marble tops and fancy hardware of metal, carved wood, porcelain were featured.

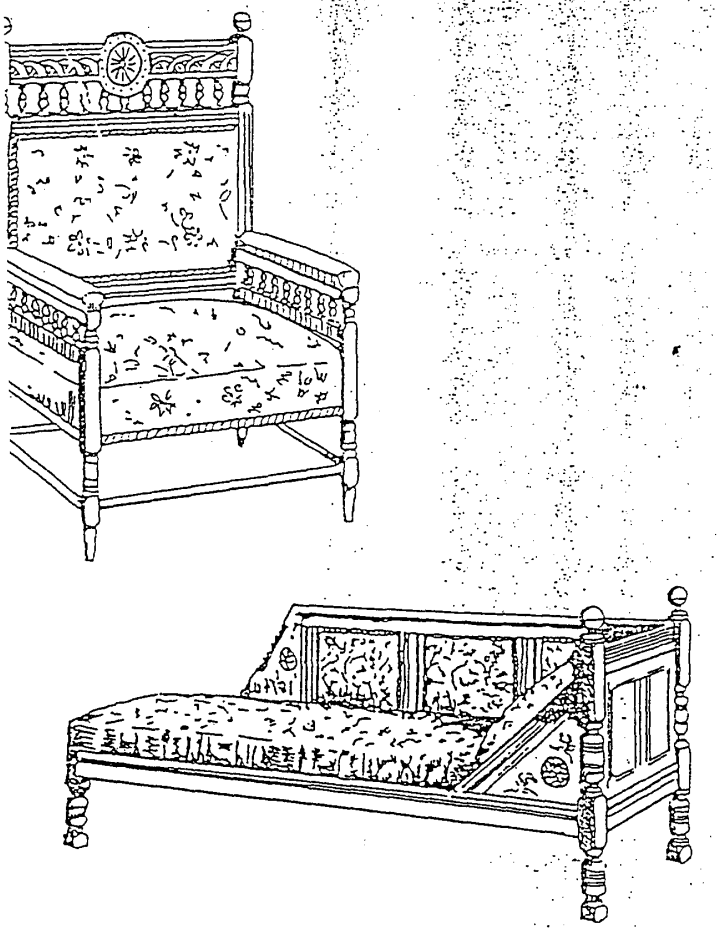
Handwork construction methods prevail with early Victorian tables, which were made by cabinetmakers or produced on order by custom shops in the larger cities. Mortise and tenon joints are used for joining legs to frame and swinging legs to pivoting brackets. The supports of a trestle table are braced by single stretchers. Table tops consist overhang the beds; on a drop table the overhang is 2-4 inche the ends. Drop leaves, when rai are supported by swinging leg more frequently by pull or pivc brackets built into the side of table frame.



EASTLAKE (1870'S—1880'S)

ıe Eastlake style of furniture takes name from the English architect, rniture designer, and writer, ıarles Lock Eastlake, who lived ɔm 1836 to 1906. His book, Hints Household Taste, was published London in 1868 and in Boston ur years later. It produced a revo- ion in design and a revival of ndcraftsmanship which became own as the Arts and Crafts Move- ɛnt. However, it was not only the stom designers who were inspired by Eastlake's ideas, but the manufacturers of the machine-made furniture which Eastlake deplored also copied the Eastlake style as it was illustrated in his book.

In Hints on Household Taste, Eastlake espoused "honesty" in construction and finishing. He called for hand crafted solid wood furniture with rectangular joinery. He condemned the practice of using stains and varnishes to disguise inexpensive woods, calling instead for oiled, naturally colored finishes. Eastlak wrote, "The present system (French-polishing, or literally va nishing, furniture is destructive of a artistic effect in its appearance, be cause the surface of wood thus lac quered can never change its colo or acquire that rich hue which is on of the charms of old cabinet work The use of rugged woods like oa and the elimination of stuck-o decorations are also characteristi of Eastlake furniture. As mentione above, Eastlake also inspired th manufacturers of machine-mad furniture to explore the decorativ possibilities of their machines. The developed incised lines, chip carv ing, and stuck- on bits of moldin and turning among other things.



Eastlake's reforming ideas wer particularly inspiring to William Mor ris who, in turn, became the leade of the Arts and Crafts movement ir England. Sometimes called the "new Renaissance style", "neo medieval", "plank construction", o "Art Furniture", (a term originated b Eastlake), the Eastlake style wa most popular in the 1870s and 80s and at that time became a kind o catch-all term meaning differen things to different people. Eastlake himself commenting on his in- fluence in the United States, said, "I find American tradesmen continu- ally advertising what they are pleased to call Eastlake furniture. with the production of which I have had nothing whatever to do, and for the taste of which I should be very sorry to be considered responsible."

Henry Hobson Richardson, an American architect, was one of the foremost proponents of the Eastlake style in United States. The furniture he designed and built for the Woburn Public Library and the North Eastern Library in Mas- sachusetts are very similar to pieces which appear in the illustrations to Hints on Household Taste.

MISSION (mid 1890'S--1915)

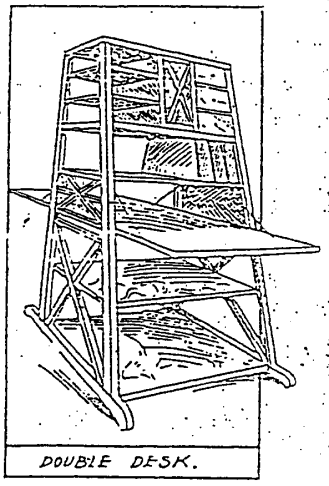
What came to be known as Mission style furniture, originated in the western United States in the mid-1890's and was manufactured, mainly in the east, until about 1915. It has been suggested that it all began when members of a church in San Francisco were unable to afford to buy furnishings for their church. They decided to build their own, imitating the work of Indian craftsmen who built furniture for the Spanish mission stations in Mexico and in the west and southwestern parts of the U.S. A decorator sent models of the pieces made for the church to Joseph McHugh, a manufacturer in New York, who began to produce his own versions of this solid, simple furniture.

Constructed almost exclusively of weathered or fumed oak and characterized by straight lines, and mortise, tenon, and dowel joinery, Mission furniture was an American outgrowth of the English Arts and Crafts movement. This movement emphasized handcrafted pieces made of native materials with polished finishes.

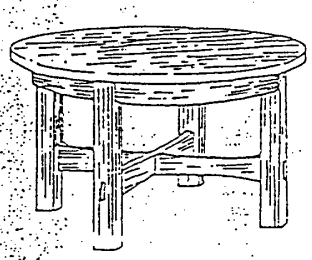
Gustav Stickley, who became leading manufacturer of Miss style furniture, introduced "Craftsman" collection at the fu ture exposition in Grand Rap Michigan in 1900. Stickley saw Mission furniture in opposition to "reign of marble tops and silk upl stery" of the Victorian era.

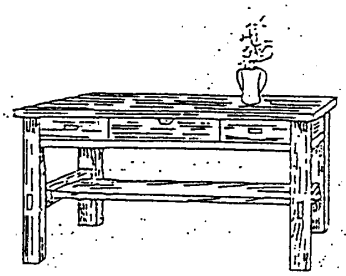
Upholstered pieces were cove with leather. And, while Miss style furniture was usually free of namentation, large nail heads, s ple cut out patterns hand-hammered copper appliq were sometimes used for decc tion. At the height of Mission fu ture's popularity, from 1900 to ab 1913, Stickley established Craftsman workshops near Sy cuse, New York; the Craftsm Farms in New Jersey; the Cra man Magazine; and the Craftsm Building in New York City, wh contained a home- builders' exhi a library and a lecture hall. Elb Hubbard, a competitor of Stickl established a commune in E Aurora, New York, to build Miss furniture and to build the charac of young people who came there work. The English labeled their v sion of the Mission style "quai That term is also used in various vertisements which appeared American newspapers and ma zines in the early 1900's. Oth called their conceptions "Gothic

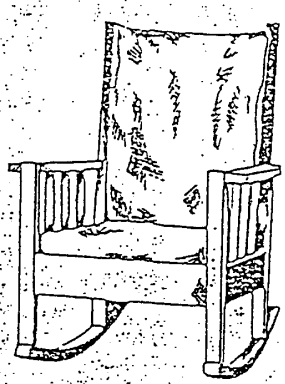
The Mission style is not wid sold by today's retailers of home f nishings. It is not mass produced purchase by the general consum — it was never meant to be. For t modern collector, Mission furnitu offers the opportunity to own har crafted and hand finished pieces relatively moderate prices. It can blended with more contempor pieces because of its square, cle lines.



From Furniture World, September 10, 1903







BAUHAUS (1920'S—1930'S)

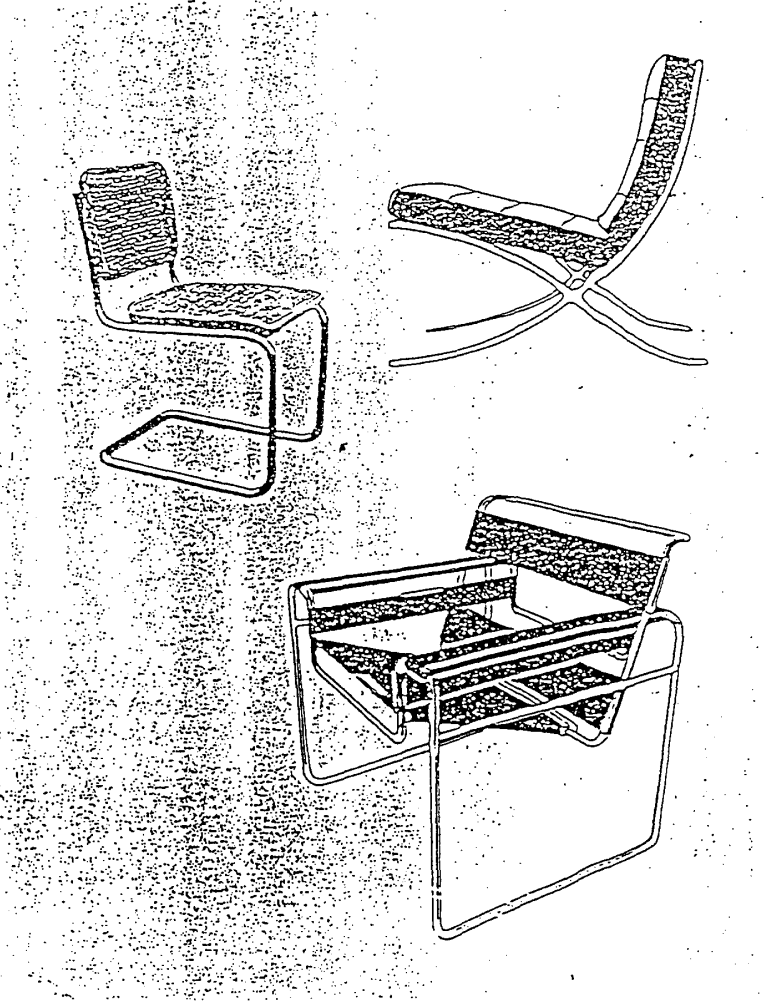
uhaus literally means "architec-
e house" from the German word
ıuen"— "to build". The Bauhaus
s an art and design academy
ınded by Walter Gropius in Wei-
ır, Germany, in 1919. Though it
erated for only 14 years before
ng shut down by Hitler, its faculty
d students were responsible for
stallizing a new international
le which radically changed the
aracter of furniture design and
nufacture.

While William Morris and his fol-
vers in the Arts and Crafts move-
ınt turned their backs on
chines and sought to preserve
t which was handcrafted, the
rman strain of this movement be-
ved in combining the talents of ar-
s, architects, and manufacturers/
chinists. In 1919, the Bauhaus
s formed to bring all these ele-
nts of art and commerce
ether.

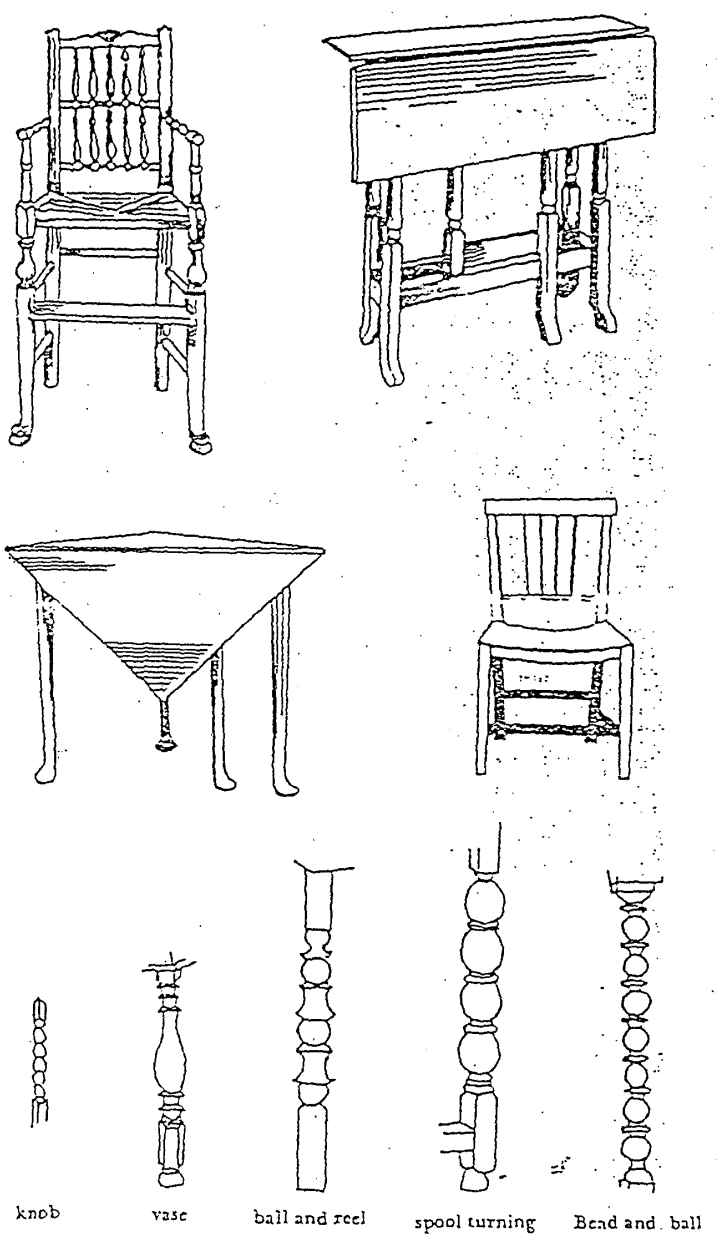
The key words at the Bauhaus
re function and construction.
ılter Gropius, founder and first
ector of the Bauhaus, wanted to
ercome the separation between
s and crafts. His ideal was an ar-
craftsman who could combine
poetic with the practical. Stu-
ıts and teachers studied both de-
n theory and the machinery of
duction seeking always to com-
e art and technology. The results
e functional pieces made of in-
strially - produced materials and
ıracterized by innovative cur-
ıear design.

Perhaps the most widely recog-
ed and enduring examples of
ıhaus design are the chairs of
rcel Breuer and Mies van der
ıe, the last director of the Bau-
ıs school. Breuer's chairs, made
ɔent tubular steel are still being
duced and sought after today.
"Wassily" arm chair, made of
kel-plated steel tubing and
ther is named for the abstract ar-
tist Wassily Kandinsky. His "Cantilever" chair is notable because it was the first to be made of one continuous piece of tubing with no joints. The "Barcelona" chair was designed by Mies van der Rohe for the German pavilion at the Barcelona International Exposition of 1929. It too, continues to be produced today. Featuring x-shaped, chrome-plated, strap steel legs and upholstered cushions and back, the "Barcelona" chair is a classic of Bauhaus design.

The Bauhaus style of the 1920s and 30s, characterized by innovative use of building materials and emphasis on functional needs, led the way in developing design theory for the twentieth century.



ENGLISH COUNTRY



English Country furniture be differentiated from Eng "town furnitu re" by its rela simplicity and functional charac Country designs were most o adapted from furniture styles of wealthy classes and executed readily available woods.

Most foreign influences usu came in through the court and aristocracy, and slowly see down through the country aristo cy to the middle classes (where t existed) or the artisans a tradespeople. In England this s ration process was slow. The lo classes were wedded to the sim forms, and the provincial ge were conservative. Thus, in the glish countryside, oak furnit prevailed throughout the Wal Age.

An interesting aspect of Eng country furniture, is the fact that one piece of furniture was made a single craftsman. There was sawyer who cut the wood, the tu er who turned the arms, legs a spindles on his lathe, the car who decorated the panels a friezes with his carving, and most important of all the joiner, v finished the furniture.

In the early seventeenth centu dining tables, serving tabl benches and stools, storage che and beds were the major furnit pieces. They were made mostly oak. Serving tables, composed o trestle and board set up agains side wall were called 'side-boar

In the 18th century, country t sideboards used oak for details n mally executed in walnut in urb types. These retained some of Jacobean and Queen Anne deta used in the latter.

Some country furniture desig and treatments that marked period were: the simple windsc trestle-foot gateleg, the rush se country chippendale, escritoire, a

ENGLISH COUNTRY

he etagere.

Gateleg tables of the late seven-eenth century had legs that were al-vays 'turned'. There are various inds of turning: baluster, barley-ugar twist, bead and ball, knob, all and reel, and spool. The legs erminated either in small round nobs, or more rarely, 'Spanish' et, which were rectangular ribbed et widening at the base.

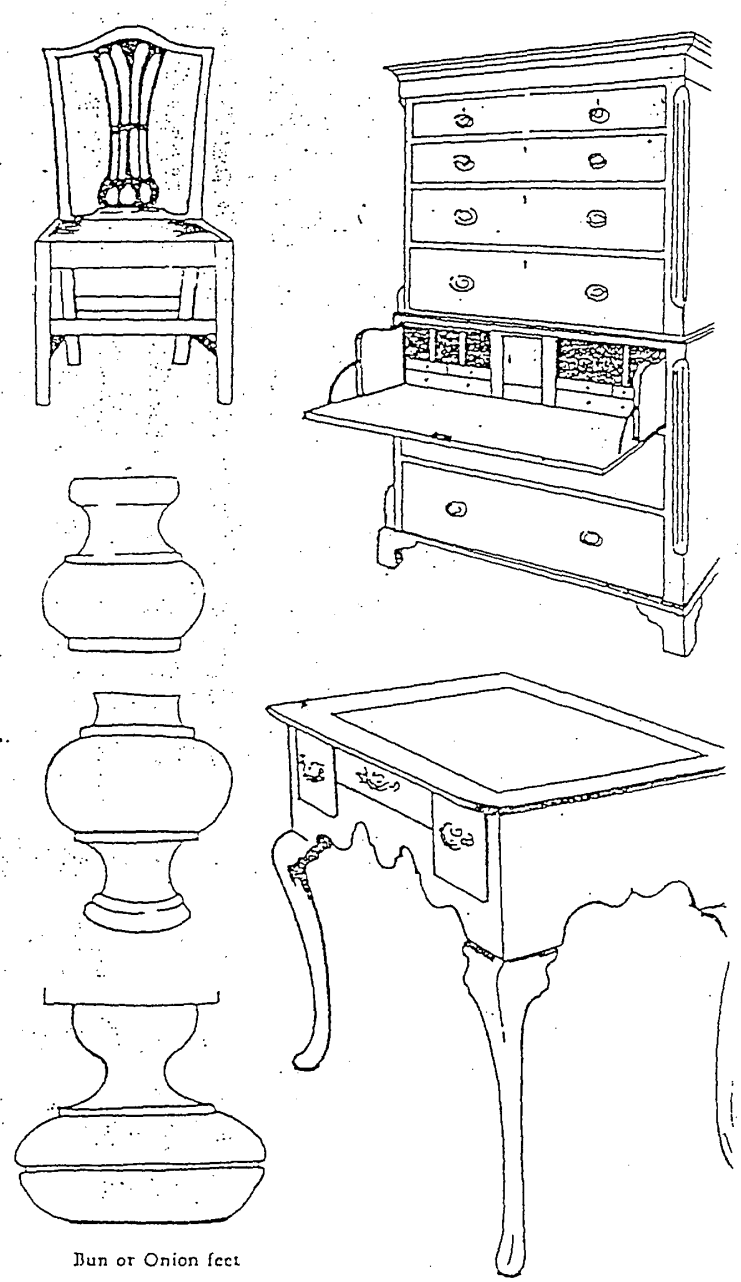
Also produced were yeoman and op-leaf tables. Yeoman tables, are form of small, seventeenth-entury gate-leg with one flap only. nglish country drop-leaf tables had ain rounded legs on club feet, or ibriole legs on spade, pad, or claw id ball feet.

The earliest form of Windsor was e comb-back. Some of the earlier mb-backs had cabriole legs, and de thick seats that looked like a ddle.

Also produced were hoop-back, eel-back, ladder-back chairs and ndsor chairs with generous cabri-e or simply turned legs.

Early seventeenth century beds re made of four simple wooden sts holding the tester from which tains hung. By the eighteenth ntury, beds came to be familiarly own as "Four- Posters", even ugh the only posts that showed re those at the foot of the bed, se at the head being hidden by ngings.

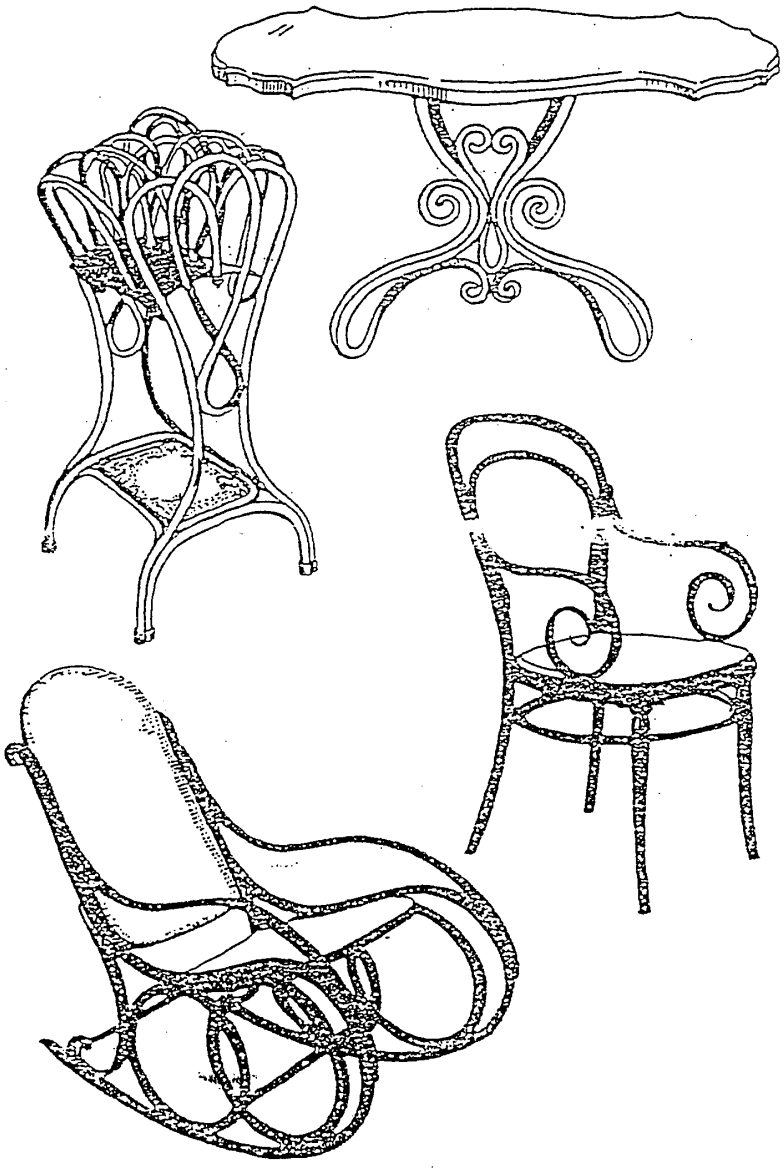
n mid-Victorian times when ises became less drafty, the ter was discarded. The bottom ts were shortened and held a ped foot board. A half-tester at top was substituted, and there e two curtains at the head of the only. About 1820, the foot posts e much heavier and the carving them not nearly so fine. And ie ten years later the half-tester ame more popular than the four ter, and continued to be so until end of the century.



Bun or Onion feet

BENTWOOD/THONET (1830--1871)

In 1830, a German cabinetmaker named Michael Thonet first began experimenting with the process of bending wood to form various chair parts-back rails, arms, legs, etc. By 1836, he had perfected a method of soaking stacks of thin veneer in hot glue to render the wood pliable enough to be molded into bent forms. Thonet was soon



turning out entire chairs ma this fashion. His design was weight, inexpensive and stur was soon to become the cl chair associated with Eurc cafes.

This is how it all began for net, who then founded the furr company in 1853 with his five which became the largest producer of furniture in the w

Thonet manufactured an a ing diversity of furniture: table fas, chairs, bedsteads, mi washstands, clocks, towel r etageres, cradles, wardrobes, brella stands, and many other i for home, office and comm use.

Between 1876 and 1888, se important designs were create the first folding chair, a rocking and the first "tip-up" theater se .Other noteworthy designs inc Thonet's bentwood rocking (perhaps the most famous Thonet chairs): the famous sidechair, considered by man classic bentwood cafe cha reclining couch # 1; many exam of invalid and hospital furni standard furniture in small size children; a variety of non-bentv furniture, including Windsor ch traditional German peasant f ture, and imitation bamboo pie

The Daum chair was later ac to the Thonet catalogues as m No. 4. On November 1, 1853. Gebruder Thonet, Thonet Brot of Vienna, was formed, for his sons. That year they received a perial monopoly patent "for production of chairs and table made of bentwood," which exp in 1869. The largest-selling was model No. 14, one of the plest most understated chairs designed.

Today, Michael Thonet's b wood furniture remains an im tant contribution to design hist and is widely reproduced.

SHAKER

The Shakers, originally a religious sect, founded independent communities in the 19th :entury. They were chiefly rural and :elf-sustaining. Their furniture was :imple and straight forward in de-:ign; soundly constructed, often vell proportioned and charming in letail. Almost unornamented, and ıvariably constructed of local voods such as pine, walnut, maple nd fruitwoods, the Shaker produc-ons are among the best of the rural .merican types.

Many types of wood were used ecause the furniture was made in arious Shaker settlements, scat-ered through the United States om the east coast to the mid-west. lost of the pieces were made from ld-growth pine, but maple, cherry, pple, and pear woods were also sed. Maple was used for pegs, ıobs, posts, rungs and chair slats. herry was the favored wood for ta-e tops, while ash and hickory were sed in the bent pieces such as ckers, rungs, slats, and arms.

One of the chief characteristics of ıaker furniture is that it is light in eight so it can be moved for clean-g. Because their religion required Shaker to attempt perfection at all nes, Shaker furniture could never found with poor finishings, un-ished back wood, sloppy paint, or ıeven parts.

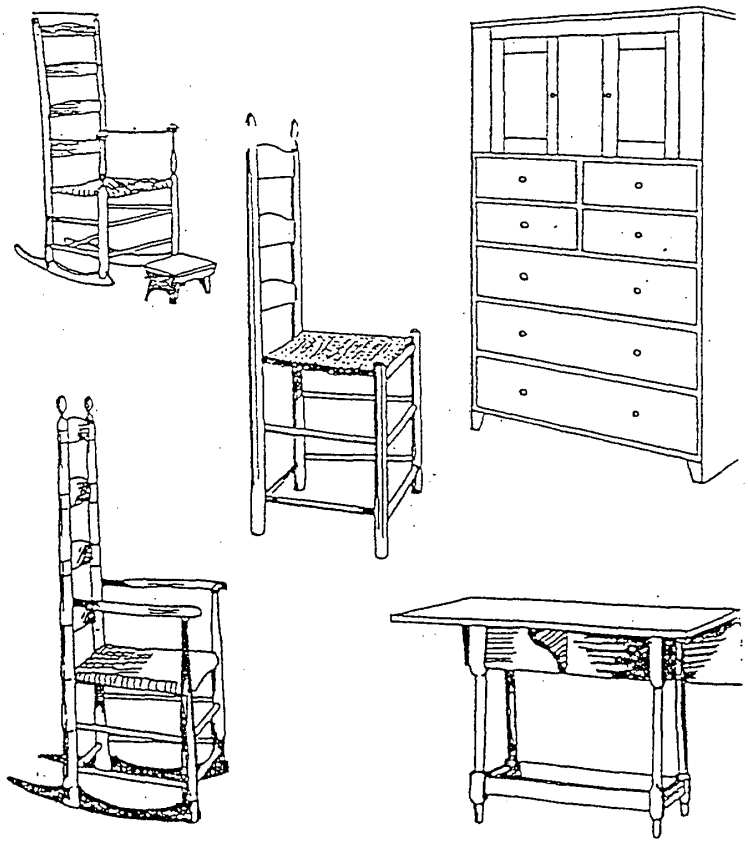
The earliest chairs and tables ere painted or stained red. Later e Shakers used a very light stain that the grain of the wood owed. The earliest chair seats re made of rush, splint, or straw, ıile the later ones used the aracteristic woven tape seats. An sily identified feature is the acorn-aped finial used on the chairs. air legs were tapered, without a t. Rockers were popular. Many of m had a special tilting device in-ıted by the Shakers. Other fea-es of Shaker chairs were drawers lt underneath sewing chairs, and od across the back of the top of chair, which was used for a fold-ed blanket or cushion ties.

Most dining chairs had one slat across the back, and were so low that they could be pushed under the table when not in use. Shaker chairs were made for both men or women, but the sister's chair had a lower seat than the brother's. Rock-ers had straight lines, with taped seats and acorn finials. There were five types of rockers with each one named for its special feature: the scroll-arm, rolled-arm, front-upright with mushroom ends, cross- rail, and armless-sewing rockers.

The Shakers made a trestle-type table with a shoe foot during the 1800-1860 period. They also made a sawbuck table that was used i the kitchen and for ironing.

Shaker chests were made wit simple molded edges. There was n brass hardware. The wooden knob on the drawers were mushroor turned. Sharply angled bracket fee were used, and narrow cupboar doors were held with ingeniou wrought-iron catches. Many of th chests, cupboards, and cabinet were built into the room.

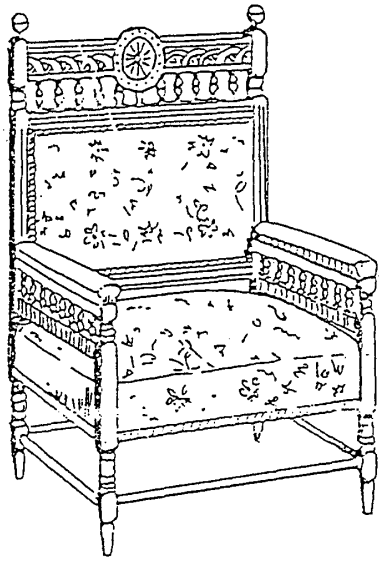
As the religion declined, outsid influences crept into the designs and the lightweight simple lines dis appeared. Today, many companie reproduce Country furniture o Shaker design.



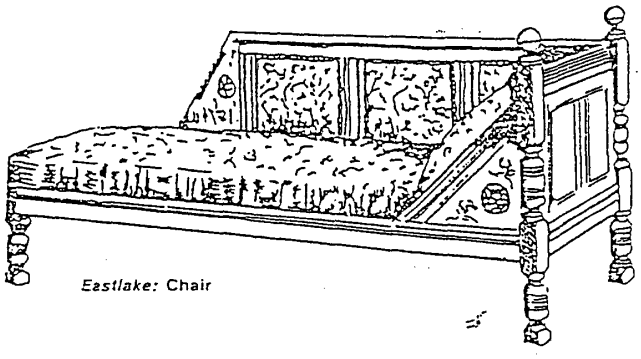
MODERN ROOTS/ARTS & CRAFTS

The arts and crafts movement began partly as a revolt against the social consequences of the industrial revolution and also against the proliferation of Victorian age mass produced furniture whose design and execution was controlled by machinists and industrialists rather than artists and craftsmen.

Later, the lofty goals that inspired the direction of the arts and crafts movement were sublimated as the movement became a style which was widely interpreted by the machinists and industrialists for mass consumption. Still, the ideas of the founders and the principals of good simple design were re-



Eastlake: Lounge



Eastlake: Chair

interpreted later by the Baul school and others who laid the sis for Modern design.

Eastlake: The Eastlake style o niture takes its name from the glish architect, furniture desi and writer Charles Locke East (1836-1906). His book, Hints Household Taste, was publishe London in 1868 and in Boston years later. It produced a revol in design and a revival of h craftsmanship which bec known as the Arts and Crafts M ment. However, it was not only custom designers who were spired by Eastlake's ideas. manufacturers of the mach made furniture which East deplored also copied the East style as it was illustrated in his b

In Hints on Household Ta Eastlake encouraged "honesty construction and finishing. called for hand crafted, solid w furniture with rectangular join He condemned the practice o ing stains and varnishes to disg inexpensive woods, calling inst for oiled, naturally colored finis Eastlake wrote, "The present s tem of French-polishing, or liter varnishing furniture is destructiv all artistic effect in its appearar because the surface of wood t lacquered can never change color, or acquire that rich hue w is one of the charms of old cabi work." The use of rugged woods oak and the elimination of stuck decorations are also characteri of Eastlake furniture. As mentio above, Eastlake also inspired manufacturers of machine-m furniture to explore the decora possibilities of their machines... itating his hand-work with s things as glued on moldings machine-reproduced architect detail.

Eastlake's reforming ideas w particularly inspiring to William M ris, who in turn, became the lea

MODERN ROOTS/EASTLAKE/MORRIS

of the Arts and Crafts movement in England. Sometimes called the "new Renaissance style", "neo-medieval", "plank construction", or "Art Furniture" (a term originated by Eastlake), the Eastlake style was most popular in the 1870s and 80s and became a kind of catch-all term meaning different things to different people. Eastlake himself commenting on his influence in the United States, said, "I find American tradesmen continually advertising what hey are pleased to call Eastlake furniture, the production of which I have had nothing whatever to do, and for the taste of which I should be very sorry to be considered esponsible."

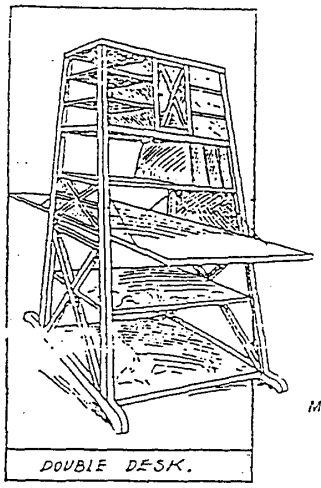
Henry Hobson Richardson, an American architect, was one of the oremost proponents of the Eastlake tyle in the United States. The furniture he designed for the Woburn Public Library and the North Eastern Library in Massachusetts re very similar to pieces which appear in the illustrations to Hints on Household Taste.

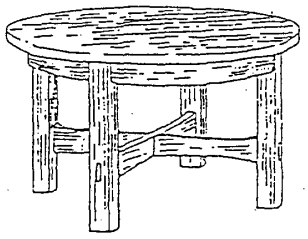
Morris: William Morris 1834-1896 as an English Architect and artist. e founded a movement which ounned the application of technology to the production of inexpensive rniture. Morris' furniture pieces ere simple hand made adaptaons based on medieval crafts.

His view of the value of mass oduction and the evils of industrialization were shared by many of e founders of the modern movement, even though his solution unned the technology which in any ways defined Modernism. orris envisioned a "Socialist" world here artist and craftsman worked harmony using simple methods to oduce basic goods. In contrast, e Modern movement attempted to orm the system by creating good ven progressively social) designs using technology, rather than iding with bad and cheap copies historical designs.

Paradoxically, Morris' furniture was crafted in a manner that made it available only to the very rich. In another twist of fate, his designs were eventually adapted by the commercial establishment who ignored his social credo and creative format. His ideas did help spawn the Arts and Crafts style 1900-1920 and laid the foundation for later work the Modern movement.

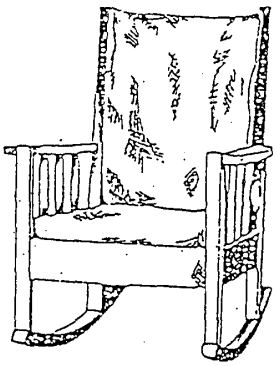
Mission: What came to be know as Mission style furniture, originated in the western United States the mid1890's and was manufactured, mainly in the east, until abo 1915. It has been suggested that all began when members of

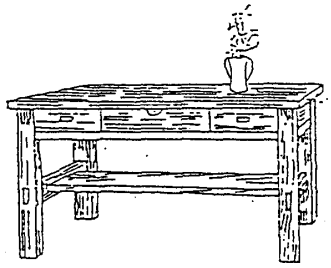




Mission: From FURNITURE WORLD 9/10/1903

Mission: From FURNITURE WORLD 9/10/1903





MODERN ROOTS/MISSION

church in San Francisco were unable to afford to buy furnishings for their church. They decided to build their own, imitating the work of Indian craftsmen who built furniture for the Spanish mission stations in Mexico and in the west and southwestern parts of the U.S. A decorator sent models of the pieces made for the church to Joseph McHugh, a manufacturer in New York, who began to produce his own versions of this solid, simple furniture.

Constructed almost exclusively of weathered or fumed oak, and characterized by straight lines, and mortise, tenon, and dowel joinery, Mission furniture was an American outgrowth of the English Arts a Crafts movement. This moveme emphasized hand crafted piec made of native materials with u polished finishes.

Gustave Stickley, who becar the leading manufacturer of Missi style furniture, introduced h "Craftsman" collection at the fur ture exposition in Grand Rapic Michigan, in 1900. Stickley saw h Mission furniture in opposition to t "reign of marble tops and silk uph stery" of the Victorian era.

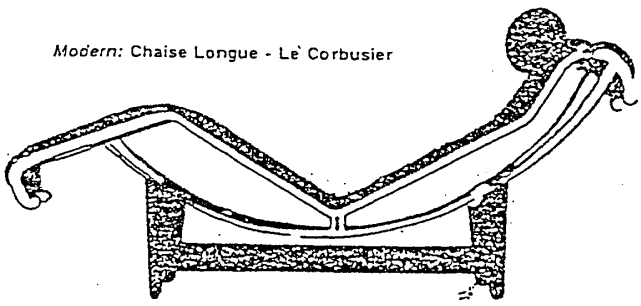
Upholstered pieces were cover with leather. And, while Missi style furniture was usually free of (namentation, large nail heads, sir ple cut out patterns hand-hammered copper appliqu were sometimes used for decor tion. At the height of Mission fur ture's popularity, from 1900 to abo 1912, Stickley established th Craftsman workshops near Syr cuse, New York; the Craftsma Farms in New Jersey; the Craft man Magazine; and the Craftsma Building in New York City, whic contained a home builders' exhib a library and a lecture hall. Elbe Hubbard, a competitor of Stickle established a commune in Ea Aurora, New York, to build Missic furniture and to build the charact of young people who came there work. The English labeled their ve sion of the Mission style "quaint That term is also used in various a vertisements which appeared American newspapers and mag zines in the early 1900s. Othe called their conceptions "Gothic.

