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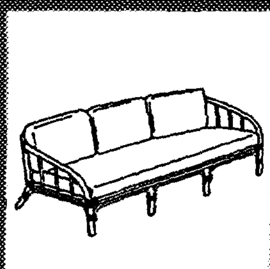
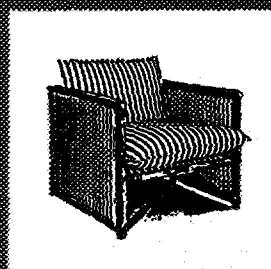
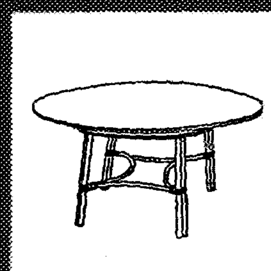
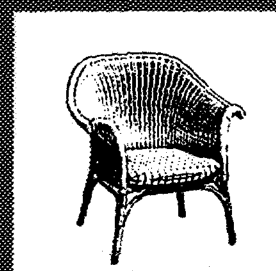
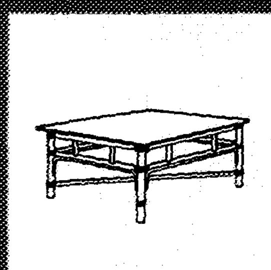
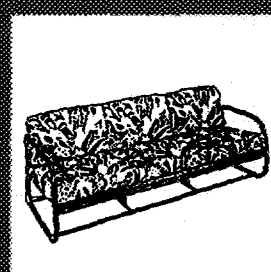
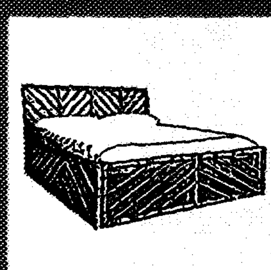
Design and Manufacture of Bamboo and Rattan Furniture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UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

DESIGN AND MANUFACTURE OF BAMBOO AND RATTAN FURNITURE

General Studies Series

DESIGN AND MANUFACTURE OF BAMBOO AND RATTAN FURNITURE

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
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Preface

Rattan is a useful raw material for the production of a certain type of furniture. So is bamboo, but to a far lesser extent. Not only is such furniture common in the countries where these materials grow but it is also in great demand in the developed countries of Europe, North America, Japan and Oceania, provided it meets the requirements of aesthetic and ergonomically sound design, robust construction, high quality and competitive price.

A rattan furniture industry is an attractive investment for a number of reasons. It creates employment in rural areas and can become an earner of foreign currencies. It is a typical labour-intensive industry, and the few machines needed can be produced locally in many developing countries. However, since past research had concentrated on the silvicultural harvesting of rattan and bamboo and their curing and storage, there was a need for diffusing information on the industrial use of these materials. Thus, at the request of the Food and Agriculture Organization of the United Nations (FAO) and using funds from the United Nations Development Programme (UNDP) and the International Development and Research Centre (IDRC), the United Nations Industrial Development Organization (UNIDO) conducted a regional workshop on the design and manufacture of bamboo and rattan furniture, at Jakarta in March 1989.

The proceedings of the workshop, which brought together 167 participants from 7 countries, were published by the technical assistance project under whose aegis the workshop had been held. However, since the material compiled was of interest to a far wider audience, it was decided to reissue the proceedings as a UNIDO sales publication, deleting the chapter on marketing and including new material in the chapters on furniture design and production technology.

It is hoped that this manual will increase the awareness of the results that can be achieved when rattan furniture factories are established according to rational industrial procedures. It is also hoped that it will be of use to teachers in training institutions in developing countries.

Explanatory notes

For the purposes of this study, which needs to treat geographical rather than political entities, it is sometimes convenient to refer to parts of countries or to islands that comprise different countries or parts of countries. Borneo, for example, is the island that comprises Brunei Darussalam; Sabah and Sarawak (states of Malaysia); and Kalimantan (four provinces of Indonesia). The island of New Guinea comprises, in the west, Irian Jaya (a province of Indonesia) and, in the east, mainland Papua New Guinea. The islands Sumatra, Java and Sulawesi are all provinces of Indonesia.

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I. RATTAN BIOLOGY, CULTIVATION AND CONSERVATION

N. Manokaran*

Introduction

Rattans are spiny climbing plants belonging to the subfamily Calamoideae, the scaly fruited palms [1]. In all, the rattans of the world may number only about 600 species in 13 genera. Ten genera occur in the islands and countries of south-east Asia and Oceania: Borneo, Java, New Guinea, Sumatra and Sulawesi and Australia, Cambodia, southern China, Fiji, the north-eastern and southern parts of India, Lao People's Democratic Republic, Peninsular Malaysia, Myanmar, Philippines, Sri Lanka, Thailand and Viet Nam. These genera are *Calamus, Daemonorops, Korthalsia, Plectocomia, Plectomiopsis, Myrialepis, Calospatha, Ceratolobus, Pogonotium* and *Retispartha* [2, 3, 4]. Elsewhere, rattans are found only in West Africa (four genera, of which three are endemic: *Calamus, Laccosperma* and *Oncocalamus*).

In the rattan plant, the stem is covered by a spine-bearing leaf sheath. When the stem becomes mature, the leaf sheath detaches and eventually drops off. It is the bare rattan stem that is used in the construction of cane furniture (rattan sticks, cane, core and split cane are used). In rural areas, both large and slender rattans are used for numerous purposes, such as building houses and bridges and making twine, rope and fishtraps.

Rattans, termed a minor forest product, have been exploited and utilized for several centuries, and during the last few decades the trade in rattans and rattan products has grown to become a multi-million-dollar business [5]. About 90 per cent of the world's raw material supply comes from the wild, and the remaining 10 per cent from plantations in Central and South Kalimantan provinces in Indonesia [6]. Only recently, beginning in 1979, were plantations established in Malaysia (about 4,000 ha in the state of Sabah) [7], and first harvesting is expected to begin soon. Large-scale plantations have also been established recently in southern China [8].

With about 300 of the world's 600 species occurring throughout its islands, Indonesia is the world's main producer of rattans, accounting for about 90 per cent of the raw material supply. However, not all species are useful from the commercial point of view. For example, only about 20 per cent of the rattans of Peninsular Malaysia are used commercially. The rest bear canes of poor quality or, in some cases, produce only very short stems of non-commercial lengths. Most of the world's 600 rattan species do not enter the trade for these reasons.

The most important rattans are the Manau cane of the furniture trade, *Calamus manan*, found in abundance only in Peninsular Malaysia and Sumatra and rarely in Borneo [9]; Rota sega (*Calamus caesius*), found only in Peninsular Malaysia, Sumatra, Borneo [10] and the Philippines [11]; and Rotan irit (*Calamus trachycoleus*), found only in southern Borneo [10].

Calamus manan has stems reaching 8 cm in diameter without the leaf sheath. Bare canes of *C. caesius* and *C. trachycoleus* have smaller stems, with diameters ranging from 7 to 15 mm.

Current supply situation

In Indonesia, the rattan harvest has been about 120,000 tonnes annually for several years [12]. Raw rattan production is less than 10,000 tonnes annually in China, but this is sufficient for domestic needs [13]. The annual allowable cut in the Philippines in 1983 was about 58 million lineal metres [14], but cane supplies were also imported from neighbouring countries. Similar information is not available for other countries in the region.

Rattan morphology

While some species of rattans, e.g. *Calamus castaneus*, are almost stemless or have only very short stems, stems of other species grow to very great lengths. A length of about 185 m was recorded by Burkill [15] for the large-diameter (18 mm) Manau cane (*C. manan*) liked by the furniture trade.

Some rattans grow as single-stemmed individuals; others exhibit a clustering habit, i.e. they have numerous stems [2]. This feature is of economic significance. Single-stemmed species like *C. manan* and *C. tumidus* are one-harvest rattans. Clustering species like *C. caesius* and *C. trachycoleus* and all species of *Korthalsia* are reharvestable. The clustering habit is brought about by

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suckers forming at the base of the stem and then growing directly into aerial stems or passing through an intermediate stolon stage that metamorphoses into an aerial stem. In *C. caesius*, the very short stolons lead to the formation of very dense clumps; in *C. trachycoleus*, diffuse open clusters are formed by the long, above-ground stolons.

Most climbing species of rattan possess a climbing organ, the cirrus. This is the extension of the leaf apex that bears reflexed thorns in whorls or singly. Other species of rattan, only from the genus *Calamus*, bear a flagellum. This climbing organ with a dense covering of reflexed thorns is a whip originating from the top of the leaf sheath opposite the leaf base. The flagella or cirri become attached to neighbouring trees and enable the plant to climb.

Flowering and fruiting

Information on the time taken from inflorescence emergence to fruit maturation has been reported for only two species of rattans. In *C. caesius* and *C. speciossisimus*, ripe fruits were observed 16-18 months from inflorescence emergence [16]. Flowering in *C. caesius* was found to be annual, and Manokaran observed that fruits formed during a season when unripe fruits from the previous season were still on the stem [16].

Calamus, the genus containing the species that are important commercially, is dioecious, i.e. fruits and progeny are produced only by the female plants. *Daemonorops*, *Plectocomia*, *Plectocomiopsis*, *Myrialepis*, *Calospatha*, *Ceratolobus*, *Pogonotium* and *Retispatha*, other genera found in South-East Asia, are also dioecious [2]. In this region, only the genus *Korthalsia* is monoecious.

In dioecious species, fruit production will be somewhat influenced by the distribution and ratio of sexes in any locality. For example, in a survey of *C. tumidus* at Pasoh Forest Reserve in Peninsular Malaysia, 10 out of 26 mature individuals were identified as female plants [17]. This finding was based on the presence of hundreds of seeds that had only recently germinated in the immediate vicinity of the parent plants. The remaining 16 plants were considered to be males.

All species in the genus *Calamus* have lateral inflorescences [18], and the stem continues to grow after one flowering occasion, producing several occasions of flowering, usually with more than one inflorescence being produced at a time. Eventually the stem dies of old age or injury. This type of flowering is termed pleonanthic, and seed production is more than once per stem. Theoretically, single-stemmed species such as *C. manan* may produce fewer fruits per plant than clustering species such as *C. caesius*, *C. trachycoleus* and *C. scipionum*. Species of some of the other genera are hapaxanthic; in these species the stem becomes exhausted by the simultaneous formation of inflorescences at the topmost nodes, and there will only be one occasion of flowering per stem.

Based on fruit counts from identified stems of various species, Manokaran [19] has reported that *C. caesius* can have more than 2,000 fruits maturing on a stem at any one time, and on one occasion about 3,000 fruits were obtained from one stem. *C. scipionum* and *C. manan* can likewise have 2,000-3,000 and 3,000-5,000 fruits or more, respectively. Thus, during the lifetime of each stem of these species, the number of fruits produced probably runs into tens of thousands. With the clustering species, the number of fruits increases according to the number of mature stems produced. At the other end of the scale, the rare *Pogonotium divaricatum* produces only one or two fruits per inflorescence and *C. gonospermus*, five fruits [20]. The solitary, high-quality, small-diameter rattan *C. laevigatus* may produce only 400-500 fruits on any one occasion [19]. Based on fruits purchased for raising seedlings, the solitary *C. tumidus* and the clustering *C. ornatus*, both commercial canes, may produce, respectively, 3,000-4,000 and up to 1,000 fruits per stem [17].

Germination

Rattan fruits are normally one seeded and covered with a fleshy layer, or sarcotesta, and a scaly pericarp. The pericarp of the rattan fruits can be broken either by beating them with a piece of wood or by stamping on them. The pericarp is then removed by hand.

The sarcotesta, which adheres firmly to the seed, is partly removed by rubbing the seed in water. This layer has to be cleaned by rubbing because it is often attacked by fungus, resulting in poor germination. The sarcotesta can also be removed by rubbing seeds gently on coarse wire mesh [21]. By this method, between 60 and 80 per cent germination is obtained, depending on the maturity and freshness of the seeds.

Seeds are normally sown in nursery beds immediately after they have been extracted and cleaned. The sowing medium consists of 75 per cent forest topsoil and 25 per cent sand. Manokaran [22] found a generally slow rate of germination for a wide variety of rattan species. For seeds of *C. manan* and *C. caesius*, Darus [21] found that germination began 2-3 weeks after sowing and was completed after 9-10 weeks.

The potting of rattan seedlings

Seedlings 2-3 cm high, with the primary leaf unexpanded at this stage, can be transplanted to potting bags from the nursery bed. The nursery bed is watered first to facilitate the transfer, which is done manually. A flat wooden spade 3 cm wide and 10 cm long is used to dig and lift the seedlings from the bed. Care is taken to ensure that roots of the seedlings are not damaged in the process.

Black plastic bags with holes at the bottom for drainage are the usual containers used in the nursery for potting. For rattan seedlings, the bags are 8 cm in diameter, 16 cm high and 0.05 mm thick.

The standard nursery soil mixture of 75 per cent forest topsoil (taken to a depth of 60 cm) and 25 per cent sand has been found to be adequate for rattan seedlings. As is the general practice, 2.3 kg of triple superphosphate and 1.6 kg of ground magnesium limestone are added to every 1 m^3 of soil mixture before filling the bags. The soil mixture is then poured into the potting bags through a funnel until the bags are filled to the brim.