The Mission style is not wide sold by today's home furnishing retailers. It is not mass produced f purchase by the gener consumer—it was never meant be. The Stickley Company, st manufactures Mission furniture. can be blended with more conter porary pieces because of its squar clean lines.

Modern: Cantilever Chair - Marcel Bruer

Modern: Pedestal Chair - Eero Saarinen

Modern: Chaise Longue - Le Corbusier



MODERN FURNITURE / INTERNATIONAL STYLE

• BAUHAUS •

Bauhaus literally means "architecture house" and is derived from the German word "bauen" - "to build". The Bauhaus was an art and design academy founded by Walter Gropius in Weimar, Germany, in 1919. Though it operated for only 14 years before being shut down by Hitler, its faculty and students were responsible for crystallizing a new international style which radically changed the character of furniture design and manufacturing.

While William Morris and his followers in the Arts and Crafts movement turned their backs on machines and sought to preserve that which was handcrafted, the human strain of this movement began in combining the talents of artists, architects and manufacturers/machinists. In 1919 the Bauhaus was formed to bring all these elements of art and commerce together.

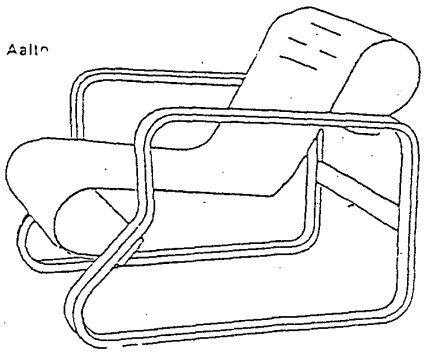
The key words at the Bauhaus were form and function. Walter Gropius, founder and first director of the Bauhaus, wanted to combine the poetic with the practical. Students and teachers studied both design theory and the machinery of production seeking always to combine art and technology. The results were functional pieces made of industrially produced materials, and characterized by innovative current design. Members of the Bauhaus school worked in materials really suited to their conception of the modern age... especially metal, glass and leather. They generally disliked traditional bulky upholstered styles and so replaced stuffing and coil springs with other engineered materials.

The Bauhaus style of the 1920s and 1930s characterized by innovative use of building materials and an emphasis on functional needs, led the way in developing design theory for the twentieth century.

• INFLUENTIAL DESIGNERS •

Marcel Breuer: Joining the Bauhaus as a student, Marcel Breuer distinguished himself as the creator of many innovative and functional modern designs in the 1920s. His work was primarily of bent metal tubing. It had a light, airy, look which was meant to become part of an architectural space rather than the focus of attention. His famous "Wassily" chair of nickel plated steel tubing and leather, named for the abstract artist Wassily Kandinsky, was more complex than many of his other designs. He generally was a minimalist who tried to create furniture which was functional and com

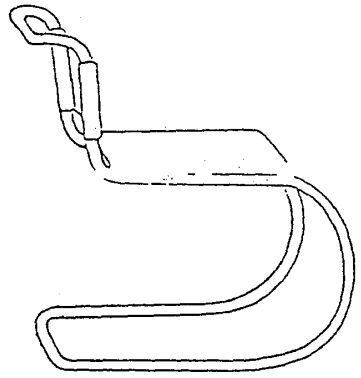
Modern: "Paimo" - Alvar Aalto



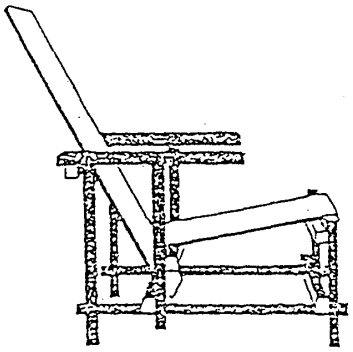
Modern: Eames Lounge - Charles and Ray Eames

MODERN ROOTS / PIONEERS

Modern: Cantilever Chair - Mies van der Rohe



odern: "Red & Blue Chair" - Gerrit T. Rietveld



fortable but did not convey the personality of the owner. True to the Bauhaus school of thought, he worked closely with industry, including the prestigious firm of Thonet (maker of bentwood chairs) to design furniture like his famous cantilever chair which could be easily and economically mass produced. Incidentally, Breuer was not the creator of the cantilever chair concept, an honor which was claimed by the Dutch designer Mart Stam in 1925.

Mies van der Rohe: Another Bauhaus architect and designer, and the last director of the Bauhaus, Ludwig Mies van der Rohe (1886-1969) pioneered the "international style of architecture" which emphasized open interior space and prohibited applied architectural decoration. His chairs often had elegant frames composed of steel tubing. Mies van der Rohe's most famous work, the "Barcelona Chair" was made of chrome plated flat steel configured in an x shape with tufted upholstered cushions. The flat tubing required hand finishing and was more difficult and expensive to manufacture than many other designs originating from the Bauhaus school. He is also known for his own version of the cantilever chair which had a gently curved (instead of rigid angular) elegant looking base.

Le Corbusier: Charles-Edouard Jeanneret (Le Corbusier) 1887-1865, a Swiss born architect is known for the furniture he designed in the mid 1920s... especially his functional metal Chaise Longue which was composed of a contoured lounging surface supported on two adjustable arcs. An admirer of Thonet's bentwood designs, Le Corbusier designed chairs with rotating bases and movable backs, modular "storage walls" and slab tables made of glass.

Charles Eames: Charles E and his wife Ray are best knc their development of the téc gy for commercial product molded plywood chairs in 194 chairs and modular storage u they designed were artistic a as technological and comm successes. The Herman Company worked with Charle Ray Eames to produce ma their best designs.

Eero Saarinen: An architec occasionally designed furr Saarinen was a contempori Eames. His best known cre were upholstered chairs with ed fiberglas shells and m pedestal based furniture. Saa also designed furniture with tu metal, wire mesh and lami wood frames. Many of his p were manufactured by Knoi sociates.

Alvar Aalto: Finnish architect Aalto's (1898-1976) designs marketed by Artek in the U States. Many of his designs laminated birch frames w provided an open, airy suppc structure similar in "feel" to the lar metal frames created by the haus architects. His furniture h sculptural quality and a wa which made it appealing to American consumer of reside furniture.

Rietveld: Gerrit Rietve (1888-1964) sculptural, abs wooden forms are strikingly d ent. He was a member of the Stijl" (Netherlands) school. Sinc believed that the function of f ture changed over time, he disc ed the notion of the Bauhaus sc that "form follows function". Inst he produced designs that were ercises in spatial relationships. were most often painted bl white, yellow, red and blue.

MODERN / POST MODERN / LATE MODERN

The development of "modern style" furniture over the past 100 years has been made possible by the adaptation of new materials and industrial processes to furniture design. The word "modern" is defined as... "of , relating to , or having the characteristics of a movement or style in the arts marked by a break with traditional esp. academic forms and techniques of expression, an emphasis upon experimentation, boldness and creative originality." In keeping with this definition, the emergence of the Modern style era just after the industrial revolution was marked by a profound change in the way furniture was designed... away from adapting machinery to produce approximate often poor quality reproductions of historical styles, toward matching materials and design specifications to the manufacturing process to produce high quality, architecturally appropriate products. The modern movement was also fueled by the new aesthetic and socially progressive ideas of some of its founders.

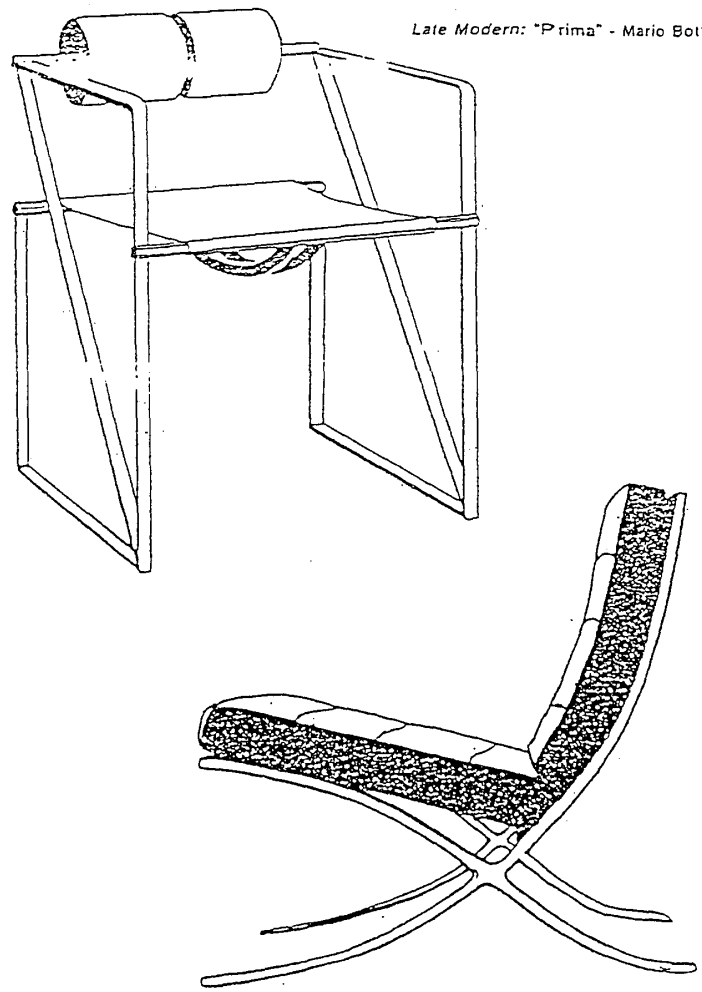
Just as 18th century furniture styles are closely linked to Adams, Chippendale, Sheraton, and Hepplewhite,... Modern design is also associated with pre-eminent individuals. Instead of just using style and ornament as a primary tool, modern furniture designers differed from their immediate predecessors in that they used emerging technology and bold new concepts to define their work. Eames, Thonet, Marcel Breuer and Mies van der Rohe are just a few who conceptualized furniture pieces that have become the "classics" of the Modern idiom. The work of some of these great architect/designers is described in the "Roots" section.

• POST MODERN •

The term Post modern is often used to describe designs that are "modern", architectural or functional in character, but also incorporate references to historical ornament, wild colors, interesting, shocking or strange designs. One of the most famous Post Modern architects Robert Venturi, designed bent plywood chairs that are reminiscent of Sheraton, Queen Anne and Chippendale, but are brightly colored. Post modern designers argue that there is a certain predictability in modern design that can be mitigated by a theatrical approach to design.

• LATE MODERN •

Late modern designs, in contrast



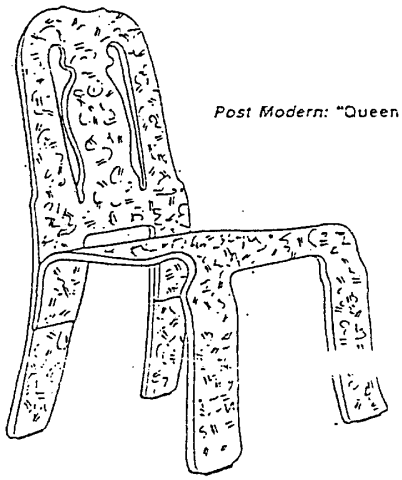
Late Modern: "Prima" - Mario Botta

Modern: "Barcelona Chair" - Mies van der Rohe

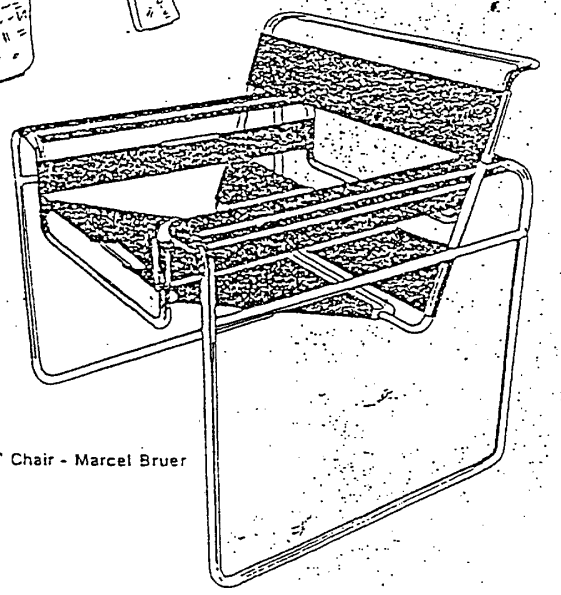
MODERN / CONTEMPORARY FURNITURE

to post modern, are based on simple utilitarian forms, which may employ unorthodox geometry, incorporate a variety of materials and include complex, engineered or luxurious elements.

It is interesting to note that although the founders of the modern movement sought to produce well designed, economical furniture that could be used by the "common man", most "working people" in the industrialized world purchase traditional, carved wood, ornamented, stuffed, and massive furniture for their living rooms. The best market for modern design has always been in the high-end and contract/institutional market. Late modern designs are often designed for this market, and often have no pretense of being designed for economical mass use.



Post Modern: "Queen Anne" - Robert Venturi



Modern: "Wassily" Chair - Marcel Bruer

• HIGH TECH •

High tech designs are based a functionalism derived from the u of cutting edge materials assoc ed with high technology industr such as computer, aerospace or omedical engineering. High Te can be considered a spec category of Late Modern desig

• CONTEMPORARY •

Today, "Modern", "Post Mode and "Late Modern" furnitu been embraced and used most tensively by architects and spec ers in the commercial/ offi contract market. In fact, many chitects and modern style thusiasts view furniture made today's production methods in tra tional styles as being nostalgic a ostentatious. These same peo "look down" on many Contempor designs because they incorpor styling, or fashion treatments wh may not be directly relate function... or forsake function for sake of a sleek "Contempor look".

The Contemporary designat as it is used at retail has becom category which encompasses al the modern styles. It includes fu ture of excellent and poor quality well as good and bad design. F niture labeled Contempora generally makes less of a desigr technological statement than true classics of modern design... stead defining a style which inc porates flat surfaces, straight lir and graceful curves. The utility each piece is usually apparent v incidental details having be reduced in favor of clean lines a attractive proportions. Many C temporary furniture designs inc porate a variety of materials (gla metal, stone) but do not necess ly make use of more technologi ly advanced manufactur processes or materials.

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WOOD PROPERTIES RELATING TO PROCESSING

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1. Introduction

• Wood comes from trees. This is the most important fact to remember in understanding the nature of wood. Whatever quality or shortcomings wood posses are traceable to the tree whence it came. Wood evolved as a functional tissue of plants rather than a material designed to satisfy the needs of woodworkers. Thus, knowing wood as it grows in nature is basic to working successfully with it.
•Understanding cell structure is the key to appreciating what happens when wood is sanded across the grain, or why stain penetrates unevenly, or why adhesives bleed through some veneers but not others.

2. Understanding wood-the nature of wood

• Trees have certain common characteristics. All are vascular, perennial plants capable of secondary thickening, that is, of adding yearly growth to previous growth. The visible portion of the tree has a main supporting **stem or trunk.** If large enough for conversion into sawn-timber or veneer, the trunk is often termed the **bole.** The trunk is the principal source of wood used by woodworkers, although pieces having unusual beauty and utility also come from other parts of the tree.
• At the periphery of the log surface, the bark layer can be recognized easily. Within the bark, and comprising the bulk of the stem, is the wood, which is characterized by its many growth rings concentrically arranged around the central pith. Between the bark and the wood is the cambium, a microscopically thin layer of living cells. The tree stem parts are accumulations of countless cells. The cell is the basic structural unit of plant material. Each cell consists of an outer cell wall surrounding an inner cell cavity.
2.1 Growth rings: Activity of the cambium continuous as long as environmental conditions are suitable and the tree is healthy. In the temperate climate , the characteristic annual cycle includes a growing and a dormant season. In most trees the nature of wood cell formation is similarly cyclic, resulting in visible **growth layers.** These increments are also called **growth rings,** or **annual rings** when formed in associated with yearly growth. Where there is visible

contrast within a single growth ring, the first formed layer is termed **earlywood,** the remainder **latewood.** The terms **springwood** and **summerwood** are also used to indicate these layers but they are misleading in suggesting a correlation with the calendar seasons of the year. In some species no separable earlywood and latewood portions may occur, or the ring may have indistinct or gradual transition from earlywood to latewood. In some tropical areas growth may continue with little interruption, although intermittent rainfall may cause erratic layering of wood.

2.2 Grain □ No discussion of wood can proceed very far without encountering the word **grain.** There are well over 50 ways in which this word can be used in some ten different categories. Examples are as follows:

A. Planes and surface
END GRAIN, LONGITUDINAL GRAIN, SIDE GRAIN, FACE GRAIN, RADIAL GRAIN, TANGENTIAL GRAIN, LONG GRAIN

B. Growth-ring placement
BASTARD GRAIN, PLAIN GRAIN, SIDE GRAIN, EDGE GRAIN, QUARTER GRAIN, SLASH GRAIN, FLAT GRAIN, RADIAL GRAIN, TANGENTIAL GRAIN, MIXED GRAIN, RIFT GRAIN, VERTICAL GRAIN

C. Growth-ring width
CLOSE GRAIN, DENSE GRAIN, NARROW GRAIN, COARSE GRAIN, FINE GRAIN, OPEN GRAIN

D. Earlywood/ latewood contrast
EVEN GRAIN, UNEVEN GRAIN

E. Alignment of longitudinal cells
ACROSS-THE-GRAIN, ALONG-THE-GRAIN, AGAINST-THE-GRAIN, CROSS GRAIN, CURLY GRAIN, DIP GRAIN, GRAIN DIRECTION, INTERLOCKED GRAIN, SHORT GRAIN, SLOPE-OF-GRAIN, SPIRAL GRAIN, STEEP GRAIN, STRAIGHT GRAIN, WAVY GRAIN, WITH-THE-GRAIN

F. Relative pore size
CLOSED GRAIN, COARSE GRAIN, FINE GRAIN, OPEN GRAIN

G. Figure types

BIRD'S-EYE GRAIN, BLISTER GRAIN, COMB GRAIN, CROTCH GRAIN, CURLY GRAIN, FEATHER GRAIN, FIDDLEBACK GRAIN, FLAME GRAIN, LEAF GRAIN, NEEDLE-POINT GRAIN, QUILTED GRAIN, RIFT GRAIN, SILVER GRAIN, STRIPE GRAIN, TIGER GRAIN

H. Machining defects

CHIPPED GRAIN, FUZZY GRAIN, LOOSENED GRAIN, RAISED GRAIN, SHELLED GRAIN, TORN GRAIN, WOOLLY GRAIN

I. Figure imitation

GRAINING, WOODGRAIN DESIGN

J. Surface failure

SHORT IN THE GRAIN.

2.3 Sapwood and heartwood

- **Sapwood** is involved in sap conduction upward in the tree.
- Some nonliving prosenchyma cells are active in conduction, and the living parenchyma cells also store food.
- In the center of the stem, nearest the pith, the prosenchyma cells cease to conduct sap and the parenchyma cells die. The sapwood is thus transformed into **heartwood.**
- The transition to heartwood is also accompanied by the formation in the cell wall of material called **extractives.**
- To the woodworkers, the most significant aspect of heartwood extractives is color, for the sapwood of all species ranges from whitish or cream to perhaps yellowish or light tan. The dark, distinctive colors we associate with various woods- the rich brown of black walnut, or the reddish black striping of rosewood-are the result of heartwood extractives.
- Sapwood is not generally resistant to fungi, so any noteworthy decay resistance of a species is due to extractives that are toxic to fungi.
- Heartwood extractives may change the properties of the wood in other ways as well, In some species, they reduce the permeability of the wood tissue, making the heartwood slower to dry and difficult or impossible to impregnate with chemical preservatives.
- Extractives often make the heartwood a little denser than the

sapwood, and also a little more stable in changing moisture conditions. Though when green, sapwood sometimes contains moisture five times as much as heartwood, it shrinks more than heartwood because of its lack of extractives.
-Extractives materials in the heartwood of some species may be so abrasive that they dull cutting tools, and they may contribute to the wood's surface hardness. But as sapwood becomes heartwood, no cells are added or taken away, nor do any cells change shape. The basic strength of both is not affected.

2.4 Structural arrangement

Because of the arrangement of the layers of growth in the tree, as well as the vertical or horizontal orientation of the individual cells, it is appropriate to consider the structure of wood in three-dimensional terms.

-Transverse plane, cross-sectional plane: One plane is perpendicular to the stem axis. **(X)**

-Longitudinal plane, vertical plane (L)

-Radial plane: Because the tree cross section is analogous to a circle, plane passing through the pith of the wood (as a radius of the circle) is called radial plane or surface. **(R)**

-Tangential plane: A plane parallel to the pith, but not passing through it, forms a tangent to the circular growth ring structure and is termed a tangential plane or surface. **(T)**

- In describing lumber or pieces of wood, the term **end-grain surface** or simply **end grain** refers to the transverse surface. By contrast, any plane running parallel to the pith is either **side grain** or **longitudinal surface**. One method of producing such pieces is first to saw the log into longitudinal quarters and then to saw each quarter radially. Pieces so produced are said to be **quartersawn** and their surfaces are **quarter-grain, comb grain or rift grain.** These terms are flexible and may be applied to pieces in which the growth rings form angles of anywhere from 45 to 90 degree with the surface.
- Lumber and veneer whose face orientation is approximately tangential are said to be **flatsawn, flat-grained** or **tangential-grained. Plain grain** and **slash grain** are sometimes used synonymously with flatsawn. All these terms can include

growth-ring orientations from 0 to 45 degree with the surface.

- The term **mixed grain** refers to quantities of lumber having both edge-grain and flatsawn pieces. **Bastard grain** usually refers to growth rings oriented from 30 to 60 degree with the surface.

2.5 Density and specific gravity

- **Density** is expressed as weight per unit volume, customarily as pounds per cubic foot (English) or grams per cubic centimeter (metric). Water has a density of 62.4 lb/ ft^3, or 1 g/ cm^3.
- **Specific gravity** is the ratio of the density of a substance to the density of a standard substance (water, in the case of wood and other solids). It is often called the **density index**.
- In measuring density and specific gravity, it is customary to use oven-dry weight and current volume. Because of volumetric shrinkage and swelling, the volume of wood may vary slightly with moisture content.
- Density is the single most important indicator of strength in wood and may therefore predict such characteristics as hardness, ease of machining and nailing resistance. Dense woods generally shrink and swell more, and usually present greater problems in drying. The densest woods also make the best fuel.

2.6 Systematic classification

Kingdom: Plant
Division: spermatophytes (seed plants)
Subdivision: gymnosperms (naked seeds)- all trees producing **softwood** lumber.
Angiosperms (covered seeds)-all trees yielding **hardwood** lumber.
Order: ex: coniferales
Family: ex: *Pinaceae*
Genus: *Pinus*
Species: *strobus*

A particular species of wood is designated by the combination of **genus** (generic name) and **species** (specific epithet) . –*Pinus strobes*
for eastern white pine. A full scientific designation includes the name

(or abbreviated name if well known). of the botanist who classified the species. Eastern white pine would be written *Pinus strobes L.* Familiarity with scientific names is important for two reasons. First, there is often a difference between the common name used for a tree and lumber that comes from it. Second, there is a great deal of inconsistency among common names. A single species may have several common names, especially in different localities.

2.7 Figure in wood

Figure in wood results from a combination of particular anatomical features (from normal growth structure to various abnormalities and extractives) plus the orientation of the surface that results from cutting.

2.8 Knots

- Increase value: beautiful works of craftsmanship and art
- Decrease value : defects,(A) lumber grading system based on their size and number of clear areas among the knots.(B) hand tools could not deal with them.

2.9 Abnormal wood

-Juvenile wood : The first growth rings added around the pith may not be typical of the mature wood formed by the tree. This core of atypical tissue is termed juvenile wood. It is prevalent among conifers, especially plantation-grown trees, which grow rapidly until eventual crown closure. Then competition with other trees slows the growth to a more normal rate.

-Juvenile wood is characterized by wider growth rings of lower-density wood and less strength. It may also have abnormal shrinkage properties which result in greater tendency to warp, especially by twisting. Pieces of wood including (or very near) the pith should be suspect. Some trees and species show little or no juvenile-wood abnormality.

-Reaction wood is a term applied to abnormal wood formed in tree stems and limbs that are other than erect, that is, parallel to the pull of gravity. It occurred in leaning trunks. Causes for leaning stems

include partial uprooting by storms, severe bending under snow or ice, and tree growth toward sunlight available from only one direction. Reaction-wood formation seems to include a mechanism for redirecting stem growth to the vertical, resulting in a bowing of the stem. Therefore, boards or pieces from a log with noticeable bow should be suspected of containing reaction wood.

In softwood species, reaction forms principally toward the underside of the leaning stem. Because the pull of gravity presumably puts the lower side of the leaning trunk in compression, reaction wood in conifers is termed **compression wood**. The part of the growth ring containing reaction wood is usually wider than normal, resulting in an eccentrically shaped stem with the pith offset toward the upper side. The abnormal tracheids usually appear to form wider than normal latewood, and uneven grain formed.

The two main disadvantages of compression wood for the woodworker are its effects on strength and shrinkage. Since reaction –wood tracheids are thick-walled, the wood is usually dense than normal. But because they contain less cellulose than normal, and the cellulose chains are not as parallel to the long direction of the cells, the wood is weaker than normal. The woodworker is especially aware of the abnormally hard but brittle quality of compression wood. In finishing, compression wood may not stain uniformly with normal wood. The carpenter notices the difficulty in driving nails and the greater tendency to split. For structural uses where load-bearing capacity is vital, as in ladder rails, unknowing use of reaction wood has resulted in fatality, because the wood breaks suddenly when bent and at lower than expected loads. The second major problem with compression wood is its abnormal longitudinal shrinkage. Normal wood shrinks so slightly along the grain that it is usually negligible. Compression wood shrinks up to 10 to 20 times the normal amount. And, since its uneven shrinkage, drying of reaction wood or changes in moisture content often result in warp. In woodworking, attempts to ripsaw pieces containing reaction wood may result in the wood's pinching against the saw or its splaying widely apart as the cut progresses.

In hardwood trees, reaction wood forms predominately toward the upper side of the leaning stem. Because gravity causes the upper side to be tension, it is termed **tension wood**. It is often quite difficult

to detect. Its abnormal fibers actually contain a greater than normal amount of cellulose. This wood is commonly stronger than normal. Often concern to the woodworker is the way this wood machines. Fiber structure does not sever cleanly but leaves a fuzzy or woolly surface. Upon finishing, stain is absorbed irregularly and the surface appears blotchy. As with compression wood, longitudinal shrinkage in tension wood is both irregular and greater than normal, resulting in warping and machining problems.

2.10 Fungi and Insect damage

Wood kept under favorable conditions apparently lasts indefinitely-artifacts in excellent condition have been recovered from ancient Egyptian tombs.

Biodegradation of wood is accomplished in part by insects and marine borers, but the greatest degree of deterioration is the work of **-wood-inhibiting fungi**.

There are four basic requirements for wood-inhibiting fungi to thrive. Fungi can be controlled by rendering any one of these unsuitable.

(A) Temperature is the first condition- between 75 □ and 90 □ is optimum. Beyond the extremes of 40 □ and 105 □, growth essentially stops.

(B) Fungi also need oxygen. Waterlogged wood does not decay because of the absence of oxygen. Approximately 20% air volume in the wood is needed for fungi development.

(C) Moisture content is also a factor. The optimum level is at or slightly above the fiber saturation point(about 30%), in which the cell walls are saturated but the cell cavities are essentially empty. Fungi can develop at MC as low as 20%. Drying wood quickly down to below 20% MC and keeping it dry is the principal way to prevent fungal deterioration, and one of the main reasons for drying wood is to prevent fungi from developing.

(D) Food is the fourth requirement. The sapwood of most species is suitable, both because it lacks extractives and because it contains carbohydrates stored in parenchyma cells. The heartwood may be naturally decay-resistant if extractives are toxic or repellent to fungi. Woods vary considerably in decay resistance or durability. Where it is impossible or impractical to keep wood below 20% MC,

the next best approach is to choose a durable wood, or wood that has been impregnated with a chemical preservative. The subject of fungi control also have to do with drying wood, with finishing and treating it.

3. Water and wood

-Everyone has been introduced to the interaction of water and wood, for everyone has seen the problems that result when wood shrinks and swells. The bureau drawer that slides freely in dry season but sticks tightly in rain season is an all too familiar example of dimensional response of wood to changes in atmosphere humility. Warp and surface checks in lumber, loose tool handles and out-of-round turning are also common symptoms. Although other consequences of moisture- such as fungal discoloration or gluing failure- can plague the woodworker, dimensional problems are by far the most common and troublesome.

-Wood in trees is wet. Very wet. The cell structure contains excessive water(sap) and is fully swollen. But under conditions where wood is commonly used, much of this water will dry out and the wood will partially shrink. Eventually a fluctuating moisture balance between the dryness of the wood and the humidity of its environment will be reached. The obvious goal is twofold: first, to dry wood(and thereby preshrink it) to a moisture content with its eventual environment, and second, to control any subsequent gain or loss of moisture in order to minimize dimensional change. To overcome problems, the woodworkers must understand the initial drying of sap from freshly cut wood, as well as the continuing exchange of moisture between the wood and the surrounding atmosphere.

3.1 Moisture content (MC)

The MC of wood is measured as the ratio of the weight of water in a given piece of wood to the weight of the wood when it is completely dry. The water-free weight of wood is usually referred to as the oven-dry weight, because drying in an oven is a common method of obtaining it. This ratio is traditionally expressed as

percent moisture content.

3.2 Relative humidity(RH)

-Humidity is a general term referring to water or moisture in vapor form in the atmosphere.

-Absolute humidity refers to the actual quantity of moisture present in air. This is usually expressed in grains per cubic foot [1 grain = 1/7000 lb. advp.(avoirdupois).] or in grams per cubic meter. The amount of water the air can hold varies with temperature. At 70 □, for example, the air can hold a maximum of 8 grains of moisture per cubic foot.

-Relative humidity(RH) is the ratio of the amount of moisture in the air at a certain temperature to the amount it would be able to hold at that temperature. If the air at 70 □, for example, held 4 grains of water per cu. Ft., the RH would be 50%, because the air is capable of holding 8 grains at 70 □. The **dew point** is the temperature at which water vapor condenses from the air. In buildings we routinely manipulate nature's air, mainly by heating it up when it is too cold, to a lesser extent by cooling it, and least of all by adding or subtracting moisture from it. It is important to realize the effect of our heating or cooling air without accompanying humidification or dehumidification. Heating air increases its ability to hold moisture. If we increase the temperature of air while the absolute humidity is unchanged, the relative humidity will be lowered. In subzero winter weather, outdoor air has a low absolute humidity as it seeps into our homes. When we heat it to near 70 □ without adding moisture, the RH drops very low. Conversely, summer air usually holds an abundance of moisture because of is high temperature. If we cool the air, thus reducing its capacity to hold moisture, the RH(which may be high to begin with) rises even higher.

3.3 Free water and bound water

The liquid content of the living trees, call **sap**, is primary water, but also contains dissolved minerals, nutrients from the soil and carbohydrates manufactured by the foliage. For our purposes we can consider moisture or water in wood to mean either the original sap of the tree or water from other sources that is subsequently

picked up by dry wood. Water can return to wood from countless sources, ranging from rain to the moisture in humid air.

To visualize the condition of moisture in the wood of a standing tree, imagine a sopping-wet sponge just pulled from a pail of water. The sponge is analogous to growing wood in that the cell walls are fully saturated and swollen and the cell cavities are partially to completely filled with water. If we squeeze the sponge the water pours forth. Similarly the water in wood cell cavities, called **free water**, can be squeezed from wood.

Now imagine thoroughly wringing out a wet sponge until no further water is evident. The sponge remains full-sized, flexible and damp to the touch. In wood, the comparable condition is called the **fiber saturation point(FSP)**. In this state, the cell cavities are emptied of free water, but the cell walls are still saturated and thus still in their weakest condition. Only when water leaves the cell walls does the wood begin to shrink and increase in strength.

This water remaining in the cell walls is called **bound water**. In contrast to free water, which is held in cell cavities like water in a tumbler, the bound water is held by physical forces of attraction within the cell walls. Just as a sponge must be left to dry—and shrink and harden—so must the bound water be removed by placing the wood in a relative dry atmosphere. How much of the bound water is lost(and therefore how much shrinkage takes place) will depend on the RH of the atmosphere. If the air is at 100%RH, no bound water will be lost. To remove all the bound water, the wood would have to be placed in an oven or desiccator, or in a vacuum where the RH is zero. Obviously, we use wood where the RH is somewhere between 100% to zero, so only part of the bound water is lost.

- The **FSP** may vary among different species. In general, its value for most common species is about 30% MC. In species having a high extractive content(for example, redwood and mahogany) the FSP will be noticeably lower, around 22% to 24%. For those low in extractives such as birch, the FSP might range as high as 35%.

3.4 Equilibrium moisture content (EMC)

Wood always remains hygroscopic—it responds to changes in

atmospheric humidity and loses bound water as the RH drops, regaining bound water as the RH increases. For a given RH level, a balance is eventually reached at which the wood is no longer gaining or losing moisture. When this balance of moisture exchange is established, the amount of bound water eventually contained in a piece of wood is called the **EMC** of the wood. This is the most important item in this section. A good starting point is to remember that 50%RH gives an approximate 9% EMC. Then note that 65%RH gives about 12% EMC, 75%RH gives about 14% EMC. And 100%RH always gives total fiber saturation. Temperature also has an effect upon EMC. EMC data mentioned above is for 70 □, but at intermediate levels the EMC would be about one percentage point lower for every 25 to 30 □ elevation in temperature.

In addition, when wood is losing moisture(desorbing) the EMC curve is slightly higher than when the wood is picking up moisture(adsorbing). This is called the **hysteresis effect.**

Depending on the degree of environmental control, especially the extent to which we heat during the winter, humidity can vary widely indoors. In summer, with doors and windows open, interiors may approach outdoor conditions. In winter, when buildings are heated, we reach the low extreme. If its RH drops to 6%, that surfaces of unprotected wood or thin veneers would drop to below 2% MC. Undoubtedly, humidifiers and the domestic activities of cooking, washing and even breathing add some moisture to the air, not to mention the moisture being released by the wood itself. In summer the situation is reversed. The humidity could approach 100%. The MC of wood may raise to 23%. And this situation is probably typical of many areas of the country where summers are warm and humid and winters are bitter cold. It is important to realize that if the absolute humidity of air is unchanged, lowering the temperature of the air raises the relative humidity and heating the air lowers the relative humidity.

As will be emphasized again in discussing shrinkage, such seasonal extremes must be averaged. The low moisture conditions associated with winter, spring and fall weather seem to outweigh the effects of short-term, high-humidity summer extremes. Thus 7.5% to 8.0% MC is an appropriate average for this kind of area. To bring

wood to such low levels it must either be stored indoors or dried in a kiln. Since the latter is the usual practice, the term **kiln-dried** usually means dried to a level appropriate for interior use. To the cabinetmaker, then, kiln-dried suggests a moisture content of below 10%.

In structure lumber, however, **air-dried** levels of moisture content are considered adequate. In this context, kiln-dried may mean 19% or less. In some cases, structural lumber is kiln-dried mainly to reduce its weight for more economical shipping, to kill fungi or other wood-destroying organisms, or simply to speed up the drying process, even though the final MC may be scarcely below the FSP. So the term kiln-dried alone should not be blindly interpreted to indicate any particular moisture content.

One of the more unfortunate yet common fallacies is that kiln-drying leaves wood irreversibly dry, and that once dried the wood somehow becomes dimensionally stable. In reality, if dry wood is stored under relatively moist conditions, bound water will be re-adsorbed to the EMC.

When we deal with modified wood products, such as particleboard, hardboard or decorative laminates, the adhesives and other additives involved as well as the heat applied in manufacture may influence the EMC considerably. For example, at a relative humidity of 40%, where wood might come to an EMC of about 7.5%, particleboard might average 7%, hardboards 5% and decorative laminates as low as 3.5%. Even among different species, the EMC at 40% RH may vary from 6.5% to 8.5% MC. Someone once suggested the concept of thinking of an **equilibrium relative humidity(ERH)** rather than an **equilibrium moisture content(EMC),** to emphasize the fact that relative humidity determines EMC, not the other way around. It is prudent to think that ' my lumber should be at equilibrium with 40% RH" rather than that ", my lumber should be at 7.5% MC".

3.5 Green vs. air-dried vs. Kiln-dried

-In general, the hardwoods have initial moisture contents in the 60% to 100% range. In soft species, the general case seems to be that the heartwood has a fairly low moisture content, often scarcely above the FSP, while the sapwood is considerably higher. Among the

lower-density species such as balsa or even pine, the sapwood MC often exceeds 200%.

-There is considerable confusion over the meaning of the word **green** in reference to wood. It is often used to indicate the condition of **freshly cut** wood from a living tree. But because most properties of wood are unchanged regardless of the amount of free water it contains, we consider **any wood above the FSP as green**, even when the condition has been restored by wetting previously dried wood.

-Exposed to outdoor conditions, wood will lose its free water and eventually become **air-dry.** This term is used in many confusing ways, but should generally be taken to mean that the MC is in equilibrium with the outdoor atmosphere of a particular area. The amount of time to air-dry of course depends on the species, the thickness, the weather conditions and so forth.

-The term **kiln-dried** usually means dried to a level appropriate for interior use. To the cabinetmaker, then, kiln-dried suggests a MC of below 10%. In structural lumber, however, air-dried levels of MC are considered adequate. In this context, kiln-dried may mean 19% or less. In some cases, structural lumber is kiln-dried mainly to reduce its weight for more economical shipping, to kill fungi or other wood-destroying organisms, or simply o speed up the drying process, even though the final MC may be scarcely below the FSP. So the term kiln-dried alone should not be blindly interpreted to indicate any particular moisture content.

4. Dimensional change in wood

4.1 Shrinkage and swelling

-Wood shrinks or swells due to loss or gain of bound water from the cell walls. The amount of movement varies according to the orientation of the wood cells and is usually measured separately in the three principal directions: tangential, radial and longitudinal. The total amount of linear shrinkage that takes place in a given direction from the green to the oven-dry condition is customarily expressed as a percentage of the green dimensions. This total shrinkage is figured as follows:

$S = (Dg - Dod)/Dg \times 100$

Where S = the total shrinkage, in percent(St = tangential shrinkage, Sr = radial shrinkage, Sl = longitudinal shrinkage, Dg = green dimension, Dod = oven-dry dimension.

-**Total shrinkage of wood along the grain is normally only about 0.1%.** In normal wood, longitudinal shrinkage is considered negligible. In juvenile wood or in reaction wood, longitudinal shrinkage can be as much as 2%, about 20 times that of normal wood. Abnormal wood usually develops unevenly in severity and distribution, and the resulting uneven longitudinal shrinkage may cause severe warping. In practice, however, we usually can forget about the longitudinal shrinkage of normal wood.

-Transverse shrinkage, on the other hand, is significant. The shrinkage values show considerable difference among different species. Tangential shrinkage is always greater than radial. Tangential shrinkage ranges from 4% in teak to 12.7% in overcup oak, with an overall average of 7.95%. Radial shrinkage values range from 2.2% for teak or redwood to 8.5% for eastern hophornbeam, averaging 4.39%. **It is reasonable to think of wood as having roughly 8% tangential shrinkage and 4% radial shrinkage.**

- Over the entire range of moisture content- from FSP to oven-dry – shrinkage is approximately proportional to moisture loss.

4.2 Estimating shrinkage and swelling

A way to estimate the shrinkage, once we know the EMC, is by the formula: □D = Di S (□MC/fsp)

Where □D = change in dimension due to shrinkage

Di = initial dimension

S = total shrinkage percentage. From lab. Data, use St (tangential shrinkage) for flatsawn, Sr (radial shrinkage) for edge-grain lnmber

□MC = change in moisture content

fsp = fiber saturation point(average value = 28%)

(In using the formula, remember that 8.6% means 0.086)

- Since the formula applied only to moisture gain or lose below FSP, no values above FSP should be considered.

-Because the shrinkage percentages are based upon shrinkage from the green condition, the above formula is accurate only for shrinkage starting from the green condition, as in the original computation. For shrinkage of wood starting at a partially dry

condition, the above formula will introduce an average error of about 5% of the calculated change in dimension. Therefore, a more refined estimate is desirable, the following formula should be used: □D = □Di (MCi □ MCf)□+□fsp/S□fsp□MCi□

Where MCi = initial MC

MCf = final MC

4.3 Uneven shrinkage and swelling

-Change in dimension is only one consequence of shrinkage or swelling. Even more serious effects may result when shrinkage or swelling is uneven throughout the piece even though it is very small in magnitude. **Warp**, which is the distortion of a piece from its desired or intended shape, usually results from variable shrinkage that causes stress in the piece. **Cup** is a form of warp that is characterized by deviation from flatness across the width of a board. **Bow** is deviation from lengthwise flatness in a board. **Crook** is departure in end-to end straightness along the edge of a board. **Twist** signifies that the four corners of a flat face lie in the same plane. **Kink** describes a localized crook, due to a knot.

-When uneven shrinkage causes stress that exceeds the perpendicular-to-grain strength of the wood, separation of cells occurs along the grain. Such failures are termed **checks.** Although most common on the surfaces and ends of pieces, they may also occur internally. A square or rectangular piece with diagonally orientation growth rings will shrink twice as much across one diagonal than the other, distorting the board into a diamond- the term diamonding designates the effect.

-Probably the most familiar manifestation of shrinkage is the radial **cracking** of logs or log sections caused by the stress resulting from greater tangential shrinkage, which cannot be accommodated by distortion alone. The stress eventually becomes great enough to crack the wood radially.

Sometimes a disc can be dried without cracking. Success is favored by a number of factors. Species with low shrinkage percentage and low tangential-to-radial shrinkage ratios are better prospects.

4.4 Perpendicular-to-grain vs. parallel-to-grain

-A second type of dimensional behavior that causes problems is the

wide discrepancy between perpendicular-to-grain dimensional movement and the nearby negligible longitudinal instability. A classic problem is the mitered joint. The joint opens on the outside in summer humidity, and no the inside in winter dryness. This one is familiar because it is out in plain sight. But a hidden example of problems caused by differences in longitudinal and transverse shrinkage is the mortise-and-tenon joint.

-Wobbly chairs are caused principally by the difference between the dimensional change of a mortise and the dimensional change of a tenon. The simplest joint is a round tenon in a drilled hole or mortise, as in the insertion of a chair rung into a chair leg. Perpendicular to the grain direction of the chair leg, the tenon and the hole shrink and swell by about the same amount in diameter. In the direction of the leg the hole is virtually stable; the rung, however, will have pronounced dimensional response, especially if the growth ring orientation of the rung is vertical in the joint.

4.5 Uneven drying

-A third cause of dimensional troubles is uneven shrinkage due to uneven drying. A familiar case is when a pile of air-dry lumber is brought into a heated building. Cupping soon develops on the top boards as the exposed faces dry and shrink first. The cupping back and forth of a tabletop finished only on the upper face is another common example. But perhaps the most universal problem is **end-checking**. Water moves longitudinally through wood 10 to 15 times faster than it moves perpendicular to the grain. Therefore, end-grain surfaces rapidly lose their moisture and will be first to drop to below FSP and begin to shrink. If the shrinkage exceeds about 1.5%, tension failure in the form of end-checking may occur. Therefore, drying from the board should be uniformly slow because most molecules will escape through the side grain. The objective of end-coating boards with sealers is to prevent rapid end-drying and create uniform side-grain drying right to the end of the board.

4.6 Variation in shrinkage properties

-A fourth category of troublesome uneven shrinkage results when shrinkage properties vary within a given piece of wood- a characteristic of juvenile and reaction wood. Typically, the severity of

reaction wood varies within a given piece, or it may even be combined in the piece with normal wood. Bow and crook are commonly traceable to such variable longitudinal shrinkage. Twist is sometimes the result of uneven reaction wood formation but most pronounced twist is usually associated with spiral grain. Those boards that form veritable propellers are usually caused by spiral grain.

-In some species, extractives may significantly reduce shrinkage of heartwood as compared to sapwood. Such differences between dimensional change may also produce troublesome results in boards. The sapwood/heartwood shrinkage difference is also responsible in part for the uneven thickness variation. In any case, the practice of matching sapwood to sapwood and heartwood to heartwood is a logical one.

5. Coping with wood movement

-Preshrinking wood by seasoning, as obvious as it is, is too important to pass over lightly. Although wood is dried for many reasons (to reduce weight, to prevent deterioration by fungi, to increase strength, to permit gluing and finishing) the principal objective is to have shrinkage take place before rather than after the final product is completed. The key to this approach is drying the wood to a moisture content consistent with the average relative humidity in which the finished piece will be used.

-Preshrinking wood is one thing, keeping it there is another. Careful attention must be given to the second basic consideration-**atmospheric control**. Air conditioning is effective, but not always possible or even sensible, except for priceless museum objects and the like. Another approach is to control humidity through **isolation**, by keeping the wood in a reasonably air tight container. This may be a small display box, a glass jar, a plastic bag or simply a coat of finish.

-As a companion to proper preshrinking, an effective finish is the most relied-upon approach to minimizing dimensional response in our variable atmosphere.

-**Mechanical restraint**

-Cross-ply construction of plywood

-Balanced construction

-Chemical stabilizing

6. Water gradient and drying stress

-**Moisture gradient:** Water in wood normally moves from zones of higher to zones of lower moisture content. This fact supports the familiar statement that " wood dries from the outside in," which means that the surface of the wood must be drier than the interior if moisture is to be removed. In drying, the surface fibers of the heartwood of most species attain moisture equilibrium with the surrounding atmosphere almost as soon as drying begins, and at this time a **moisture gradient** begins to develop.

-**Casehardening** is the inevitable result of the drying stresses associated with shrinkage- the stresses persisting when the wood is uniformly dry. Whether or not it is considered to be a defect depends on the final use of the dried material. Casehardening can be relieved in a compartment dry kiln by a conditioning treatment.

7. Equalizing and conditioning treatment

-Frequently the moisture content varies considerably among boards in a kiln charge during the final stage of drying. Such variation may cause serious trouble during storage, fabrication, or use. Also, satisfactory relief of drying stresses(casehardening) of all boards in a charge cannot be obtained if the MC varies too much. Therefore, use an **equalizing treatment** to overcome excessive variation in MC near the end of drying.

-If the boards are to be re-sawed, ripped into thin strips, or machined non-uniformly, use a **conditioning treatment**. Such a treatment accomplishes two things: it relives drying stresses, and it produces a more uniform moisture content throughout the thickness of the boards. Drying stresses and non-uniformly of moisture can result in serious deformation during fabrication and use.

7.1 Equalizing treatment

-The procedure for equalizing a kiln charge of lumber is as follows:
(1) Start equalizing when the driest kiln sample in the charge has reached an average moisture content 2 % below the desired final

average moisture content. If, for example, the desired final average moisture content is 8%,equalizing would be started when the driest kiln sample reaches 6%. (2) As soon as the driest sample reaches the moisture value stated in step 1, establish an equalizing EMC in the kiln equal to that value. In the example given in (1), the equalizing EMC would be 6%. During equalizing, use as high a dry-bulb temperature as the drying schedule permits.

(3) Continue equalizing until the wettest sample reaches the desired final average MC. In the example given in step 1, the wettest sample would be dried to 8%.

- If the equalizing treatment is to be followed by a conditioning treatment, it may be at times be necessary to lower the temperature to obtain the desired conditioning EMC condition. When this is necessary, begin lowering the temperature 12 to 24 hours prior to the start of conditioning. Also lower the wet-bulb temperature to maintain the desired equalizing EMC.

7.2 Conditioning treatment

-The conditioning treatment, whether or not preceded by an equalizing treatment, should not be started until the average MC of the wettest sample reaches the desired final average MC.

-The procedure for conditioning a kiln charge of lumber is as follows:

(1) The conditioning temperature is the same as the final step of the drying schedule or the highest temperature at which the conditioning EMC can be controlled. For softwoods set the wet-bulb temperature so the conditioning EMC will be 3 % above the desired final average MC. For hardwoods the conditioning EMC is 4 % above the desired final average MC. For example, assume that this case involves a hardwood, a final desired MC of 8 %, and a conditioning temperature of 170□. The conditioning temperature EMC is 12%. At 170□, an 8 degree wet-bulb depression will give an EMC of 12.4%. If the material was a softwood, the conditioning EMC would be 11% and the wet-bulb depression 10 degree.

(2) continue conditioning until satisfactory stress relief is attained.

-Method of cutting specimens for casehardening tests, material that is less than 1 1/2 inches thick is cut into three prongs, and the middle prong is removed, material that is 1 1/2 inches or thicker is cut into six

prongs, and the second and fifth prongs are removed.

WOOD PROPERTIES RELATING TO PROCESSING (I)

Dr. CHENG-JUNG LIN

Head and Professor
Dept. of Wood Industry
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Wood Properties Relating to Processing (I)

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Taiwan, R.O.C.

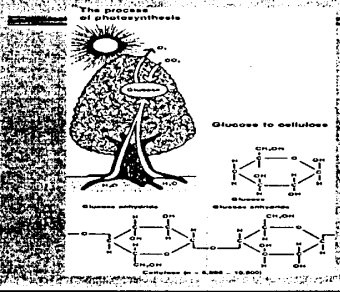
The nature of wood-
Properties common to all woods(1)

- Stems have a predominantly vertical arrangement and radial symmetry.
- Wood is cellular in structure—the principal chemical constituents are cellulose, hemi-cellulose and lignin.
- Hygroscopic substance

The nature of wood-
Properties common to all woods(2)

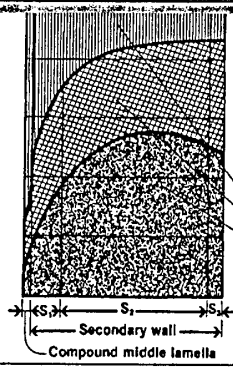
- Anisotropic in nature
- Deteriorated by sunlight, weather and heat and is susceptible to attack by fungi, microorganisms and insects.
- Flammable, especially when dry.

The process of photosynthesis

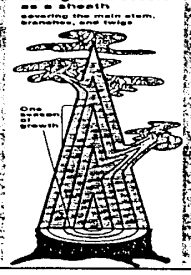


Distribution of organic compounds

within various cell wall layers of a softwood

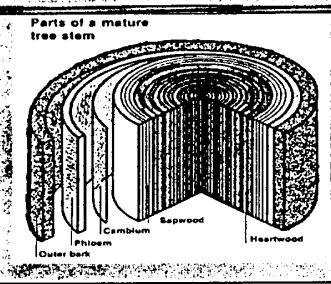


Trunk and Bole

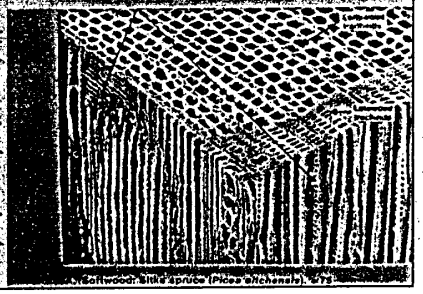


- The trunk is the principal source of wood used by woodworkers, although pieces having unusually beauty and utility also come from other parts of the tree.

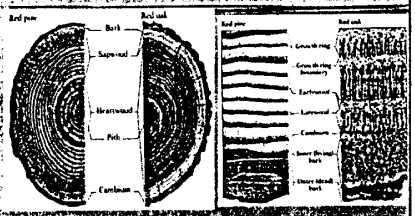
Parts of a mature tree stem



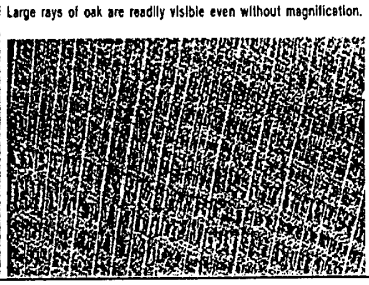
Principal cell types of softwoods



Annual rings (or Growth rings)—earlywood & latewood



Large rays of oak are readily visible even without magnification.



Figure, grain and texture

- Figure: Any distinctive appearance on a longitudinal wood surface resulting from anatomical structure, irregular coloration or defects.
- Grain: Among its uses are direction of cells, surface appearance or figure, growth-ring placement, plane of cut, growth rate, earlywood/latewood contrast, relative cell size, machining defects or artificial decorative effects.

Figure, grain and texture

- Texture: Relative cell size indicated by adjectives from fine to coarse; in softwoods, determined by relative tracheid diameter, in hardwoods, determined by relative pore diameter. Also, sometimes used to indicate evenness of grain, e.g., uniform texture, and uniformity in size and distribution of pores, e.g., even texture.

Wood grain

* Wood grain can be used in some ten different categories. Examples are as follows:

* **1. Planes and Surface**
  end grain, longitudinal grain, side grain, radial grain, tangential grain

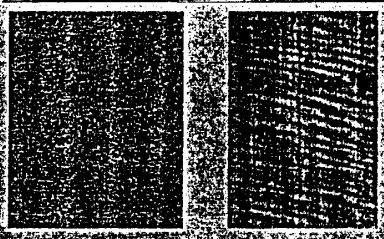
Wood grain

* **2. Growth-ring placement**
  Plain grain, flat grain, mixed grain, bastard grain, radial grain, tangential grain
* **3. Growth-ring width**
  Close grain, open grain, dense grain, coarse grain, fine grain, narrow grain

Wood grain

* **4. Earlywood/latewood contrast**
  Even grain, uneven grain
* **5. Alignment of longitudinal cells**
  Across-the-grain, along-the-grain, against-the-grain, curly grain, grain direction, interlocked grain, slope-of-grain, straight grain, wavy grain

Interlocked grain & Wavy grain



Wood grain

* **6. Relative pore size**
  Closed grain, coarse grain, fine grain, open grain
* **7. Figure types**
  Bird's-eye grain, blister grain, comb grain, crotch grain, curly grain, fiddleback grain, stripe grain, tiger grain

Wood grain

* **8. Machining defects**
  Chipped grain, fuzzy grain, loosened grain, raised grain, torn grain, woolly grain
* **9. Figure imitation**
  Graining, wood grain design
* **10. Surface failure**
  Short in the grain

Fuzzy grain

Torn grain

Large rays of oak are readily visible even without magnification.

- Sap wood and Heartwood

Sapwood and heartwood

Sapwood and heartwood

- Sapwood is involved in sap conduction upward in the tree. Some nonliving prosenchyma cells are active in conduction, and the living parenchyma cells also store food.
- Sapwood is not generally resistant to fungi, so any noteworthy decay resistance of a species is due to extractives that are toxic to fungi.
- When green, sapwood sometimes contains moisture five times as much as heartwood, it shrinks more than heartwood because of its lack of extractives.

Sapwood is easy attacked by fungi (blue stain)

Sapwood and heartwood

- In the center of the stem, nearest the pith, the prosenchyma cells cease to conduct sap and the parenchyma cells die. The sapwood is thus transformed into heartwood.
- The transition to heartwood is also accompanied by the formation in the cell wall of material called extractives.

Sapwood and heartwood

- To the woodworkers, the most significant aspect of heartwood extractives is color, for the sapwood of all species ranges from whitish or cream to perhaps yellowish or light tan. The dark, distinctive colors we associate with various woods—the rich brown of black walnut, or the reddish black striping of rosewood—are the result of heartwood extractives.

Sapwood and heartwood

- Heartwood extractives may change the properties of the wood in other ways as well. In some species, they reduce the permeability of the wood tissue, making the heartwood slower to dry and difficult or impossible to impregnate with chemicals or preservatives.
- Extractives often make the heartwood a little denser than the sapwood and also a little more stable in changing moisture conditions.

Sapwood and heartwood

- Extractives materials in the heartwood of some species may be so abrasive that they dull cutting tools, and they may contribute to the wood's surface hardness.
- As sapwood becomes heartwood, no cells are added or taken away, nor do any cells change shape. The basic strength of both is not affected.

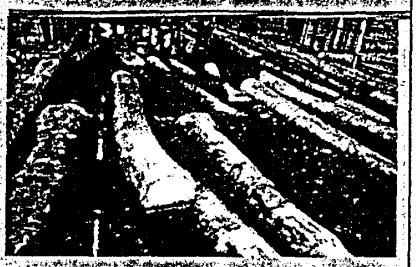
Properties of Heartwood

- Heartwood may be darker in color than sapwood.
- Heartwood may be highly decay- and insect-resistant.
- Heartwood may be difficult to penetrate with liquids.
- Heartwood may be difficult to dry.

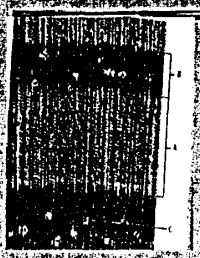
Properties of Heartwood

- Heartwood may have a distinct odor.
- Heartwood may have a slightly higher weight per unit volume than sapwood.
- Several other properties such as low hygroscopicity and a reduced fiber saturation point might be happened, but note that strength does not be affected.

Cooking logs can changes the color also caused by extractives



Southern yellow pine (cross section)



* B: Latewood
* A: earlywood
* C: Resin canals

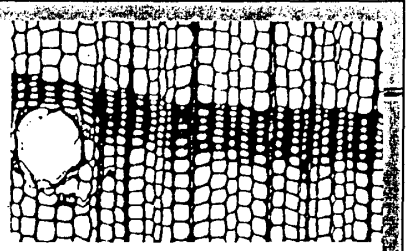
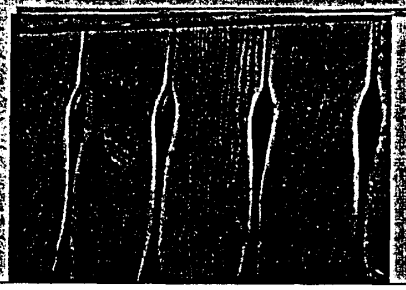


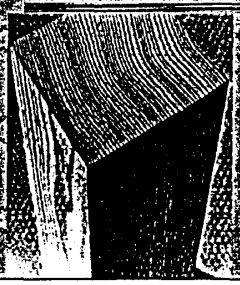
Fig. 4.7
Resin canals characterize some softwoods
Transverse view of ponderosa pine (*Pinus ponderosa*). x85

Unless resins are solidified, or 'set,' by high temperatures in kiln-drying, droplets of resin may exude from the canals, as on the surface of this turned baluster of eastern white pine. Resin droplets remain sticky for a time but then harden. They can be removed

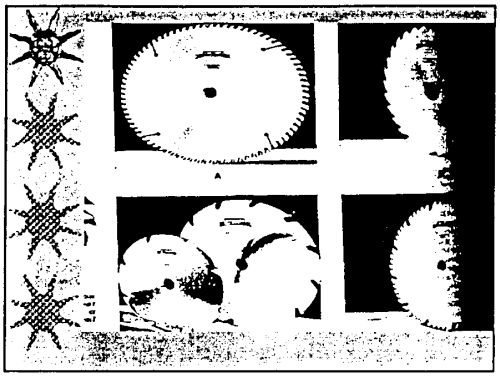
Resin canals (ageing spots)

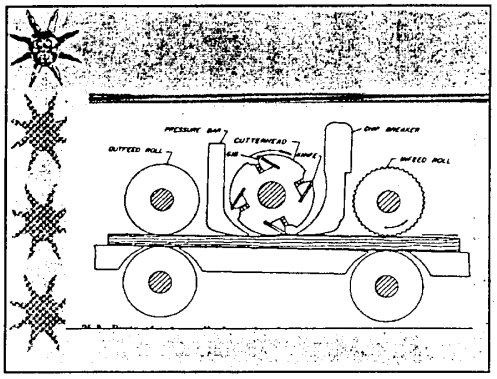


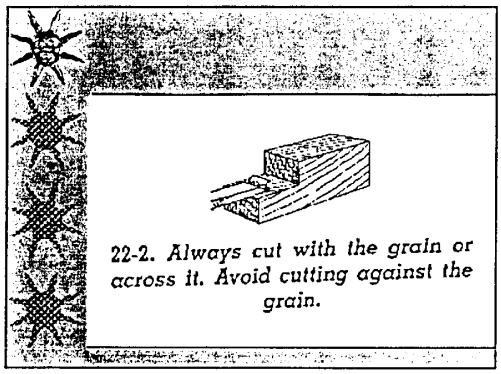
Structural Arrangement— Anisotropic (Three planes)



* Block of Douglas fir is cut to show three planes: the transverse or cross-sectional (X), the radial (R), and the tangential (T) surfaces.





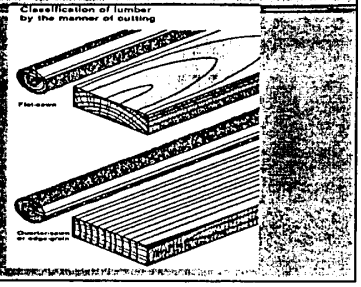


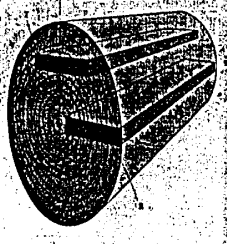
22-2. *Always cut with the grain or across it. Avoid cutting against the grain.*

Structural arrangement and grain

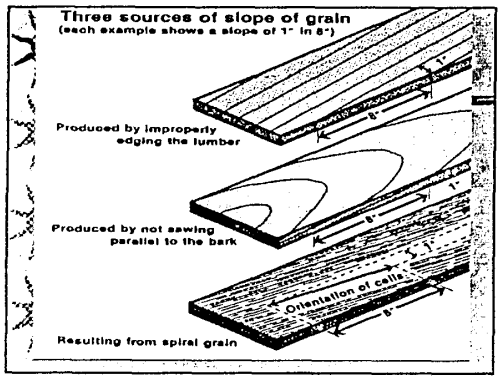
- **Quarter-grain** : growth rings form angles of anywhere from 45-90 degree with the surface
- **Flat-grain** : growth rings orientations from 0-45 degree with the surface
- **Mixed grain** : lumber having both edge-grain and flatsawn pieces
- **Bastard grain** : growth rings oriented from 30-60 degree with the surface

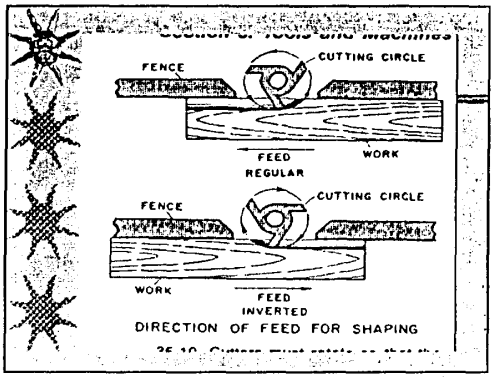
Classification of lumber by the manner of cutting



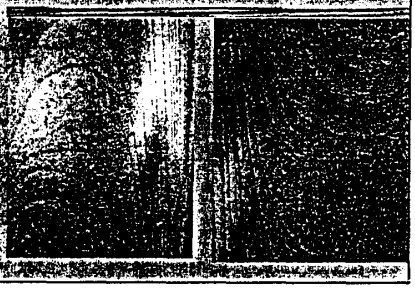


- **In a flat-grained or flat-sawn board (T), the growth rings are approximately parallel to the wide faces.**
- **In an edge-grained or quarter-sawn board (R), the rings are approximately perpendicular to the wide faces.**





Torn grain



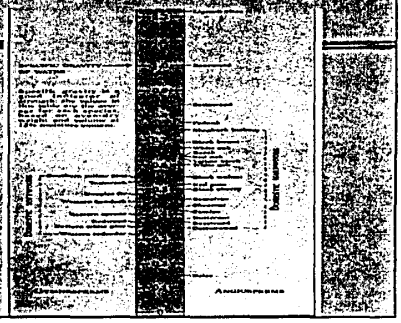
Density and specific gravity

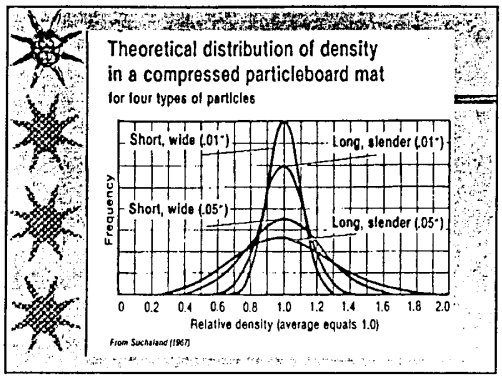
- Density is expressed as weight per unit volume.
- Specific gravity is the ratio of the density of a substance to the density of a standard substance (water, in the case of wood and other solids).
- In measuring density and sp. gr., it is customary to use oven-dry weight and current volume. Because of volumetric shrinkage and swelling, the volume of wood may vary slightly with moisture content.

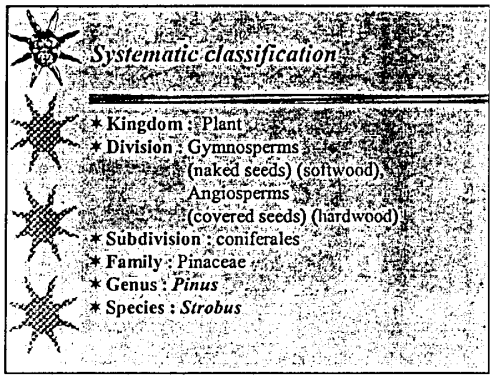
Density and specific gravity

- Density is the single most important indicator of strength in wood and may therefore predict such characteristics as hardness, ease of machining, and nailing resistance.
- Dense woods generally shrink and swell more, and usually present greater problems in drying.
- The densest woods also make the best fuel.

Specific gravity of some common species




Theoretical distribution of density
in a compressed particleboard mat
for four types of particles
Short, wide (.01")
Long, slender (.01")
Short, wide (.05")
Long, slender (.05")
Frequency
0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0
Relative density (average equals 1.0)
From Suchsland (1967)


Systematic classification
Kingdom : Plant
Division : Gymnosperms
(naked seeds) (softwood),
Angiosperms
(covered seeds) (hardwood)
Subdivision : coniferales
Family : Pinaceae
Genus : Pinus
Species : Strobus

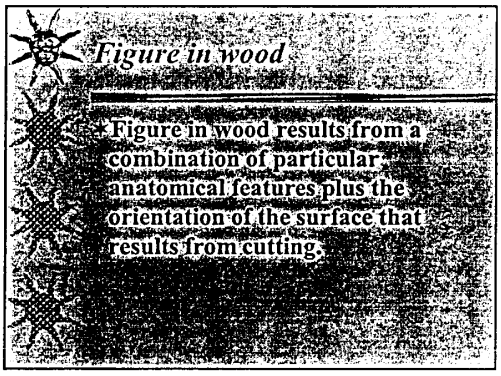
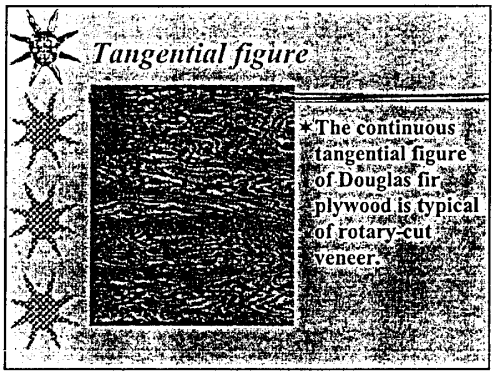
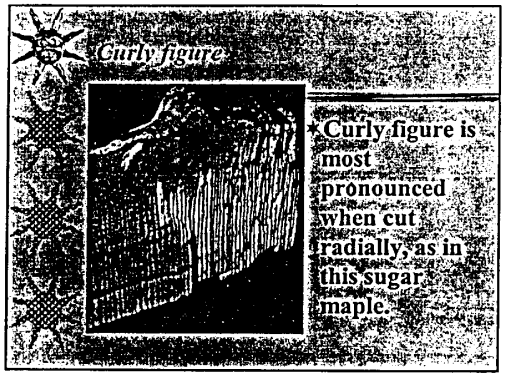
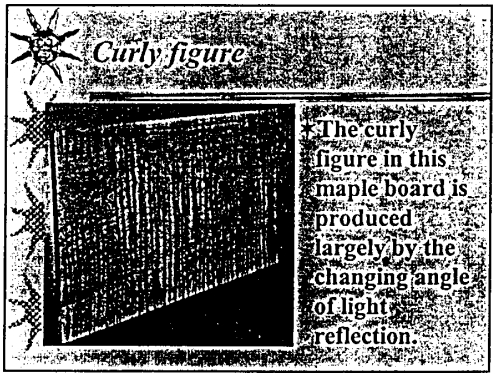


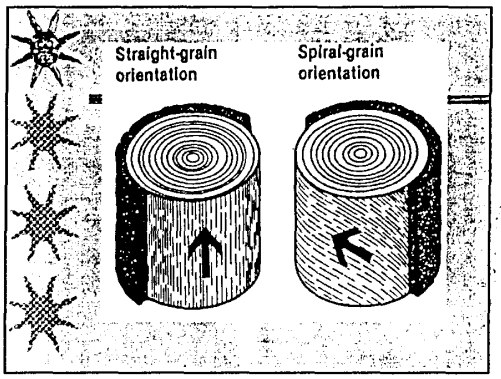
Figure in wood
Figure in wood results from a combination of particular anatomical features plus the orientation of the surface that results from cutting.


Tangential figure
The continuous tangential figure of Douglas fir plywood is typical of rotary-cut veneer.

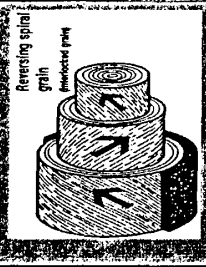

Curly figure
Curly figure is most pronounced when cut radially, as in this sugar maple.


Curly figure
The curly figure in this maple board is produced largely by the changing angle of light reflection.

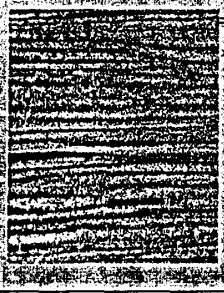
Fiddle-back mahogany



Reversing spiral grain (interlocked grain)



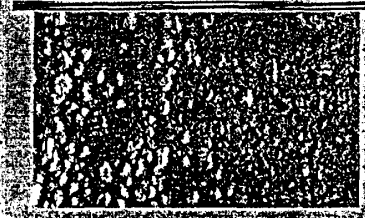
Ribbon or stripe figure



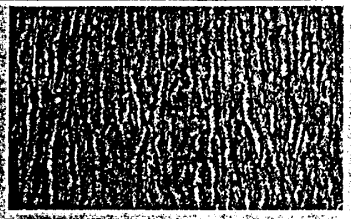
- Ribbon or stripe figure in mahogany veneer. Pattern is created by varied vessel lengths and light reflection.

Bird's-eye maple

Grain deviation associated with blister figure



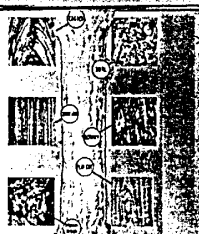
Quilted figure in maple



Burl on a red oak stem

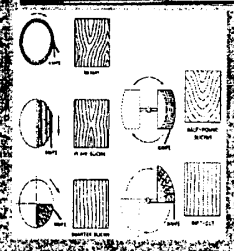
Walnut burl veneer

Grain patterns and location

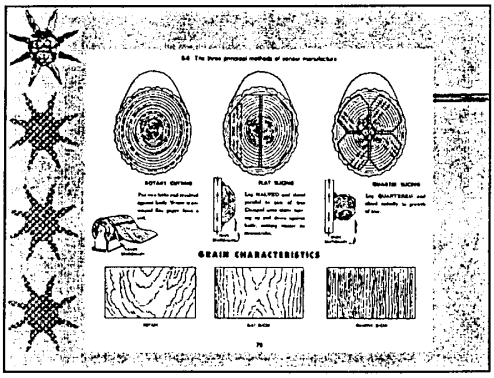


- Cutting the veneer from various sections of the tree produces different grain patterns.

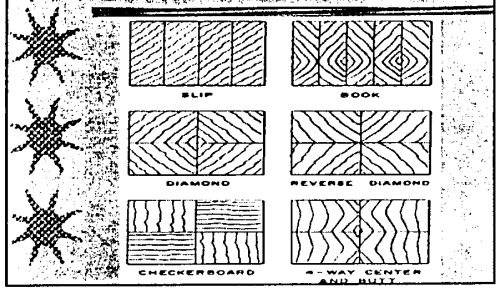
Cutting methods and figure pattern



- The cutting method is an important factor in producing veneers of different appearance.

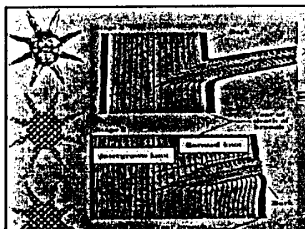


Common kinds of matching



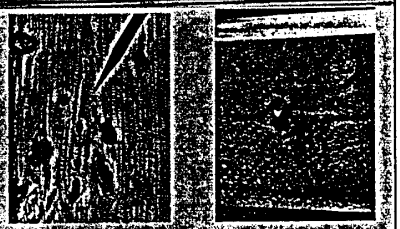
Knots

- Value-added or value-reduced is depending on where the wood be used for.

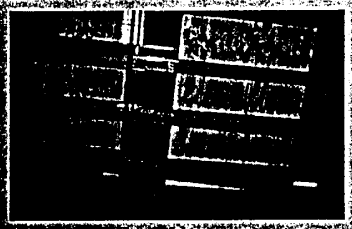


- A knot is the basal portion of a branch whose structure becomes surrounded by the enlarging stem. Since branches begin with lateral buds, knots can always be traced back to the pith of the main stem.

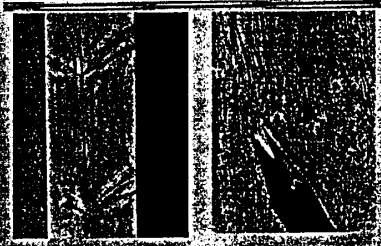
Tight round knots (left) and Loose round knot (right)



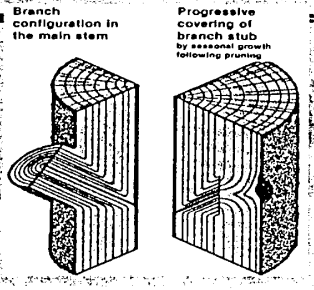
Loose round knots shall be troublesome in plywood manufacturing



Spike knots (left) and Pin knots (right)



Pruning to get good quality wood

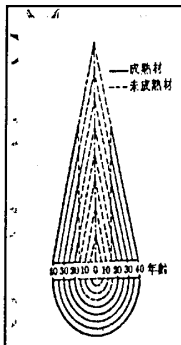


Abnormal wood

- Juvenile wood
- Reaction wood
  - Compression wood
  - Tension wood

Juvenile wood

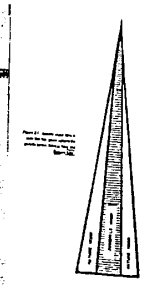
- Wide growth rings surrounding the pith are juvenile wood, which is lighter and weaker than narrow-ringed mature wood.
- Needle scars also indicate juvenile wood.



- Solid line: Mature wood
- Dot line: Juvenile wood
- Figure: Age

Old hypothesis in formation of juvenile wood

- Old hypothesis in formation of juvenile wood is crown-formed wood. Young trees with full crowns covering most of the bole produce juvenile wood almost exclusively for the first few years of growth. As the crown recedes, the zone of juvenile wood also recedes upward and remains within the general confines of the crown.
- The net result is a core of juvenile wood in the inner trunk of the tree that corresponds to the approximately length of the active crown at the time of wood formation (Larson 1962).



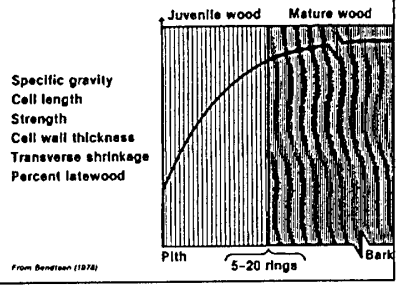
- An important new theory on juvenile wood formation developed by Dr. K.C. Yang

Yangis Theory

* Juvenile wood is the secondary xylem at the center of a tree formed through the life of the tree. The width or duration of juvenile wood decreases upward to the tree crown. This width is species-specific, can be affected by environment conditions, and is the result of an aging process of the cambial initials.

Juvenile to mature wood transition in conifers

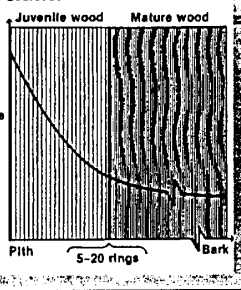
Many properties show gradual increase



From Bendtsen (1978)

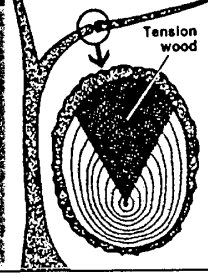
Juvenile to mature wood transition in conifers

Some properties show decrease

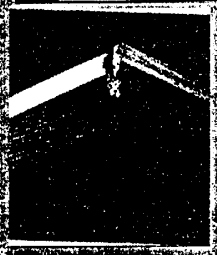


From Bendtsen (1978)

Elliptical stems often indicate tension wood



Reaction wood

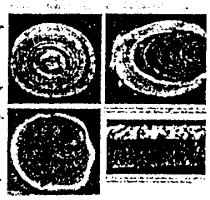


* Brash failure in reaction wood

Compression wood

* Compression wood in pine may appear as a dark streak on a quartersawn board, right, or as an abrupt change from normal light-colored sapwood to dark, center, on a flatsawn board, left, abnormal appearance of earlywood and latewood

Tension wood



* Tension wood looks silvery in aspen, above left. Eccentric rings in cherry, above right, and red oak, below left, also indicate tension wood.
* The abnormal fibers left a woolly surface on the cottonwood when it was sawn from the log.