Seedlings are potted under shade. A hole of sufficient depth and width is created in the centre of the bag of soil using a spade 2-3 cm wide and 10-15 cm long. The seedlings are placed with the root system in the hole and the soil around pressed firmly. The soil in the bag is then lightly watered.

The potting bags, which contain a seedling each, are placed side by side on concrete beds. These beds should be in the east-west direction to avoid direct heat from the sun at sunrise and sunset.

The maintenance of rattan seedlings

Seedlings are kept in the nursery until they are transplanted to the field. They should not be completely exposed as their leaves would be scorched by the sun's rays [23, 24]. The concrete bed is therefore provided with a thatch of palm leaves on sarlon net roofing, which gives light shade. Overshading stunts the growth of the seedlings.

Maintenance consists essentially of watering, fertilizer application, weeding and disease control. Darus and Aminah [25] have summarized these procedures: following general nursery practice for all kinds of potted seedlings, rattan seedlings are watered twice a day. This is done once in the morning and once in the late afternoon. If it has rained earlier, watering is skipped for that day. To ensure healthy growth, foliar fertilization is carried out four times a year. Bayfolan (11 per cent N, 8 per cent P_2O_2, 6 per cent K_2O and trace elements) is sprayed at the rate of 2-3 ml per litre water per 100 seedlings. Weeds have not been found to be a serious problem for the potted seedlings, and weeding is done only when necessary during the first six months.

Norani and others [26] noted that leaf diseases are the most common diseases for various species of rattan seedlings in the nursery, and that when they are severe, the seedlings may die. They identified several fungal pathogens that caused shot holes, brown rings or brown spots. The application of a fungicide is recommended whenever disease symptoms appear.

A serious outbreak of leaf blight on *C. trachycoleus*, caused primarily by *Colletotrichum gloesporoides*, devastated almost 30 per cent of the growing stock in the nursery at the Forest Research Institute Malaysia, at Kepong, in early 1983. The disease, to which *C. manan* and *C. caesius* seedlings were found to be resistant, was controlled by spraying Bayleton (0.02 per cent concentration) over the entire nursery stock at 10-day intervals. All diseased seedlings were burnt. Norani and others [26] have recommended burning out old stock in the field, spacing seedlings to avoid crowding and avoiding excessive watering.

In general, rattan seedlings may be kept in the nursery for up to 8-12 months, by which time they may have reached a height of between 30 and 40 cm. They should then be transplanted to the field.

Large-scale rattan cultivation: the Kalimantan experience

Two species of small-diameter canes, *C. caesius* and *C. trachycoleus*, were brought into cultivation in Kalimantan, in or about 1850 by missionaries [27]. *C. trachycoleus*, which is endemic to the area, and, to a lesser extent, *C. caesius* are cultivated extensively in alluvial flats along the Barito River and its tributaries in Central and South Kalimantan provinces by villagers who depend almost entirely on this crop for their livelihood. Recent accounts of this smallholder cultivation, over an estimated area of 15,000-20,000 ha, can be found in Menon [5] and Manokaran [28].

Both *C. trachycoleus* and *C. caesius* are clustering species. As mentioned earlier, *C. trachycoleus* develops diffuse, open clusters rather than the dense clumps of *C. caesius* and it spreads by lax, above-ground stolons [10]. This means that there is little competition between aerial stems of the same individual; in *C. caesius*, the close nature of the clump results in considerable competition between stems. Furthermore, the first harvest of *C. trachycoleus* in the Barito River area, said to be about 7 tonnes/ha, is 7-10 years after planting, with three more harvests in alternate years before replanting is done because of decreasing yield [10, 28]. The first harvest of *C. caesius*, giving a yield only half that for *C. trachycoleus*, is in the ninth year after planting; the second harvest four years later is followed by replanting [10]. The villagers in the central and southern Kalimantan regions of the Barito River therefore prefer *C. trachycoleus* to *C. caesius* as a plantation species.

The raw material from the plantations along the Barito River feeds the rattan industry in southern Kalimantan (Central and South Kalimantan provinces). The small-diameter canes, mainly *C. trachycoleus* and, to a lesser extent, *C. caesius*, form the bulk of the rattan industry there and, until recently, were mainly exported in the round form to Hong Kong and Singapore. This renewable resource from the plantations has also given rise to a labour-intensive weaving industry, and in recent years there has been a surge in the export of *lampit* (matting), *tikar* (fine matting) and other finished products, as well as of core and peel, unwoven and woven, of the small-diameter canes.

The Kalimantan experience is proof that these two species could be cultivated successfully on a large scale and a viable export industry developed for the semi-processed and finished products. As these species, particularly *C. trachycoleus*, are planted in seasonally flooded areas in Kalimantan, such ever-wet areas, unsuitable for agricultural crops, could easily be made productive by cultivating these rattans. As mentioned earlier, a rattan plantation of about 4,000 ha has already been established in Sabah. The plantation is mainly of *C. trachycoleus* (seeds are obtained from Kalimantan) but also of *C. caesius* (seeds are obtained locally); it is in a severely inundated floor plain not suitable for agricultural development [7].

The large-scale cultivation of rattans has also been carried out in recent years in southern China. The two species in cultivation are small-diameter rattans, *Calamus tetradactylus* (5-8 mm) and *Daemonorops margaritae* (10-15 mm).

Cultivation on a small scale

Although *C. caesius* and *C. trachycoleus* are cultivated along the Barito River in Kalimantan as a village crop, the vast hectarage planted means that in total these are large-scale cultivations. At the other end of the scale, *C. caesius* has been planted in small plots at the edges of villages by rural people in Sabah [29] and Sarawak [30] in Malaysia. *C. manan* is also said to be planted on a smallholding basis in South Kalimantan [28]. In the main, these plantings are for domestic purposes.

The introduction of useful species for cultivation

No large-diameter cane has yet been cultivated on a large scale, and the rotation age of some such canes is likely to be 15 years or more [31]. The premier cane, *C. manan*, is a difficult plantation species because of its solitary habit. Trial plantings of this species have been carried out by the Forest Research Institute Malaysia in logged and secondary forests and on a small scale as an intercrop in rubber (*Hevea brasiliensis*) plantations [32, 33]. The species has also been introduced into Sabah for planting purposes. There is a need for introducing into the countries of the region good quality, large-diameter cane species that cluster freely. Dransfield [34] has listed several such species, including *C. merrillii* of the Philippines, *C. zollingeri* and *C. inops* of Sulawesi, *C. andamanicus* of the Andaman Islands (India), *C. ovoideus* and *C. zeylanicus* of Sri Lanka and *C. subinermis* of Sabah. *C. manan*, however, is the supreme large-diameter rattan, and the suckering forms reported by Manokaran [35] need to be selected for cultivation.

Harvesting and processing

An account of harvesting, drying and treatment of canes is given in Menon [10], and the notes below are extracted from that publication. In the wild, the stem of mature canes is cut 30-200 cm above the ground with a *parang* and dislodged from the support tree by pulling the base of the stem with short, strong tugs. The collector climbs a neighbouring tree to cut the rattan stem free if it is entangled in the canopy, sometimes abandoning part of the stem if it cannot be freed. The thorny leaf sheaths on the younger parts of the stem are removed by twisting the cane around a tree trunk as the cane is being pulled down. Two or three men are required to harvest large rattans, which are usually attached firmly in the canopy. The uppermost 3-4 m of the rattan is usually discarded because it is soft and immature and hence useless.

A mechanical harvester that would allow canes to be harvested without wastage has recently been developed by the Indonesian Rattan Project, funded by the International Development Research Center (IDRC) of Canada, at the Forest Research and Development Agency, Bogor.

Harvested rattans are immediately cut into lengths and bundled before being carried out of the forest. Large-diameter canes are cut into 5-7 m or 8-9 m lengths, bent in two and bundled. The bundles of canes are then transported to the processing yard.

At the processing yard, large-diameter canes and also some small-diameter ones are boiled in a mixture of diesel and coconut oil in varying proportions for varying periods of time. The oil boiling process is said to remove the large quantities of gums and resins and most of the moisture in the canes. Removal of the gum and resins is said to make the canes more durable.

Treated canes are rubbed with sawdust or gunnysack. The large-diameter canes are tied loosely at one end and stood upright with the untied end on the ground and the basal ends spread out forming a cone. The smaller-diameter canes are hung over wooden stands or spread over the ground, over a wooden frame on the ground or on wooden racks. Following drying, the rattan is bundled and stored until sold.

The preservation of genetic resources

In recent years, widespread forest clearing, with accompanying changes to the forest ecosystem, and intensive harvesting of canes to satisfy demands of world trade are factors that have contributed to genetic erosion and threatened the stability of rattan populations in the wild. Kiew and Dransfield [36] have described the conservation status of the 104 rattan species of Peninsular Malaysia (see table) following the usage of the International Union for Conservation of Nature and Natural Resources [37]. In general, the commercial species are considered to be vulnerable, meaning that the species are under threat, and if that threat (logging) continues, they are in danger of becoming extinct.

Table 1. Conservation status of rattans of Peninsular Malaysia

Status	*No. of species*
Endangered	13
Vulnerable/endangered	41
Vulnerable	44
Rare	4
Not threatened	2

Source: R. Kiew and J. Dransfield, "The conservation of palms in Malaya", *Malayan Naturalist*, vol. 41, No. 1, pp. 24-31.

Rattan generic resources could be conserved to varying degrees, in the same way as is possible with other plant materials. Species could be conserved in *(a)* cultivation or in silvicultural plots, *(b)* arboreta or botanic gardens, *(c)* seed banks or as tissue-cultured material and (*d*) national parks or nature reserves. They could also be conserved by controlling exploitation and by promoting less-known species.

Cultivation/silvicultural plots

C. caesius and *C. trachycoleus* will be perpetuated because they are in large-scale cultivation in Kalimantan and Sabah. Similarly, *C. tetradactylus* and *Daemonorops margaritae* will also be perpetuated because they are in cultivation in southern China. These four species, together with several other commercially important species, have been the subject of silvicultural trials during the last decade or so [31, 38, 8]. They will also enjoy some form of protection for as long as the silvicultural plots remain intact and function as seed sources.

Conservation in this manner is only for elite species. Almost invariably the genetic base is narrow because seedlings for the plantings would have come from a limited number of mother plants, with no criteria applied in seed collection. Provenance trials on a regional basis, none of which are at present being carried out for rattans, would certainly help to widen the genetic base.

Arboretums or botanic gardens

A very wide range of species, whether common or rare, local or exotic, valuable or otherwise, could be conserved in arboretums or botanic gardens. Rattan gardens are, in fact, now being developed in countries like Indonesia, China and Malaysia through projects funded by IDRC.

As space is usually limiting in such gardens, it will be possible to plant only a limited number of individuals of each species. The number of individuals of certain species may also be restricted owing to difficulties in obtaining seeds, particularly of the less common species. The result is that there is no genetic variability; in practice, all individuals of a species in the garden are likely to be from the seeds of a single mother plant.

Of the Asiatic rattans, only species of the genus *Korthalsia* are monoecious; species of the remaining genera are dioecious [2]. Thus a sufficient number of individuals of the dioecious genera needs to be planted in the garden to be sure of obtaining both male and female plants. In one reported case [17], all four individuals of the *Calamus filipendulus* planted in the grounds of the Forest Research Institute Malaysia were found to be males when they began flowering.

Seed banks or tissue-cultured material

Under the banner of the IDRC-sponsored rattan projects, some exchange of seeds has taken place during the last few years between countries like Malaysia, China, Indonesia, India and Thailand. The plants raised are expected to be planted in the respective rattan gardens. The exchange of seeds of species common to the countries will help to redistribute genetic material to preserve diversity.

Rattan seeds are recalcitrant. Of the species tested so far, the longest period of seed storage under laboratory conditions was about six months, with a viability of over 50 per cent [39]. This is obviously unattractive when one considers that the rotation age, depending on species, is from 7 to 15 years or more for some commercial species. This is in contrast to most grain crops, whose seeds can be kept viable for several decades under suitable storage conditions. The storage of rattan seeds for the purpose of genetic conservation is therefore not a viable proposition in the light of present knowledge.

Tissue culture experiments on some rattan species have been in progress during the last few years [40, 41], the purpose being to eventually mass-produce plantlets of superior genotypes. Though plantlets of *C. manan* have been produced and have recently been transplanted to the field, the number obtained was only 20 [42]. Once the methodology for mass production is available and can be used successfully with a wide range of rattan species, such a micropropagation technique could be used for conservation purposes. However, care would have to be taken to ensure that genetic variability is not reduced because of dependence on a limited number of clones of easily multiplied material.

National parks or nature reserves

The conservation of whole systems, through the establishment of national parks or nature reserves, is a means of conserving the vigour and the variability of wild germ plasm. Wild populations of rattans, particularly those with increasing economic value, will have to be widely available for purposes of genetic selection and breeding. Very strict control will have to be maintained to ensure that elite species are not illegally removed from the parks or reserves.