Tension Wood

* **Sawing through tension wood zones can result in formation of fuzzy surfaces.**

Wood decayed by fungi

* White rots develop and dark zone lines form.
* Brown rots

Insects damage

* Termites
* Powder-post beetles
* Marine borers

Powder-post beetles attacked chair seat

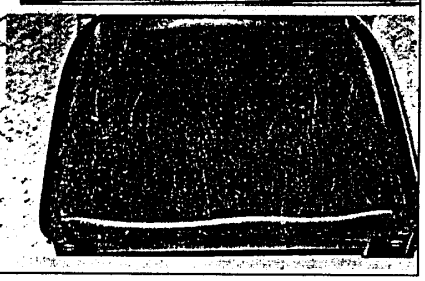


Table 14.1. Grouping of species for structural plywood

Group 1	Group 2	Group 3	Group 4	Group 5
Apitong	Cedar, Port Orford	Alder, red	Aspen	Basswood
Beech, American	Douglas-fir No. 2*	Birch, paper	Bigtooth	Poplar, balsam
Birch	Fir	Cedar, Alaska	Quaking	
Sweet	Balsam	Fir, subalpine	Cativo	
Yellow	California red	Hemlock, eastern	Cedar	
Douglas-fir No. 1*	Grand	Maple, bigleaf	Incense	
Kerning	Noble	Pine	Western red	
Larch, western	Pacific silver	Jack	Cottonwood	
Maple, sugar	White	Lodgepole	Eastern	
Pine	Hemlock, western	Ponderosa	Black (western poplar)	
Caribbean	Lauan	Spruce	Pine	
Ocote	Maple, black	Redwood	Eastern white	
Pine, southern	Meranti, red	Spruce	Sugar	
Loblolly	Pine	Engelmann		
Longleaf	Pond	White		
Shortleaf	Red			
Slash	Virginia			
Tanoak	Western white			
	Spruce			
	Black			
	Red			
	Sitka			
	Sweetgum			
	Tamarack			

WOOD PROPERTIES RELATING TO PROCESSING (II)

Dr. CHENG-JUNG LIN

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National Pingtung University of Science and Technology

Wood Properties Relating to Processing (II)

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Head and Professor of Dept. of Wood Industry
National Pingtung University
of Science and Technology
TAIWAN, R.O.C.

Water and Wood-1

* Someone once quipped that more than 90% of all problems with wood involve moisture.
* Everyone has experienced the problems that result when wood shrinks and swells.
* The bureau drawer that slides freely in January but sticks tightly in May is an all too familiar example of the dimensional response of wood to change in atmospheric humidity.

Table 8.4. Moisture content of green wood

Species	Moisture content	
	Heartwood	Sapwood
	(%)	
Hardwoods		
White ash	46	44
Aspen	95	113
Yellow birch	74	72
American elm	95	92
Sugar maple	65	72
Northern red oak	80	69
White oak	64	78
Sweetgum	79	137
Black walnut	90	73
Softwoods		
Western redcedar	58	249
Douglas-fir	37	113
White fir	98	160
Ponderosa pine	40	148
Loblolly pine	33	110
Redwood	86	210
Eastern spruce	34	128
Sitka spruce	41	142

Source: USFPL (1987).

Water and Wood-2

* Warp and surface checks in lumber, loose tool handles and out-of-round turnings are also common symptoms.
* Although other consequences of moisture—such as fungal discoloration or gluing failures—can annoy the woodworker, dimensional problems are by far the most common and troublesome.

Water and Wood-3

* The obvious goal of drying wood is twofold: first, to dry wood (and thereby preshrink it) to a moisture content consistent with its eventual environment, and second, to control any subsequent gain or loss of moisture in order to minimize dimensional change.

Moisture content

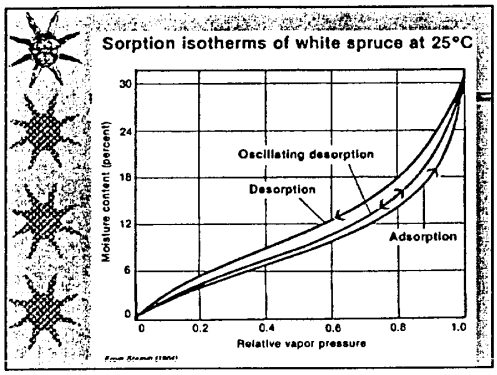
* The moisture content (MC) of wood is measured as the ratio of the weight of water in a given piece of wood to the weight of the wood when it is completely dry.
* The water-free weight of wood is usually referred to as the oven-dry weight, because drying in an oven is a common methods of obtaining it.
* This ratio is traditionally expressed as percent moisture content.

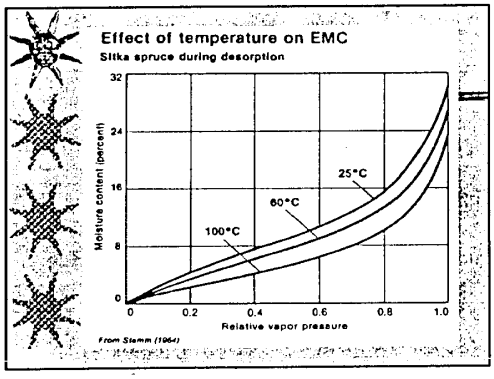
Relative humidity-1

* Humidity is a general term referring to water or moisture in vapor form in the atmosphere.
* Absolute humidity refers to the actual quantity of moisture present in air. This is usually expressed in grains per cubic foot(1 grain = 1/7000 lb. avdp.) or in grams per cubic meter.
* The amount of water the air can hold varies with temperature.

Relative humidity-2

* Relative humidity (RH) is the ratio of the amount of moisture in the air at a certain temperature to the amount it would be able to hold at that temperature.
* If the air at 70□, for example, held 4 grains of water per cu. Ft., the relative humidity would be 50%, because the air is capable of holding 8 grains at that temperature. If the absolute humidity were 6 grains per cu. Ft., the RH would be 75%.





Dew point

* The dew point is the temperature at which water vapor condenses from the air.
* Air at 70 □ and 50% RH has a dew point of 49.3 □. Air with that much moisture, when cooled to 49.3 □, can hold no more moisture, and it is therefore at 100% RH.

Free water and bound water-1

* The liquid content of the living trees, call sap, is primary water, but also contains dissolved minerals, nutrients from the soil and carbohydrates manufactured by the foliage. For our purposes we can consider moisture or water in wood to mean either the original sap of the tree or water from other sources that is subsequently picked up by dry wood. Water can return to wood from countless sources, ranging from rain to the moisture in humid air.

Free water and bound water -2

* The water in wood cell cavities is called free water.
* The fiber saturation point (FSP) is in the state, the cell cavities are emptied of free water, but the cell walls are still saturated and thus still in their weakest condition. Only when water leaves the cell walls does the wood begin to shrink and increase in strength.

The fiber saturation point of several species

Species	Fiber saturation point (% MC)
Southern yellow pine	29
Sitka spruce	28
Western redcedar	18
Redwood	22
Teak	18
Rosewood	15

Source: Higgins (1957).

Free water and bound water -3

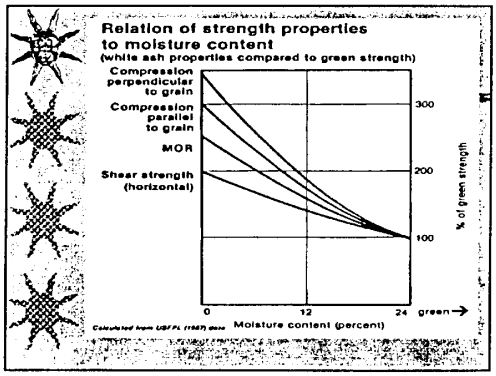
* The water remaining in the cell walls is called bound water. The bound water is held by physical forces of attraction within the cell walls.
* The bound water must be removed by placing the wood in a relative dry atmosphere. How much of the bound water is lost (and therefore how much shrinkage takes place) will depend on the RH of the atmosphere.

Free water and bound water -4

* If the air is at 100%RH, no bound water will be lost. To remove all the bound water, the wood would have to be placed in an oven or desiccator, or in a vacuum where the RH is zero. Obviously, we use wood where the RH is somewhere between 100% to zero, so only part of the bound water is lost.

Free water and bound water -5

* The FSP may vary among different species. In general, its value for most common species is about 30% MC. In species having a high extractive content (for example, redwood and mahogany) the FSP will be noticeably lower, around 22% to 24%. For those low in extractives such as birch, the FSP might range as high as 35%.



Equilibrium moisture content (EMC) 1

* Wood always remains hygroscopic—it responds to changes in atmospheric humidity and loses bound water as the RH drops, regaining bound water as the RH increases. For a given RH level, a balance is eventually reached at which the wood is no longer gaining or losing moisture. When this balance of moisture exchange is established, the amount of bound water eventually contained in a piece of wood is called the EMC of the wood.

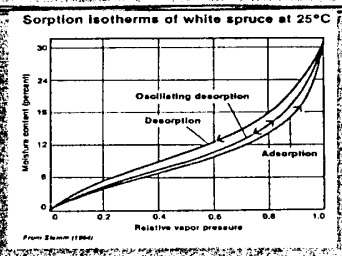
Equilibrium moisture content (EMC) 2

* EMC is the most important item in this section. A good starting point is to remember that 50%RH gives an approximate 9% EMC. Then note that 65%RH gives about 12% EMC, 75%RH gives about 14% EMC. And 100%RH always gives total fiber saturation. Temperature also has an effect upon EMC. EMC data mentioned above is for 70 □, but at intermediate levels the EMC would be about one percentage point lower for every 25 to 30 □ elevation in temperature.

Equilibrium moisture content (EMC) 3

* when wood is losing moisture (desorbing) the EMC curve is slightly higher than when the wood is picking up moisture (adsorbing). This is called the hysteresis effect.

Hysteresis effect



Equilibrium moisture content (EMC) 4

* It is important to realize that if the absolute humidity of air is unchanged, lowering the temperature of the air raises the relative humidity and heating the air lowers the relative humidity.
* The term kiln-dried usually means dried to a level appropriate for interior use. To the cabinetmaker, then, kiln-dried suggests a moisture content of below 10%.

Equilibrium moisture content (EMC) 5

* In structure lumber, however, air-dried levels of moisture content are considered adequate. In this context, kiln-dried may mean 19% or less. In some cases, structural lumber is kiln-dried mainly to reduce its weight for more economical shipping, to kill fungi or other wood-destroying organisms, or simply to speed up the drying process, even though the final MC may be scarcely below the FSP. So the term kiln-dried alone should not be blindly interpreted to indicate any particular moisture content.

Equilibrium moisture content (EMC)

* Once dried the wood somehow becomes dimensionally stable. In reality, if dry wood is stored under relatively moist conditions, bound water will be readsorbed to the EMC.

Green vs. Air-dried vs. kiln-dried-1

* There is considerable confusion over the meaning of the word **green** in reference to wood. It is often used to indicate the condition of freshly cut wood from a living tree. But because most properties of wood are unchanged regardless of the amount of free water it contains, we consider any wood above the FSP as green, even when the condition has been restored by wetting previously dried wood.

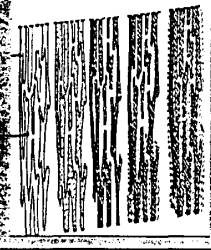
Green vs. Air-dried vs. kiln-dried-2

* Exposed to outdoor conditions, wood will lose its free water and eventually become **air-dry**. This term is used in many confusing ways, but should generally be taken to mean that the MC is in equilibrium with the outdoor atmosphere of a particular area. The amount of time to air-dry of course depends on the species, the thickness, the weather conditions and so forth.

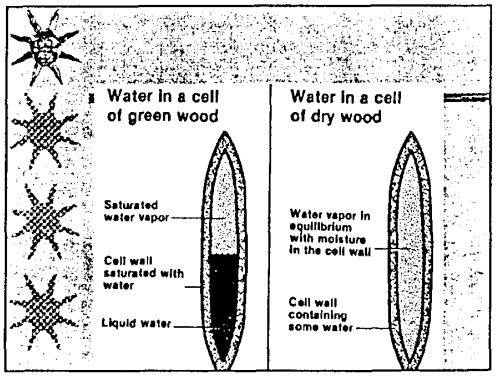
Green vs. Air-dried vs. kiln-dried-3

* The term **kiln-dried** usually means dried to a level appropriate for interior use. To the cabinetmaker, then, kiln-dried suggests a MC of below 10%. In structural lumber, however, air-dried levels of MC are considered adequate. In this context, kiln-dried may mean 19% or less. In some cases, structural lumber is kiln-dried mainly to reduce its weight for more economical shipping , to kill fungi or other wood-destroying organisms, or simply to speed up the drying process, even though the final MC may be scarcely below the FSP. So the term **kiln-dried** alone should not be blindly interpreted to indicate any particular moisture content.

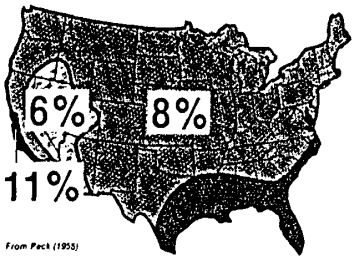
Moisture in wood



* Oven-dry wood
* Air-dry wood
* Wood MC at F.S.P.
* Wood MC over F.S.P.
* Green wood



Recommended moisture content
(average for interior woodwork)



From Peck (1955)

Piano keyboard twisting caused by the EMC problem

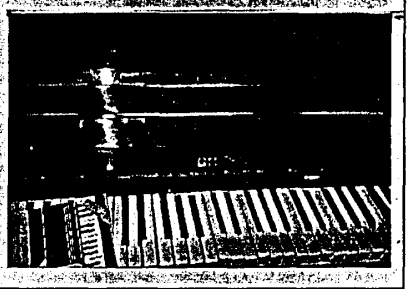


Table 8.3. *Equilibrium moisture content of typical forest products at 70°F (21°C)*

Relative humidity	Wood	Softwood plywood	Particle-board	Oil-treated hardboard	High-pressure laminate
(%)			(% MC)		
30	6.0	6.0	6.6	4.0	3.0
42	8.0	7.0	7.5	4.6	3.3
65	12.0	11.0	9.3	6.9	5.1
80	16.1	15.0	11.6	9.5	6.6
90	20.6	19.0	16.6	10.8	9.1

Source: Heebink (1966).

Table 8.2. *Percent moisture content of wood in equilibrium with dry-bulb temperatures and relative humidity conditions*

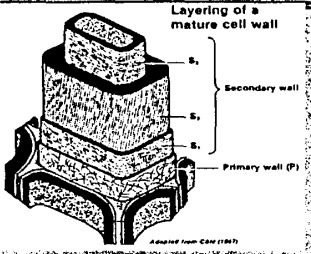
Dry bulb		Relative humidity							
°F	(°C)	20%	30%	40%	50%	60%	70%	80%	90%
30	(-1)	4.6	6.3	7.9	9.5	11.3	13.5	16.5	21.0
50	(10)	4.6	6.3	7.9	9.5	11.2	13.4	16.4	20.9
70	(21)	4.5	6.2	7.7	9.2	11.0	13.1	16.0	20.5
90	(32)	4.3	5.9	7.4	8.9	10.5	12.6	15.4	19.8
110	(43)	4.0	5.6	7.0	8.4	10.0	12.0	14.7	19.1
130	(54)	3.7	5.2	6.6	7.9	9.4	11.3	14.0	18.2
150	(66)	3.4	4.8	6.1	7.4	8.8	10.6	13.1	17.2
170	(77)	3.0	4.3	5.6	6.8	8.2	9.9	12.3	16.2

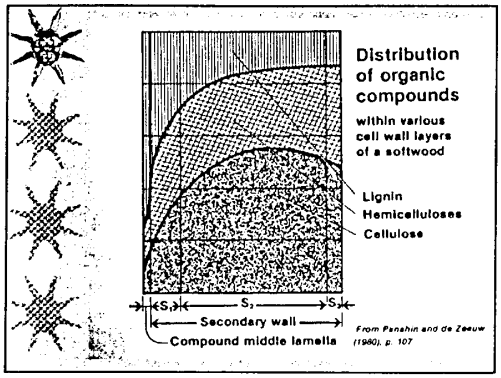
Source: Adapted from USFPL (1987).

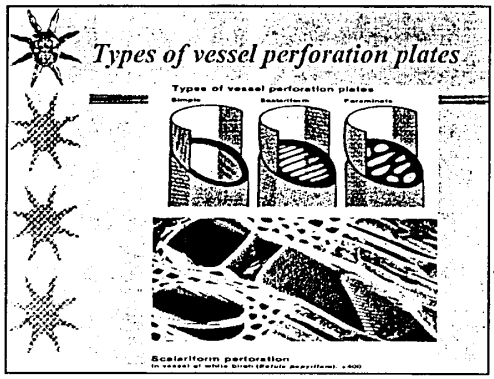
Shrinkage and swelling

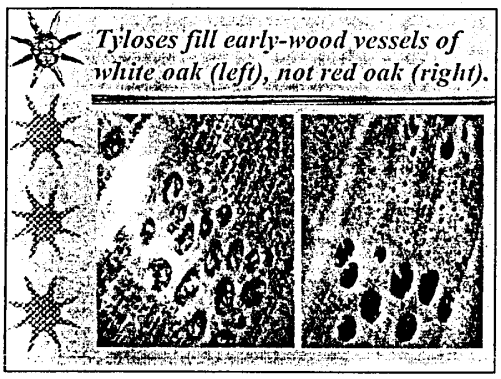
- Wood shrinks or swells due to loss or gain of bound water from the cell walls.
- The amount of movement varies according to the orientation of the wood cells and is usually measured separately in the three principal directions: tangential, radial and longitudinal.

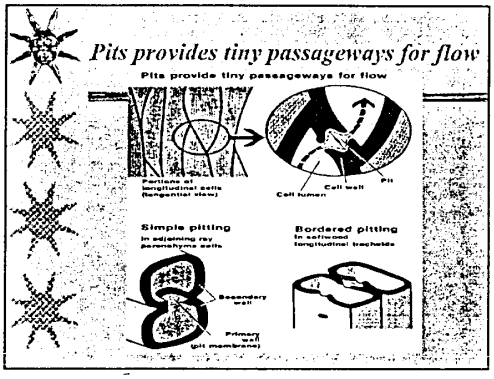
The formation of cell walls

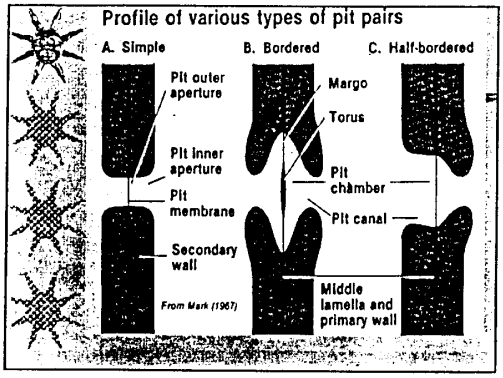


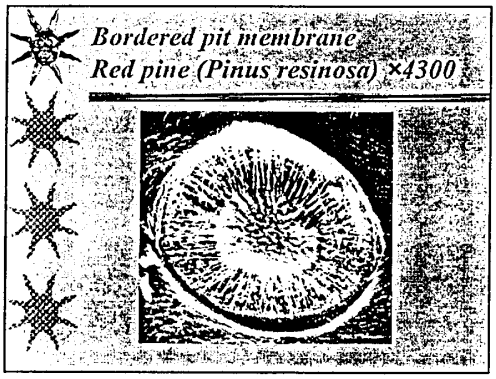

Distribution of organic compounds
within various cell wall layers of a softwood
Lignin
Hemicelluloses
Cellulose
S1
S2
S3
Secondary wall
Compound middle lamella
From Panshin and de Zeeuw (1980), p. 107

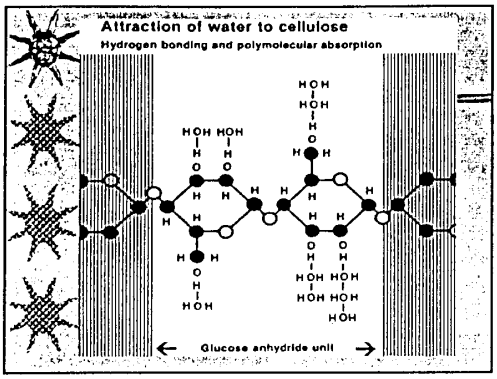

Types of vessel perforation plates
Types of vessel perforation plates
Simple
Scalariform
Foraminate
Scalariform perforation

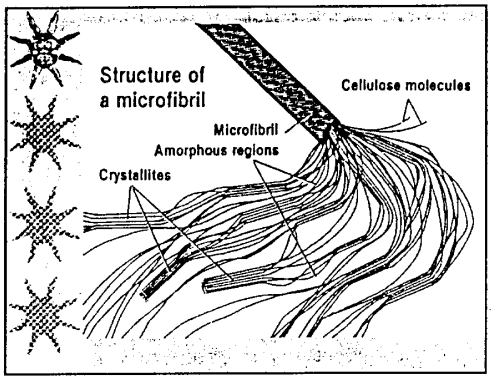

Tyloses fill early-wood vessels of white oak (left), not red oak (right).

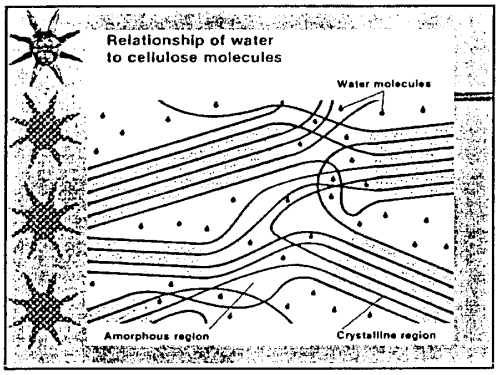

Pits provides tiny passageways for flow
Pits provide tiny passageways for flow
Cell lumen
Cell wall
Pit
Simple pitting
Bordered pitting
Secondary wall
Primary wall (pit membrane)

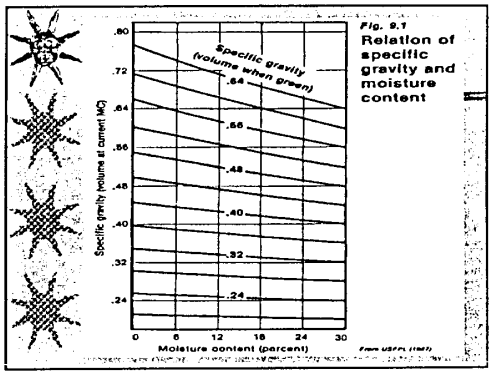

Profile of various types of pit pairs
A. Simple
B. Bordered
C. Half-bordered
Pit outer aperture
Pit inner aperture
Pit membrane
Secondary wall
From Mark (1967)
Margo
Torus
Pit chamber
Pit canal
Middle lamella and primary wall


Bordered pit membrane, Red pine (Pinus resinosa) ×4300









Total amount of linear shrinkage -1

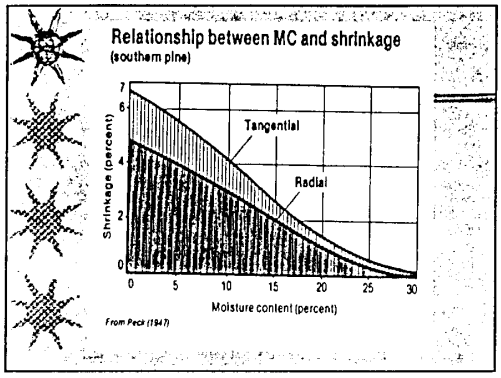
- The total amount of linear shrinkage that takes place in a given direction from the green to the oven-dry condition is customarily expressed as a percentage of the green dimensions. This total shrinkage is figured as follows:

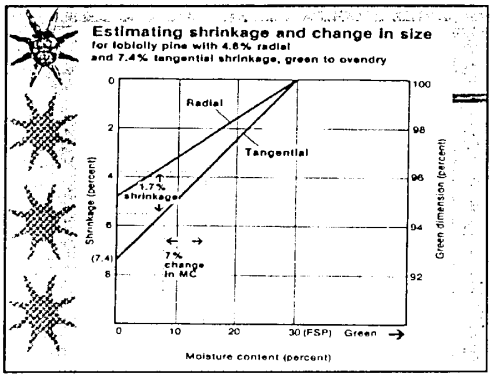
$$S = (Dg - Dod) / Dg \times 100\ (\%)$$

Where S = the total shrinkage, in percent, St = tangential shrinkage, Sr = radial shrinkage, Sl = longitudinal shrinkage, Dg = green dimension, Dod = oven-dry dimension.

Total amount of linear shrinkage -2

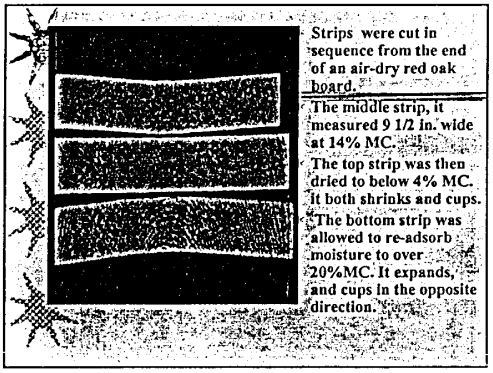
- **Total shrinkage of wood along the grain is normally only about 0.1%.**
- **It is reasonable to think of wood as having roughly 8% tangential shrinkage and 4% radial shrinkage.**
- In general, someone said that shrinkage among T : R : L = 10 : 5 : 0.5





Uneven shrinkage and swelling

* Change in dimension is only one consequence of shrinkage or swelling.
* Even more serious effects may result when shrinkage or swelling is uneven throughout the piece even though it is very small in magnitude.



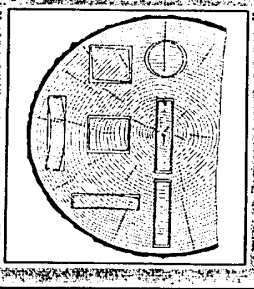
Strips were cut in sequence from the end of an air-dry red oak board.

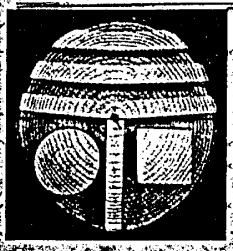
The middle strip, it measured 9 1/2 in. wide at 14% MC.

The top strip was then dried to below 4% MC. It both shrinks and cups.

The bottom strip was allowed to re-adsorb moisture to over 20%MC. It expands, and cups in the opposite direction.

Different cuts of wood will shrink differently





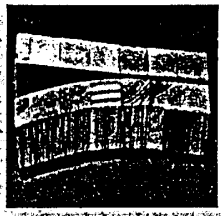
* Various shapes of red pine have been dried and superimposed on their original positions on an adjacent log section.

The greater tangential than radial shrinkage causes squares to become diamond-shaped, cylinders to become oval

Quarter-sawn boards seldom warp

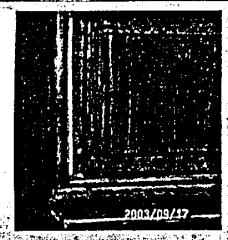
Flat-sawn boards cup away from the pith.

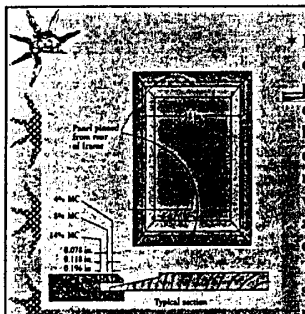
The importance of balance structure



* The consequences of unbalanced construction are evident here, where cross-band and face veneer have been band-sawn off one side of a strip of lumber-core panel.

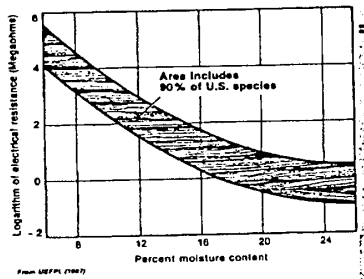
Panel Shrinks due to loss of water in a frame-and-panel construction





* In frame-and-panel construction, a panel pinned only at the center top and bottom is free to expand and contract within a rectangular frame, which moves little along the grain with changes in humidity. The cross section shows estimated positions of the panel at different moisture levels.

Relationship of electrical resistance to moisture content



Electrical resistance type of moisture meter

* A resistance meter with external electrodes, which are driven into the board. The center pin gauges penetration.

Several types of hand-held moisture meters

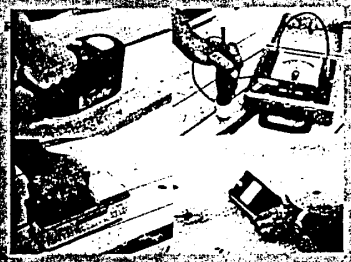


Table 8.6. Kiln drying schedules for drying 1-in. basswood and white oak lumber

Basswood			White oak		
	Kiln conditions			Kiln conditions	
Moisture content	Temperature	Relative humidity	Moisture content	Temperature	Relative humidity
(%)	(°F) (°C)	(%)	(%)	(°F) (°C)	(%)
Above 60	160 (71)	58			
60	160 (71)	43			
50	160 (71)	31	Above 40	110 (43)	87
40	160 (71)	21	40	110 (43)	84
35	160 (71)	21	35	110 (43)	75
30	170 (77)	24	30	120 (49)	62
25	170 (77)	24	25	130 (54)	35
20	180 (82)	26	20	140 (60)	25
15	180 (82)	26	15	180 (82)	26

Source: USDA For. Serv. (1961).

Table 8.7. Approximate schedules for high-temperature drying of southern yellow pine

Thickness (in.)	Width (in.)	Time (hr)	Dry-bulb temperature (°F)	Wet-bulb temperature (°F)
1	4-10	14-18	230	180
1.75	4-10	22-26	240	180

Source: Denig et al. (1993).

Defects of wood drying under unsuitable conditions

- Surface checks and end checks
- Collapse
- Honeycomb checks
- Casehardening
- Warp
  - Cup, bow, twist, diamonding, crook and kink.

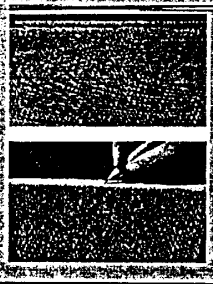
Drying Defects

- When uneven shrinkage causes stress that exceeds the perpendicular-to-grain strength of the wood, separation of cells occurs along the grain. Such failures are termed **checks.**

Types of Warp

- **Warp:** Which is the distortion of a piece from its desired or intended shape, usually results from variable shrinkage that causes stress in the piece. Cup is a form of warp that is characterized by deviation from flatness across the width of a board. Bow is deviation from lengthwise flatness in a board. Crook is departure in end-to end straightness along the edge of a board. Twist signifies that the four corners of a flat face lie in the same plane. Kink describes a localized crook, due to a knot.

Surface checks and end checks

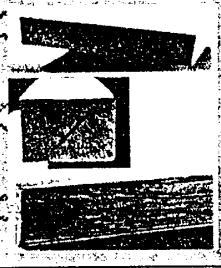


- Surface checks developed as oak board dried.
- Crosscutting reveals surface checks penetrating deeply into oak board.

Collapse occurred in drying

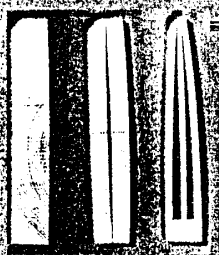
* Extreme compression stress in drying may cause wood cells in the core to buckle or collapse, as in this imbuya board, which was sawn rectangular.

Honeycomb checks



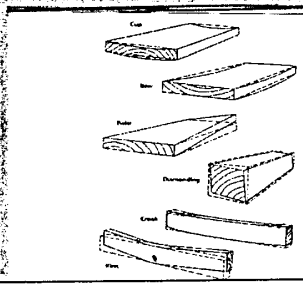
* Honeycomb checks in a red oak board follow the planes of the large rays.
* Honeycombing in a maple square.
* Surface planning reveals the honeycombing in an oak board.

Casehardening

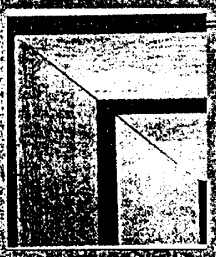


* A wafer cut from a kiln-dried plank of white ash shows no symptoms of stress (left). After re-sawing (center) reveals the casehardened condition. Kiln operators cut fork-shaped sections that reveal casehardening when prongs curve inward (right).

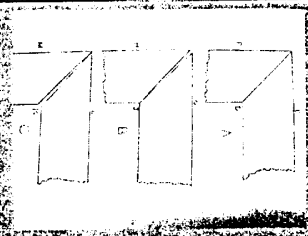
Drying defects- warp



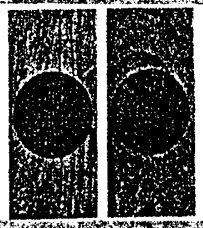
Perpendicular-to-grain vs. parallel-to-grain



* Wood frame corners were tightly mitered when originally assembled. The upper one was dried, and the lower one dampened. Because wood is stable along the grain but shrinks and swells across the grain.



Perpendicular-to-grain vs. parallel-to-grain-2



* Drastic moisture cycling of dowel joints with vertical growth-ring orientation results in compression set and loosening of an unglued joint, left. Glue reduces the extent of loosening, right. Note glue failure at top of joint.

Coping with Wood Movement-1

* **Preshrinking** wood by seasoning, as obvious as it is, is too important to pass over lightly. Although wood is dried for many reasons (to reduce weight, to prevent deterioration by fungi, to increase strength, to permit gluing and finishing) the principal objective is to have shrinkage take place before rather than after the final product is completed. The key to this approach is drying the wood to a moisture content consistent with the average relative humidity in which the finished piece will be used.

Coping with Wood Movement-2

* Preshrinking wood is one thing, keeping it there is another. Careful attention must be given to the second basic consideration-**atmospheric control**. Air conditioning is effective, but not always possible or even sensible, except for priceless museum objects and the like. Another approach is to control humidity through **isolation**, by keeping the wood in a reasonably air tight container. This may be a small display box, a glass jar, a plastic bag or simply a coat of finish.

Coping with Wood Movement-3

* As a companion to proper preshrinking, an effective finish is the most relied-upon approach to minimizing dimensional response in our variable atmosphere.

Coping with Wood Movement-4

* **Mechanical restraint**
  - Cross-ply construction of plywood
  - Balanced construction
  - Chemical stabilizing

Moisture Gradient

* Water in wood normally moves from zones of higher to zones of lower moisture content. This fact supports the familiar statement that " wood dries from the outside in," which means that the surface of the wood must be drier than the interior if moisture is to be removed.
* In drying, the surface fibers of the heartwood of most species attain moisture equilibrium with the surrounding atmosphere almost as soon as drying begins, and at this time a moisture gradient begins to develop.

Casehardening

* **Casehardening** is the inevitable result of the drying stresses associated with shrinkage--the stresses persisting when the wood is uniformly dry. Whether or not it is considered to be a defect depends on the final use of the dried material. Casehardening can be relieved in a compartment dry kiln by a **conditioning treatment.**

Equalizing Treatment-1

* Frequently the moisture content varies considerably among boards in a kiln charge during the final stage of drying. Such variation may cause serious trouble during storage, fabrication, or use. Also, satisfactory relief of drying stresses (casehardening) of all boards in a charge cannot be obtained if the MC varies too much. Therefore, use an **equalizing treatment** to overcome excessive variation in MC near the end of drying.

Equalizing Treatment-2

* The procedure for equalizing a kiln charge of lumber is as follows:
* (1) Start equalizing when the driest kiln sample in the charge has reached an average moisture content 2-% below the desired final average moisture content. If, for example, the desired final average moisture content is 8%, equalizing would be started when the driest kiln sample reaches 6% MC.

Equalizing Treatment-3

* (2) As soon as the driest sample reaches the moisture value stated in step 1, establish an equalizing EMC in the kiln equal to that value. In the example given in (1), the equalizing EMC would be 6%. During equalizing, use as high a dry-bulb temperature as the drying schedule permits.

Equalizing Treatment-4

* (3) Continue equalizing until the wettest sample reaches the desired final average MC. In the example given in step 1, the wettest sample would be dried to 8%.

Equalizing Treatment-5

* If the **equalizing treatment** is to be followed by a **conditioning treatment**, it may be at times be necessary to lower the temperature to obtain the desired conditioning EMC condition. When this is necessary, begin lowering the temperature 12 to 24 hours prior to the start of conditioning. Also lower the wet-bulb temperature to maintain the desired equalizing EMC.

Conditioning Treatment-1

* If the boards are to be re-sawed, ripped into thin strips, or machined non-uniformly, use a **conditioning treatment.** Such a treatment accomplishes two things: it relives drying stresses, and it produces a more uniform moisture content throughout the thickness of the boards. Drying stresses and non-uniformly of moisture can result in serious deformation during fabrication and use.

Conditioning Treatment-2

* The conditioning treatment, whether or not preceded by an equalizing treatment, should not be started until the average MC of the wettest sample reaches the desired final average MC.

Conditioning Treatment-3

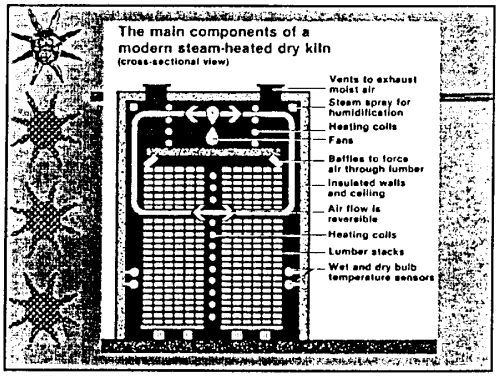
* The procedure for conditioning a kiln charge of lumber is as follows:
* (1) The conditioning temperature is the same as the final step of the drying schedule or the highest temperature at which the conditioning EMC can be controlled. For softwoods set the wet-bulb temperature so the conditioning EMC will be 3 % above the desired final average MC. For hardwoods the conditioning EMC Is 4 % above the desired final average MC.

Conditioning Treatment-4

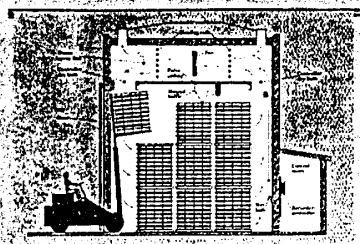
* For example, assume that this case involves a hardwood, a final desired MC of 8 %, and a conditioning temperature of 170□. The conditioning temperature EMC is 12%. At 170□, an 8 degree wet-bulb depression will give an EMC of 12.4%.
* If the material was a softwood, the conditioning EMC would be 11% and the wet-bulb depression 10 degree.

Conditioning Treatment-5

* (2) continue conditioning until satisfactory stress relief is attained.
* -Method of cutting specimens for casehardening tests, material that is less than 1 1/2 inches thick is cut into three prongs, and the middle prong is removed, material that is 1 1/2 inches or thicker is cut into six prongs, and the second and fifth prongs are removed.



A typical commercial package-loaded kiln.



Kiln drying schedules for drying 1-in. basswood and white oak lumber

Basswood			White oak		
	Kiln conditions			Kiln conditions	
Moisture content	Temperature	Relative humidity	Moisture content	Temperature	Relative humidity
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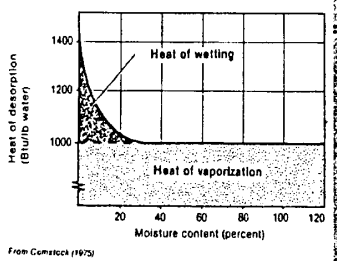
60	160 (71)	43			
50	160 (71)	31	Above 40	110 (43)	87
40	160 (71)	21	40	110 (43)	84
35	160 (71)	21	35	110 (43)	75
30	170 (77)	24	30	120 (49)	62
25	170 (77)	24	25	130 (54)	35
20	180 (82)	26	20	140 (60)	25
15	180 (82)	26	15	180 (82)	26

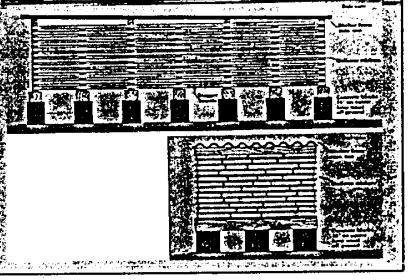
Source: USDA For. Serv. (1961).