Controlling exploitation

There is a need also to effect stricter control over exploitation, perhaps by granting concessions for rattan collection that define property rights over a long time. This may help to reduce the harvesting of wild rattans that may not have flowered and fruited and hence have yet to contribute to the development of progeny.

Promoting less-known species

There is a need for botanical surveys to discover unknown rattans of high quality from regions where the flora is poorly known. The qualities of any such rattans need to be tested and the plantation potential gauged from silvicultural trials before large-scale cultivation is attempted. At the same time, and as mentioned before, good quality species from one area need to be introduced into cultivation in other areas and the usage of these canes promoted. A list of some promising canes can be found in Dransfield [34].

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II. THE SUPPLY OF RATTAN FOR INDUSTRIAL USE

Toga Silitonga*

An introduction to Indonesian rattan

Definition

Rattan is a climbing flora that belongs to the Palmae family. At least seven genera are found in Indonesia. Of these, *Calamus*, *Daemonorops*, *Korthalsia* and *Plectocomia* are the most common genera producing commercial canes. The scientific and local names of Indonesian rattans are listed in annex I.

Corollary

Rattan used in industrial applications is usually classified as large-diameter or small-diameter:

Name	*Cane diameter*	*Obtained from*
Calamus ornatus	Large	Java, Sulawesi
C. manan	Large	Sumatra, Kalimantan
C. inops	Large	Sulawesi
Daemonorops fissus	Large	Sumatra, Kalimantan
C. symphysipus	Large	Sulawesi
C. javensis	Small	Java
Daemonorops rubra	Small	Java
C. caesius	Small	Sumatra
C. trachycoleus	Small	Sumatra

Information on these species and their distribution is presented in annex II. Not all the species are presently marketable, because their properties and market demand are not well understood.

At this time most of the rattans in the furniture trade come from natural forest. Ordinarily, rattan is collected by farmers as a part-time job.

Rattan cultivation started as early as the 1850s, but only on a small scale. Most of the cultivated rattans are of small diameter. The total area now cultivated exceeds 15,000 hectares, spread over eight provinces of Indonesia.

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The working characteristics of rattans

The characteristics of rattan are important not only for end-users and manufacturers but also for furniture designers. In the making of furniture and handicrafts, a fair knowledge of the material's characteristics is required, especially in so far as they concern the processing and finishing stages.

Some important points on working characteristics

It is important to understand the advantages of this material and its limitations. In many cases designers could improve the quality of their work by obtaining technical information from the craftsmen.

Most canes have wide pores and, consequently, a lower specific gravity than wood. Manau rattan is denser than other species. The cortex, a thin layer on the cane surface, is usually thicker and denser than the core (inner) part. The core has almost no pith, but if it has, the density gradient from pith outward is small.

As in the case of wood, cane material is non-uniform. Since it consists of fibrous material extending along the longitudinal axis, the tensile strength is much higher along this axis than in the radial and tangential directions.

The most common cane-destroying organisms are blue stain and pinhole borers. Both organisms can easily penetrate from the cortex inward. The removal of the cortex will expose the less dense part, which is more vulnerable to the attacking organisms.

Based on chemical analyses, rattan canes contain more pentosan and less lignin than wood. It is generally assumed that these factors are responsible for the fact that rattans bend easily at elevated temperatures and maintain their shape after cooling.

For several species, especially those from *Daemonorops*, such as bubuai, the density gradient in the core is quite distinct. Many presently non-commercial rattans are found to have this property.

Green cane can contain up to 130 per cent moisture. In drying, moisture escapes from all of the cane surface but most noticeably from the exposed ends. The drying rate is normally satisfactory by the air-drying method, but too slow a rate could allow blue stain to attack.

Early treatment (oil bathing)

Bathing canes in oil at an elevated temperature helps to improve their quality:

(a) It removes dirt and fats or wax from the cane surface;

(b) It improves colour;

(c) Boiling in kerosene improves lustre;

(d) It reduces the moisture content;

(e) It also removes any borer eggs laid on the cane surface.

Swelling and shrinking behaviour

For ripe cane, the ratio between shrinkage in the radial and tangential directions (R/T ratio) is approximately unity; for immature canes, this ratio is always less than unity. Thus, immature canes shrink more severely on the surface and become wrinkled when dried, with the wrinkle ordinarily continuing into the core. The utilization of immature cane is therefore highly inadvisable.

Cane characteristics

Good quality canes usually are those having long intervals between nodes, little taper, a cylindrical shape and only a small increase in diameter at the nodes. Cane with a large taper is not very suitable for furniture. Low-density cane requires special fastening material (screws, nails etc.). Decayed canes are liable to rupture and split when they are bent.

Current supply situation

Rattan supply

At present rattan comes mainly from naturally grown rattan harvested from the natural forest. Most of the supply of marketable rattan comes from three islands: Sumatra, Kalimantan and Sulawesi. It was recently discovered that the forests of Maluku and Irian Jaya are rich in rattan, but supplies from these areas are still unexploited.

Naturally grown rattan is found further and further away from existing roads and rivers, so that the collectors, for whom this is a part-time job, are reluctant to collect it owing to high transportation costs. As a result, the cultivation of rattan is now being encouraged, although its importance is just beginning to be recognized.

There are a number of reasons for cultivating rattan:

(a) To increase the productivity of forest land;

(b) To ensure a good supply of species in demand;

(c) To ensure that species in demand do not become extinct.

The current views on the rattan resource situation are as follows:

(a) The stock of small-diameter raw rattan species suitable for current production is adequate;

(b) There is some unease over the long-term supply, particularly in respect to the larger-diameter poles (28 mm and upwards). The rattan cultivation programme should give high priority to the development of large-diameter rattans;

(c) The time-to-harvest of large-diameter rattan is estimated at 20-25 years.

The protection and conservation of supplies

The main points to be considered in relation to the protection and conservation of supplies are as follows:

(a) Improved methods of harvesting could reduce the amount of waste by up to 30 per cent;

(b) Protecting raw cane from blue stain and borers can significantly improve the quality of the harvested material;

(c) The careful preparation of poles and careful dimensioning, cutting and processing could significantly reduce waste;

(d) Ways must be found, especially at the design stage, to increase the use of small-diameter rattans;

(e) Good drying and treatment practice is necessary;

(f) The surface of the rattan should be coated as soon as possible;

(g) Chemicals suitable for protecting wood from organisms are also usually suitable for protecting rattan or rattan products. Annex III provides further information.

Current production

Before 1983, exports of raw rattan were around 100,000 tonnes per year. Potential production is estimated at almost 575,000 tonnes per year (see annex IV). This figure would include the rattans presently considered to be non-commercial species and those in remote areas. It is also estimated that rattan supply could be maintained at 300,000 tonnes per year on a sustainable yield basis.

Measures to secure future supply

To secure the future supply of rattan, efforts should be directed at the following:

(a) Controlling exploitation of the natural forest resource;

(b) Promoting the lesser known species of rattan for industrial use;

(c) Establishing seed orchards for longer term use;

(d) Developing effective harvesting procedures;

(e) Improving processing and drying methods.

The standardization of grading rules

Before 1979, rattan exports from Indonesia were mostly in the form of raw cane. At that time, the rattan grading rules were largely geared to foreign buyers, and they were not standardized. In 1979, the Indonesian Government started requiring that rattan should be processed into half-finished forms before export. Later, the Government said that as of the beginning of 1987, rattan should be exported as finished products. Those decisions and their effect on the rattan trade must influence the standardization of grading rules in Indonesia.

Defects in large canes are related to several factors: moisture content, handling during collection, transportation, treatment and immaturity. Depending on the treatment it has received and the processing stages it has undergone, the rattan is usually in one of three forms: *(a)* raw cane, if there has been no processing, *(b)* half-finished, commonly known as washed and sulphurized, or *(c)* finished product, such as webbing, weaving, basketry and furniture.

Logically, a standard grading rule is required for each product. The standard can be different but the type of defect will be similar. This is especially true for those defects that are inherent to the canes. Since such defects will be carried over to the end products, all defects in the raw canes will also be defects in the half-finished and finished products.

Standard grades for the raw canes of Indonesian rattans

The standard grades for the raw canes of Indonesian rattans are as follows:

(a) Prime quality (P): canes of this quality are canes free from defects. Such canes promise the maximum material utilization from a given piece of cane;

(b) Grade A: canes with limited defects. Such canes can be used to make high quality, but not prime quality, rattan products;

(c) Grade B: canes with several defects, which can be used for specific purposes to produce fair quality products;

(d) Grades C and D: canes of lower quality than A or B.

The characteristics on which canes are judged are as follows:

(a) Size: length, diameter, taper;

(b) Cane condition: straightness, cylindricity, flexibility, density, nodal length and uniformity of diameter;

(c) Colour: base colour according to species, lustre etc.;

(d) Defects: rupture and split, wrinkle, stain, pinholes.

The grading stages for large-diameter rattan are shown in figure 1; those for small-diameter cane are shown in figure 2.

Figure 1. Grading for large rattan poles

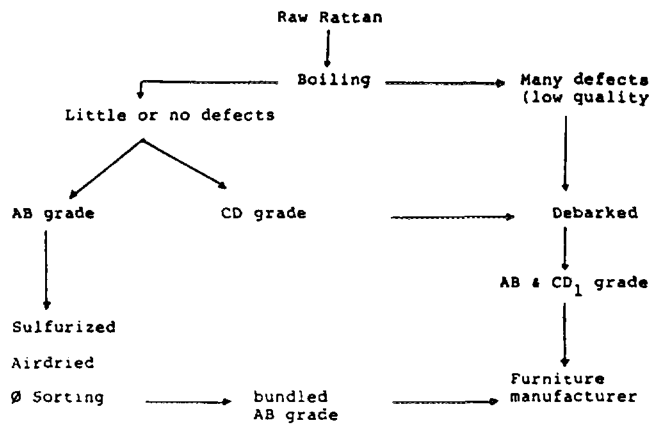
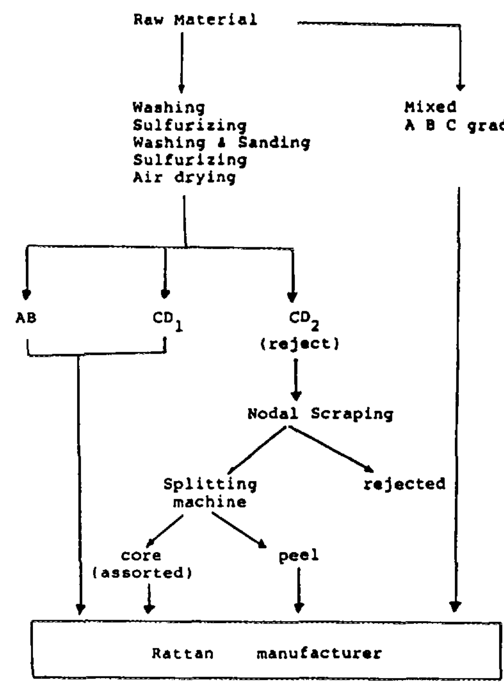