Energy required to evaporate water from wood

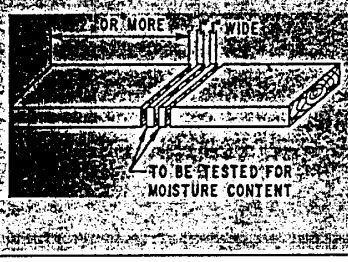


From Comstock (1975)

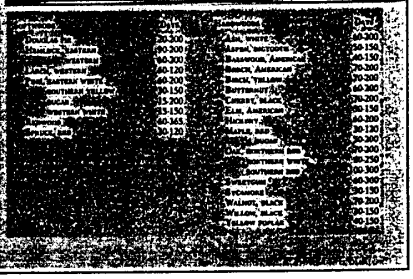
How to build a lumber pile



To check moisture content, cut samples carefully

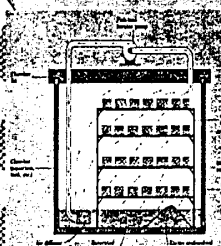


Approximate time to air-dry 4/4 lumber to 20% MC



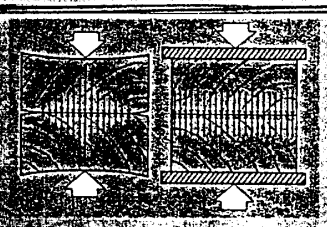
Suggested salts for controlling relative humidity in closed containers.

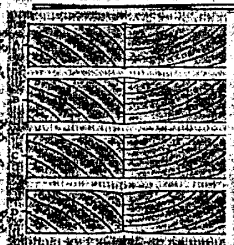
Approx. EMC** (%)	RH *** (%)	Chemical Salt	
4.5	20.0	$KC_2H_3O_2$	Potassium acetate
6.0	32.0	$CaCl_2 \cdot 2H_2O$	Calcium chloride
6.5	33.5	$MgCl_2 \cdot 6H_2O$	Magnesium chloride
8.0	42.0	$Zn(NO_3)_2 \cdot 6H_2O$	Zinc nitrate
10.0	58.0	$NaBr$	Sodium bromide
12.0	66.0	$NaNO_2$	Sodium nitrite
14.5	76.0	$NaC_2H_3O_2 \cdot 3H_2O$	Sodium acetate
16.0	80.5	$(NH_4)_2SO_4$	Ammonium sulfate
17.5	84.0	KBr	Potassium bromide
20.0	90.0	$ZnSO_4 \cdot 7H_2O$	Zinc sulfate
24.0	95.0	$NaSO_4$	Sodium sulfate



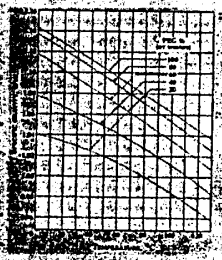
* An ordinary aquarium can be converted to a conditioning chamber for small wood samples. Relative humidity is controlled by passing air through a saturated water solution of a selected chemical salt.

Cover boards distribute clamping pressure evenly

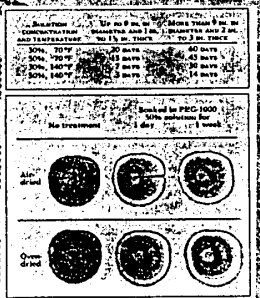




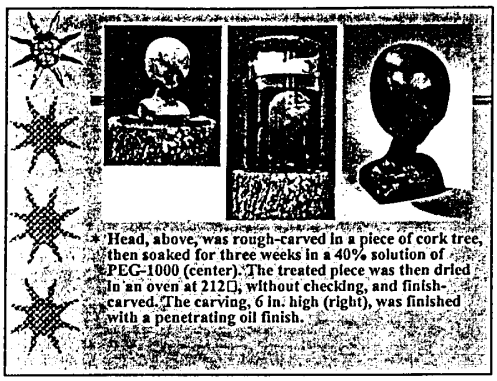
* When an edge-glued panel (A) is surfaced while the glue-line is still swollen with moisture (B, C), a sunken joint (D) is the result.



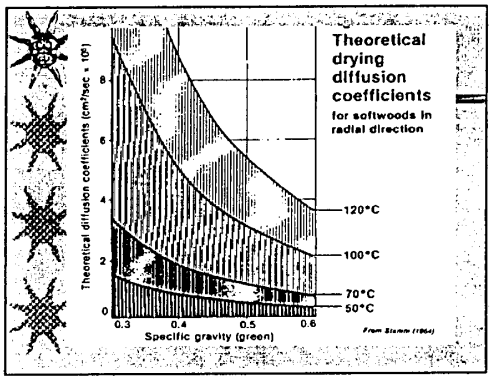
* Specific gravity of aqueous solutions of PEG. Periodic monitoring with a hydrometer allows one to keep the solution up to original strength.

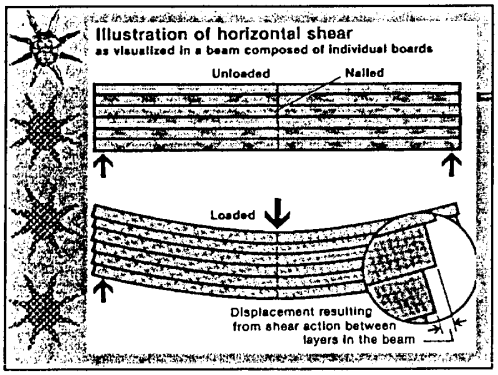


* Suggested period of soak for walnut discs. Below, discs properly treated with polyethylene glycol will dry without the usual radial cracking.



Head, above, was rough-carved in a piece of cork tree, then soaked for three weeks in a 40% solution of PEG-1000 (center). The treated piece was then dried in an oven at 212□, without checking, and finish-carved. The carving, 6 in. high (right), was finished with a penetrating oil finish.





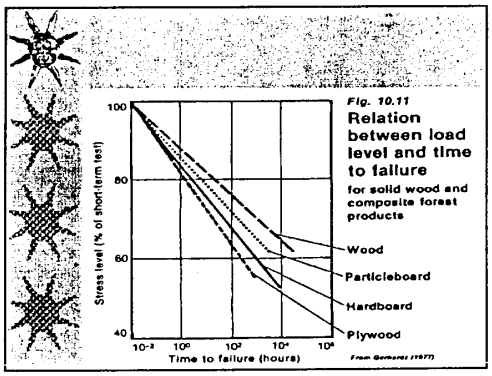
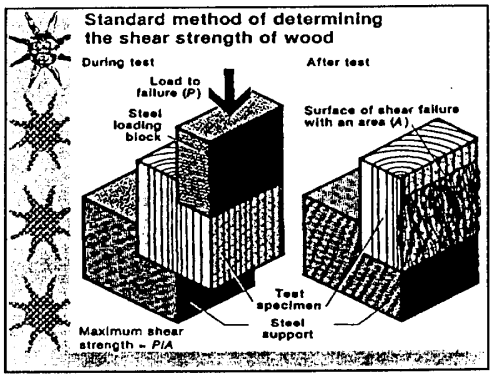
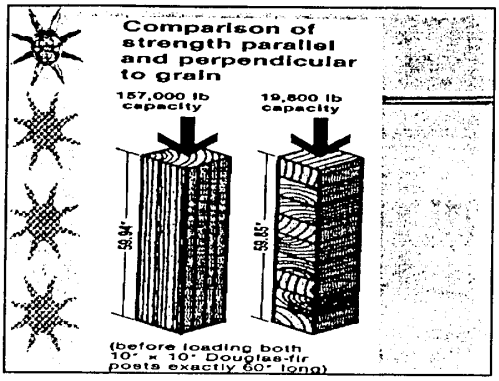


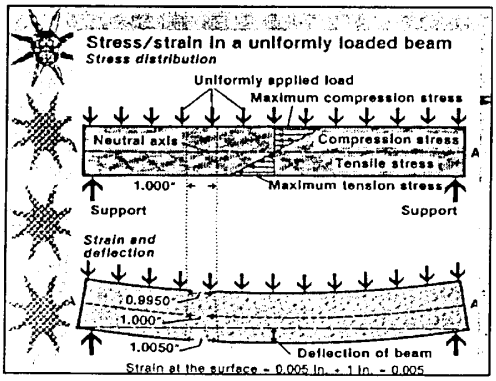
Table 10.2. Relationship between mechanical properties and specific gravities for softwoods

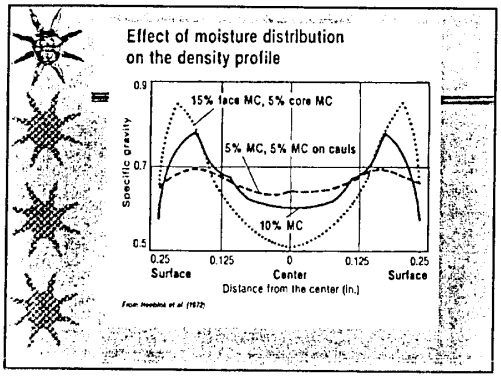
Property	Strength prediction from SG	Estimated strength at selected specific gravities (SG @ 12% MC) 0.30	0.40	0.50	0.60
Bending					
MOR (psi)	$25600 \times SG^{1.00}$	7230	9780	12360	14970
MOE (10^6 psi)	$3.13 \times SG^{0.99}$	1.06	1.37	1.68	1.98
Compression parallel to the grain					
Maximum crushing strength (psi)	$14600 \times SG^{1.02}$	4270	5730	7200	8670
MOE 10^6 psi)	$3.72 \times SG^{0.91}$	1.24	1.62	1.98	2.34
Compression perpendicular to the grain					
Stress at proportional limit (psi)	$2540 \times SG^{1.00}$	348	560	809	1094
Side hardness (lb)	$3770 \times SG^{1.24}$	251	480	793	1194

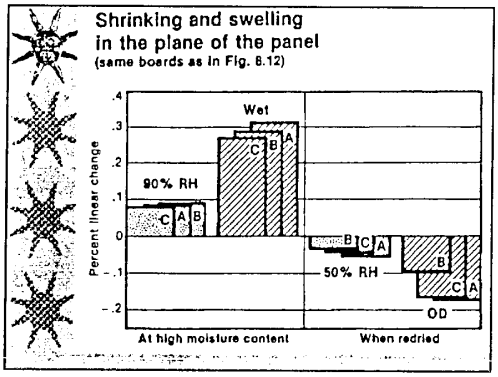
Source: USFPL (1987).

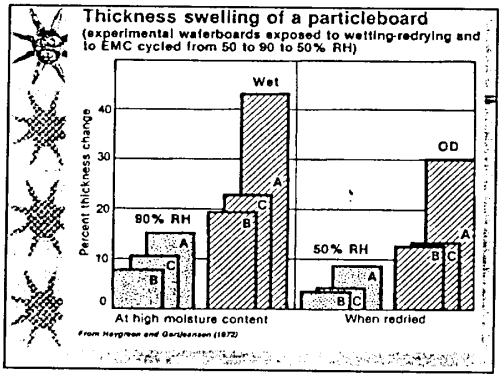


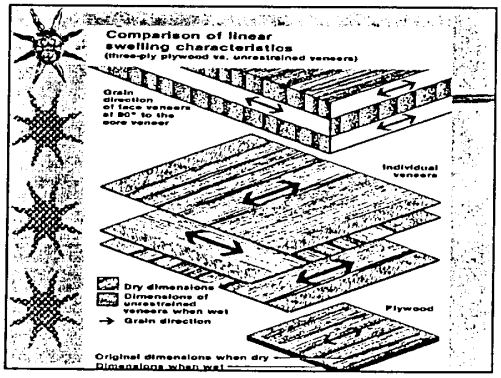

Comparison of strength parallel and perpendicular to grain
157,000 lb capacity
19,800 lb capacity
59.94"
59.85"
(before loading both 10" × 10" Douglas-fir posts exactly 60" long)


Stress/strain in a uniformly loaded beam
Stress distribution
Uniformly applied load
Maximum compression stress
Neutral axis
Compression stress
Tensile stress
1.000"
Maximum tension stress
Support
Support
Strain and deflection
0.9950"
1.000"
1.0050"
Deflection of beam
Strain at the surface = 0.005 in. ÷ 1 in. = 0.005


Effect of moisture distribution on the density profile
15% face MC, 5% core MC
5% MC, 5% MC on cauls
10% MC
Specific gravity
0.9
0.7
0.5
0.25
0.125
0
0.125
0.25
Surface
Center
Surface
Distance from the center (in.)


Shrinking and swelling in the plane of the panel
(same boards as in Fig. 8.12)
Wet
90% RH
50% RH
OD
Percent linear change
.4
.3
.2
.1
0
-.1
-.2
A
B
C
At high moisture content
When redried


Thickness swelling of a particleboard
(experimental waterboards exposed to wetting-redrying and to EMC cycled from 50 to 90 to 50% RH)
Wet
OD
90% RH
50% RH
Percent thickness change
40
30
20
10
0
A
B
C
At high moisture content
When redried


Comparison of linear swelling characteristics
(three-ply plywood vs. unrestrained veneers)
Grain direction of face veneers at 90° to the core veneer
Individual veneers
Plywood
Dry dimensions
Dimensions of unrestrained veneers when wet
Grain direction
Original dimensions when dry
Dimensions when wet

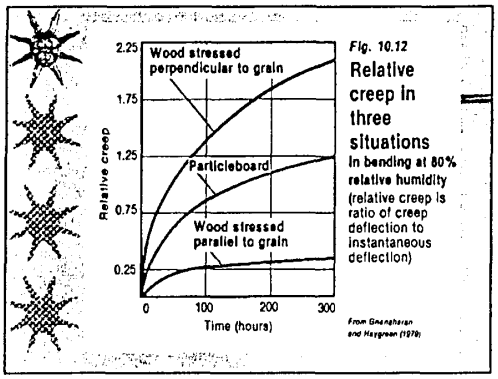
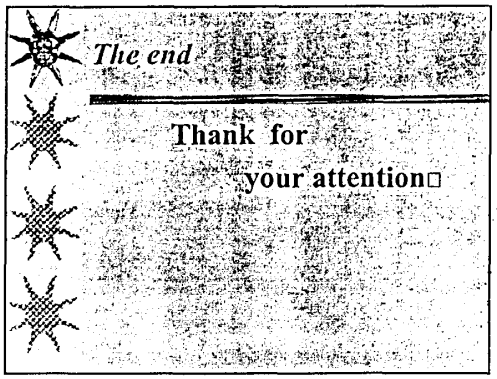


Fig. 10.12
Relative creep in three situations
In bending at 80% relative humidity
(relative creep is ratio of creep deflection to instantaneous deflection)

From Gheopharan and Haygreen (1979)



WOOD ADHESIVES AND ADHESION

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1. Introduction

1.1 What is adhesion ?

1.2 Five links theory

1.3 Importance of wood gluing

A. Wood is light-weight, high-strength
B. Easy to gluing
C. Value-added
D. Cover wood original defects
E. Utilizing small-size and low value wood
F. High reliability & durability

1.4 Classification of wood adhesives

1.4.1Based on chemical component

A. Inorganic
B. Organic B-1. Natural high polymer compound
B-2.Synthetic high polymer compound
C-1. Synthetic rubber
C-2. Synthetic resin
D-1. Thermoplastic resin
D-2. Thermosetting resin

1.4.2 Based on raw materials

A. Proteins A-1. Animal protein: ex. animal glue, casein glue, blood albumin glue

A-2. Plant protein: ex. Soybean glue, corn gluten glue

B. Hydrocarbons: ex. Starch , dextrin

C. Resins C-1. Natural resin

C-2. Synthetic resin C-2-1. Thermoplastic resin

C-2-2. Thermosetting resin

D. Rubbers D-1. Natural rubber

D-2. Synthetic rubber: ex. SBR, ABS, Neoprene

1.4.3. Based on appearance

A. Solution type□UF, PF, RF

B. Emulsion type: PVAc emulsion, EVA emulsion

C. Foam type: add blow agent for volume extending

D. Paste type: Dextrin

E. Film type: Tego-film

F. Solid type: Hot melt adhesive

G. Powder type: Powder UF

H. Pressure sensitive type: Gum tape

I. Remoisten type: Back glue of mail stamp

1.4.4 Based on curing or solidification methods

A. Cured by heat

B. Cured by hardener

C. Solidification by solvent evaporation

D. Solidification by cooling

1.5 Requirements of wood adhesive

1.5.1 Based on application

A. Mass production, low cost

B. Good bond quality

C. High reliability and durability

D. Easy to apply

E. Proper pot life

F. Curing at room temperature to medium high

G. Water soluble is desired

H. Good storage life

1.5.2 Based on physical or chemical properties

A. Must be a liquid

B. Good wettability to adherend

C. Can be cured or solidified

D. Finally to be a polymer

E. Small shrinkage in gluing process

F. Initial tacky property

G. Proper viscosity

1.6 Theory of adhesion

A. Mechanical adhesion: Anchor effect or key-in effect

B. Specific adhesion: van der Waals' force
Orientation effect, induced effect and dispersion effect

C. Chemical adhesion: Chemical bond/dispersion force/orientation and induced force=2000/ 100/ 0-5

D. H-bond

E. Polarity: Like dissolve in like

1.7 Gluing process

1.7.1 Adhesive choice

A. Type of adherend

B. Combining method: Hot or cold pressing

C. Quality required

D. Economic concern

E. Others: Odor, toxicity, color and storage life

1.7.2 Glue mixing

A. Viscosity adjustment : reducer, thickening agent

B. Filling

C. Colorant

D. Hardener

E. Others: retarder, fire-resistant, preservatives, ferroelectrics

1.7.3 Surface preparation of adherend

A. Water extruding-- drying

B. Sweep saw dust away

C. De-grease

D. De-lubricant

E. Remove coating

F. Planning and sanding- straight plane and right angle to each others

G. Others

1.7.4 Spreading style, location and rate

A. Spreading style: full spread, spot spread, margin spread,
spot and margin spread

B. Spreading location: Simple side spreading
and double sides spreading

C. Spreading rate: In general, lumber edge-gluing between the level of 260-320 g/m^2, veneer overlaying between the level of 70-120 g/m^2.

1.7.5 Glue applicator

A. Simple applicator: brush, roller, sieve plate

B. Semi-automatic applicator: spreading gun with hose supply system

C. Automatic applicator: roller coater, Robert applicator

D. Hot melt applicator: gun type, HMA banding machine

1.7.6 Gluing

A. Open assembly gluing

B. Closed assembly gluing

C. Re-active gluing: solvent reactive, heat reactive

1.7.7 Pressing

In general, UF bonding works need pressure of 5-20 kgf/cm^2, plywood manufacture needs 8-12 kgf/cm^2.

1.7.8 Heating

UF bonded works need 105-110□, PF 135-150□.

1.7.9 Mature period or aging time

2. Factors of adherend affect the bonding properties

2.1 Wood species

2.2 Specific gravity

2.3 Extractives

2.4 PH value of wood

2.5 Defects of wood

2.6 MC of adherend

A. Effect of lumber MC before gluing

B. Effect of MC after gluing and EMC on the bond strength

2.7 Flatness of lamina surface

2.8 Fiber orientation

2.9 Pollution degree on gluing surfaces

2.10 Fresh degree of gluing surfaces

3 Factors of adhesive affect the bonding properties

3.1 Wettability

3.2 Polarity

3.3 Degree of polymerization or molecular weight

3.4 Physical and chemical properties of glue

A. Residue stress in the glue lines

B. Resist to the aging

C. Effect of hardener

D. Effect of fortifier, filler and extender
E. Solid content and resin content
F. Pot life, gel time and curing time
G. Degree of polymerization
H. Viscosity
I. pH
J. Storage life

4. Factors of gluing engineer affect the bonding properties

4.1 Glue mixing

4.2 Spreading rate and glue line thickness

4.3 Assembly time

4.4 Pressure

A. sp.gr. 0.2—0.4 pressure 5—7 kgf/cm^2
B. sp.gr. 0.4—0.7 pressure 10-15 kgf/cm^2
C. sp.gr. 0.7—1.0 pressure 15—20 kgf/cm^2

4.5 Temperature and time during pressing

A. Heating by hot press
UF plywood 105-120□ 20-30 sec/ mm
PF plywood 130-150□ 40-60 sec/ mm
UF+PVAc fancy overlay 105-120□ 60-90 sec.

B. Heating by oven(hot air)

C. Heating by high frequency generator
Hardwood 70-75 in^2/ kW.min.□unit time energy efficiency□
Softwood 100-125 in^2/ kW.min.

Heat time□min.□□Total gluing area□in^2□÷ □unit time energy efficiency□in^2/ kW.min□ × H.F. out-put□kW□ × H.F. heating efficiency□50-60□□

And, H.F. out-put□kW□□ H.F. set voltage□kV□ × plate current □A□

D. Heating by steam injection

4.6 Mature period or aging time

5.Adhesives for Vinyl and Paper laminating Products

5.1 Laminating or overlaying methods

A. Wet combining
B. Semi-wet combining

C. Dry combining/ thermoplastic mounting

5.2 Laminating adhesives

5.2.1 Solvent borne urethane adhesives

5.2.2 Epoxy adhesives

5.2.3 Urea-formaldehyde resin adhesive

5.2.4 Polyvinyl acetate emulsion adhesive

5.3 Requirements for laminating adhesives

A. Non-staining

B. Non-creep

C. Non-telegraphing

D. Wet tack

6. Adhesives for Furniture Making and Their Bonding Techniques

Technical points for laminating veneer on wood products

A. Glue performance

B. Extruding out and staining troubles

C. Check on laminating veneer

6.1 Adhesives for veneer laminating

A. UF/PVAc

Adhesive	100	Spreading rate	10-12 g / 30×30 cm^2
Wheat flour	40	Assembly time	5 min.
NH_4Cl	0.5	Pressing conditions	110□, 6 kgf/cm^2, 60 sec.

B. Neutral α-olefin resin adhesive

- No formaldehyde emission
- Commercial name- Neutral kura-tack
- Ammonia as buffer, some wood has risk of color stain

Adhesive	100	Spreading rate	10-12 g / 30×30 cm^2
Wheat flour	40	Assembly time	15 min.
Cross-linking agent	50	Pressing conditions	110□, 6 kgf/cm^2, 60 sec.

C. Amino powder adhesive

Adhesive A (powder)	35	Spreading rate	10-12 g / 30×30 cm^2
Adhesive B	100	Assembly time	20 min.
Wheat flour	35	Pressing conditions	110□, 6 kgf/cm^2, 60 sec.
Water	80		

D. PVAc emulsion adhesive

- Straight PVAc (S.C.=40-45%)
- Closed assembly (10 min.)
- Pressing (iron, roller press)

E. Animal glue

- Glue : water = 1 : 2.5 (80 □ dissolve)
- Spreading → drying → assembly → iron heat re-active
- Veneer formalin treatment before heating to improve water resistant
- No extruding, clean surface
- Ebony veneer laminating

6.2 Adhesives for Flush Panel Making

- Flush panel composed by plywood skin, core and glue.
- Features
  - Plywood used as material, high bond strength is unnecessary.
  - For mass production, shorten press time is concerned.
  - Balance structure absolutely demanded
- **Types of adhesive**

A. No-clamp type PVAc emulsion

--Solid content over 45%

--Good initial tackiness

--Temp. over 20 □, press time 30 min. enough for getting initial bond strength

--No clamp ≠ no pressure needed

B. α-olefin resin adhesive

--Resin is a copolymer of isobutylene and maleic anhydride (s.c.=35-55%), hardener is epoxy compounds (dosage=2-5%).

(belong to 2-can glues)
--pH about 13, alkali stain trouble concerned
--Speed gluing cycle, but pot life is limited.

C. PVAc modified with*α*-olefin resin adhesive
-- PVAc modified by olefin resin
--Neutral (pH about 7)
--Solid content = 60% (about)
--Press time : 20 min.
--If glue lines need heat resistant ,
cross-linking agent should be mixed.

6.3 Adhesives for Edge-gluing

A. Hot melt adhesives
B. Animal glue
C. Synthetic rubber- chloroprene

6.4 Adhesives for Furniture Parts Assembly

A. PVAc emulsion
B. UF/PVAc
C. EVA emulsion
D. API or EPI (Aqueous Vinyl Polymer Isocyanate,
Emulsion Polymer Isocyanate,
Water Borne Vinyl Urethane Adhesive)

7. Conclusions

To get good bonding properties
- understanding wood
- understanding adhesives
- good knowledge to practice gluing technique

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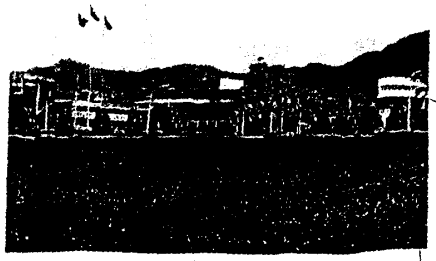
National Pingtung University of Science and Technology

TAIWAN, R.O.C.

A CORNER OF NPUST
Welcome to visit us

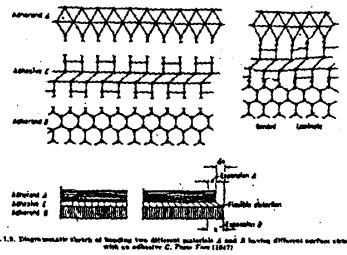


Introduction

- What is adhesion ?

  Adhesive: A substance capable of holding materials together by surface attachment.

  Adhesion: The property that causes one material to stick to another by the physical and/or chemical force between adhesive and adherend.
- Five links theory
- Importance of wood gluing



Introduction

- What is adhesion ?
- Five links theory
- Importance of wood gluing

Wood adhesion mechanism –Five links theory

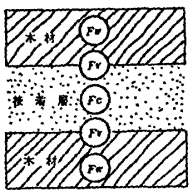
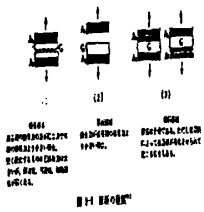


図 5-4 木材の接着機構
(Five Links)[4]

- Fw : strength of wood
- Fv : van del Waals force of interface (adhesion force)
- Fc : cohesion of glue
- Ideal adhesion:
  Fv> Fw and Fc>Fw

Types of bonding failure



- (1) cohesive failure
  Fw, Fv>Fc
- (2) interface failure
  Fw, Fc> Fv
- (3) wood failure
  Fc, Fv> Fw

7
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Introduction

Importance of wood gluing

- Wood is light-weight, high-strength
- Easy to gluing
- Value-added
- Cover wood original defects
- Utilizing small-size and low value wood
- High reliability & durability

8
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Compare among wood joints
(□ ;excellent or easy, o :good, □: no bad, × :bad)

Item	Nail & bolt	Tenon joint	Adhesion
Preparation	□	×	o
Skill	□	×	o
Thin material	×	×	□
Joint speed	□	o	o~×
Works' cutting	×	o	o
Anti-deformation	□	o	□
Beauty appearance	×	o	□
Antishrinkage	□	□	□
Durability	□	□	o~□
Sealing effect		×	□
Repair	o	×	□

9
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Wood gluing products

	Performance demanded			Resources demanded			
	Decorative	quality improve	dimension	Small dia. Or short branch	Low grade, high value added	Use wastes or residues	Use high grade log
plywood	o	o	o	o	o		o
PB		o	o	o	o	o	
FB		o	o	o	o	o	
LVL		o	o	o	o		
Glulam	o	o	o	o	o		
moulding	o	o	o				o
Secondary process plywood	o		o		o		o
Furniture	o	o	o		o		o
Structural panel	o	o	o	o			
Sport &	o	o	o				o

10
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Introduction

- Classification of wood adhesives
- Based on chemical component
- Based on raw materials
- Based on appearance
- Based on curing or solidification methods

11
2003/12/8

Based on Chemical Components

A. Inorganic
B. Organic
  B-1. Natural high polymer compound
  B-2.Synthetic high polymer compound
    C-1. Synthetic rubber
    C-2. Synthetic resin
      D-1. Thermoplastic resin
      D-2. Thermosetting resin

12
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Based on raw materials

A. Proteins A-1. Animal protein: ex. animal glue, casein glue, blood albumin glue
A-2. Plant protein: ex. Soybean glue, corn gluten glue
B. Hydrocarbons: ex. Starch , dextrin
C. Resins C-1. Natural resin
C-2. Synthetic resin
C-2-1. Thermoplastic resin
C-2-2. Thermosetting resin
D. Rubbers D-1. Natural rubber
D-2. Synthetic rubber: ex. SBR, ABS, Neoprene

13
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Based on appearance

A. Solution type□UF, PF, RF
B. Emulsion type: PVAc emulsion, EVA emulsion
C. Foam type: add blow agent for volume extending
D. Paste type: Dextrin
E. Film type: Tego film
F. Solid type: Hot melt adhesive
G. Powder type: Powder UF
H. Pressure sensitive type: Gum tape
I. Re-moistenable type: Back glue of mail stamp

14
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Based on curing or solidification methods

A. Cured by heat, ex. UF, PF
B. Cured by hardener, ex. UF, RF
C. Solidification by solvent evaporation
D. Solidification by cooling, ex. HMA

15
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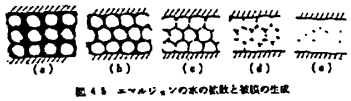
Film formation of emulsion through evaporation



16
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Requirements of wood adhesive

Based on application
A. Mass production, low cost
B. Good bond quality
C. High reliability and durability
D. Easy to apply
E. Proper pot life
F. Curing at room temperature
G. Water soluble is desired
H. Good storage life

17
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Requirements of wood adhesive

Based on physical or chemical properties
A. Must be a liquid
B. Good wettability to adherend
C. Can be cured or solidified
D. Finally to be a polymer
E. Small shrinkage in gluing process
F. Initial tacky property
G. Proper viscosity

18
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Liquid drop wetting on solid surface

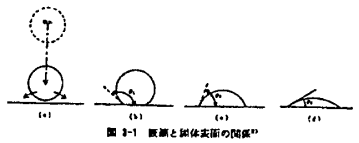


図 3-1 液滴と固体表面の関係

19

Theory of adhesion

A. Mechanical adhesion: Anchor effect or key-in effect
B. Specific adhesion: van der Waals' force orientation effect, induced effect and dispersion effect
C. Chemical adhesion: Chemical bond/dispersion force/orientation and induced force=2000/ 100/ 0-5
D. H-bond
E. Polarity: Like dissolve in like

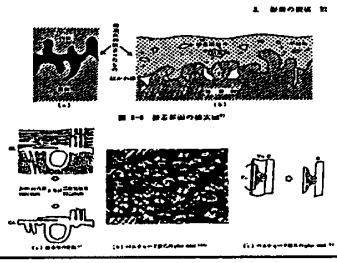
20

Bonding forces

Adhesion
A. mechanical adhesion (anchor effect)
B. specific adhesion
B-1 chemical adhesion
B-1-1 primary bonding : ion bond, covalent bond and metal bond
B-1-2 H-bonding
B-2 van der Waals' force : orientation, induced and dispersion force

21

Evidence for anchor effect



22

Reaction between diisocyanate, wood and water (Chemical adhesion)

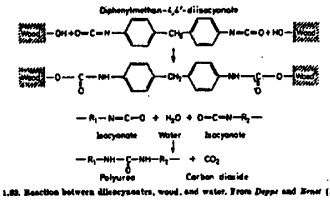


Fig. 1.88. Reaction between diisocyanates, wood, and water. From Deppe and Ernst (1971)

23

Bonding energy and bonding distance

Bonding type	Bonding distance (A= 10^{-8}cm)	Bonding energy (kcal/ mole)
Van der Waals' force	3-5	0.5-5
H-bonding	2-3	5-10
Primary bonding	1-2	50-200

24

Factors affect the bonding properties

- Adherend (Wood properties)
- Adhesives (Adhesive properties)
- Gluing engineer (Gluing conditions)

25
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Factors of adherend affect the bonding properties

- Wood species
- Specific gravity
- Extractives
- PH value of wood
- Defects of wood
- MC of adherend
- Flatness of lamina surface
- Fiber direction
- Pollution degree on gluing surfaces
- Fresh degree of gluing surfaces

26
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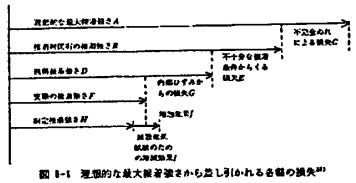

27
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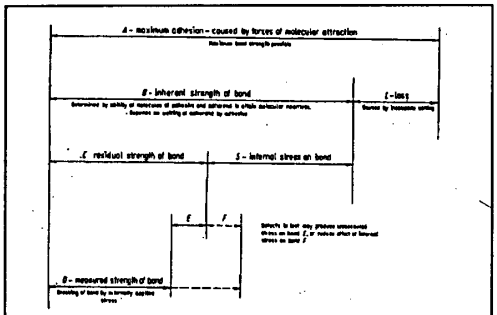

28

Wood properties affect bonding strength

- Species
- Specific gravity

29
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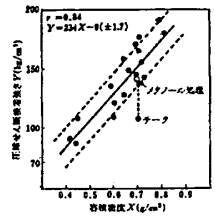
Relationship between sp.gr. (X) & shear bond strength (Y)



30
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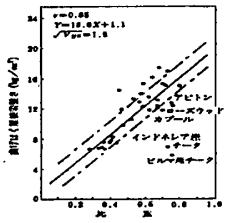
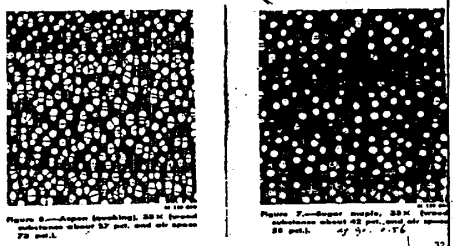
Specific gravity (X) vs. bending peel strength (Y)



31

Higher sp. gr. means higher percent of cell wall substance and larger area for bonding



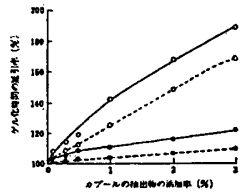
32

Wood properties affect bonding strength

- Extractives
- pH
- Defects

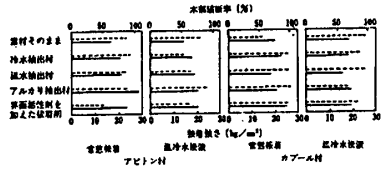
33

Gel time extended by extractives
X: dosage of kapur extractractives
Y: gel time increment rate



34

Bond strength of extracted apitong and kapur with various methods
(solid line : bond strength; dot line: wood failure)



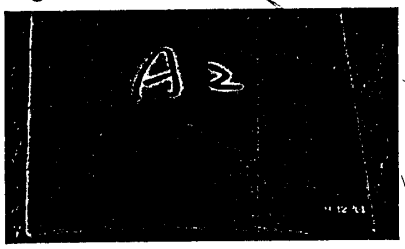
35

Wood properties affect bonding strength

- Moisture content
- Surfaces roughness
- Fiber orientation
- Pollution degree
- Fresh degree

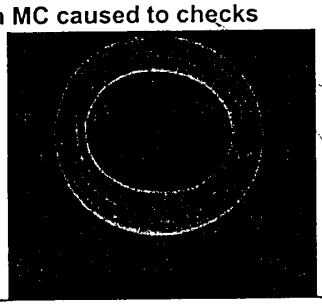
36

Veneer laminated product having high MC caused to checks



37

Veneer laminated product having high MC caused to checks



38

Lumber MC (X) before gluing vs. bond strength (Y)

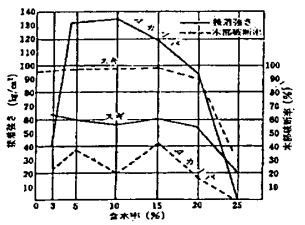


図 6-8 接着時の含水率と接着性能の関係（ユリア樹脂接着剤）[80]

39

Veneer MC (X) vs. plywood bond strength (Y)

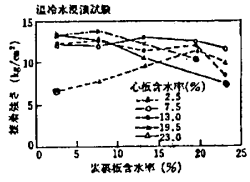


図 6-9 単板含水率と単板接着強さ[81]

40

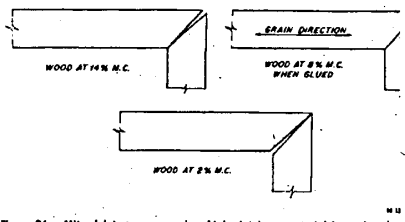
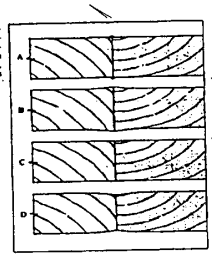


Figure 26.—Miter joints can open when high-shrinkage material is used and w variations in moisture content occur. A glued spline or other reinforcement reduce or prevent joint separation. Vertical-grained material, having lower shri age in width, will reduce chances for separation of this type of joint.

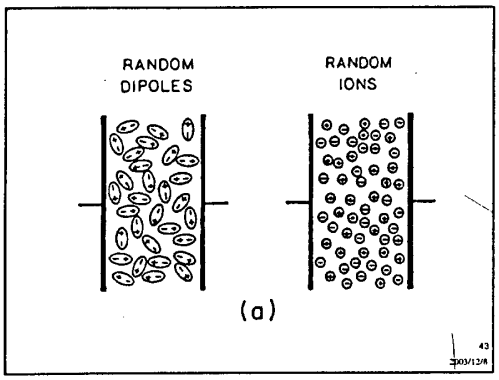
41

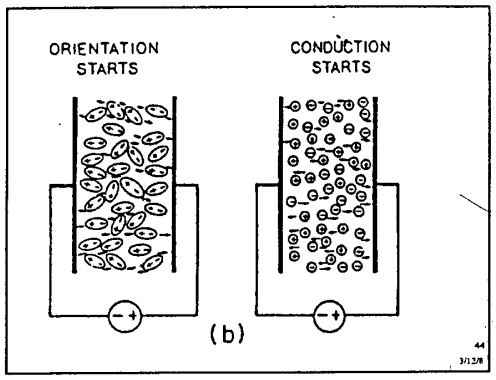
Sunken joint

2—When an edge-glued panel (A) is surfaced while the glueline is still swollen with moisture (B, C), a sunken joint (D) is the result.



42





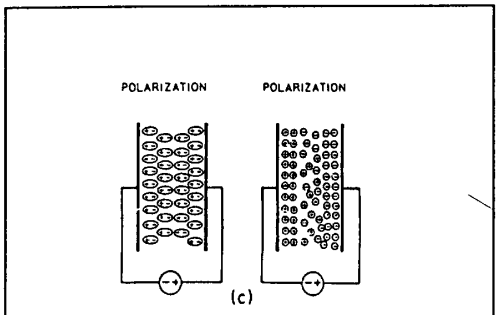
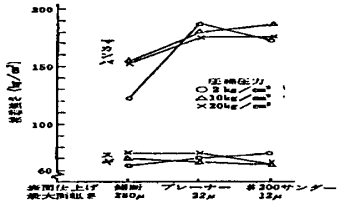


FIGURE 3 Idealized view of the polarization due to dipoles and ions: (a) unpolarized; (b) orientation and conduction begins; (c) fully polarized. In actual materials, both processes can occur simultaneously.

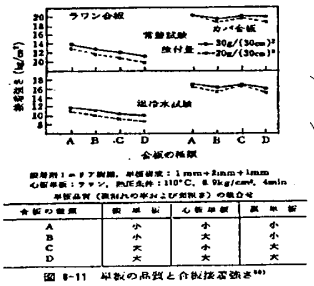
Wood properties affect bonding strength

- Moisture content
- Surfaces roughness
- Fiber orientation
- Pollution degree
- Fresh degree

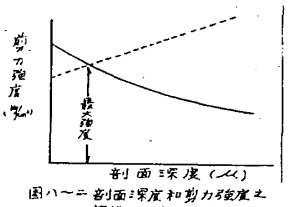
Surface roughness (X) vs. bond strength (Y) (Legends were pressure)



Veneer quality vs. plywood bond strength



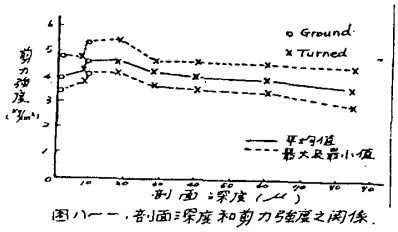
Profile depth (X) vs. shear bond strength (Y) [Theoretical description]



図ハー二 剖面深度和剪力強度之関係，決定於兩相矛盾的影响因子。

49
2003/12/8

Profile depth (X) vs. shear bond strength (Y) [Practical results]



図ハー一，剖面深度和剪力強度之関係。

50
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Wood properties affect bonding strength

- Moisture content
- Surfaces roughness
- Fiber orientation
- Pollution degree
- Fresh degree

51
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Bond strength of 2 lamina with different grain orientation (in plane)

表 8-4 2枚の板の木目方向が異なる場合の接着強さ[4]

樹種	木目方向のなす角度	0°	15°	30°	45°	60°	75°	90°
スギ	引張強さ (kg/cm²)	65.1	54.9	40.6	30.2	24.5	20.4	18.0
	木部破断率(%)	89	62	54	45	30	24	32
ホワイトラワン	引張強さ (kg/cm²)	84.1	72.4	64.5	58.9	44.5	36.6	33.3
	木部破断率(%)	89	51	59	67	28	21	51

注）接着剤：ユリア樹脂，比圧縮圧力：10kg/cm²，試験法：圧縮せん断

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52
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Bond strength of 2 lamina with different grain orientation (out-plane)

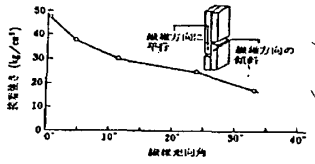

図 8-13 繊維方向角と接着強さの関係（接着層に対して垂直方向）[55]

53
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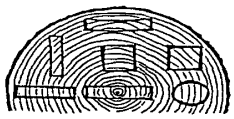
Anisotropic; shrinkage T/R/L= 10/5/0.5-1



異方性：收縮比例 T:R:L = 10:5:0.5～1

54
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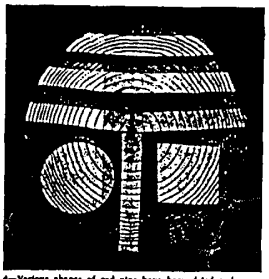

4—Various shapes of red pine have been dried and superimposed on their original positions on an adjacent log section. The greater tangential than radial shrinkage causes squares to become diamond-shaped, cylinders to become oval. Quarter-sawn boards seldom warp, but flat-sawn boards cup away from the pith.

55

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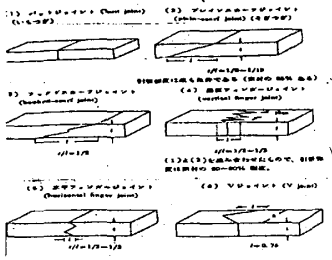
Strength retention in different type of wood joints



56

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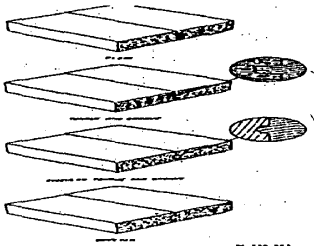
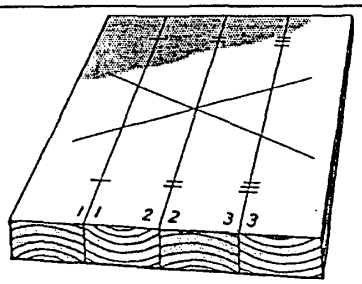
Edge joints



57

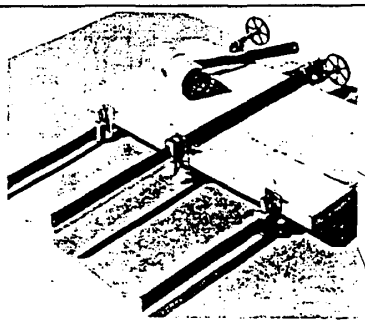
2003/12/8



13-6. Pieces arranged with the annual rings in opposite directions.

58

2003/12/8

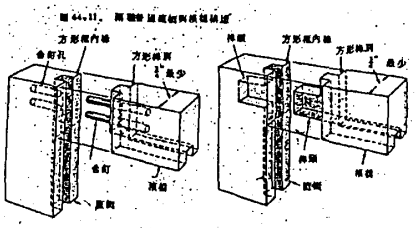


13-7a. Note that the clamps should be alternated, one from or from the opposite side.

59

2003/12/8

Dowel and tenon joints



60

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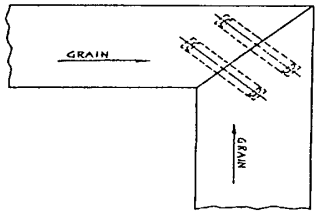
Mitered joint with dowels



61
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Corrugated fasteners used on a mitered joint

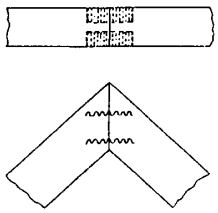

Figure IX: Corrugated fasteners used on a mitered joint.

62
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Wood properties affect bonding strength

- Moisture content
- Surfaces roughness
- Fiber orientation
- Pollution degree
- Fresh degree

63
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Surface pollution vs. bond strength

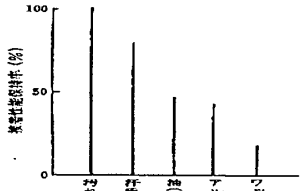

図 8-14 接着材面の汚れと接着性[40]

64
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Wood properties affect bonding strength

- Moisture content
- Surfaces roughness
- Fiber orientation
- Pollution degree
- Fresh degree

65
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The wettability (Y) of glycerol on wood vs. fresh degree (X)

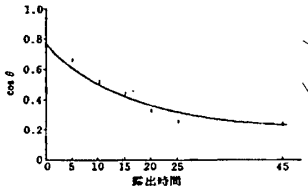

図 6-12 ダグラスファーの晩材の切断後露出時間とグリセロール (γ_{LV}=63.40erg/cm^2) による接触角 θ の関係[40]

66
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Factors of adhesive affect the bonding properties

- Wettability
- Polarity
- Degree of polymerization or molecular weight
- Physical and chemical properties of glue

67
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Liquid on solid surface

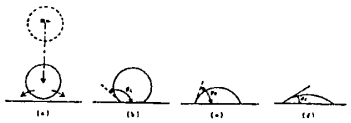

図 3-1 液滴と固体表面の関係[1]

66
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What is the good wettability?

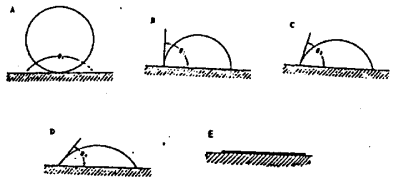

図 2－4 濡れ性A＜B＜C＜D＜E

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69
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Wettability (Y) of several species (X) used for furniture making

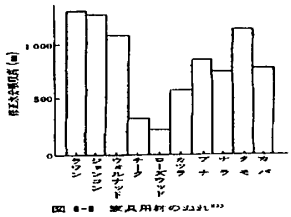

図 6-8 家具用材のぬれ[2]

70
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Contact angle (X) vs. bond strength (Y) of several tropic species

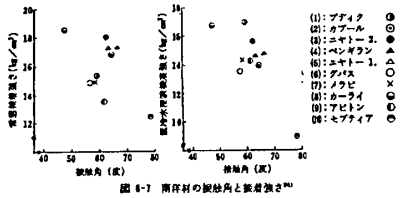

図 6-7 南洋材の接触角と接着強さ[2]

71
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Factors of adhesive affect the bonding properties

- Wettability
- Polarity
- Degree of polymerization or molecular weight
- Physical and chemical properties of glue

72
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Surface energy

- Aluminum 500
- Copper 1100
- Iron 2030
- Wood (Douglas fir) 58-61
- Melamine resin 52
- Urea resin 45
- Epoxy resin 46
- PVAc 36.5
- Polyethylene 31

73
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Surface tension force of adhesives

- Acid cure phenol resin 78 (20□, dyne/cm)
- Urea resin 63.0 (BS=96 kgf/cm²)
- Urea resin + 0.01% surfactant 56.5 (BS=108 kgf/cm²)
- Urea resin + 0.025% surfactant 49.6 (BS=116 kgf/cm²)
- Urea resin + 0.2% surfactant 38.7 (BS=85 kgf/cm²)
- RPF 48
- PVAc emulsion 38
- Epoxy 47.2

74
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Factors of adhesive affect the bonding properties

- Wettability
- Polarity
- Degree of polymerization or molecular weight
- Physical and chemical properties of glue

75
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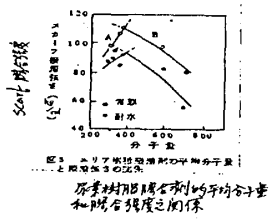
Effect of UF MW (X) on bond strength (Y)



76
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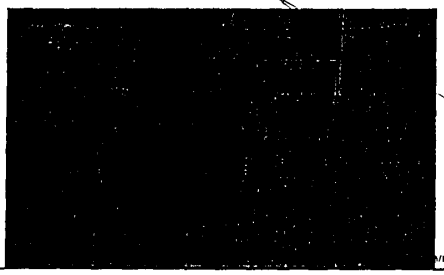
Bleeding through caused by PF resin that was cured incompletely



77
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Factors of adhesive affect the bonding properties

- Wettability
- Polarity
- Degree of polymerization or molecular weight
- Physical and chemical properties of glue

78
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Physical and chemical properties of glue

Residue stress in the glue lines
Resist to the aging
Effect of hardener
Effect of fortifier, filler and extender
Solid content and resin content

79
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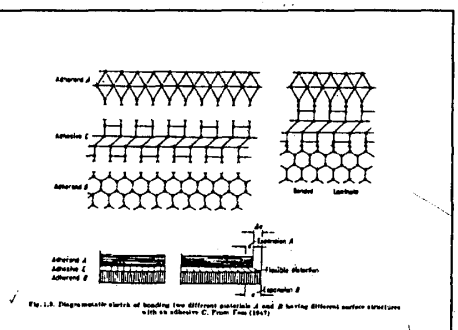

80
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Physical and chemical properties of glue

Residue stress in the glue lines
Resist to the aging
Effect of hardener
Effect of fortifier, filler and extender
Solid content and resin content

81
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Properties of room temp. setting adhesives (○:good, □:fine, ×: bad)

resin	temp	solvent	dry	Cool water	60 C water	Cyclic test	72 hr boiling
RF	Over 10 □	water	○	○	○	○	○
PF	Over 20 □	alcohol	○	○	○	○	○
MF	Over 30 □	water	○	○	○	○	□
UF	Over 5 □	water	○	○	○	×	×
PVAc	Over 5 □	water	○	□	×	×	×

82
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Estimating the durability of wood adhesives (○:very durable., □:durable, ×: no durable.)

Expose condition		PF	RF	MF	UF	PVAc
In-door	general	○	○	○	○	○
	High RH-low-RH	○	○	○	□	○
	High T	○	○	□	×	×
Out-door	open	○	○	□	×	×
	shield	○	○	○	□	□
	In water	○	○	○	□	×

83
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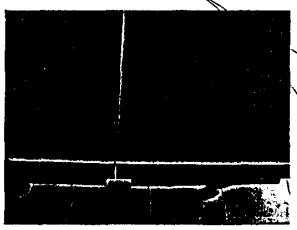
Decorative plate peeling-bonded with non-durable glue



84
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Physical and chemical properties of glue

- Residue stress in the glue lines
- Resist to the aging
- Effect of hardener
- Effect of fortifier, filler and extender
- Solid content and resin content

85

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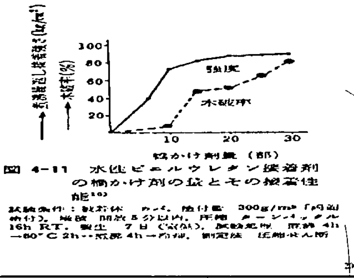
Amount of cross-linking agent (X) vs. bond strength (Y) and wood failure (lower) of water borne vinyl urethane



86

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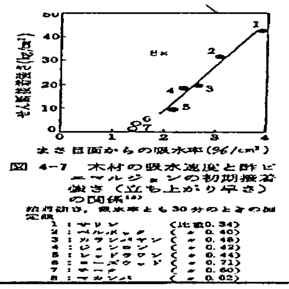
Water absorbing speed vs. bond strength development



87

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Physical and chemical properties of glue

- Residue stress in the glue lines
- Resist to the aging
- Effect of hardener
- Effect of fortifier, filler and extender
- Solid content and resin content

88

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Physical and chemical properties of glue

- Residue stress in the glue lines
- Resist to the aging
- Effect of hardener
- Effect of fortifier, filler and extender
- Solid content and resin content

89

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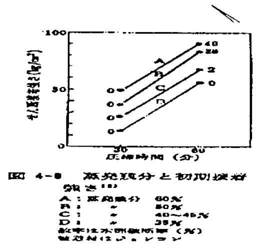
Solid content vs. bond strength development



90

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Resin content of UF vs. bond performance

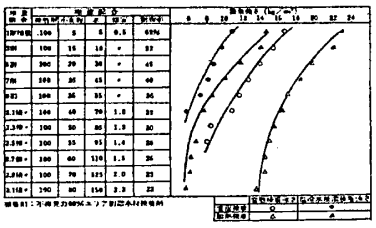

図 6-29 メラミン樹脂接着剤樹脂の樹脂率と接着性能[92]

91
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Physical and chemical properties of glue

- Pot life, gel time and curing time
- Degree of polymerization
- Viscosity
- pH
- Storage life

92
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Temperature and time (X) vs. viscosity (Y)

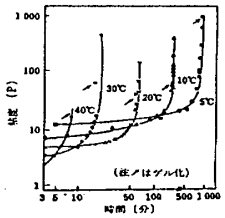

図 6-30 メラミン樹脂接着剤のゲル化するまでの放置条件と粘度上昇の関係[93]

93
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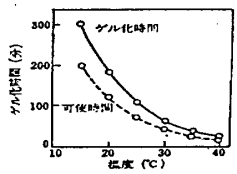
Temperature vs. pot life (lower) & gel time (upper)



配合 レゾルシノール樹脂100部，硬化剤20部

図 6-31 温度と可使時間およびゲルタイムの関係[94]

94
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Extending the pot life

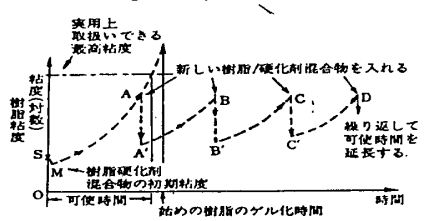

図 7-30 可使時間の延長[91]

95
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Physical and chemical properties of glue

- Curing time and temperature
- Pot life, gel time and curing time
- Degree of polymerization
- Viscosity
- pH
- Storage life

96
2003/12/8

Curing temperature & time vs. Tg

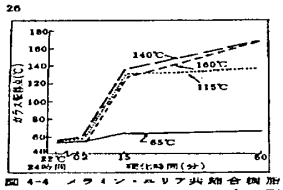

図 4-4 メラミン・ユリア共縮合樹脂（メラミン：ユリア＝6：40）の硬化温度と時間がガラス転移点に及ぼす影響[11]

97

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Vinyl urethane curing time (X) at 20 □ vs. lap joint strength (Y)

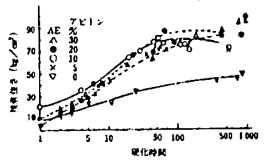

図 8-33 水性ビニルウレタン接着剤の 20°C での硬化時間とラップジョイント接着強さの関係[33]

98

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Physical and chemical properties of glue

- Pot life, gel time and curing time
- Degree of polymerization
- Viscosity
- pH
- Storage life

99

2003/12/8

Curing temperature & time (X) of RPF vs. bond strength (Y)

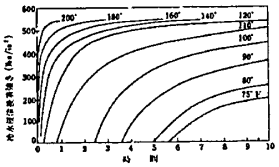

図 4-1 フェノール・レゾルシノール接着剤の硬化温度と接着強さ[3]

100

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Conversion rate (X,%) of resin vs. bond strength (Y) and wood failure (Y,%)

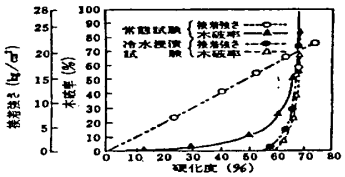

図 8-34 合板接着強さ（カナダ規格：CSA D 121）と硬化度の関係[33]

101

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Conversion rate (X,%) vs. bond strength (Y)

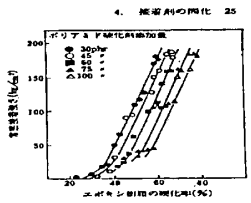

図 4-2 エポキシ樹脂の硬化率と接着強さとの関係[12]

102

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Physical and chemical properties of glue

Pot life, gel time and curing time
Degree of polymerization
Viscosity
pH
Storage life

103
2003/12/8

Viscosity of UF (X) vs. plywood durability in peeling test

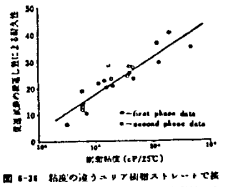

図 8-36 粘度の違うユリア樹脂ストレートで接着した合板の煮沸繰返しはく離試験による接着耐久性[81]

104
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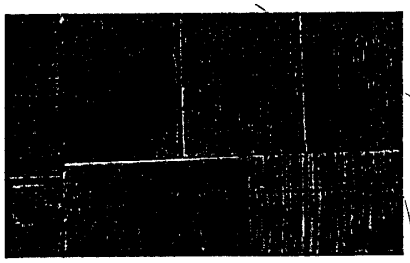
Bleeding through due to low viscosity



105
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Physical and chemical properties of glue

Pot life, gel time and curing time
Degree of polymerization
Viscosity
pH
Storage life

106
2003/12/8

Condensation rate of UF vs. pH

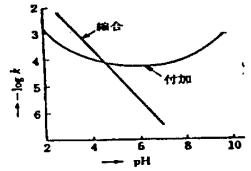

図 8-37 ユリアとホルマリンの反応の速度と pH の関係[81]

107
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pH vs. gel time of RF

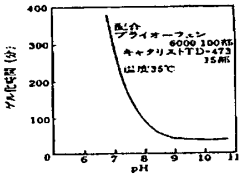

図 8-38 レゾルシノール樹脂の pH とゲルタイムの関係[113]

108
2003/12/8

pH vs. condensation rate of P & F

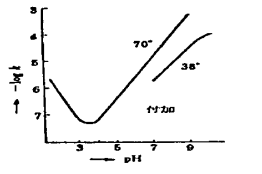

図 8-39 フェノールとホルマリンの反応の速度と pH の関係[41]

109
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Gel time vs. pH of RF resin

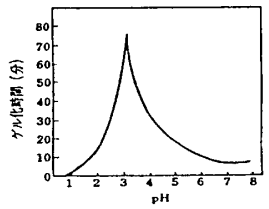

図 7-27 レゾルシノール樹脂の硬化速度に及ぼす pH の影響[83]

110
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Physical and chemical properties of glue

Pot life, gel time and curing time
Degree of polymerization
Viscosity
pH
Storage life

111
2003/12/8

Factors of gluing engineering affect the bonding properties

- Glue mixing
- Spreading rate and glue line thickness
- Assembly time
- Pressure
- Temperature and time during pressing
- Mature period or aging time

112
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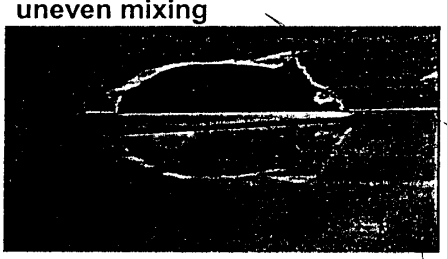
Glue line delamination due to uneven mixing



113
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Glue mixing ratio affects cutting period

Adherend	Cutting period(%)
Solid wood (control)	100
Straight UF	68.8
UF 9 parts + PVAc 1 Part	72.5
UF 8 parts + PVAc 2 parts	81.3

114
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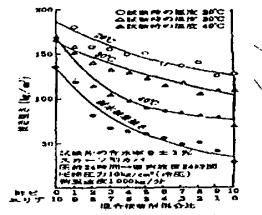
Mixing ratio of UF & PVAc vs. water resistance



115
2003/12/8

Factors of gluing engineering affect the bonding properties

- Glue mixing
- Spreading rate and glue line thickness
- Assembly time
- Pressure
- Temperature and time during pressing
- Mature period or aging time

116
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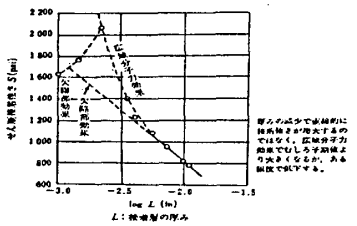
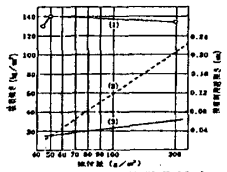
Glue lines thickness (X) vs. bond strength (Y)



117
2003/12/8

Spreading rate vs. bond strength



118
2003/12/8

Factors of gluing engineering affect the bonding properties

- Glue mixing
- Spreading rate and glue line thickness
- Assembly time
- Pressure
- Temperature and time during pressing
- Mature period or aging time

119
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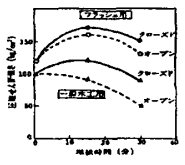
Assembly time (X) vs. bond strength (Y)



120
2003/12/8

Factors of gluing engineering affect the bonding properties

- Glue mixing
- Spreading rate and glue line thickness
- Assembly time
- Pressure
- Temperature and time during pressing
- Mature period or aging time

121

Pressure (X) vs. bond strength (Y) of plywood

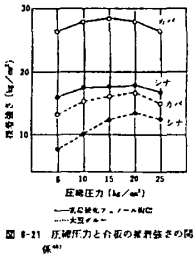


図 8-21 圧縮圧力と合板の剥離強さの関係

122

Pressure (X) vs. bond strength (rubber system)

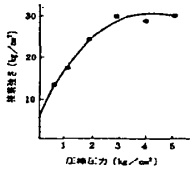
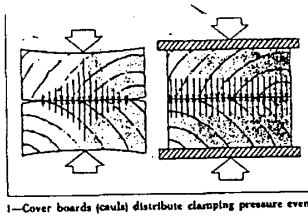


図 8-23 圧縮圧力と接着強さ（合成ゴム系）

123

Cauls distribute clamping pressure even



1—Cover boards (cauls) distribute clamping pressure even

124

Thickness change of veneer lead to uneven loading

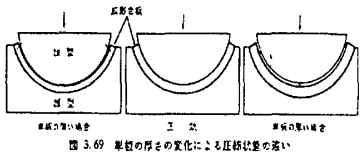
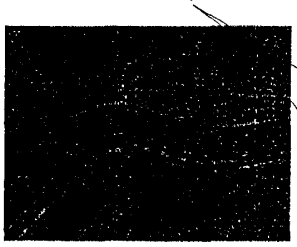


図 3.69 単板の厚さの変化による圧締状態の違い

125

Veneer laminated products



126

Factors of gluing engineering affect the bonding properties

- Glue mixing
- Spreading rate and glue line thickness
- Assembly time
- Pressure
- Temperature and time during pressing
- Mature period or aging time

127
2003/12/8

Pressing time (X) vs. bond strength (Y)

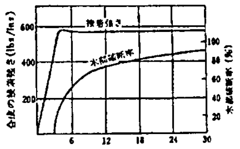


図 6-25 圧締時間と合板（カバ）の接着強さならびに木部破断率[37]（レゾルシノール樹脂接着剤）

128
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Factors of gluing engineering affect the bonding properties

- Glue mixing
- Spreading rate and glue line thickness
- Assembly time
- Pressure
- Temperature and time during pressing
- Mature period or aging time

129
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Post cure vs. bond strength

表 6-5 フェノール樹脂の熱圧後の硬化の進行[40]

煮沸繰返し試験 / 熱圧後の処理	熱圧時間 3分30秒		熱圧時間 4分30秒	
	接着強さ (kg/cm²)	木破(%)	接着強さ (kg/cm²)	木破(%)
熱圧→ただちに冷水浸漬30分→気乾	13.5	56	17.6	89
熱圧→1時間堆積→冷水浸漬30分→気乾	15.0	54	17.4	85
熱圧→120°C恒温器30分→冷水30分→気乾	15.3	77	17.4	90

注）単板構成：ホワイトラワン 1.0mm+2.4mm+1.0mm
塗付量：20g/(30cm)², 熱圧条件：125°C 6分 11 kg/cm²

130
2003/12/8

Conclusions

- To get good bonding properties
- understanding wood
- understanding adhesives
- good knowledge to practice gluing technique

131
2003/12/8

Thank For

Your Attention□

-the end-

132
2003/12/8

ADHESIVES FOR VINYL AND PAPER LAMINATING PRODUCTS AND FURNITURE MAKING

Dr. CHENG-JUNG LIN

Head and Professor
Dept. of Wood Industry
National Pingtung University of Science and Technology

Adhesives for Vinyl and Paper Laminating Products and Furniture Making

Dr. Cheng-Jung Lin

Head and Professor of Dept. of Wood Industry
National Pingtung University of Science and Technology
TAIWAN, R.O.C.

Laminating or overlaying methods

- Wet combining
- Semi-wet combining
- Dry combining/ thermoplastic mounting

Adhesives requirements for vinyl and paper laminating products

- Non-staining
- Non-creep
- Non-telegraphing
- Wet tack

Adhesives for laminating

- Solvent borne urethane adhesives
- Epoxy adhesives
- Urea-formaldehyde resin adhesive
- Polyvinyl acetate emulsion adhesive

Veneering on wood products

Technical key points

A. Good glue performance
B. No extruding out and staining surface
C. Avoid check occurring on laminating veneer

Adhesives for Furniture Making

- Adhesives for veneering
- A. UF/PVAc
- B. Neutral α-olefin resin adhesive
- C. Amino powder adhesive
- D. PVAc emulsion adhesive
- E. Animal glue

Adhesives for veneering

- A. UF/PVAc
  B. Neutral α-olefin resin adhesive
  C. Amino powder adhesive
  D. PVAc emulsion adhesive
  E. Animal glue

UF/PVAc
(Formulation example)

Adhesive	100	Spreading rate	10-12 g/ 30×30cm^2
Wheat flour	40	Assembly time	5 min.
NH_4Cl	0.5	Pressing	110□, 6 kgf/cm^2, 60 sec.

Neutral α-olefin resin adhesive

- No formaldehyde emission
- Commercial name- Neutral kura-tack
- Ammonia as buffer, some wood has risk of color stain

Neutral α-olefin resin adhesive
(Formulation example)

Adhesive	100	Spreading rate	10-12 g/ 30×30cm^2
Wheat flour	40	Assembly time	15 min
Cross-linker	50	Pressing	110□, 6 kgf/cm^2, 60 sec.

Adhesives for veneering

A. UF/PVAc
- B. Neutral α-olefin resin adhesive
- C. Amino powder adhesive
- D. PVAc emulsion adhesive
- E. Animal glue

Amino powder adhesive
(Formulation example)

Adhesive A (powder)	35	Spreading rate	10-12 g/ 30×30cm^2
Adhesive B (PVAc)	100	Assembly time	20 min.
Wheat flour	35	Pressing	110□, 6 kgf/cm^2, 60 sec.
Water	80		

Adhesives for veneering

- A. UF/PVAc
- B. Neutral α-olefin resin adhesive
- C. Amino powder adhesive
- D. PVAc emulsion adhesive
- E. Animal glue

PVAc emulsion adhesive

- Straight PVAc (S.C.=40-45%)
- Closed assembly (10 min.)
- Pressing (iron, roller press)

Adhesives for veneering

- A. UF/PVAc
- B. Neutral α-olefin resin adhesive
- C. Amino powder adhesive
- D. PVAc emulsion adhesive
- E. Animal glue

Animal glue

- Glue : water = 1 : 2.5 (80 □ dissolve)
- Spreading → drying → assembly → iron heat re-active
- Veneer formalin treatment before heating to improve water resistant
- No extruding, clean surface
- Ebony veneer laminating

Adhesion of Flush Panel Making

- Flush panel composed by plywood skin, core and glue.
- Features
  - Plywood used as material, high bond strength is unnecessary.
  - For mass production, shorten press time is concerned.
  - Balance structure absolutely demanded

Adhesives for Flush Panel Making

- No-clamp type PVAc emulsion
- α-olefin resin adhesive
- PVAc modified with α-olefin resin adhesive

No-clamp type PVAc emulsion

- Solid content over 45%
- Good initial tackiness
- Temp. over 20 □, press time 30 min. enough for getting initial bond strength
- No clamp ≠no pressure needed

α-olefin resin adhesive

- Resin is a copolymer of isobutylene and maleic anhydride (s.c.=35-55%), hardener is epoxy compounds (dosage=2-5%). (belong to 2-can glues)
- pH about 13, alkali stain trouble concerned
- Speed gluing cycle, but pot life is limited.

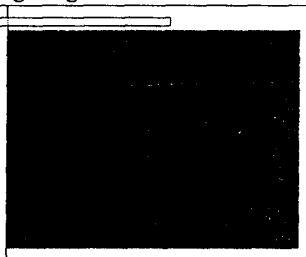
PVAc modified with α-olefin resin adhesive

- PVAc modified by olefin resin
- Neutral (pH about 7)
- Solid content = 60% (about)
- Press time : 20 min.
- If glue lines need heat resistant , crosslinker should be mixed.

Adhesives for Edge-gluing

- Hot melt adhesives
- Animal glue
- . Synthetic rubber- chloroprene

Edge-gluing with hot melt adhesive



Adhesives for Furniture Parts Assembly

- PVAc emulsion
- UF/PVAc
- EVA emulsion (parts be finished)
- API or EPI (Aqueous Vinyl Polymer Isocyanate

Conclusions

- To get good bonding properties
  - understanding wood
  - understanding adhesives
  - good knowledge to practice gluing engineering

Thank for your attention

-the end-

E & FD- for Furniture Class Presenting at Malaysia

Ergonomics & Furniture Design

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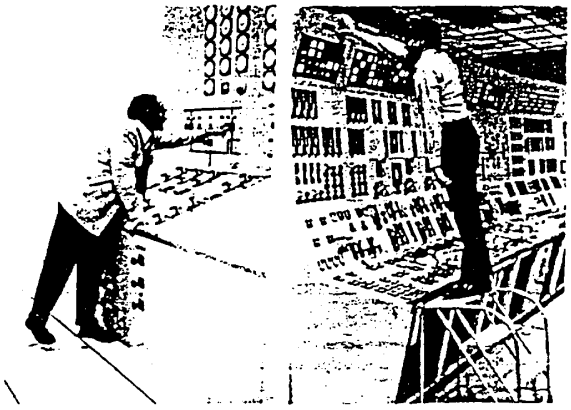
Dec. 09, 2003; from Taiwan

Ergonomics & Furniture Design

Contents

Work spaces (Introduction)

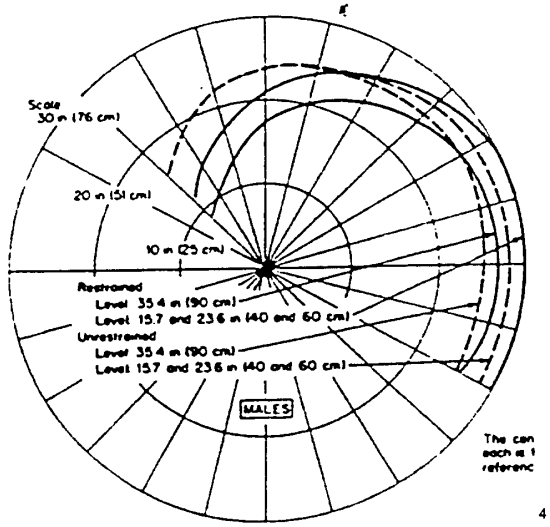


A couple of human factors problems in a nuclear power plant. In the photograph on the left, the control console is arranged so that certain controls could be accidentally activated by the knee or the hand used to brace the operator when reaching for the farthest controls. In the photograph on the right, certain of the displays are at a height that makes reading or lamp replacement a problem. Special stepladders are required. (*Copyright 1979, Electric Power Research Institute, EPRI Report NP-1118, "Human Factors Methods for Nuclear Control Room Design." Reprinted with permission.*)

3

Work spaces (Effects of DR & PR 1)

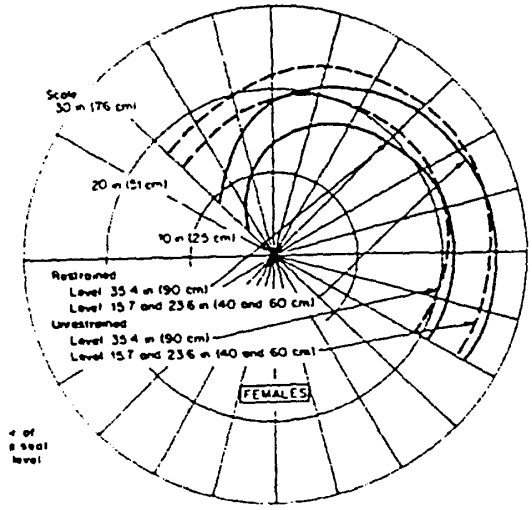
- effects of direction of reach & presence restrains



4

Work spaces (Effects of DR & PR 2)

effects of direction of reach & presence restrains



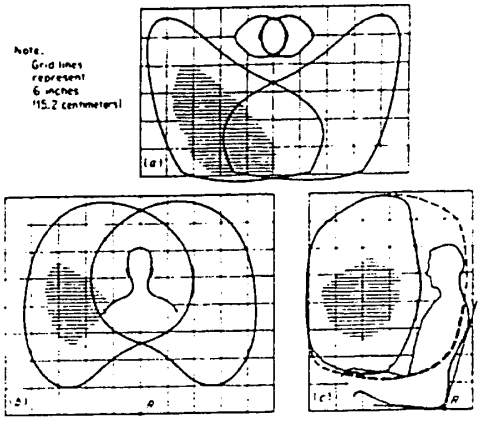
5

Work spaces (Effects of manual activity 1)

- Fingertip measurement: if an individual simply has to activate push buttons or toggle switches.
- Thumb tip measurement: as contrasted with the requirement to use knobs or to grasp levers.
- Thumb tip measurements are about 5 cm shorter than fingertip.
- A hand-grasp or griplike action limits the reach by 5 cm or more.

6

Work spaces (Effects of manual activity 2)



Strophosphere resulting from superimposition of kinetospheres of range of hand movements with a number of hand-grasp positions in three-dimensional space. The shaded areas depict the region common to all hand motions (prone, supine, inverted, and several different angles of grasps), probably the optimum region, collectively, of the different types of hand manipulations. (Source: *Adapted from Dempster, 1955.*)

7

Work spaces (Effects of apparel)

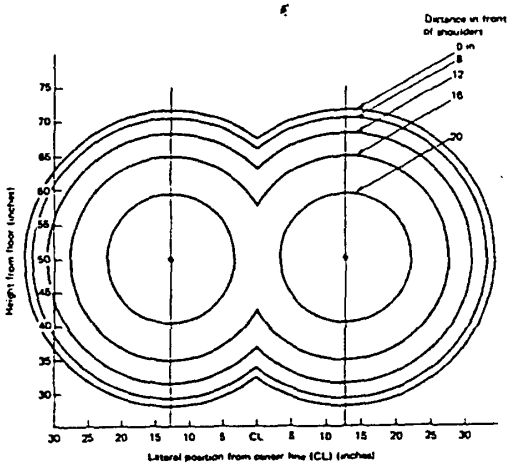
- Winter jackets restricted reach by approximately 5 cm.

8

Work spaces (envelopes for standing personnel 1)

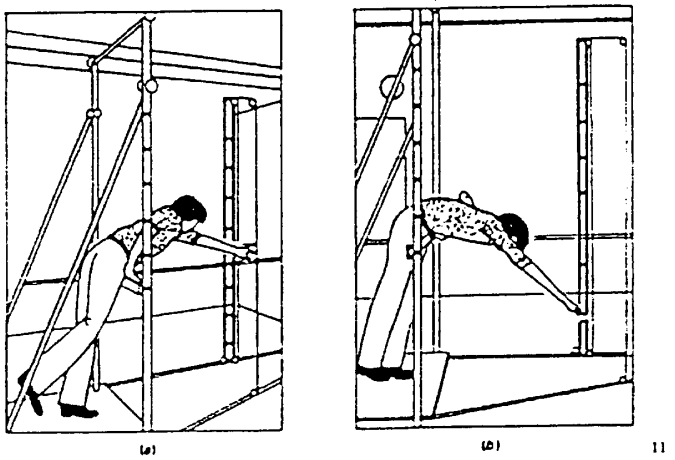
- Reach is increased by increasing the base of the feet.
- With a below-elbow prosthesis there is an average decrease in usable work space of 45 percent, and with an above-elbow prosthesis the average decrease is 83 percent.

Work spaces (envelopes for standing personnel 2)



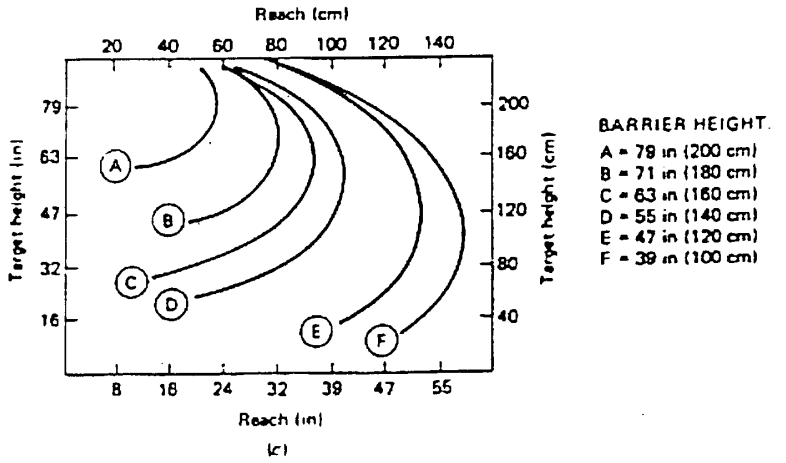
Zone of convenient reach for a 5th-percentile standing female. No bending at the waist is required and a full grip at the reach point is assumed. (*Source: Based on data from Pheasant, 1986, Table 7.8.*)

Work spaces (out of reach requirements 1)



(a) (b)

Work spaces (out of reach requirements 2)



(c)

Work spaces (Clearance requirements)

- Heavy clothing adds 10 to 15 cm to the requirements and in the case of escape hatches 25 cm.