Figure 2. Grading for small rattan poles



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Annex I

SCIENTIFIC AND LOCAL NAMES OF INDONESIAN RATTANS

Scientific name	*Local name*	*Scientific name*	*Local name*
Calamus acidus	R. asam	*Calamus warburgii*	R. suwai
Calamus adsperus	R. cacing, bogo	*Calamus zollingeri*	nango wata, wata epa
	R. ayam, howe	*Calamuss zonatus*	R. tulang
Calamus erinaceus	R. bakau	*Ceratolobus concolor*	geleng dage, hoe,
Calamus asperimus	R. leulues		uwee tikoos
Calamus axillaris	R. sega air	*Ceratolobus glaucescens*	R. caing
	R. sega, banju, pao	*Ceratolobus subangulatus*	anak nangus, piladeh
Calamus blumei	R. lilin		R. peledek
Calamus burckianus	R. sepet, balubuk,	*Ceratolobus pseudoconcolor*	R. omas
	R. kokrok		
Calamus caesius	R. sago, taman,	*Daemonorops sabut*	R. rumbai
	R. sago beras	*Daemonorops calapparia*	R. kelapa
Calamus ciliaris	R. cacing, petey	*Daemonorops crinata*	R. rumbai, bulu
Calamus conitrostris	R. tinti buku		R. getah jepungkeli
Calamus didymocarpus	uwe rongo	*Daemonorops drago*	R. jemang
Calamus diepenhorstii	R. batu	*Daemonorops formicaria*	R. sabu
Calamus flabellatus	R. rumo/raemo	*Daemonorops geniculata*	R. kurah
Calamus horrens	R. air, rawa		kemunting, gelang
Calamus heteroideus	R. korod, omas	*Daemonorops hallieriana*	R. latung
	R. tretes, korod, apu	*Daemonorops histryx*	R. sepet, omas,
Calamus hispidus	R. bulu		R. leuleus, korod
Calamus hollrungii	uawa jawa	*Daemonorops lamprolepis*	R. lita
Calamus insignis	R. batu	*Daemonorops longipes*	R. sarang buaya
Calamus inops	R. tohiti		R. tikus
Calamus javensis	R. cili, cacing,	*Daemonorops melanochaetes*	R. seel, selang,
	R. oma, halus		R. pitik pang
Calamus karuensis	R. penjalin rawa	*Daemonorops mirobilis*	R. lengkoning
Calamus leiocaulis	R. jaramasin sum		R. bambulan
Calamus manan	R. manau	*Daemonorops oblonga*	pendjalin pitik, R.
Calamus melanoloma	R. gelengdage,		beurit, ayam
	R. leuleus	*Daemonorops periacantha*	R. londoh, huwee
Calamus minahassae	anduru, lauro kumpuu		kapul, uwee landak
	kiam kumel	*Daemonorops rubra*	R. sabut, pelah,
Calamus laevigatus	R. tunggal		tretes
var. mucron		*Korthalsia angustifolia*	ayam manisvar
			manisvar
			R. ahas
Calamus muricatus	R. melukut, manau kuching,	*Korthalsia celebica*	bulu, uwee sampe,
	tunggal		banu-banu, uwa keis
Calamus optimus	R. selutup	*Korthalsia debilis*	R. dahanan
Calamus ornatus	R. senti, leudowuku,	*Korthalsia echinometro*	uwee udang, uwee hurang,
	R. jeiayam		R. lowok,
Calamus palembanicus	R. nangga		siu
Calamus pilosellus	R. lintang	*Korthalsia hispida*	R. lalun
Calamus polystachys	R. gelang	*Korthalsia junghuhnii*	R. simpang, sampai
Calamus reinwardtii	R. dedek, malam,	*Korthalsia robusta*	R. ahas
	R. tretes, cecret	*Korthalsia pauci juga*	R. belidang
Calamus rhomboideus	R. dawuh, lilin,	*korthalsia rigida*	R. paku
	muka	*Korthalsia rostrata*	R. semut, ina nut,
Calamus ridleyanus	R. batu, batu paya		simpurut, tai manuk
Calamus scipionum	R. semambu	*Korthalsia* spp.	R. lanromanu, imusai
Calamus spectabilis	R. sega peledas,	*Korthalsia lasiniosa*	R. hoe,
	katip udang		uwee tangkurungan,
			huwee dhanan

Source: *RIC Bulletin*, vol. 7, Nos. 1 and 2 (March/June 1988).

Annex II

COMMERCIAL RATTAN SPECIES OF INDONESIA AND THEIR DISTRIBUTION

						Habitat				
			Diameter							
Species/distribution	*Lustre*	*Solitary*	*Large*	*Medium*	*Small*	*Slow Drying*	*Marsh*	*Swamp area*	*Between 0 and 500 m above sea level*	*More than 500 m above sea level*
Java (25 species)										
Calamus heteroideus (R. korod)	x	–	–	–	–	x	x	–	–	–x
C. javensis (R. cilicacinig)	x	–	–	–	x	x	–	x	x	x
C. melanoloma (R. leuleur)	x	–	–	x	x	x	–	–	x	x
C. reinwardtii (R. dedek)	x	–	x	–	–	x	–	–	x	x
C. ornatus (R. seuti)	x	–	x	–	–	x	–	–	x	x
C. rhomboideus (R. bego, dawuh)	x	–	–	–	x	x	–	–	–	x
C. Viminalis (R. glatik, cacing)	x	–	x	–	–	x	–	–	x	x
Daemonorops rubra (R. pelah)	x	–	–	–	x	x	–	–	x	–
Sumatra (75 species)* and Kalimantan (100 species)*										
Calamus manan (R. manau)	–	x	x	–	–	x	–	–	x	x
C. caesius (R. sago)	x	–	–	–	x	–	–	–	x	x
C. trachycoleus (R. irit)	x	–	–	–	x	–	–	x	x	–
C. axillaris (R. sega air)	x	–	–	–	x	–	x	x	x	–
C. mucronatus (R. melikut, tunggal)	–	x	–	–	x	x	x	–	x	–
C. retrophyllus (R. tunggal, lilung)	–	x	–	–	x	x	–	–	x	–
Calamus sp. (R. putih)	x	–	–	–	x	x	–	–	x	–
C. leiocaulis (R. jermasin, ronti)	x	–	–	–	x	x	–	–	x	x
C. ornatus (R. tulang, minong)	x	–	–	–	x	x	–	–	x	x
C. javensis (R. halus, pulut merah)	x	–	–	–	x	x	–	x	x	–
D. fissus (R. latung)	x	–	x	–	–	–	–	–	–	–

			Diameter			Habitat				
Species/distribution	*Lustre*	*Solitary*	*Large*	*Medium*	*Small*	*Slow Drying*	*Marsh*	*Swamp area*	*Between 0 and 500 m above sea level*	*More than 500 m above sea level*
D. crinitus (R. jernang, getah)	x	–	–	–	x	–	x	x	x	–
D. longipes (R. tanah)	x	–	x	–	–	x	x	–	x	–
D. angustifolia (R. jernang, getah)	x	–	x	–	–	x	–	x	x	–
D. didymorphyllus (R. jernang)	x	–	–	x	x	–	–	–	–	–
Korthalsia scaphigera (R. semut)	x	–	–	–	x	x	–	–	x	–
D. sabut (R. cincin)	x	–	–	–	x	x	–	–	x	–
C. rhomboideus (R. lilin)	x	–	–	–	x	x	–	–	–	x
C. marginatus (R. manau padi, besi)	x	–	–	x	x	x	–	–	x	–
C. optimus (R. buyung, selutup)	x	–	x	–	–	x	–	–	x	–
C. scipionum (R. semambu)	x	–	x	–	–	x	–	x	x	x
C. blumei (R. lilin)	x	–	–	–	x	–	x	x	x	–
C. diepenhorstii (R. batu)	x	–	–	–	x	x	–	–	x	–
C. flabellatus (R. rumo)	x	–	–	–	x	x	–	–	x	–
C. hispidulus (R. buluh)	x	–	–	–	x	x	–	–	x	–
C. spectabilis (R. katip, udang, paladas)	x	–	–	–	x	x	–	–	x	x
C. schistacanthus (R. dandan)	x	–	–	–	x	x	–	–	x	–
K. flagellaria (R. dahanan)	x	–	x	–	–	x	x	–	x	–
Sulawesi (25 species)										
C. ornatus (R. londo, wuku)	x	–	x	–	–	x	–	–	x	x
C. inops (R. tohiti)	–	x	x	–	–	x	–	–	x	x
C. didymocarpus (R. uwe rongo, lauro, hoa)	–	x	–	x	x	x	–	–	–	x
C. minahassae (R. lauro anduru, tikus, batu)	x	–	–	–	x	x	–	–	x	–
C. insignis (R. batu)	x	–	–	–	x	x	–	–	x	–
C. lamprolepsis (R. sabut)	x	–	x	–	–	x	–	–	x	–
C. symphysipus (R. ombol, hoa)	–	x	x	–	–	x	–	–	x	x
C. zollingerii (R. hango wata, merah)	x	–	x	–	–	x	–	–	x	x
C. lamprolepsis (R. sabut, lita)	x	–	x	–	–	x	–	–	x	–

Source: J. Dransfield, "The rattans of Sabah", *Sabah Forest Record*, No. 13 (1984).

Annex III

PESTICIDES AND FUNGICIDES APPROVED FOR PRESERVATION IN INDONESIA

Formulation	*Active chemical(s)*	*Available as*	*Approved utilization*
Agrothion 50EC	Phenitrothion: 500 g/l	Concentrated emulsion	Control of Ambrosia beetles, fresh cut
Basiment 235	Dichlofluanid: 50% + 2%	Powder	Blue stain
Celcure A(P)	$CuSO_4 \cdot 5H_2O$: 32.6% $Na_2Or_2O_7 \cdot 2H_2O$: 41.0% $As_2O_5 \cdot 2H_2O$: 26.4%	Paste (95% solid)	Fungicide, termites, marine borers
Chlordane 960EC	Chlordane: 960 g/l	Concentrated emulsion	Dry wood termite, powder post beetles, soil termites
Cymbush 5EC	Cypermethrin: 50 g/l	Concentrated emulsion	Ambrosia beetles, fresh cut
Cyslin 2.5EC	Decamethrin: 25 g/l	Concentrated emulsion	Ambrosia beetles, fresh cut
Dieldrin 20EC	Dieldrin: 200 g/l	Concentrated emulsion	Soil termites
Diffusol CB	$CuSO_4$: 28.6% $Na_2Cr_2O_7$: 43.9% H_3BO_3: 27.5%	Powder (100% salt)	Fungicide, insecticide, termites
Farmay Plus	TOKTB: 108.7 g/l KTO: 109.9 g/l	Concentrated emulsion	Blue stain
Impralit CKB	$CuSO_4 \cdot 5H_2O$: 34.0% $K_2Cr_2O_7$: 38.0% $KHSO_4$: 3% H_3BO_3: 25%	Powder (97% salt)	General-purpose fungi-insecticide
Kemirin 72 P	CuO: 14.8% CrO_3: 26.6% As_2O_5: 34%	Paste (71.6% oxide)	General-purpose and marine borers
Koppers F.7	$Na_2B_4O_7 \cdot 5H_2O$: 25% H_3BO_3: 40.0% NaF: 15.0% $As_2O_5 \cdot 2H_2O$: 11.0% $Na_2Cr_2O_7 \cdot 2H_2O$: 9.0%	Powder (100% active salt)	General-purpose
Lindamul 20EC	Lindane: 200 g/l	Concentrated emulsion	Termites
Kitrol PQ 57	Cu-8-oxyquinolinolate: 50 g/l	Concentrated emulsion	Blue stain
Osmose K 33	CuO: 13.3% CrO_3: 34.2% AS_2O_5: 24.5% H_2O: 28.0%	Paste (72% active oxide)	General-purpose and marine borers
Palvonnis 61EC	Thiobendazole: 15.3 g/l p-chlorophenyl-3-iodo-propargyl formal: 46.17 g/l	Concentrated	Blue stain
Ripoord 5EC	Cypermethrin: 50 g/l	Concentrated emulsion	Ambrosia beetles
Sarmix 1200 AS	$CuSO_4 \cdot 5H_2O$: 35.0% $Na_2Cr_2O_7 \cdot 2H_2O$: 45.0% $As_2O_5 \cdot 2H_2O$: 20.0%	Concentrate	General-purpose and (75.2%) marine borers
Tanalith CT 106	$CuSO_4$: 27.4% $Na_2Cr_2O_7$: 48.2% $As_2O_5 \cdot 2H_2O$: 24.4%	Powder (100% anhydride)	General-purpose and marine borers

Source: Pestisida untuk Pertanian dan Kehutanan (1982, 1985).

Annex IV

INDONESIAN RATTAN PRODUCTION POTENTIAL FOR 16 PROVINCES[a]

Province	*Area under cultivation (thousandas of ha)*	*Production potential (tonnes/year)*
Sumatra		
Aceh	...	45 000
Riau	0	2 840
Sumatra Utara	...	6 000
Sumatra Barat	289	34 000
Jambi	400	6 900
Bengkulu	...	23 100
Sumatra Selatan	...	5 000
Lampung	...	24 500
Total Sumatra		147 340
Kalimantan		
Kalimantan Barat	600	92 500
Kalimantan Tengah	60	24 000
Kalimantan Selatan	...	7 000
Kalimantan Timur	4 375	11 650
Total Kalimantan		135 150
Sulawesi		
Sulawesi Utara	1 110	87 000
Sulawesi Tengah	1 500	18 400
Sulawesi Selatan	673	150 000
Total Sulawesi	3 283	255 400
Nusa Tenggara Barat	...	36 000
Total 16 provinces		573 890

Sources: Forest Department, 1983; *Proceedings of Diskusi Hasil Hutan Nou Kayu*, Jakarta, 1980.
[a]Based on 0.2 per cent sampling.

III. BAMBOO

Songkram Thammincha*

Introduction

Bamboo is the most universally useful plant known to man. For over half the human race, life would be completely different without it. Ubiquitous, it provides food, raw material, shelter, even medicine for the greater part of the world's population. In his history of the Chinese junk, G. R. G. Worcester catalogues the uses to which the ingenious junkmen put bamboo: "rope, tholepins, masts, sails, net floats, basket fish-traps, awnings, food baskets, beds, blinds, bottles, bridges, brooms, foot rules, food, lanterns, umbrellas, fans, brushes, buckets, chairs, chopsticks, combs, cooking gear, cups, drogues, dust pans, paper, pens, nails, pillows, tobacco pipes, boat hoods, anchors, fishing nets, fishing rods, flagpoles, hats, ladders, ladles, lamps, musical instruments, mats, tubs, caulking material, scoops, shoes, stoves, tables, tallies, tokens, torches, rat traps, flea traps, joss sticks and back scratchers" [1].

Bamboo is involved in the daily life of the people in the eastern hemisphere. The East and all its peoples can hardly be discussed without bamboo's being taken into account. As a traveller of the Victorian era, Colonel Barrington de Fonblanque, observed, a little pessimistically:

> "What would a poor [Chinese] do without the bamboo? Independently of its use as food, it provides him with the thatch that covers his house, the mat on which he sleeps, the cup from which he drinks, and the chopsticks with which he eats. He irrigates his field by means of bamboo pipe; his harvest is gathered in with a bamboo rake; his grain is sifted through a bamboo sieve, and carried away in a bamboo basket. The mast of his junk is bamboo; so is the pole of his cart. He is flogged with a bamboo cane, tortured with bamboo stakes, and finally strangled with a bamboo rope".

Most of the rural people in developing countries are in the agricultural sector. Those who live in the zone where bamboo occurs may plant bamboo as a living fence from which bamboo shoot will be used for food and bamboo culm for building material and handicrafts [2]. Bamboo always shares a major part of the houses of the people living close to the forest. Their earnings from agricultural crops are very often too small to cover their yearly expenditure, many of them being heavily in debt. Fortunately, these people can get an additional income from bamboo shoot and culm harvesting [3].

In areas where it grows naturally, bamboo is a traditional building material. Houses can be made exclusively from bamboo. Larger culms are used for the piles, stilts and the major framework. Smaller pieces are used for floors, windows and door-frames. The bamboo can be split into slats for weaving into mat walls. When the culms are split in half and the nodes removed, they can be used interlockingly to form waterproof roofs. The same ingenious application of bamboo is also carried through for furniture, fences, cages, mats, farm implements, ladders and blinds. Pipes for irrigation and guttering can also be fabricated when the nodes are removed [4]. Bamboo scaffolding is commonly used in building construction since bamboo is extremely resilient and long-lasting. Many construction workers also believe that bamboo is safer than rigid tubing. One seldom hears of bamboo scaffolding collapsing even when it is used in multi-storey construction [2].

Although bamboo has long been recognized as a multipurpose species, very useful in rural areas, it is harvested without any concern for conservation measures, and research has been virtually ignored. As a result, bamboo resources have been depleted rapidly. Though once called "the poor man's timber", it is no longer so [5].

To Western eyes, the charm of most bamboo articles is immediate, deriving from two sources—their modesty and their suitability. Most bamboo objects hardly seem manufactured; they appear more as products of nature. Shaped and refined over the years for unchanging everyday needs, their form and feel are satisfyingly appropriate, indeed inevitable. They give the impression of having generated themselves, having evolved slowly for their tasks, without acquiring complexity from man [1].

Bamboo products are usually made with low capital and are labour intensive. Mechanization plays a rather small role in the activities [6]. Moreover, bamboo craftsmanship is comparatively simple. While a certain level of competence is necessary, one need not possess a high degree of skill to fashion bamboo into an object that will stand up to practical use [7]. However, a high degree of skill and design are very important in making bamboo products for commercial purposes. Good design will contribute value added to the products.

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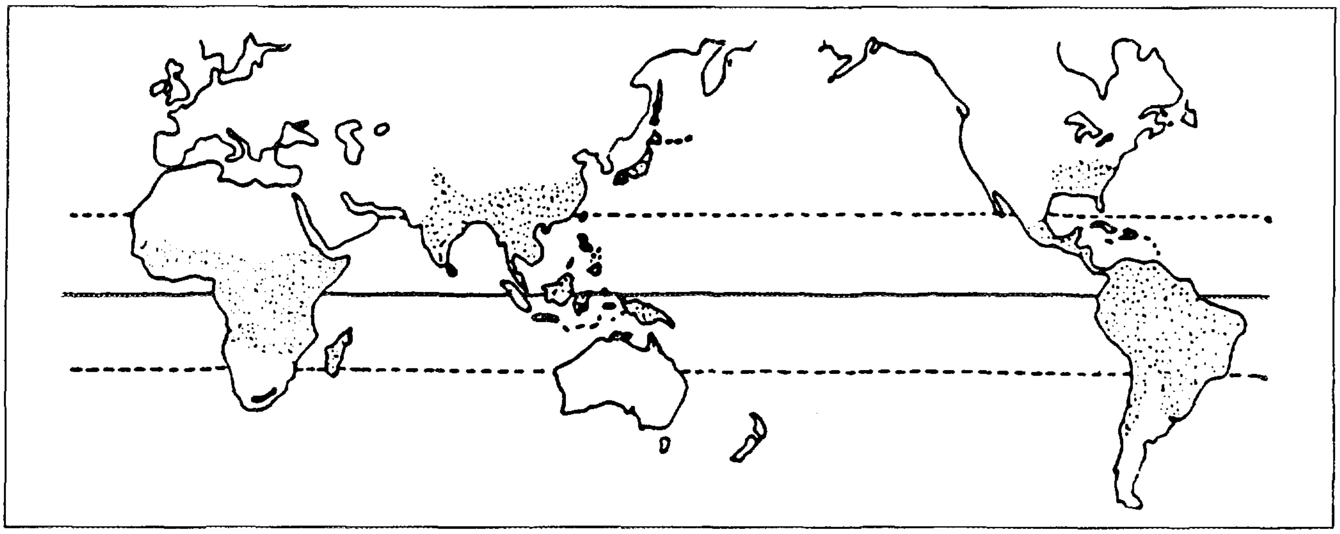
Figure 3. Worldwide distribution of bamboos



Distribution of bamboos

Bamboos are a unique group of giant arborescent grasses, in which the wood culms arise from an underground rhizome. They are set off from other grasses by the predominance of certain bambusoid structural characters, many of which are considered to be primitive.

Of very uneven geographical distribution, bamboos appear more or less prominently in the natural vegetation of many parts of the tropical, subtropical and temperate regions of the world, from sea level to the snowline.

It is reported that over 75 genera and 1,250 species of bamboos occur in the world [8]. Bamboos grow naturally on all continents except Europe [9]. The tropical belt is home to a large number of species. About 14 million hectares of the earth's surface are covered with bamboo forests; about 80 per cent of this hectarage is in Asia (from Pakistan to Japan), South-East Asia in particular [10], while only 1.5 million hectares of bamboo resource are available in Africa [11]. The worldwide distribution of bamboo is illustrated in figure 3.

Regions in Asia are rich in genera and species of bamboos. The genus *Phyllostachys* dominates in the temperate and subtropical regions, whereas the genera *Bambusa* and *Dendrocalamus* dominate in the tropical regions. Five genera occur naturally in Africa compared with 11 genera in South America. *Arundinaria giganta* and *A. tecta* are the only two native bamboo species in the United States of America [12].

In most Asian countries, bamboos are an important part of the natural environment and meet the people's daily needs. The number of species by country is presented in table 2.

Table 2. Number of species by country in Asia

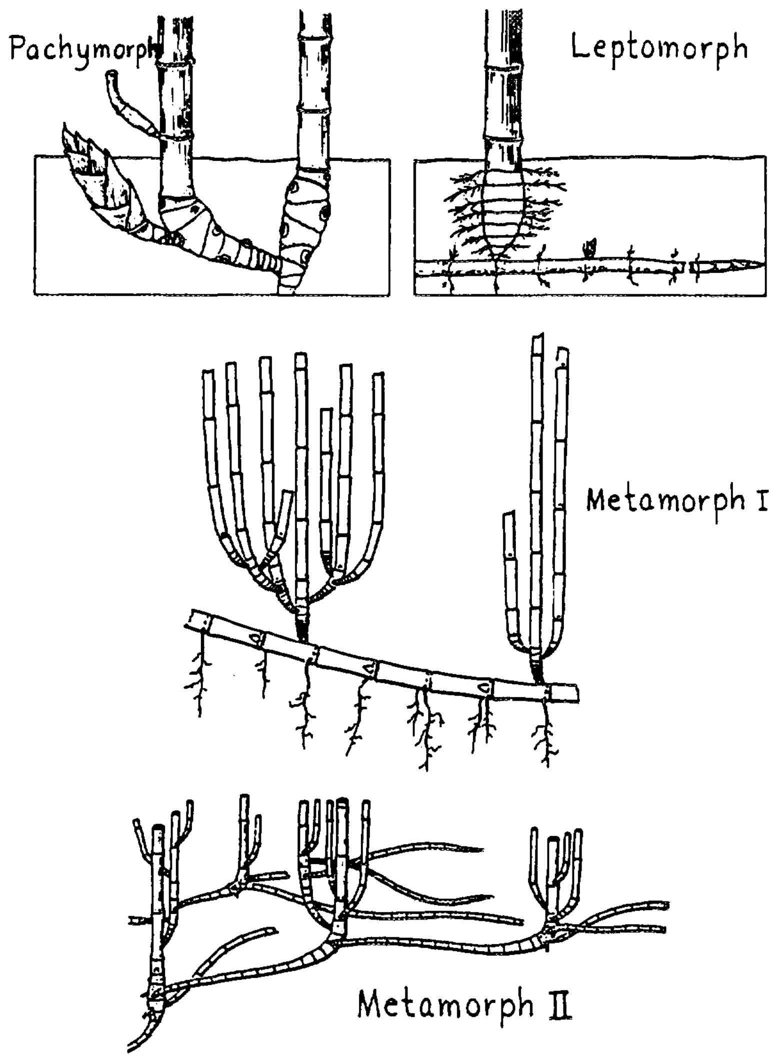
Country or area	*No. of species*	*Area (ha)*
Bangladesh	33	600 000
China	300	2 900 000
India	136	9 600 000
Indonesia	35	50 000
Japan	95	125 000
Malaysia	44	300 000
Myanmar	90	2 200 000
Papua New Guinea	26	—
Philippines	55	—
Sri Lanka	14	—
Taiwan Province of China	40	180 000
Thailand	60	810 000

Types of bamboo

The characteristics of bamboo demand the use of two special words. The term culm is used in place of trunk, which fits trees well enough but is inappropriate for bamboo since the culm grows so rapidly, has joints and is hollow. Similarly, the term root suits bamboo uneasily. Bamboo has indeed a very large growth below ground and also a small root proper, but what distinguishes it, or at least half the species, is the rhizome.

Rhizome axes are typically subterranean, and the rhizome system constitutes the structural foundation of the plant. Since this part of the plant is wholly or almost entirely out of sight and is not easily accessible, it is usually ignored by collectors, generally neglected by taxonomists and practically unknown to contemporary anatomists. Consequently, the rhizome system is one of the least well understood parts of the bamboo plant. This neglect has unfortunate consequences, because the rhizome system performs important functions in the life of the plant. Moreover, an understanding of the form of the rhizome system is prerequisite to an understanding of the culm habit, which refers to the spatial relation of the culms that make up the visible part of individual bamboo plant, whether the plant is caespitose or diffuse in its spread in space. The rhizome system assumes, in plants of different species, a number of more or less sharply distinct forms and habits of growth that may be used for the recognition and description and,

Figure 4. Types of bamboo



to a limited extent, the classification of taxonomic entities [13].

The vigorous propagation of bamboos mainly takes place asexually in the form of branching of the rhizomes. Accordingly, the propagation forms of bamboos are classified into three types, which are illustrated in figure 4 and discussed below.

Monopodial type or leptomorph type

The leptomorph rhizome is present in bamboos of temperate and warm temperate (subtropical) regions. It is proposed to call the rhizome proper "leptomorph" when it is long and slender and has the following associated characteristics: a cylindrical or subcylindrical form, with a diameter usually smaller than that of culms originating from it; internodes longer than broad, relatively uniform in length, symmetrical or nearly so, rarely solid, typically hollow, the usually narrow central lumen interrupted at each node by a diaphragm; and nodes in some genera usually somewhat elevated or inflated, in others not.

Most of the lateral buds of leptomorph rhizomes are temporarily or permanently dormant. The majority of those that germinate produce culms appearing on the ground at a certain distance. Then, newly grown culms take the single-culm formation. *Phyllostachys* is the most important genus of monopodial bamboos.

Sympodial type or pachymorph type

It is proposed to call the rhizome proper "pachymorph" when it is short and thick and has the following associated characteristics: a subfusiform (rarely subspherical), usually more or less curved (rarely straight) shape, with a maximum thickness typically somewhat greater than that of the culm into which it is always transformed apically; internodes broader than long, asymmetrical (longer on the side that bears a bud), solid (apparently never hollow); nodes not elevated or inflated; and lateral buds solitary, in the dormant state asymmetrically dome-shaped, with a subcircular margin and an intramarginal apex.

The apex of the rhizome, which has nodes but no buds (unlike the monopodial type), protrudes from the ground and grows into a culm. In the following year, the bud on the basal part of the ground starts to make a secondary culm, thus forming a clump culm. *Bambusa*, *Dendrocalamus*, *Gigantochloa*, *Schizostachyum* and *Thyrsostachys* are the major genera of sympodial bamboos.

Intermediate type or metamorph type

In some bamboos, certain axes or portion of axes of subterranean origin do not fit exactly into the categories "neck", "rhizome" and "culm base" as described for the monopodial and sympodial types. The term "metamorph" is proposed as a technical designation of such transitional axes. There are two kinds of metamorph axes: metamorph I and metamorph II.

A metamorph I axis occupies a position between the neck proper and its culm. In form, it is intermediate between a typical culm base and a pachymorph rhizome. Such axes often appear where the culms arise from lateral buds of a leptomorph rhizome tiller to form tufts. The metamorph I bamboos are in the genera *Arundinaria*, *Chimonobambusa*, *Pseudosasa*, *Semiarundinaria*, *Shibataea* and *Sinobambusa*.