Sleeper berths	length x width (cm)
Preferred position	198 x 84
Prostrate position	204 x 86
Legal specifications	190 x61

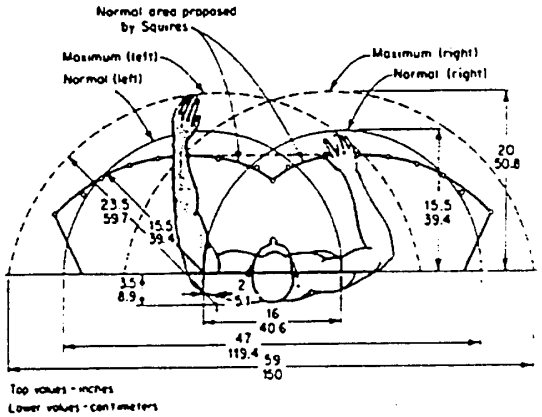
13

Work spaces (Design of worksurface 1)

- Normal area: can be conveniently reached with a sweep of the forearm while the upper arm hangs in a natural position at the side.
- Maximum area: can be reached by extending the arm from the shoulder.

14

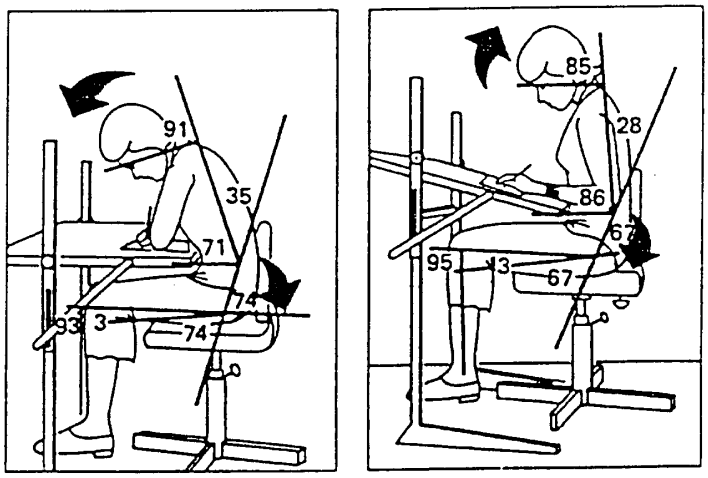
Work spaces (Design of worksurface 2)



Dimensions (in inches and centimeters) of normal and maximum working areas in horizontal plane proposed by Barnes, with normal work area proposed by Squires superimposed to show differences. (Source: *Barnes, 1963; Squires, 1956.*)

15

Work spaces (Design of worksurface 3)



(a) Horizontal surface (b) Slanted surface

16

Work spaces (Design of worksurface 4)

- Height: reduced from 76 cm (1958) to 72 cm (1970).
- 68.6 cm for fixed desk is argued by Bex (1971)
- ANSI recommends 66.5 cm as the minimum height for the underside of a nonadjustable seated work surface.
- ANSI recommends a range of height adjustments for the underside of the work surface of 51.3 to 66.5 cm.
- The working surface of fine and precision work is at 15 and 5 cm above elbow height respectively.

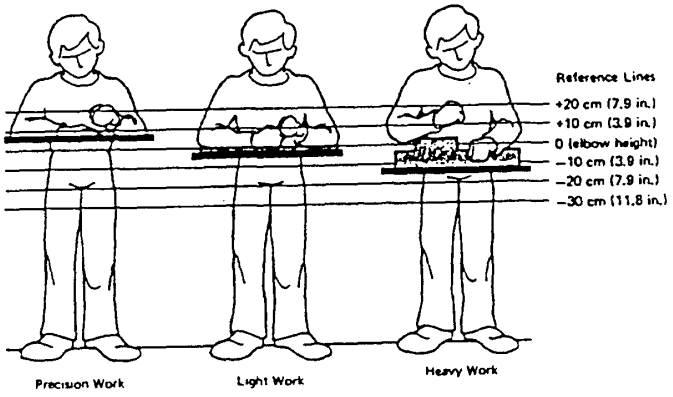
17

Work spaces (Design of worksurface 5)

- General principles for seated work surface
- If at all possible the work-surface height should be adjustable to fit individual physical dimensions and preference.
- The work surface should be at a level that places the working height at elbow height.
- The work surface should provide adequate clearance for a person's things under the work surface.

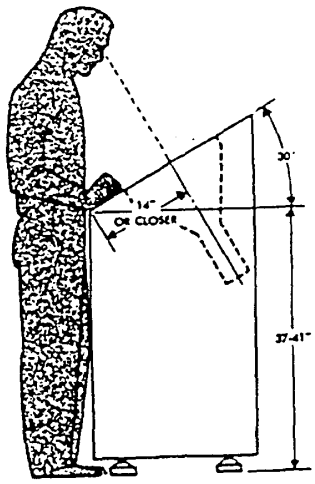
18

Work spaces (work-surface height: standing)



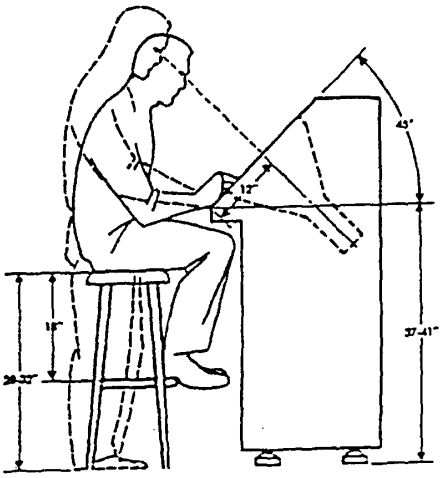
Relationship between elbow height (from floor) and recommended work-surface height for three types of work performed while standing. The zero horizontal reference line is the elbow height of the individual, and the other lines represent levels above and below. Average elbow height reported by Grandjean for Europeans is 105 cm (41.3 in) for males and 98 cm (38.6 in) for females. (*Adapted from Grandjean, 1988, Fig. 32.*)

Work spaces (work station_stand)



STAND

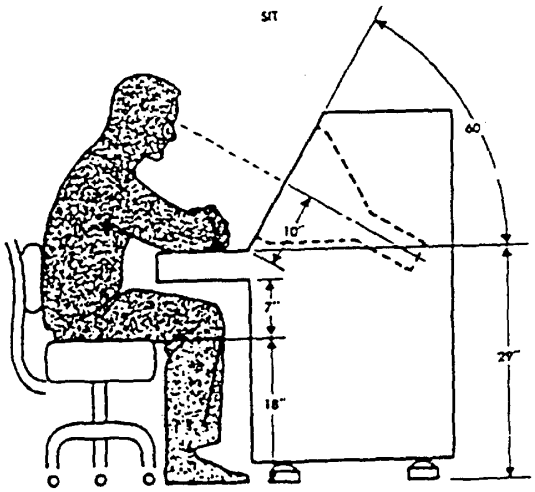
Work spaces (work station_sit-stand)



SIT-STAND

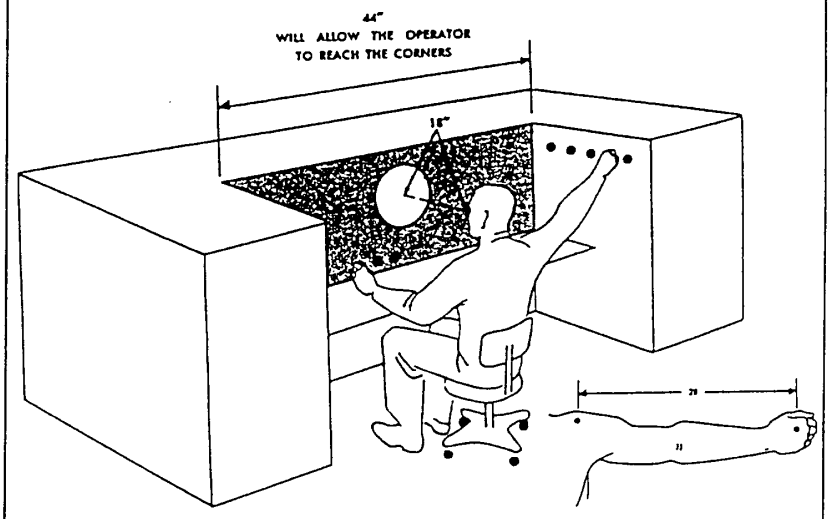
21

Work spaces (work station_sit)

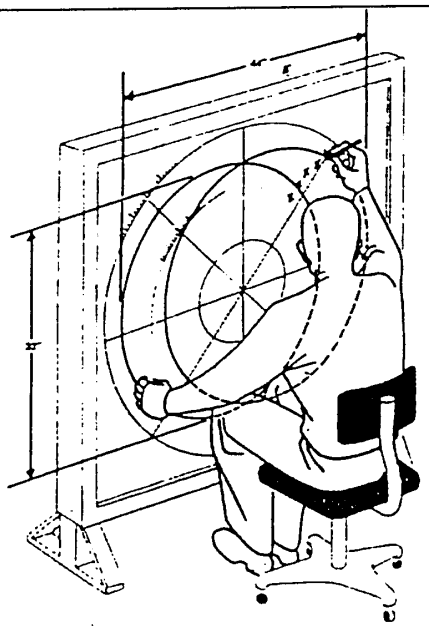


22

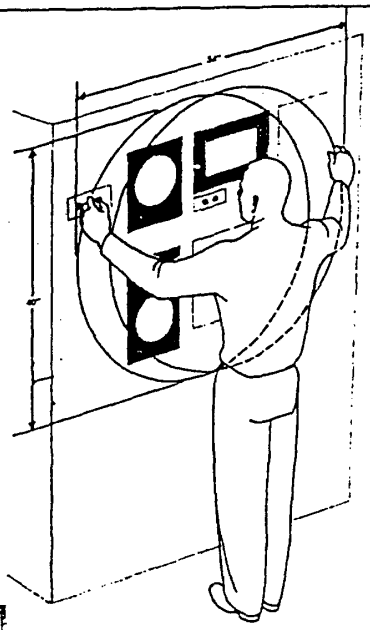
Work spaces (work station_reach 1)



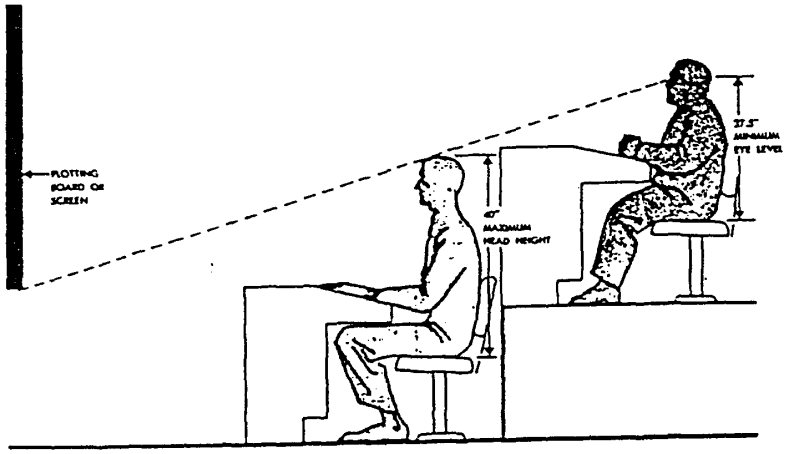
Work spaces



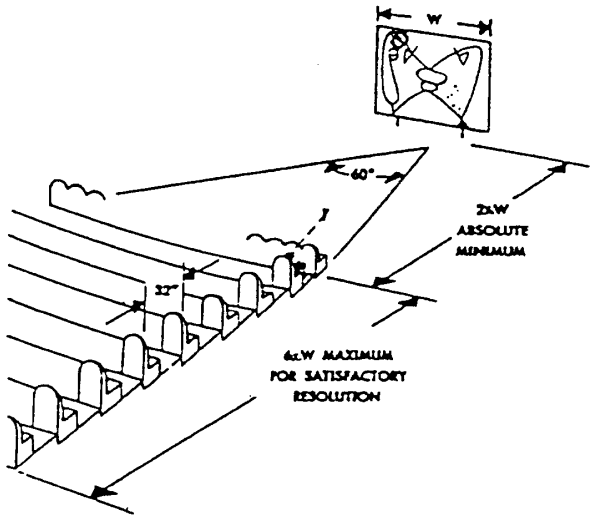
Work spaces



Work spaces (work station_reach 4)

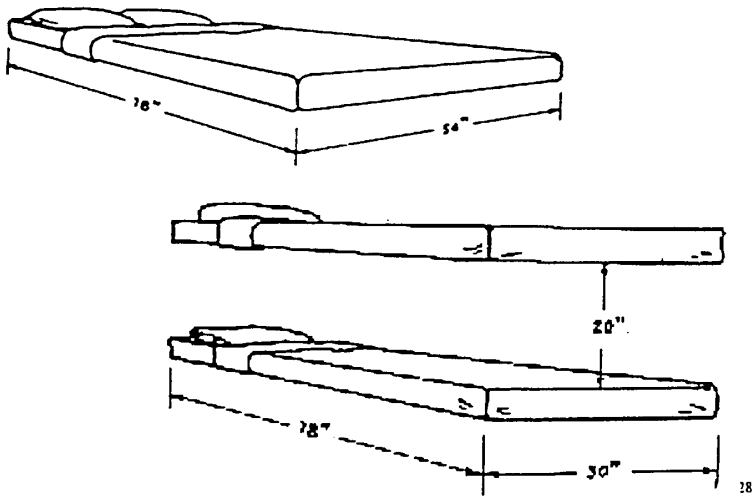


Work spaces (audience seating)



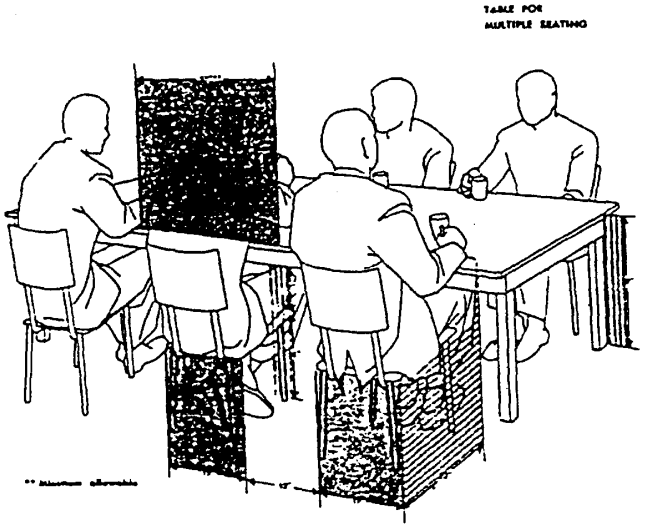
27

Work spaces (bed)



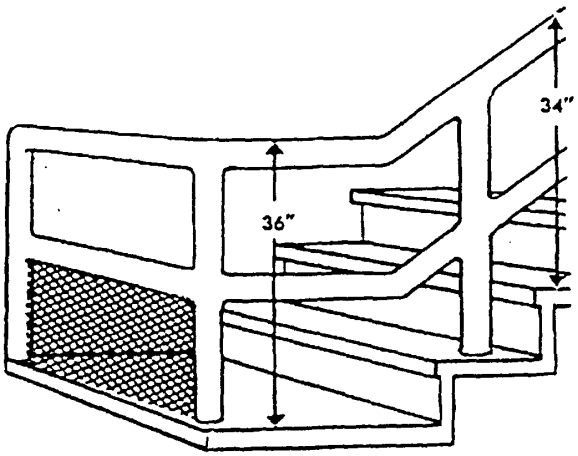
28

Work spaces (table for multiple seating)



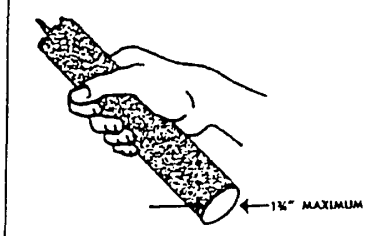
29

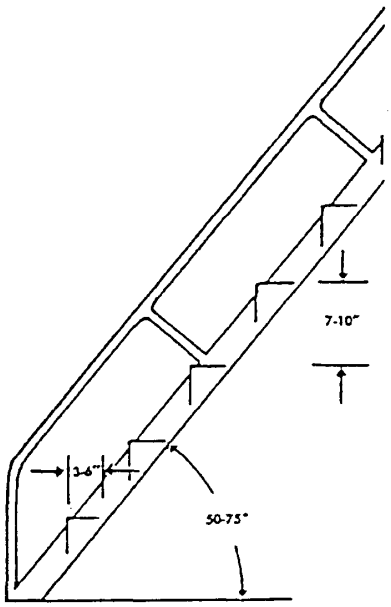
Work spaces (stairs and ladders 1)



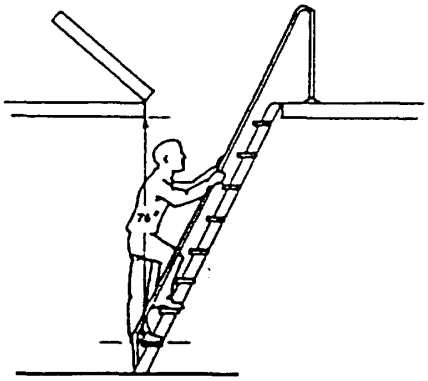
30

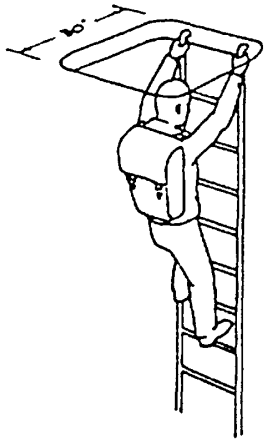
Work spaces (stairs





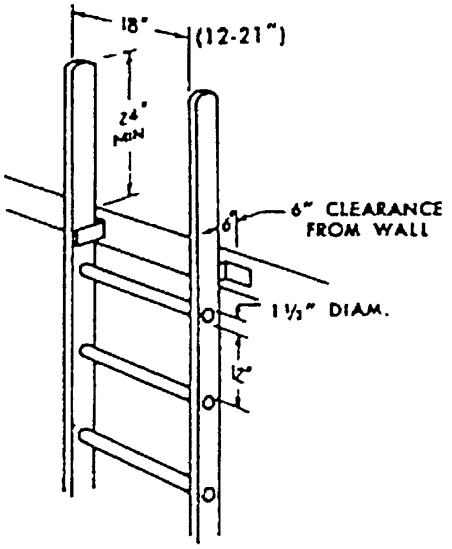
Work spaces (stairs and ladders 3)





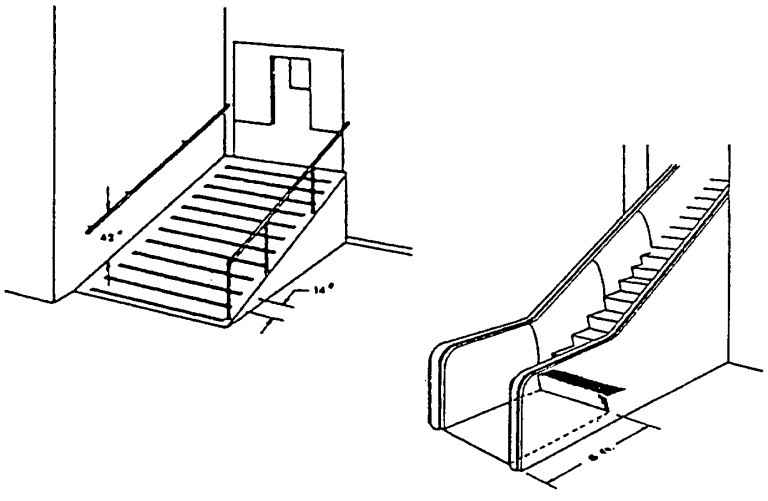
32

Work spaces

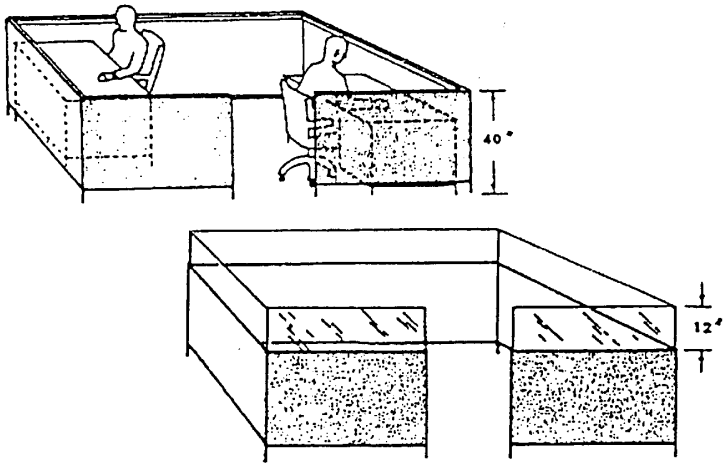


33

Work spaces (stairs and ladders 5)

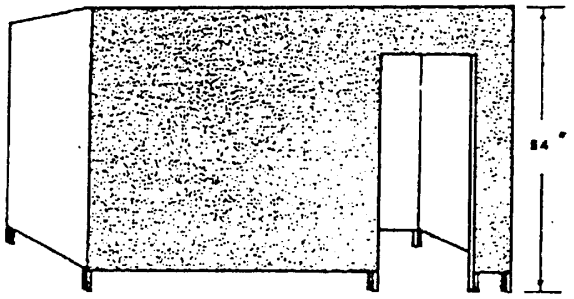


Work spaces (office 1)



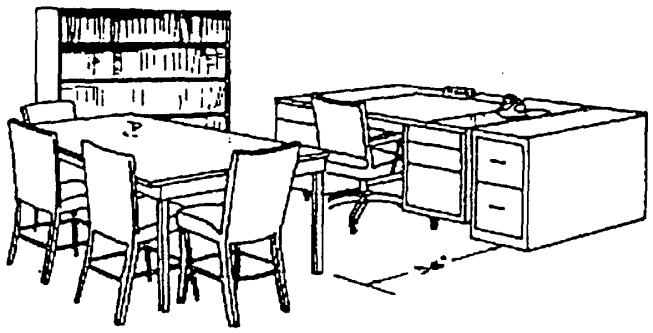
35

Work spaces (office 2)



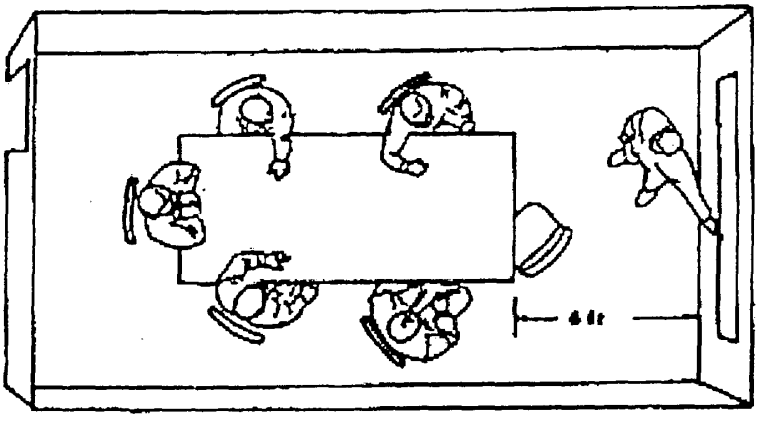
36

Work spaces (office 3)



37

Work spaces (office 4)



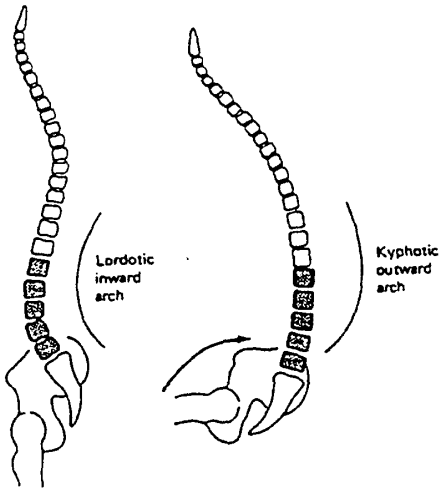
38

Science of seating (Principles of seat design)

- General principles for seat design
- Promote lumbar lordosis
- Minimum disc pressure
- Minimum static loading of the back muscles
- Reduce postural fixity
- Provide fir easy adjustability

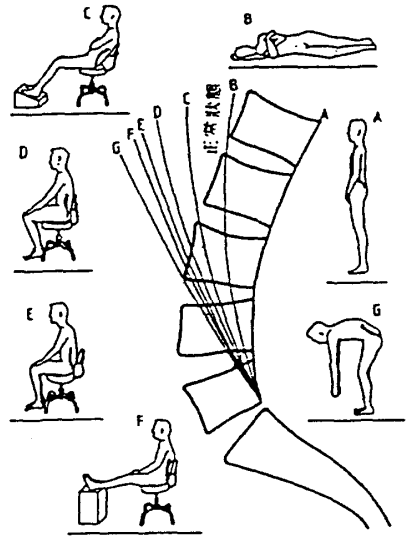
39

Science of seating (Principles of seat design 1)



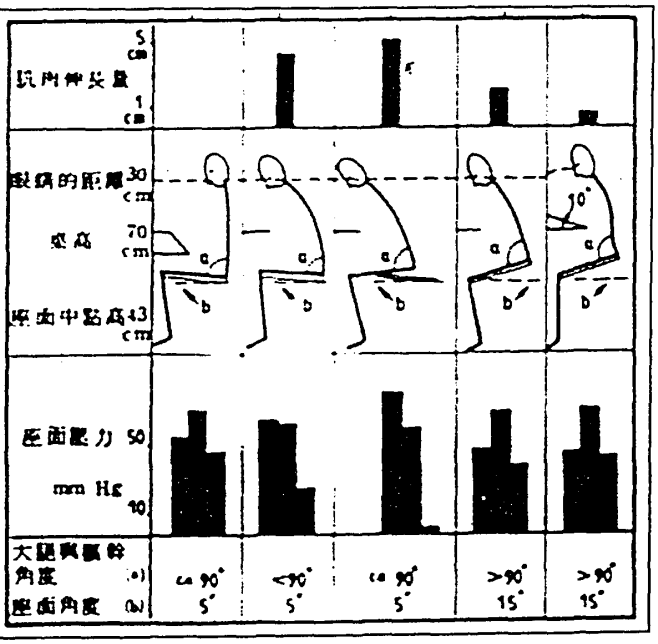
Posture of the spine when (*a*) standing and (*b*) sitting. Lumbar portion of spine is lordotic when standing and kyphotic when sitting. The shaded vertebrae are the lumbar portion of the spine. (*Source: Grandjean, 1988, Fig. 47.*)

Science of seating (Principles of seat design 2)

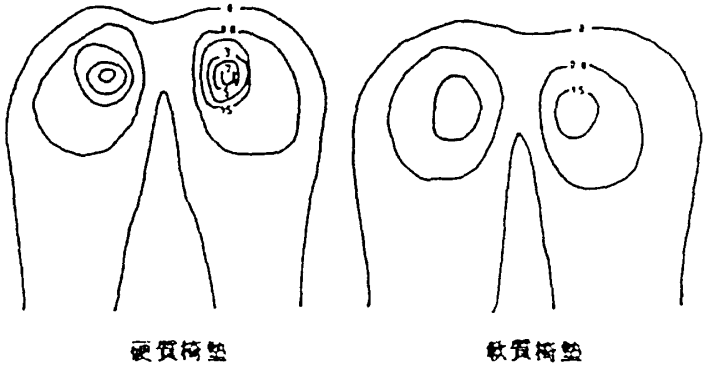


41

Science

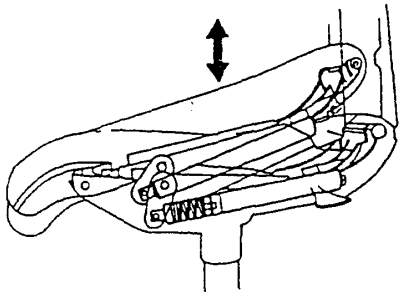


Science of seating (Principles of seat design 4)



43

Science of seating (Principles of seat design 5)

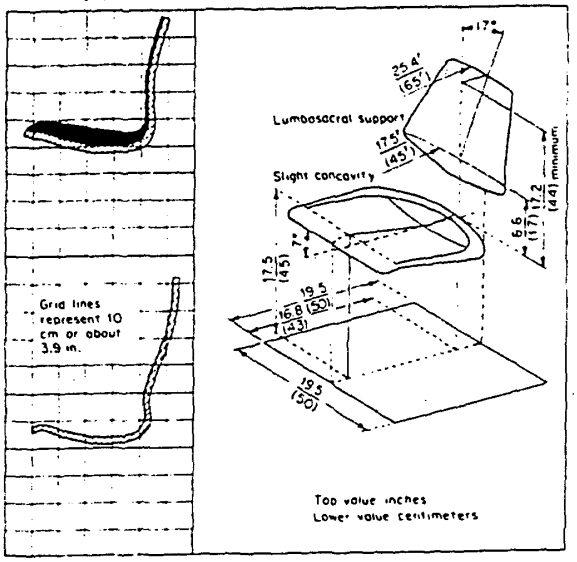


Cut-away view of the seat pan of a Cyborg chair showing the mechanism and range of dynamic change in the seat-pan angle from shifting one's body weight while sitting. The manufacturer claims this reduces postural fixity by forcing the user to change posture in response to the changing seat-pan angle. (*Source: Rudd International, Inc., Washington, DC.*)

44

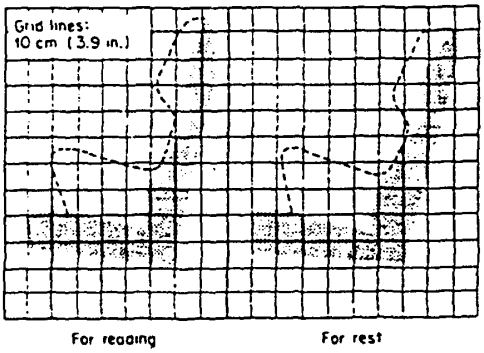
Science

Contours of the two multipurpose chairs (of 12) judged to be most comfortable by 50 subjects and the design features recommended for multipurpose chairs based on the study. (*Source: Grandjean et al., 1973, Figs. 2, 6, 13.*)



45

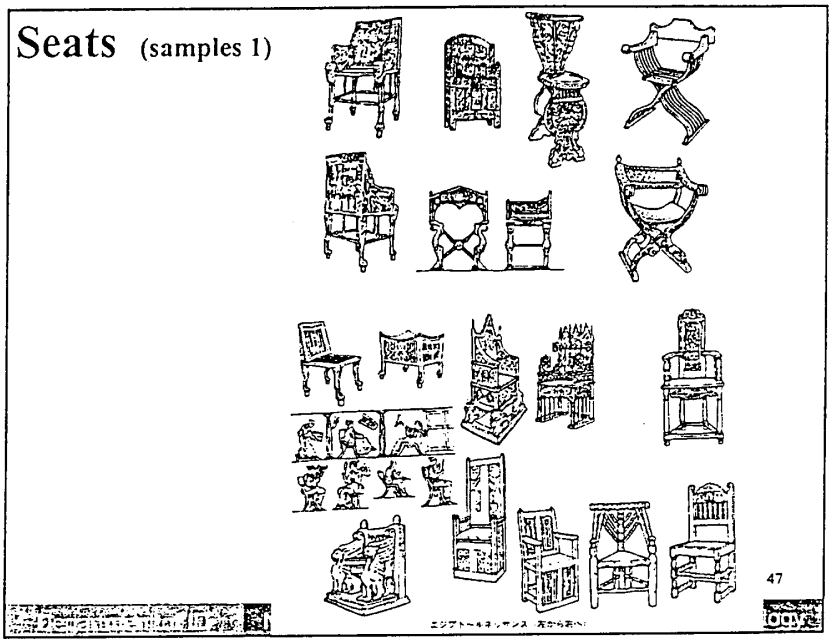
Science of seating (reading & rest chair)



Profiles of seats proposed for reading and resting. The dotted lines correspond to the armrests and a possible outer contour. The shaded area shows the surface of the seat, including upholstering to be 6 cm (2.5 in) thick. (*Source: Grandjean, Boni, and Krestz-schmer, 1969, Fig. 2, p. 310.*)

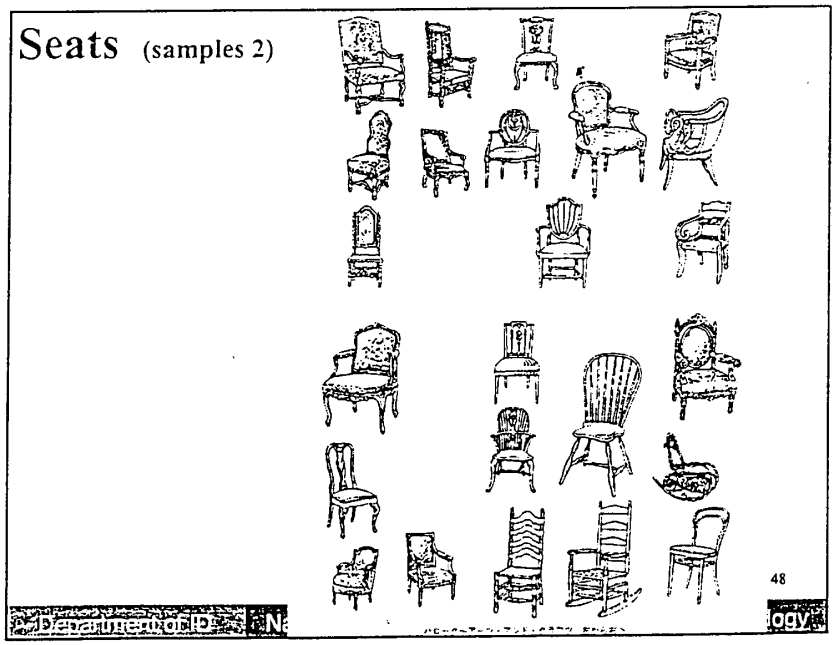
46

Seats (samples 1)



47

Seats (samples 2)

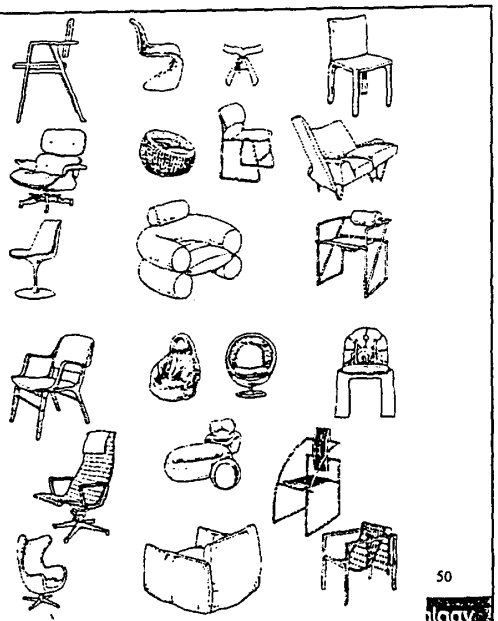


48

Seats (samples 3)

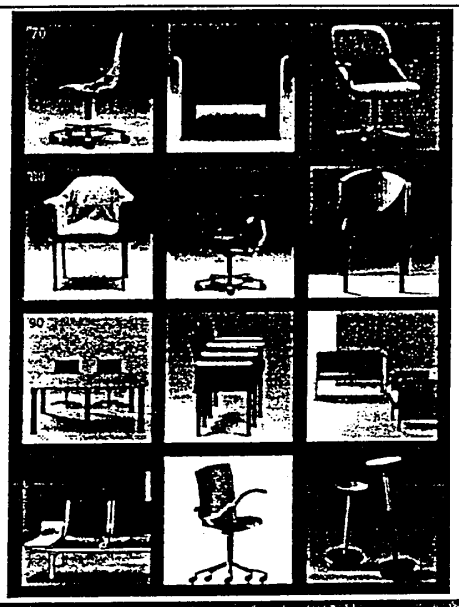
49

Seats (samples 4)

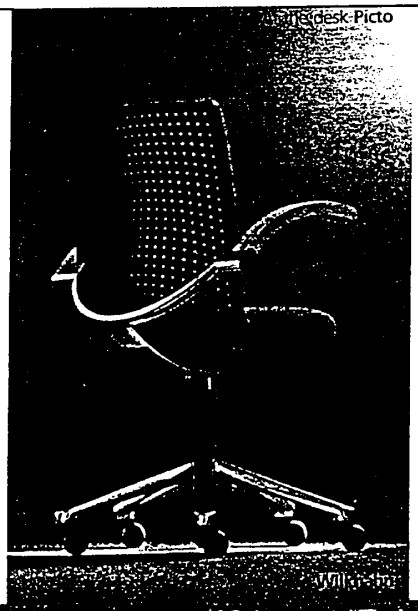


50

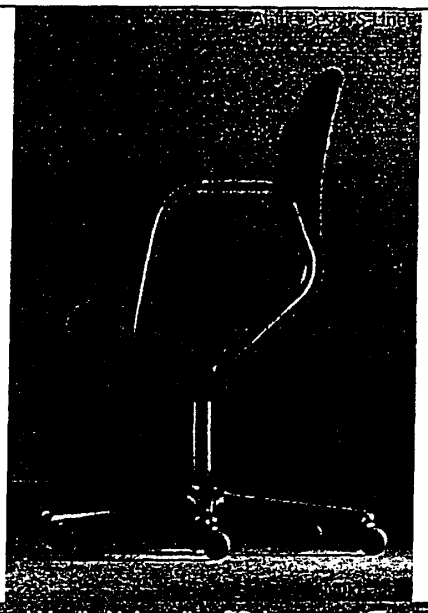
Seats (samples 5)

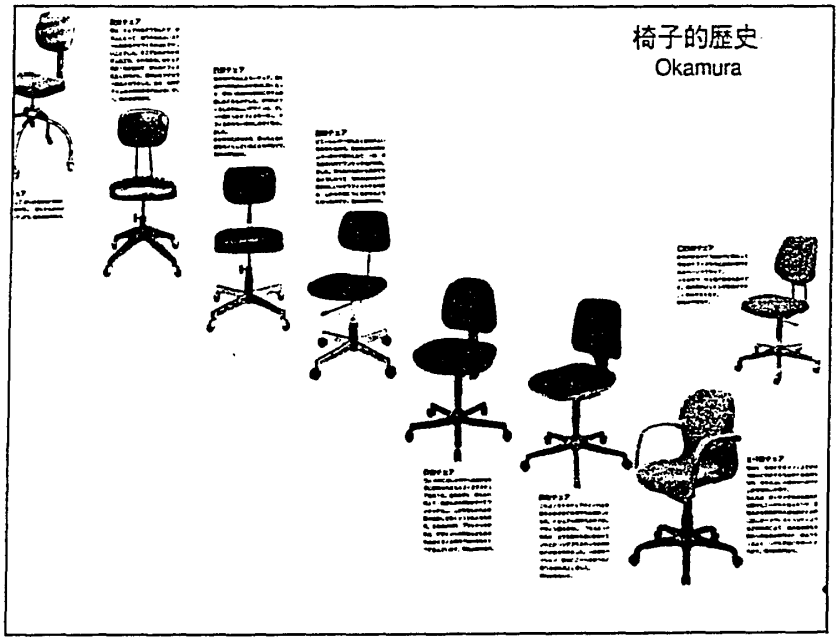


Seats (samples 6)



Seats (samples 7)

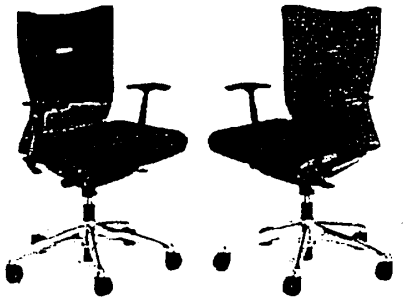




Seats (samples 9)

feego

オフィスシーティング[フィーゴ]シリーズ



55

Seats (samples 10)

56

Arrangement of components (Principles)

- Principles of arrangement of components
- Importance principle
- Frequency-of-use principle
- Functional principle
- Sequence-of-use principle

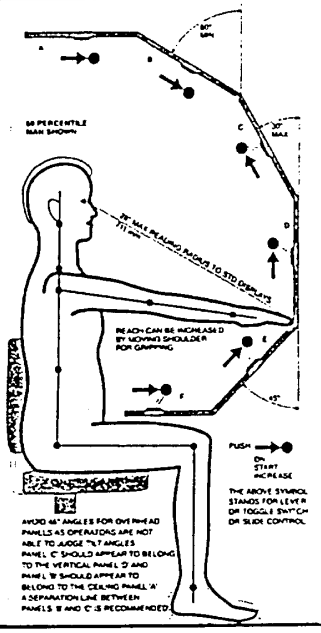
57

compatibility (Principles 1)

- Four types of compatibility
- Concept compatibility
- Movement compatibility
- Spatial compatibility
- Modality compatibility

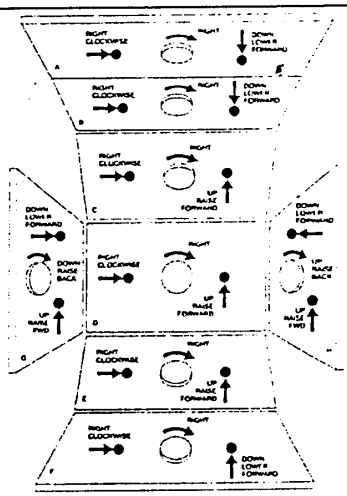
58

compatibility



59

compatibility



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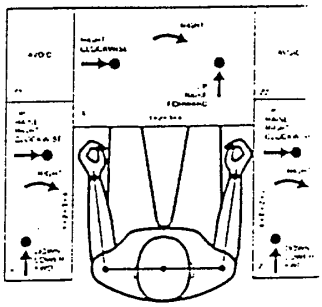
compatibility



WOOD FURNITURE FINISHING

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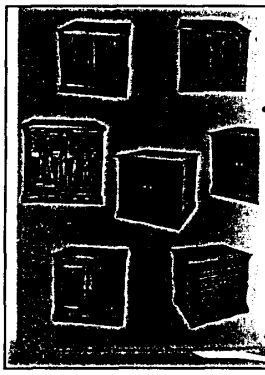
Fundamentals of Good Design

- Function
- Appearance
- Materials
- Construction



- What style or appearance do you like?