A metamorph II axis is intermediate in form and position between the apex of a rhizome (pachymorph or leptomorph) and the culm into which the rhizome is transformed apically. It appears where the transformation of the apex of a rhizome into a culm takes place gradually. This gradual change is typical wherever a leptomorph rhizome is transformed apically to form a culm. Metamorph II rhizome can be seen in bamboos of the genera *Melocanna*, *Ochlandra* and *Yushania* and are also seen in *Arundinaria pusila*.

Growth and development

Bamboo is one of the most extraordinary plants. It flowers perhaps once in a century and then dies. It grows faster than anything in the world. There are recorded instances of bamboo growing four feet in a single day. When the stem is growing above-ground, the root (rhizome) stops growing; when the stem has finished growing, then comes the turn of the root. Bamboo possesses another characteristic: its growth is completed in about two months only; thereafter it remains the same size as long as it lives [1].

The buds on the rhizome-nodes swell slowly and continuously for some months in the soil. The period of sprout emergence from the ground varies according to the species/variety, the vigour of the mother bamboo and also the local environment. Even in one bamboo grove, however, there may be great variations between the dates of early and late sprouting. The sprouting is affected by soil moisture.

After sprouts have appeared on the ground, they grow slowly at the beginning but gradually gain speed until the culms attain the maximum size, and slow down thereafter. During the growing process, shoot elongation takes place day and night; in Japan, *Phyllostachys* grows more during the day, whereas in tropical regions, bamboos grow more during the night. In a 24-hour period, bamboo increases in height between 10 and 30 cm, but reaches 50 cm for *Bambusa gigantea*, 70 cm for *B. tulda* and up to 120 cm for *Phyllostachys edulis* [9].

The sprout/shoot reaches its full diameter and full length in 30-100 days after its appearance on the ground, and thereafter the culm never increases in diameter or height. The growing period of culm is 30-80 days in single-culm species of monopodial bamboo, while it is 80-110 days for clump-forming species of the sympodial type [12].

The total length of a culm depends on the species. While temperate species reach only 2-4 m, subtropical and tropical bamboos reach 15-20 m. However, the height of some species, e.g. *Bambusa polymorpha*, *Phyllostachys pubescens* and *Dendrocalamus giganteus*, exceeds 30 m.

The diameter of the successively developed culms increases with age of the clump. A few years after germinating, the culms are small, reaching their maximum diameter after the fourth or fifth year. The average culm diameter varies with species and is also influenced by environmental conditions. Data on culm size for various species are given in table 3, and a cross-sectional view of the culms of different species of bamboo is given in figure 5.

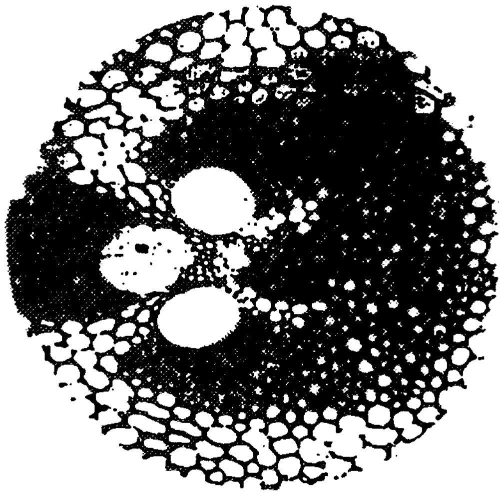
Table 3. Culm size of some bamboo species

Species	*Diameter (cm)*	*Height (m)*
Arundinaria alpina	8-10	10-20
Bambusa arundinacea	15-18	26-30
Bambusa longispiculata	6-8	15
Bambusa polymorpha	8-15	16-28
Bambusa vulgaris	5-10	8-18
Cephalostachyum pergracile	5-8	10-15
Dendrocalamus giganteus	30-35	30-35
Dendrocalamus hamiltonii	10-15	20-25
Dendrocalamus strictus	5-12	8-18
Gigantochloa apus	5-12	12-20
Guadua angustifolia	10-15	10-18
Melocanna bambusoides	5-15	13-23
Ochlandra travancorica	2-5	2-6
Oxytenanthera nigro-ciliata	6-10	10-15
Phyllostachys bambusoides	12-20	15-25
Phyllostachys pubescens	10-30	10-35

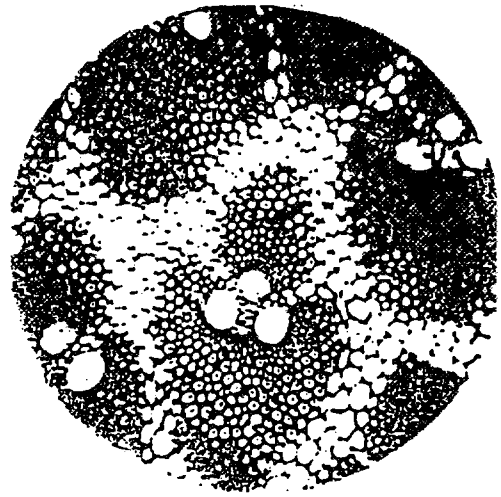
Source: W. Liese, "Bamboos — biology, silvics, properties and utilizations", *Schriftenreihe der GTZ*, No. 180 (1986), 132 pp.

Figure 6 shows a vascular bundle with two large metaxylem vessels and phoelem surrounded by fibres.

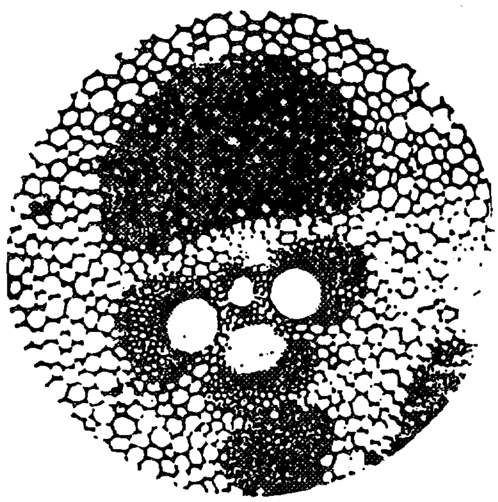
Figure 5. Cross-section of culm on certain species of bamboo



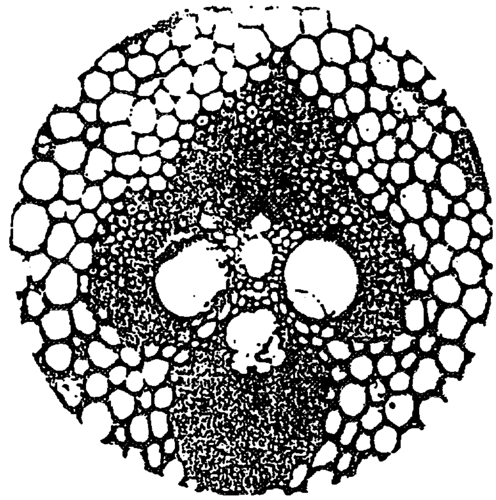
Dendrocalamus strictus



Phyllostachys reticulata

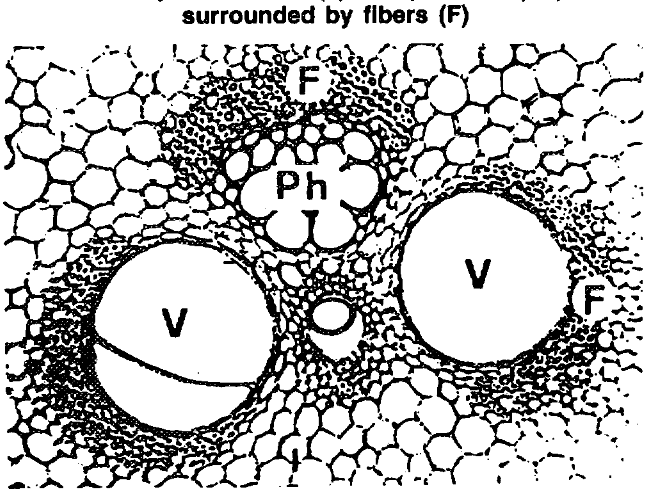


Melocanna bambusoides



Phyllostachys edulis

Figure 6. Vascular bundle with two large metaxylem vessels (v) and phoelem (Ph) surrounded by fibers (F)



Flowering

Nearly all species of bamboo seem to have their own life histories. Some species outside of the Indian-Asian tropics, and a very few in these tropics, have populations composed of individuals that grow to maturity and then flower and seed annually for many years. Such behaviour has been recorded for *Bambusa forbesii*, *B. lineata*, *Arundinaria wightiana*, *A. elegans*, *A. glomerulata*, *Ochlandra rheedei*, *O. stridula* and *Shibatea kumasaca*. The culms with inflorescences often die after the fruit has developed, but other culms and rhizomes survive and perpetuate the stand.

Many of the more common Indian-Asian species (at least 140 species) have populations made up of individuals that seed synchronously at regular and long supra-annual intervals. After growing by rhizome and branch production for a species-specific period of 3-120 years, nearly all the members of one species in one area produce wind-pollinated flowers, set large quantities of seed and die. This seed germinates immediately or when the first rains come, but it is preyed upon very heavily by local animals, highly nomadic animals and, apparently, the offspring of both. The new cohort of seedlings then grows vegetatively for the same length of time as did its parents and repeats the process [14].

By their habit of flowering, bamboos can be classified into three types:

(a) Those that flower annually or nearly so, such as *Arundinaria* spp. in India and *Schizostachyum brachycladum* in Thailand;

(b) Those that flower gregariously and periodically;

(c) Those that flower irregularly.

The flowering habit of *Bambusa* spp. and *Dendrocalamus* spp. in the tropical regions of Asia and of *Phyllostachys* and other genera in Japan belongs to types *(b)* and *(c)*. *P. edulis* flowers sporadically [12]. Most commercial bamboo species in Thailand flower sporadically, and the flowering occurs in small areas or in a few clumps [15].

Although a wide range of research and discussion is going on, the flowering of bamboo is still unexplained and mysterious. There are several theories concerning the causes of flowering and death of bamboo:

(a) Pathological theory, which postulates that flowering is brought on by the destruction of bamboo by organisms such as nematodes, fungi, insects and parasites;

(b) Periodical theory, which proposes that the cycle starts with bamboo regeneration through asexual methods (rhizome and culm elongation), reaches maturity and results in flowering;

(c) Mutation theory, which considers that bamboo regeneration through any methods of asexual propagation is mutation and brings about flowering of bamboos;

(d) Nutrition theory, which proposes that flowering and fruiting are usually the results of a physiological disturbance arising chiefly from the poor growth of the vegetative cells, brought about by an imbalance in the carbon-nitrogen ratio;

(e) Human theory, which states that human practices such as cutting and burning, induce bamboo flowering.

All these theories need to be researched further, as does the possibility that meteorological factors induce flowering [16]. Indeed, the real reasons for the sudden and unpredictable simultaneous flowering of one species over large areas are still unknown; a clarification of this matter would have tremendous economic impact and great scientific value.

One silvicultural advantage of bamboo die-off is that the sudden collapse of the bamboo understory favours the regeneration of light-demanding top-canopy trees such as teak [9].

Bamboo cultivation

Propagation

In general, sexual propagation by seeds is feasible although not always practical because seeding cycles occur only at lengthy intervals according to the species. Propagation by seed is the best method, from both the economic and genetic viewpoints. A plant that develops from seed will have its age started from zero and will be safe from flowering for the period of the flowering cycle of the species. Once bamboo sets seeds, the seed must be collected as soon as possible. A delay in seed collection will degrade the seed quality. The germinative power of bamboo seeds decreases rapidly if they are kept at ambient temperatures. Therefore, seed technology, particularly techniques for collection and storage, is of vital importance in bamboo culture.

Vegetative propagation is common since sexual propagation is difficult owing to the scarcity of seeds. The following propagation methods are generally practised:

(a) Rhizome cutting, which is the more practical method for monopodial bamboo and small and medium-sized sympodial bamboo;

(b) Culm cutting, which is suitable for medium-sized sympodial bamboo. The culm is cut into one-metre pieces and placed vertically in the ground or half-buried horizontally in the soil;

(c) Branch cutting, which is suitable for large-culm bamboo. It is a typical propagation method for *Dendrocalamus asper*.

Although vegetative propagation is commonly practised in bamboo cultivation, it should be kept in mind that the actual age of bamboo is the same in every vegetative part. This means that the plants developed from vegetative propagation will all be as old as their stock and will tend to flower and die simultaneously, a rather risky proposition if the actual age of the stock is unknown. There is no exception for plantlets from tissue culture.

Cultivation

In tropical regions, South-East Asia in particular, there is growing interest in bamboo because of its widespread distribution, ease of propagation and high rate of growth. Bamboo forests play an important role not only in the preservation of natural wealth but also as a reforestation crop that minimizes soil erosion and controls flooding. For the purposes of watershed management, species with good rooting systems or rhizome expansion should be selected.

Natural bamboo stands in the tropics have been poorly managed, resulting in the rapid depletion of bamboo resources. Apart from their depletion owing to deforestation, bamboos are harvested without concern for their conservation. Bamboo plantations are established for home uses as well as for commercial purposes.

Planting stocks prepared by the propagative methods mentioned in the previous section are kept in the nursery for about a year before being planted in the field. The planting stocks from vegetative propagation can develop to normal size earlier than those propagated from seeds. Sites for bamboo plantations are usually prepared in the same manner as when forest trees are planted; sometimes, however, the practices are more like those for horticultural crops. Planting stocks are spaced differently according to species and the purpose of the planting. For tropical species, large bamboos are planted more widely apart than smaller bamboos. For example, 4 x 4 m spacing is used for *Thyrsostachys siamensis* and 8 x 8 m spacing for *Dendrocalamus asper* in plantations in Thailand.

In the first few years, weeding is one of the problems associated with tending bamboo plantations, especially during the rainy season, in the course of which spot weeding is carried out two to three times. Annual ploughing is commonly done before the beginning of the growing season/rainy season. Intercropping with annual crops is also practised during the first few years [3].

Fertilizers are used in bamboo plantations, especially when the crop is managed for shoot production. For sympodial bamboo, the fertilizers are applied around the clump at about the crown projection line. Fertilization should be carried out about a month before the start of the growing season. N-P-Ks are the most common fertilizer used in *Dendrocalamus asper* plantations in Thailand.

The felling cycle and felling intensity are the important factors in bamboo stand management. The general practice is to select and harvest the mature culms. Culms are considered to have poor strength properties until they become mature, in two or three years. In addition, young culms contribute most of the energy storage of the rhizome. Therefore, young culms (one- to three-years-old) should not be cut, especially one-year-old culms. An unmanaged bamboo stand consists of very dense clumps and is more difficult to cut.

In most cases, the felling cycle is from three to four years, and 60-80 per cent of the culms are removed. In bamboo stands managed for shoot production, only five young culms are left uncut; therefore, culm cutting takes place annually after the end of the growing season. Top cutting is sometimes necessary in bamboo stands in temperate regions, e.g. *Phyllostachys pubescens* in China, in order to limit the damage caused by snow.

Yield

Bamboo occurs as an understory of the forest or in pure stands. Its yield varies with species and environmental conditions. For leptomorph bamboos, some typical yields per hectare are as follows: a plantation of *Phyllostachys edulis* in China, 4,500 culms; *Melocanna bambusoides* in Bangladesh, 4,000-8,000 culms; and *P. edulis* and *P. nigra* in the Republic of Korea, 2,000 culms. For sympodial bamboos, 10,000 culms in 200-300 clumps per hectare is reported for *Thyrsostachys siamensis*; 5,000-8,000 culms for *Bambusa arundinacea* in Thailand; and 600-3,200 culms in 60-120 clumps for *Dendrocalamus strictus* in India [9].

The biomass yield of bamboos varies from species to species and from site to site within the same species. The annual yield of sympodial bamboos is generally lower than that of monopodial bamboos. Table 4 shows the annual yield of bamboos of different species in different countries [9].

Table 4. Annual yield of some bamboos

(Tonnes of air-dry material per hectare)

Species	*Country or area*	*Yield*
Bambusa tuld	India	3.0
Dendrocalamus strictus	India	3.5
Melocanna baccifera	India	4.0
Melocanna bambusoides	Bangladesh	10-13
Thyrsostachys siamensis	Thailand	1.5-2.5
Phyllostachys bambusoides	Japan	10-14
Phyllostachys edulis	Japan	5-12
Phyllostachys edulis	Taiwan Province of China	8-11
Phyllostachys makinoi	Taiwan Province of China	6-8
Phyllostachys pubescens	China	5-10

The production of plantations is somewhat different from that of natural stands. Farmers in Thailand harvest 10-15 tonnes of culms per hectare per year from *Dendrocalamus asper* plantations. They also harvest 15 tonnes of shoot from the same plot of land. The production of smaller bamboo, *Thyrsostachys siamensis*, in a three-year-old plantation is presented in table 5 [6].

Table 5. Production of a 3-year-old *Thyrsostachys siamensis* plantation in Thailand

Item	*Site I*	*Site II*
Clumps per hectare	625	625
Culms per clump	38	39
Average diameter at breast high, cm	2.3	1.4
Exploitable culms per hectare	17 500	18 125
Price, baht/culm[a]	0.75	0.50

Source: S. Thammincha, "Some aspects of bamboo production and marketing", International Bamboo Workshop, Cochin, India, 1988.

[a]From July to December 1988, the exchange rate was 25.5 baht = US$ 1.

Shoot production varies in relation to species and locality. The shoot production of *Phyllostachys pubescens* stands in China ranges from 18 to 30 tonnes per hectare; that of *Dendrocalamus asper* (plantation) in Thailand ranges from 8 to 15 tonnes. Japan is the main market for steamed bamboo shoots in Asia. Table 6 shows Japan's import of steamed bamboo shoots in 1985.

Table 6. Imports of steamed bamboo shoots to Japan, 1985

Country or area	*Production (tonnes)*	*Amount (%)*
Taiwan Province of China	23 162	60.15
China	8 148	21.16
Thailand	7 179	18.65
Others	15	0.04
Total	38 504	100.00

Source: A. Potharam and S. Panchatri, "Study report on *Dendrocalamus asper* shoot production and marketing", Department of Internal Trade, Division of Marketing Economics, Bangkok, 1985, 64 pp.

Harvesting and transport

Shoots are usually harvested during the beginning and middle of the growing season. There are no specific rules for harvesting, but experience tells the farmers which shoot to harvest and which one to leave for future growth. If shoot harvesting is done properly, the yield of culm will not be interfered with, and it has been noted as well that the culm cutting yield has no significant effect on shoot production.

For leptomorph bamboos, the culm may be cut at ground level, while for pachymorph bamboos it normally takes place at 20-30 cm above the ground. For thorny pachymorph bamboos, e.g. *Bambusa arundinacea* and *B. blumeana*, cutting takes place at 2-3 m above the ground: it is impossible to cut at a lower level and remove the cut culms since the thorny branches are interwoven all over the bottom part of the clump.

The cutting of leptomorph bamboos is much more convenient than the cutting of pachymorph bamboos. Horseshoe techniques and tunnel cutting are employed to cut the latter, but these methods are not applicable to thorny bamboos.

Culm should not be cut during the growing season/rainy season since the cutting causes some damage to young shoots and young culms and retards the growth and development of the residual culms. Moreover, it is inconvenient to cut bamboo culms during the rainy season owing to poor accessibility of the forest.

There is competition between shoot harvesting and culm harvesting, and very often bamboo resources are over-exploited by these practices, especially the resources on public land where there is no efficient control by the authorities. Those who harvest shoots will take as many shoots as possible, leaving only a few shoots to develop for future growth. Those who cut culms do the same thing. In this situation, the bamboo resource is depleted rapidly. In fact, if shoot and culm harvesting are organized properly, the production of both shoot and culm can be maximized.

Bundles of cut small bamboo, as well as individual larger culms, are brought to the roadside and then transported by bullock cart, lorry, lorry with trailer, train or river raft.

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IV. BAMBOO: PHYSICAL PROPERTIES, TESTING METHODS AND MEANS OF PRESERVATION*

Achmad Sulthoni**

Introduction

This chapter assesses the anatomical, physical and mechanical characteristics of bamboo in an attempt to provide a scientific basis for its use. Because of its structure and long fibres, bamboo is considered to be one of the strongest organic materials, and engineers have even been thinking of using bamboo in place of steel for the reinforcement of concrete construction [1].

Bamboo belongs to the family of Gramineae; it grows particularly in the tropics and subtropics, with some taxa also found in the temperate climates of Japan, China, Chile and the United States of America. Altogether there are 600-700 species represented by about 60 genera. About 300 species grow in Asia, most of them in the region around the Bay of Bengal, which is also considered to be their region of origin [2].

Bamboo is an important raw material in Indonesia, particularly in the rural areas of Java. People in the villages use bamboo as a construction material for furniture and kitchenware, as a carving material, for musical instruments etc. Bamboo has been considered as one of the most convenient organic materials for such purposes because of its structure, long fibres, low cost and easy availability in most parts of Java.

In Indonesia, bamboo is found mostly in Java and South Sulawesi [3]. The geographical distribution in Java is up to 2,000 m above sea level [4]. There are more than 30 species, of which only 13 are planted by people in the villages. These are *Bambusa multiplex* Raeusch, *Bambusa spinosa* Bl., *Bambusa vulgaris* Schrad., *Bambusa bambos* Druce., *Dendrocalamus asper* Back., *Gigantochloa apus* Kurz, *Gigantochloa nigrociliata* Kurz, *Gigantochloa verticillata* Munro, *Gigantochloa hasskarliana* Back., *Schizostachyum blumei* Nees v. E., *Schizostachyum brachycladum* Kurz, *Schizostachyum zollingeri* Kurz and *Phyllostachys aurea* A. and Ch. Riv. [5].

Four species have been most extensively used by the rural people for construction and other purposes: *Gigantochloa apus* Kurz, *Gigantochloa verticillata* Munro, *Dendrocalamus asper* Back. and *Bambusa* sp. [4, 6, 7].

In 1920, the Government of Japan decided, as a matter of policy, to manage the areas of bamboo stands in order to expand and improve bamboo production in the rural areas. As a result, the area under bamboo cultivation increased to 133,000, 150,000 and 162,000 ha, respectively, in 1927, 1933 and 1939. It decreased to 114,000 ha in 1947, when agricultural land was extended to increase the food supply during the Second World War [8].

In China, there are more than 400 bamboo species and varieties belonging to 34 genera. The total area of bamboos, except small bamboo undergrowths and alpine bamboo thickets, is about 3.4 million ha, with a standing stock of 71.22 million tonnes and an annual yield of about 7 million tonnes, roughly 2 tonnes/ha. The most important commercial bamboo is *Phyllostachys pubescens*, which covers 2.42 million ha, with a standing stock of 56.55 million tonnes and an annual production of 5.0 million tonnes. Since 1950, 70 per cent of bamboo areas have been increased and 10 per cent of bamboo stands are under intensive management. Bamboos are closely associated with a Chinese civilization that can be traced back 4,800-5,300 years. Traditionally, bamboos have been widely used in agriculture, construction and rural industry and to make handicrafts and daily life commodities. The tender shoots of about a hundred bamboo species are edible. Their production amounts to over 1 million tonnes yearly. Many bamboos are used in Chinese gardens and for soil erosion control. With the increasing demand for bamboo products and improved processing techniques, the bamboo industry is growing rapidly. More than 100 factories of various sizes are engaging in the production of bamboo plywood, particle board, hardboard, laminated furniture and moulded and woven bamboo products. Several modern bamboo paper-mills are being contructed in appropriate regions where bamboos exist. Accordingly, more scientists are

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engaging in research on various aspects of bamboo production and utilization [9].

In India, out of a total forest area of 75 million ha, bamboos, natural and planted, occupy 10 million ha and constitute 13 per cent of the entire forest area, which in turn represents 23 per cent of the country's total area (329 million ha). Bamboo is extensively planted by the villagers on their marginal lands. Considering these areas and the forest areas, the estimated present production and utilization of bamboos in India is about 9.5 million tonnes. Harvesting alone requires about 71.25 million man-days of direct labour.

Properties of bamboo

Anatomy of bamboo

The properties of bamboo culms are determined mainly by their anatomical structures. Although anatomical investigations have been carried out by several research workers, only a few detailed descriptions of bamboo anatomy are available. Thus, little is known about the possibility of differentiating bamboo species on the basis of their anatomical structures [2].

Bamboo belongs to the family of Gramineae. It grows very rapidly to produce primary tissues with some kind of delay in, or even an absence of, secondary growth. The produced stem, or culm, as it is more appropriately called, is divided into small parts by lateral tissues in such a manner that two terms have been created to name them: node and internode. In the internodes, the cells are axially oriented; in the nodes, the cell elements are arranged perpendicularly to the internodal cells, forming transverse interconnections. That which is interesting in the structure of bamboo and allows it to be differentiated from wood is the absence of rays and other radial cell elements in the internodes.

Generally the outermost part of the culm is formed by a single layer of epidermal cells, and the inner side is covered by a layer of sclerenchyma cells. Therefore the lateral movement of liquid is minimized, and the pathways for penetration of liquid or water vapour are limited to the cross-ends of a culm and, to a much smaller extent, to the leaves growing at the nodes [10].

The gross anatomical structure of a transverse section of any internode of a bamboo culm is determined by the number of vascular bundles and their shape, size and arrangement [10]. Since they are much lighter in colour, the vascular bundles are easily recognized by colour differentiation from the parenchymatous cells that act as ground tissue. At the peripheral zone of the culm, the vascular bundles are small but numerous. At the inner part of the culm, they are larger but fewer. For that reason, the total number of vascular bundles decreases from the outer to inner parts within the culm and along the culm in the vertical direction, i.e. from butt to top; the pattern is reversed for density.

Bamboo culms consist of parenchyma cells, which form the ground tissue, vascular bundles and fibres [10]. The total culm consists of about 50 per cent parenchyma, 40 per cent fibres and 10 per cent conducting cells, i.e. vessels and sieve tubes.