What is coatings ?

- Paints are commonly called "surface coatings." So, coatings are usually a liquid, as they are applied to a surface or substrate , they can dry or be dried to be a tough film, or can penetrate into the inner surface to provide protective, beauty enhanced or perform some other specialized functions.
- The process of applying coatings to the surfaces of artifacts is called finishing (or coating) system.

The components of coatings

- Coatings
  A- volatile content (solvent)
  B- non-volatile content
    B-1 major component (resin and/or oil)
    B-2 minor component (drier, plasticizer)
    B-3 pigment or dye
- A & B-1 & B-2 to be clear finish or vehicle
- Vehicle & B-3 to be colored finish

Classification of coatings

- Based on raw materials
  - Nitrocellulose lacquer
  - Shellac varnish
  - Japanese lacquer
  - Oil varnish

Classification of coatings

- Based on applicators
  - Brushing finishes
  - Spraying finishes
  - Electrostatic spraying finishes
  - Dipping finishes
  - Electrostatic powder coating finishes
  - Curtain flow coating finishes

Classification of coatings

- Based on sequence of finishing system
  - Wood sealer
  - Sanding sealer
  - Top coat

Classification of coatings

- Based on film performance
  - Water proof finishes
  - Fireproof coatings
  - Acid resistant finishes
  - Oil resistant finishes
  - Anticorrosion coatings
  - Insecticide paints
  - Chemical-resistant coatings

Classification of coatings

- Based on appearance
  - Clear finishes
  - Opaque finishes
  - Flatting finishes
  - Cracking varnish

Classification of coatings

- Based on substrate
  - Exterior coatings for wood
  - Coatings for steel
  - Coatings for metals other than steel
  - Floor paints
  - Roof coatings

Classification of coatings

- Based on drying mechanism
  - Convertible coatings
    (chemical reaction,
    thermosetting)
  - Nonconvertible coatings
    (solvent evaporation,
    thermoplastic)

Classification of coatings

- Based on ingredients

A. Varnish

1. Volatile varnish : resin + solvent or nitrocellulose + Solvent

2. Oil borne varnish : resin + drying oil + solvent

- Based on ingredients

B. Enamel

1. Volatile enamel : resin (or nitrocellulose) + pigment + solvent

2. Oil enamel : resin+ drying oil + pigment + solvent

3. Water borne enamel : Water soluble resin + pigment + water

- Based on ingredients

C. Paints

1. paste paint : boiled oil + pigment

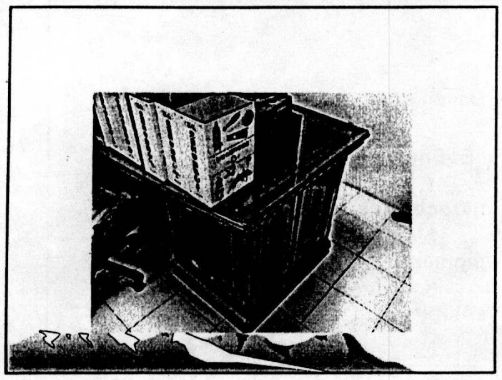
2. mixed paint : boiled oil + pigment + solvent

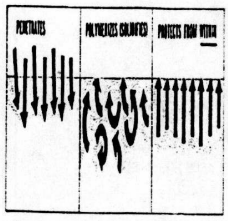
Characteristics of Wood furniture Finishing

- Diversity of wood
- More difficult than other materials to use automatic finishing system
- Clear finishing

The purposes of wood furniture finishing-1

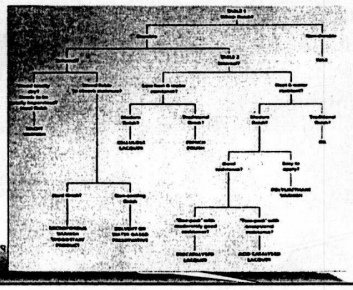
- To enhance the natural beauty of wood's grain, texture and surface markings (figure)
- To produce an even color and surface that is pleasing to look at and which fits in well with its surroundings.
- To protect the wood from a wide variety of things that will destroy, damage or disfigure it in some way.





A chemical action takes place when the material is applied

Which finish do you need ?



Lacquer or shellac is not heat-resistant.

Comparison of Wood coatings general used

	NC Lacq.	PU Lacq.
Gradients	Nitrocellulose	Polyol & Polyisocyanate
Setting types	Solvent vaporization	Additional polymerization
Drying time (min. ,set to touch)	6 min.	20 min
Drying time (min., full drying)	1-2 hour	16 hour

Comparison of Wood coatings general used (continue)

Hardness (pencil)	F- HB	H-2H
Gloss (60°)	75-80	90-95
Heat resistance	Poor	Good
Solvent resistance	Poor	Good
Impact test (1 kg)	40 cm	50 cm
Pencil hardness: 9H...H,F,HB,B...6B		

General components of NC Lacquer Thinner

Components	Weight percent (%)
Ethyl acetate	20
Butyl acetate	5
Amyl acetate	4
n-butanol	5
Cellosolve	4
Toluene	62
Total	100

Lacquer-1

- Lacquer is commonly defined as any finishing material that dried quickly by evaporation to form a protective film on a wood surface. Because they are fast-drying, lacquer are used primarily for high production. Usually they have fewer solids than varnishes do, and they require more coats to achieve a sufficient buildup. Lacquers are usually applied by spraying.

Lacquer-2

- Advantages

  - Lacquers are fast-drying. Therefore several coats can be applied in a short time. It is not necessary to have special drying equipment.

  - A lacquer coating is thin and clear. This is well suited to contemporary styles that require a close-to-the-wood appearance.

Lacquer-3

- Advantages

  - Damage in lacquer finishes is easy to repair.

  - Have good durability. Relatively high in resistance to damage by water, beverages and food.

  - Do not get soft and tacky when exposed to extreme temperatures.

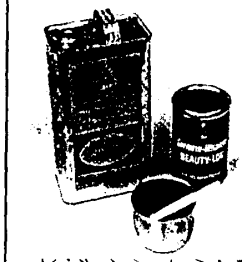
  - Easy to rub, polish, and wax.

Lacquer-4

- Disadvantages
- Are not highly resistant to such substances as nail polish and perfume.
- Excessive moisture (ex. In a bathroom) may cause the lacquer to peel off the wood. Also, white water spots may develop.
- Dry so rapidly that it is difficult to apply them with a brush.
- Are not as tough as some of the newer synthetic finishes.

Finishes system matching

Sealer	Top coating	
NC	NC Excellent	AA.. Bad
	PU Fine	PE... Bad
AA	NC Bad	AA Fine
	PU Fine	PE Bad
PE	NC Excellent	AA Bad
	PU Excellent	PE Good
PU	NC Excellent	AA Bad
	PU Excellent	PE Bad



Thin varnishes with either mineral spirits or turpentine always read the label on the container for the proper choice.

Thin shellac with denatured alcohol.

polyurethane varnish develops an extremely hard finish.

The lacquer and the lacquer thinner must be compatible.

You can apply brushing lacquer with a brush.

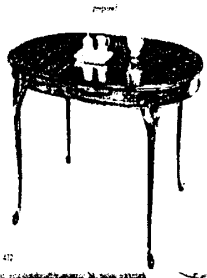
Gloss lacquer produces the highest degree of sheen.

Dull lacquer produces little or no sheen.

A finish brings out the beauty of the wood.

But it also makes surface defects more noticeable.

Surface preparation-1



A beautiful finish cannot be achieved unless the surface first is properly prepared

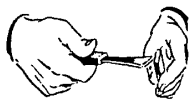
Surface preparation-2

- Good-quality paint may obliterate minor imperfections, but a coat of varnish or lacquer can do nothing to improve the appearance of wood that has been inadequately prepared.
- The very first application of clear finish invariably exposes flaws that were completely undetectable before.

Surface preparation-3

- Work systematically to eradicating all obvious blemishes before sanding the wood smooth with progressively finer abrasives.
- Works include: filling cracks and holes, patching and plugging, Disguising repairs and scraping and/ or sanding.

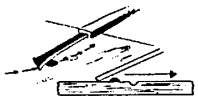
Surface preparation-4



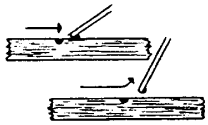
Picking up the material with the knife

Roll the knife over and drop the material onto the defect on the back stroke.

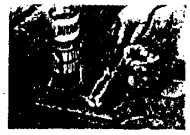
Surface preparation-5



Now pull the knife forward over the defect. Never allow the hot knife to come to a stop



Pick up the excess material with the end of the knife. Notice how the knife is brought up to a vertical position at the end of the stroke



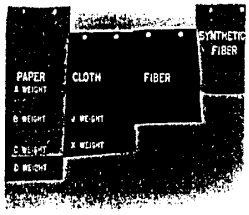
Water putty can repair major defects.

Putty filler containers should be closed when the filler is not being used.

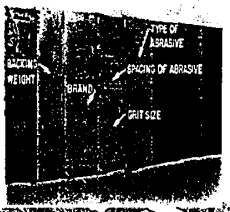
Removing Hardware

- The preliminary fitting of hardware is usually done while the product is in the white wood (unfinished) stage. Holes and openings are drilled for handles, catches, locks, or other hardware. Most of these items, except certain hinges, are removed before bleaching, final sanding, and finishing.

Understanding Abrasive materials



Abrasive backings come in different materials and weights.

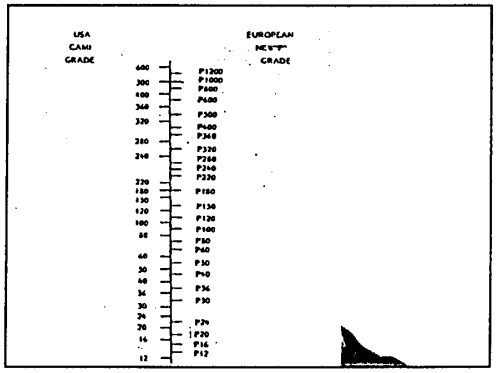


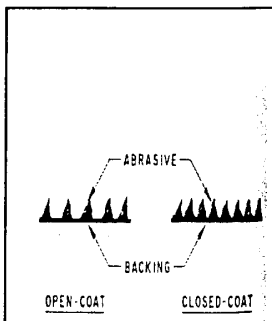
The backs of abrasive papers give much information.

GRIT SIZES

	Mesh or Grit No.	Symbols for 9 Grade	General Uses
VERY FINE	400	10/0	For polishing and finishing after stain, varnish, etc., has been applied.
	360	—	
	320	9/0	
	280	8/0	
	240	7/0	
	220	6/0	
FINE	180	5/0	For finish sanding and before staining or sealing
	150	4/0	
	120	3/0	
MEDIUM	100	2/0	For sanding to remove final rough texture
	90	1/0	
	80	½	
COARSE	50	1	For sanding after very rough texture is removed.
	40	1½	
	36	2	
VERY COARSE	30	2½	For very rough, unfinished wood surfaces
	24	3	
	20	3½	
	16	4	

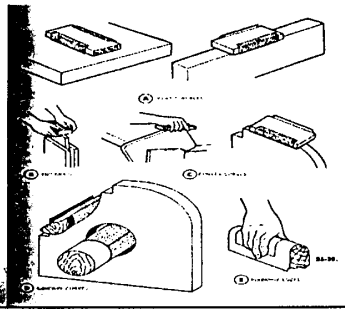
This table shows the uses for various abrasive grit sizes.





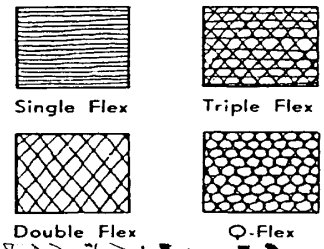
Open-coat abrasives have large spaces between the particles of abrasive. Close-coat abrasives have very small spaces.

Hand sanding methods

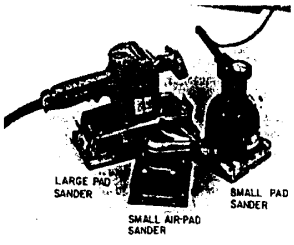


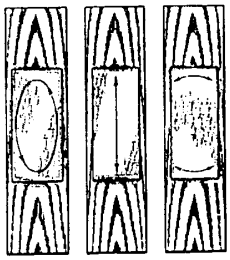
Flex the abrasive paper over a sharp edge to break the sizing coat.

Types of flexing



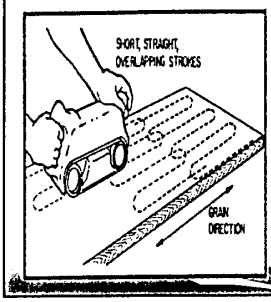
Types of pad sanders



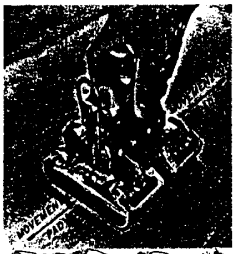


- Three kinds of sanding action found in finishing sanders. Orbital and multi-motion action causes some cross-grain scratches. Straight-line action is like hand sanding and results in the best surface.

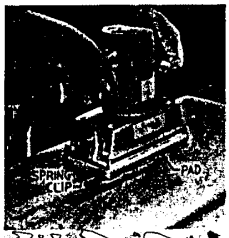
- Hold the belt sander properly. Move it in a straight line.



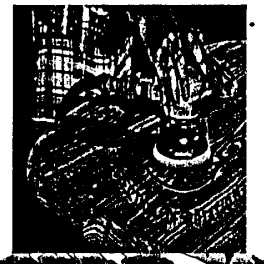
To reduce sanding marks, keep the sander moving in the recommended pattern.



A straight-line sander produces scratches with the grain.

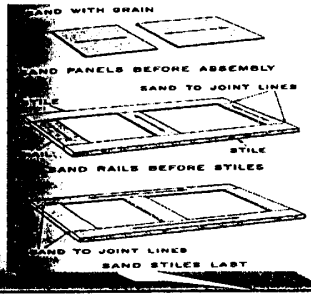


Spring clips hold the sandpaper on the pad of the sander.

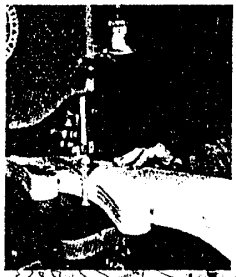


- A disc sander removes mater quickly, But if careless be taken, easy to cause grit scratches on the surface.

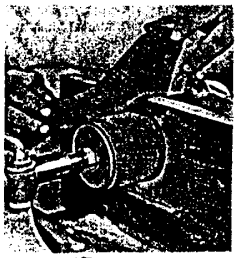
Steps in sanding a panel door



Using the hand-stroke belt sander to sand a wide tabletop. The operator is using a flat-bottom block with round edges. Concave or convex surfaces can be sanded with a sanding block of proper shape. Stroke sanding should be the last machine sanding of the wood before finishing. Therefore it is important to obtain a very smooth surface.

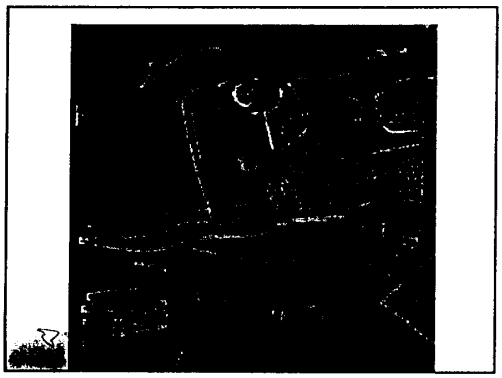


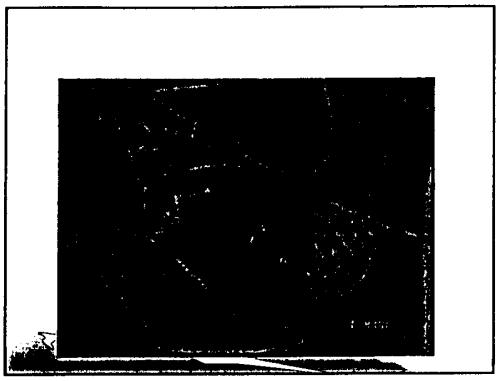
Sanding the edge of an irregular shape on the band saw

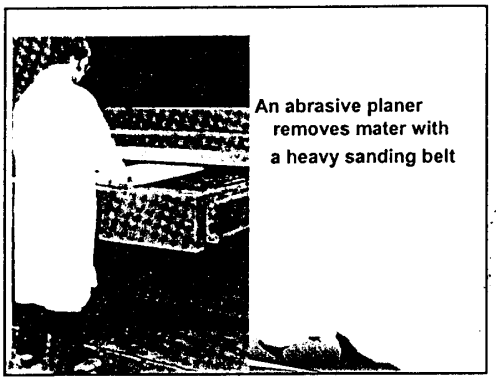


Sanding the edge of a leg on a sanding drum mounted in a lathe.

The rotary sanding attachment has brushes and abrasive strips







An abrasive planer removes mater with a heavy sanding belt

Final Sanding of Casework and Built-ins

- The final sanding of casework and built-ins depends on the kind of finish to be applied and the quality of construction. If paint or some other opaque finish is used, final sanding with 1 (50) or 1/2 (60) garnet paper is satisfactory. However, if a transparent finish is to be applied, the surfaces should be given a final sanding with 2/0 (100) garnet paper.
- Care should be taken so that there are no cross scratches, especially where there is a solid wood frame around a plywood center.

Final Sanding of Furniture-1

- Final sanding is usually done after the product has been assembled. The exterior surfaces are sanded with portable belt and finishing sanders.
- Sides and fronts of drawers are sanded as they fitted into the case or cabinet. Hand sanding must also be done.

Final Sanding of Furniture-2

- There is no complete agreement among finishers as to what constitutes suitable sanding before finishing.
- Some finishers recommend that the final sanding be done with garnet paper at least as fine as 6/0 (220) for dense woods like oak or maple and 7/0 (240) for low-density woods.
- Generally the surface should be hand sanded with 3/0 (120) to 5/0 (180) garnet paper. Remember that sanding must always be done with the grain.

Another method of preparing wood for finishing-1-1

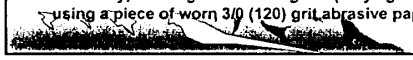
- Some finishers recommend that, before final finishing, a glue size (mixing one-fourth pound of liquid animal glue for every gallon of warm water) be applied to the exterior surface to hold the wood fibers firmly in place during finishing. This is applied with a brush and allowed to dry thoroughly. Then the final sanding is done.
- This procedure is particularly recommended for the fibrous woods.

Another method of preparing wood for finishing-1-2

- Care must be taken in the final sanding since, if too much of the size is left on the surface, it will interfere with the finishing process. On the other hand. If too much sanding is done, all of the size will be sanded away.

Another method of preparing wood for finishing-2-1

- Sponge the surface with warm water to raise the grain.
- Sand with the grain, using 3/0 (120) grit abrasive paper.
- Apply a light sealer to the surface. The sealer should be one part final finishing material, such as varnish or lacquer, and five parts thinner. Use turpentine or mineral spirits to thin varnish; use lacquer thinner for lacquer. This application will hold any loose fibers in place.
- When dry, sand again with the grain (very lightly) using a piece of worn 3/0 (120) grit abrasive paper.



Finishing Procedures-1

- Today woodworkers have a wide choice of materials for finishing. Besides the traditional varnish and lacquer, there are polyurethane finishes for durability, wipe-on finishes for ease, and oil finishes for the natural look. No one type of finish will serve all purpose. Every type has different advantage and disadvantage. Try several finishes on scrap material and choose the one that best suits your project.

Finishing Procedures-2

- Several steps may be necessary to obtain a final finish. However, the steps are not the same for every kind of finish. As a matter of fact, some good finishes can be obtained through processes involving just three, two or even one step.
- The finishing process to choose depends partly on the type of wood and the appearance wanted. Also it is important to consider what finishing facilities and equipment are available.

Finishing System-1

- The following are some of the basic steps necessary for a fine wood finish.
- Bleaching: Bleaching removes color from wood. It is necessary for very light and for medium-light or honey-colored finishes. Many of the natural and darker finishes require no bleaching. Bleaching is also done when the natural color of the wood is to be changed.

Finishing System-2

- Pre-staining (sap staining) or equalizing

  Sap staining is necessary when starting with natural woods in which color variation is great.

  A good example of this is walnut, in which the sap wood is very light and the heartwood is quite dark.

  Sap staining is also done when different kinds of wood, such as gum and mahogany, are combined in the same product and a uniform color is desired for the final finish.

Finishing System-3

- Staining and Coloring (Body staining)

  Staining adds color to the wood and emphasizes the grain. It is also done to change the tone or shade of a wood surface.

  Many kinds of stains or toners can be used.

Finishing System-4

- **Wash coating**

  Wash coating is done to keep the stain from bleeding into the filler and to provide a hard surface for applying the filler.

  The wash coating is a very thin coating of shellac or lacquer sealer that leaves the pores open so that filler can be added. A good sealer for many stains is a wash coat of white shellac that is a mixture of seven parts alcohol to one part of four-pound-cut shellac.

  Lacquer sealers are frequently used for wash coating when the final finish is to be spray lacquer.

Finishing System-5

- **Filling**

  Fillers add color and close the pores of wood. Closed-grained woods with very small pores such as pine, cherry, poplar, fir, and cedar require no filler. Others such as birch, gum, and maple may take a liquid filler. Open-grained woods, particularly oak, mahogany, and walnut, require a paste filler.

  With these woods, the filler is sometimes eliminated to give the wood an open-pore appearance. For blond finishes, the filler can be zinc oxide or a natural paste that is a light color in oil,

Finishing System -5-1

- **Sealing or Wash Coating**

  A sealer or wash coat is applied over the filler to prevent color from bleeding into the finish. A good sealer for most finishes is a shellac wash coat. If a lacquer finish is to be applied, a lacquer sealer can be used in place of the wash coat of shellac.

Finishing System-6

- **Glazing**

  Glazing is the application of a coat of thin, transparent finishing material over filler or sealer to give a highlighted, shaded, or antique effect. This is used most frequently in the finer finishes. To antique by glazing, thoroughly wipe off the glaze from the flat surfaces and edges that should appear worn, and leave the glaze in the recessed areas.

Finishing System-7

- **Topcoating**

  A varnish, synthetic, or lacquer finish can be applied as topcoat after all coloring and filling have been completed.

Finishing System-8

- Rubbing, Polishing, and Cleaning

  After the topcoat in on, the surface is rubbed, polished, and waxed to a high sheen.

Finishing Open-Grained Wood-1

1. Apply a thin glue size mixed in water (1 part hide glue to five parts water). Allow to dry.

   The purpose of the glue size is to make sure the thin, hair-like wood fibers are held down or held up so that they will be removed when sanded.

   Sand the surface well with 3/0 (120) garnet paper. Clean thoroughly with a tack rag.

Finishing Open-Grained Wood-2

- 2. Apply water stain and allow it to dry thoroughly. Sand lightly with 3/0 (120) garnet paper.
- 3. Apply a wash coat of shellac or lacquer sealer. Allow it to dry three to four hours. Then sand the surface with 5/0 (180) garnet paper.

Finishing Open-Grained Wood-3

- 4. Apply a colored filler with a brush. Rub across grain with a circular motion, forcing the filler into the pores. Then wipe across grain with burlap to remove excess filler. Next wipe along the grain with a fine cloth, using a light stroke to even up the surface. Allow it to dry thoroughly(overnight).

Finishing Open-Grained Wood-4

- 5. Apply a sealer coat of shellac or lacquer, allow to dry, and sand with 6/0 (220) or 7/0 (240) garnet paper.
- 6. A glaze can be applied over the sealer to give a highlighted, shaded. Or antique effect. This step is not necessary for Contemporary or Modern finishes.

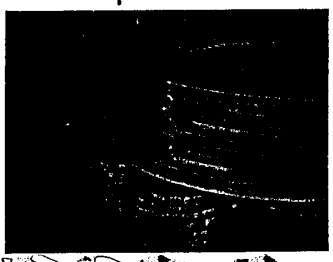
Finishing Open-Grained Wood-5

- 7. Apply three coats of lacquer with sufficient drying time between each coat. Sand lightly.
- 8. Rub to a light sheen with pumice stone and water or paraffin oil.
- 9. Rub with a good paste wax and polish.

Example of the Finishing System-1

- Edge sealer (Fiberboard)
- Sanding (Fiberboard)
- Basecoat (Fiberboard)
- Sap stain or pre-staining
- Body stain
- Wash coat (wood sealer)
- [Sanding, 240-280-grit]
- {Filling} (filler)
- {Sealing} (Sanding sealer)

Edge sealer applying on MDF products



The Finishing System-1

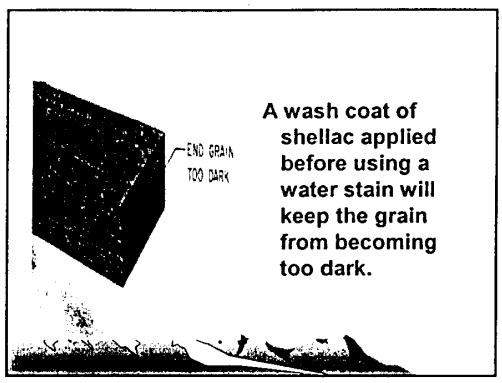
- Edge sealer (Fiberboard)
- Sanding (Fiberboard)
- Basecoat (Fiberboard)
- Sap stain or pre-staining
- Body stain
- Wash coat (wood sealer)
- [Sanding, 240-280-grit]
- {Filling} (filler)
- {Sealing} (Sanding sealer)

- No sap stain applied on the works

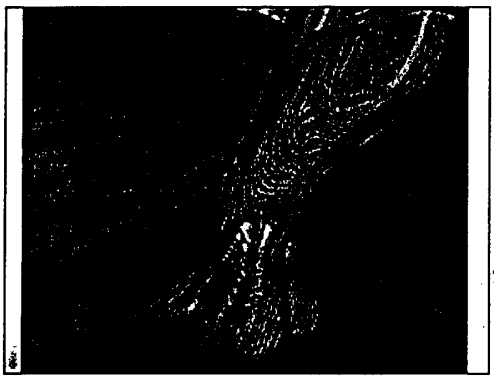
NGR stain and lacquer sealer can be mixed together and sprayed onto the surface.

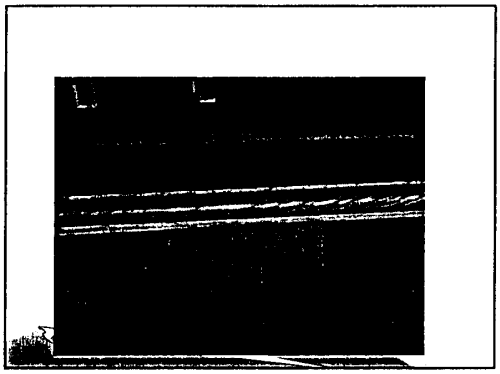
The Finishing System-1

- Edge sealer (Fiberboard)
- Sanding (Fiberboard)
- Basecoat (Fiberboard)
- Sap stain or pre-staining
- Body stain
- Wash coat (wood sealer)
- [Sanding, 240-280-grit]
- {Filling} (filler)
- {Sealing} (Sanding sealer)



A wash coat of shellac applied before using a water stain will keep the grain from becoming too dark.



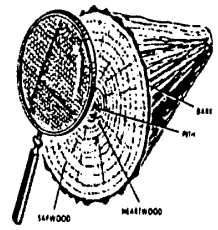


Defect from filling before wash-coating applied

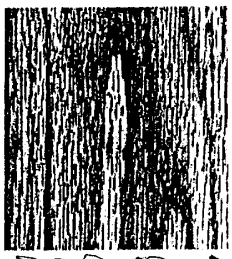
Wash-coating is absolutely needed for an oily wood.

The Finishing System-1

- Edge sealer (Fiberboard)
- Sanding (Fiberboard)
- Basecoat (Fiberboard)
- Sap stain or pre-staining
- Body stain
- Wash coat (wood sealer)
- [Sanding, 240-280-grit]
- {Filling} (filler)
- {Sealing} (Sanding sealer)

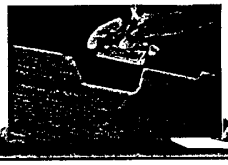


Many hardwoods contain large vessels and are very porous. When this lumber is surfaced, the tubular cells are ruptured, leaving tiny troughs that run lengthwise.



Unfilled pores make a filler necessary for certain hardwoods. This sample is red oak.

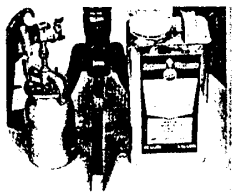
Applying filler with a brush. Brush first with the grain.



Brush across grain, over the first filler coat. Rub into the pores

The Finishing System-1

- Edge sealer (Fiberboard)
- Sanding (Fiberboard)
- Basecoat (Fiberboard)
- Sap stain or pre-staining
- Body stain
- Wash coat (wood sealer)
- [Sanding, 240-280-grit]
- {Filling} (filler)
- {Sealing} (Sanding sealer)

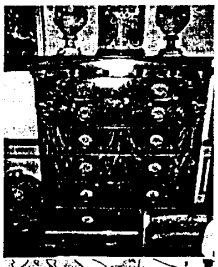


- Sanding sealer prevents stain or filler from bleeding through the finish.

The Finishing System-2

. Glaze (wipe, high-light)
. {Sanding sealer}
. {Sanding, 240-280}
. Spattering and distressing
- cow-tail stain, crayon mark, dry brush, physical distress- chain, clinker, rasp, nut strand, hammer..)

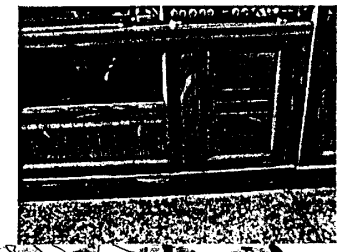
- Glazing color remains in low spots of carvings or edge-molding to accentuates these figures.



- The high light or strike-out is to emphasize wood figure by sanding out undertone color along the borders of the lines of figure.

- Shading suggests the accumulation of dirt and old polish.

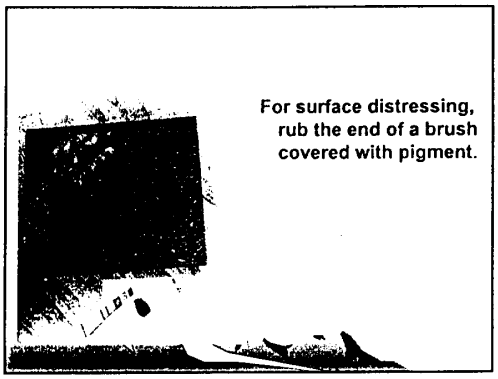
High-light was not treated in the proper way.



The Finishing System-2

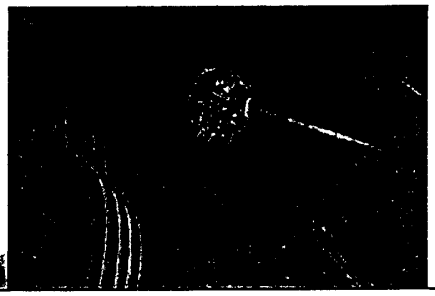
. Glaze (wipe, high-light)
. {Sanding sealer}
. {Sanding, 240-280}
. Spattering and distressing
- cow-tail stain, crayon mark, dry brush, physical distress- chain, clinker, rasp, nut strand, hammer..)

Distressing tools

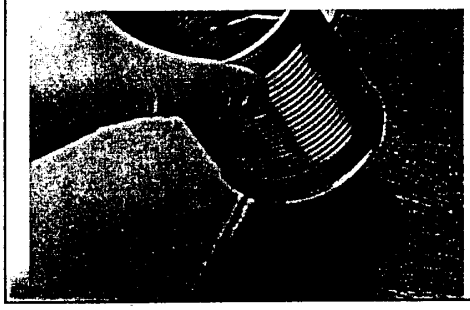


Cow-tailed work piece

Nailed Hammer for Distressing

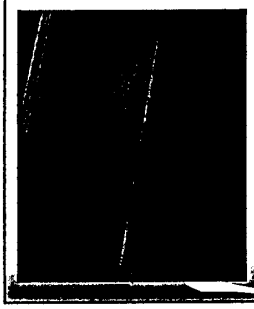


Another Kind of Ageing Treatment



Nut strand

Imitation Wormholes

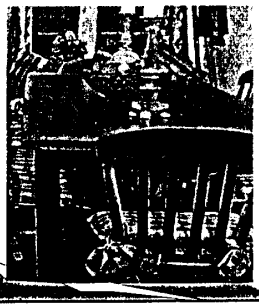


- Imitation wormholes give the impression of antique furniture.
- They can be made by spattering and/or other hand tools.

Imitation Wormholes- cross section

Work Piece with Ageing effect

Ageing Effect

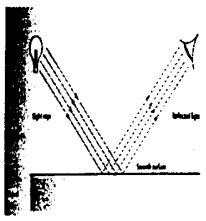


The Finishing System-3

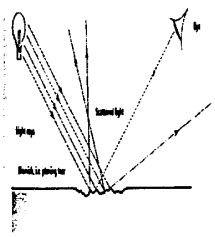
. First lacquer (top coat)
. Pad stain (or Padding)
. Second lacquer (top coat)
. [Sanding, 320-grit]
. Third lacquer (top coat)
. Rubbing (lubricant, 400-600-grit & oooo Steel wool)
. Polishing

Rubbing

Polishing



A smooth, mirror-like surface reflects light uniformly so that we can see perfect reflections of objects placed in front.

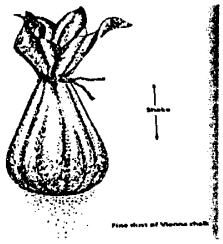


Blemishes, such as planning tears, will scatter light in all directions, making the area appear darker and duller because less light reaches our eyes.

Gloss lacquer produces the highest degree of sheen.

Dull lacquer produces little or no sheen.

The pounce bag



- The acid finish: using the pounce bag.

The acid finish: burnishing.

Dulling with steel wool and wax polish.

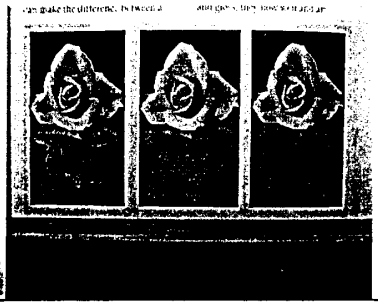
Dulling with pumice and a soft brush.

Use pumice power and a dulling brush or shoe brush on dry gloss varnish to produce a satin finish. Put a small quantity of pumice powder into a shallow tray

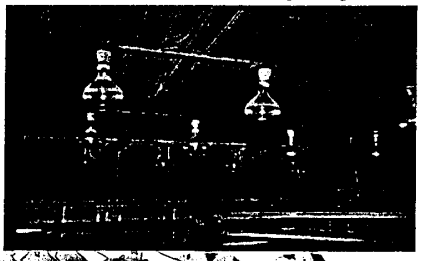
- A dulling brush has short soft bristles, rather like a shoe brush. Load the dulling brush with pumice powder by dipping it into the tray and picking up the power.

Once loaded, work the dulling brush in straight strokes along the grain over the whole surface. For curved piece, use a soft cloth, and pumice powder. Apply evenly, and do not miss any parts. Keep rubbing until the desired satin finish is produced.

Gloss finish, satin finish and flat finish



Heating apparatus is necessary when it is a rainy day.



Uneven surface caused from uncompleted surface preparation or uneven shrinkage of high MC material