Parenchyma cells acting as ground tissue are composed of masses of thin-walled cells that are connected to one another by numerous pits for transporting liquid. They are either elongated or cube like and relatively short. Their cytoplasm is more viscous and thus has a longer life. In this parenchyma ground tissue the vessels and fibres are embedded. In addition, the ground tissue is lined on the outer and inner sides by special terminal layers. The layers are heavily cutinized by a fatty and waxy protective cuticle, which prevents the loss of water from the culm. This phenomenon has been detected because it also blocks the flow of preservatives into the culm. The outside part has a heavy deposit of silica, which makes the bamboo impervious to moisture and increases its strength. The outer wall is 10 times as resistant to tearing as ordinary cellulose walls [2, 11, 12].

Bamboo fibres are characterized by sclerenchyma cells, which are dead, long, thick walled and serve as a strengthening material. Usually they surround the vascular bundles and are separated by parenchyma, but sometimes they gather together, forming bundles of sclerenchyma. Just inside the outer skin of the culm, a couple of layers of heavy sclerenchyma cells are found.

The length of the fibres depends on the species, but it also varies within species. The study of the fibre dimensions of *Bambusa vulgaris* Schrad., *Bambusa arundinacea* Willd. and *Gigantochloa asper* Backer shows fibre lengths of 2.3, 2.7 and 3.8 mm, respectively [10]. Furthermore, it is stated that the distribution of fibre lengths is influenced by the culm factor. Fibres in the outer part of the culm are, on average, longer than those in the inner part. A similar trend is observed at the axial direction in the internodes, i.e. from the nodes to the centre of the internodes, the fibre length increases, but along the culm the fibre length decreases.

The conducting cells of bamboo are composed of vessels and sieve tube cells. They differ from each other in shape and structure. The vessels transport water and other liquids from the root to the leaves, while the sieve tubes do the reverse. In the transverse section, the sieve tube cells or phloem are located near the epidermis. They are made up of large, thin-walled cells. The vessel cells forming the xylem are located inside the phloem and are made up of thicker walled cells [2, 11, 12].

Physical properties of bamboo

From the anatomical and chemical points of view, almost all the components of bamboo are also present in wood. For this reason it may be correct to conclude that all factors affecting wood physically would have similar effects on bamboo. Basically all the physical properties of organic matter such as wood and bamboo are determined by factors inherent in its structural organization. These may be summarized in terms of the amount of cell wall substance present in a given volume of bamboo, the amount of water present in the cell wall and the kind, size, proportions and arrangement of the cells making up the bamboo tissue [10, 13, 14].

Specific gravity of bamboo

Specific gravity is usually expressed as a ratio of the weight of the substance to the weight of an equal volume of water and is abbreviated as sp. gr. or G. It is a relative index of the quantity of bamboo substance present in a specific volume. It also indicates the total volume of air in the bamboo that may be capable of absorbing water and other liquid. In other words, it shows the maximum capacity for holding water, or the maximum moisture content.

Bamboo is a hygroscopic material, i.e. it has an affinity for water in both liquid and vapour form. Since the ability of wood or bamboo to absorb and lose water is dependent on the temperature and humidity of the surrounding atmosphere, the amount of moisture in bamboo fluctuates with changes in atmospheric conditions. Owing to this relationship, the volume of the wood or bamboo, which is greatly influenced by the amount of water present in it, will significantly affect the value of the specific gravity. For this reason, when stating the specific gravity it is necessary to specify the moisture content of the wood or bamboo when the volume was determined [14].

In general terms, the specific gravity of bamboo or wood depends on the size of the cells, the thickness of the cell walls and the number of cells of various kinds, in terms of both size and thickness of the cell wall. Fibres, which account for 40 per cent of the bamboo, are particularly important in the determination of specific gravity, since their small cross-sections allow a great number of them to be massed in a small space. Fibres are composed of sclerenchyma cells with thick walls and small lumina, which reduces the total air space in a specific volume. Parenchyma cells, which account for 50 per cent of the volume of the bamboo, are composed of cube-like and elongated cells with thin walls and large lumina, which increases the total air space. These two distinct areas will produce two significantly different values of specific gravity, the latter being lower than the former.

Moisture content and dimensional changes in bamboo

As mentioned earlier, bamboo is similar to wood, which can absorb water from, and lose water to, the surrounding atmosphere in the form of liquid or vapour. The rate of absorbing and/or losing water vapour or liquid depends on the relative pressure differential between the wood or bamboo and the atmosphere.

The addition of water or other polar liquids to the cell wall substance causes the microfibrillar net to expand in proportion to the amount of liquid placed among the amorphous portion of the cellulosic microfibrils. This expansion in volume continues until the fibre saturation point has been reached. For bamboo, the fibre saturation point was found to be about 20 per cent for *Dendrocalamus strictus* and 13 per cent for *Phyllostachys pubescens*. The further addition of water or other polar liquid to the wood or bamboo produces no change in the volume of the wall substance because this excess water above the fibre saturation level is concentrated in the lumen.

On the other hand, the removal of moisture from the cell wall below the fibre saturation point causes the wall to shrink. These dimensional changes are expressed as a percentage of the maximum dimension of the wood or bamboo, that is, its green volume [14].

The magnitude of the dimensional changes in bamboo is directly related to the amount of cell wall material present. Generally, shrinking and swelling in bamboo or wood increase with increasing specific gravity.

The observed dimensional changes in wood or bamboo are unequal along the three structural directions, i.e. these materials exhibit anisotropy. The least shrinkage occurs in the longitudinal direction, while the most occurs in the tangential direction and is generally twice that in the radial direction. This order of magnitude of shrinkage is certainly true in wood but still questionable in bamboo. The large difference in shrinkage values exists for two reasons:

(a) The cell wall of wood consists of reinforcing microfibrils of high tensile strength along their axes, embedded in an essentially amorphous matrix of lignin and hemicellulosic materials. The microfibrils change very little in response to the addition and removal of water and other liquids. However, the matrix of lignin and hemicelluloses changes its dimension more or less equally in all directions (omnidirectional property). This situation produces small longitudinal but considerable lateral dimensional changes;

(b) The majority of cells in wood are arranged with their long axes in the longitudinal direction.

The situation is somewhat different in bamboo, which has no radial cell elements in the internodes.

Mechanical properties of bamboo

The mechanical properties of wood or bamboo are an expression of their behaviour under applied forces. This behaviour is modified in a number of ways depending upon the kinds of force exerted on the bamboo and the way in which it is applied. Force expressed per unit area or volume is known as stress (σ). Depending on the action on the body of wood or bamboo, this force is called comprehensive stress if it shortens the dimension or reduces the volume of the body, tensile stress if it increases the dimension or volume of the body and shear stress if it causes one portion of the body to move with respect to the other in a direction parallel to their plane of contact. A specific bending stress is produced by the combination of the three previous stresses.

In all real materials the stresses that act on a body produce a change in shape and size. This distortion resulting from applied stress is called strain (ε) and is expressed in terms of deformation per unit area or volume.

Bending strength of bamboo

As mentioned earlier, bending stresses are the result of a combination of all three primary stresses, compressive, tensile and shear, which act together and cause flexure, or bending, in the body. The bending of bamboo as an important factor in building construction has been studied by Limaye [1], Sekhar, Rawat and Bhatari [15] and recently by Janssen [12, 16].

Using *Dendrocalamus strictus* for testing the strength of bamboo, Limaye [1] found several points of interest:

(a) Specimens with a node in the centre at the loading point showed a higher strength but a lower stiffness in static bending than those with the loading point between two nodes;

(b) The difference in static bending strengths of specimens from different positions along the culm was significant. Specimens from bottom positions, i.e. near the ground, were stronger than those from middle and top postions but were less stiff. This was due to the increase in sclerenchyma cells in the higher positions;

(c) There was practically no difference between the strength of six-month-old and one-year-old bamboo. The increase in strength during the second year was about 33 per cent and during the next half year was only 30 per cent. This was due to the relationship between the lignification process and gain of strength of bamboo;

(d) The seasoning of mature bamboos increased their strength by 40-50 per cent. This was caused by the negative correlation between moisture content and strength of the bamboo.

Age of mechanical maturity

Janssen [16] investigated the shape and size of the samples used for the test. It was concluded that the unsplit (round) samples produced lower bending strengths than the split, flat and thin (split-flat-thin) samples.

The relationship between bending strength and mass per volume can be described by the ratio $\sigma = 0.14$ G, but since failure in bending is due to shear in the neutral axis, the ratio may be replaced by the ratio between the shear stress (τ) and the mass per volume. Janssen [16] calculated these values and related them to the age and diameter of culm of the samples and then concluded that the ratio $\sigma = 0.021$ G was more appropriate. The age at which bamboo attained mechanical maturity seemed to be more than 2.5 years.

Compression strength of bamboo

Bamboo has two different compression strengths according to the direction of the applied forces. The first is compression parallel to the grain, the second is compression perpendicular to the grain. Both of them are stresses that act on the body of the bamboo, shortening its dimension or reducing the volume of the bamboo.

Janssen [16], testing the species *Bambusa blumeana*, came to the following conclusions:

(a) The compressive strength parallel to the grain increased with decreasing moisture content. This was due to more compact cellulosic tissue and an absence of water molecules in the microfibrillar net;

(b) Samples from higher positions produced stronger compressive strengths than samples from lower positions due to the greater number of sclerenchyma cells;

(c) The height of the specimens and the absence of nodes had no significant effect on compressive strength;

(d) Failure was due to splitting, which was an excess of the tensile strain on the pectin holding the fibres together.

As reported by Janssen [16], Motoi Ota, studying the relationship between compression strength and structure of the split bamboo, differentiated positions in the transverse direction: outer, middle and inner part. He found that the outer part produced higher strength due to the relatively greater number of sclerenchyma cells and the density of the bundles sheath, i.e. sclerenchyma and conducting cells.

Similarly, Janssen [16] summarized the ratio between ultimate compressive stress (σ) and mass per volume *(G)* in two formulas, the first for dry condition and the second for green condition: $\sigma = 0.096$ G and $\sigma = 0.075$ G. Panshin and de Zeeuw [14] calculated these ratios for wood ($\sigma = 0.084$ G and $\sigma = 0.046$ G for dry and green condition, respectively). The lower compressive strength of wood may be due to the difference in cellulose content, which is 55 per cent for bamboo and 50 per cent for wood [16].

Tensile strength of bamboo

There are two different tensile strengths of bamboo, depending on the direction of forces applied to the body of the bamboo. The first is tension parallel to the grain, the second is tension perpendicular to the grain. Both are stresses that act on the body of the bamboo and that tend to increase its length dimension or its volume. Tension strength parallel to the grain is much greater than that perpendicular to the grain. The latter is correlated with the cleavage strength.

Janssen [16] tried to relate tension parallel to the grain to the sclerenchyma cells content and/or the cellulose content. The suggested theoretically calculated tension strength of 375 N/mm^2 was based on the following idea: sclerenchyma cells of bamboo consisted of 40 per cent lumen, 50 per cent cell wall with microfibrillar net axially oriented and 10 per cent cell wall with microfibrillar net spirally oriented. The 50 per cent cell wall consisted of almost equal portions of lignin and cellulose. The latter had tension strength of about 1,500 N/mm^2. Therefore the tension strength parallel to the grain could be calculated as the product of the percentage of cellulose in the microfibrillar net that was axially oriented and the tension strength of cellulose. This was numerically expressed as follows:

$$50 \text{ per cent} \times 50 \text{ per cent} \times 1{,}500 \text{ N/mm}^2 = 375 \text{ N/mm}^2$$

Syafii [17], studying the influence of the dimensions of the samples of four bamboo species, using ASTM standard D143-52, obtained tensile strengths of 1,300-2,100 kg/cm^2.

Shear strength of bamboo

Shear stresses are the result of forces that tend to cause one portion of the body of bamboo to move with respect to the other in a direction parallel to their plane of contact.

Shear is important in bamboo, because it is the weakest point. Data from shear tests by Janssen showed that bamboo was as strong as wood in tension and bending strength but much weaker in shear [16]. The problem of bending in the use of bamboo in structures is the shear. In bending, failure comes not from an excess load over the tensile strength of the fibres but from a loss of cohesion between fibres, in which shear plays an important role.

Janssen [12] mentioned that the moisture content, height and form of the specimens and the nodes and internodes and their position along the culm all had a significant influence on the shear strength of bamboo. His results are summarized below:

(a) The shear strength of bamboo decreased with increasing moisture content;

(b) The maximum shear stress was reached at 8 m height; the shorter or the greater the length, the lower the shear stress. Lower stress at shorter lengths was due to local irregularities, while lower stress at greater lengths was due to the fact that what was happening at the ends had no effect on the central part;

(c) In internodes, all the fibres ran parallel to each other and had a better shear strength; in the nodes, many vessels crossed the fibres to reach the diaphragm inside the nodes and reduced the shear strength;

(d) The shear stress decreased slightly from bottom to top; the decrease was not correlated with the percentage of sclerenchyma cells, which also increased from bottom to top, but was, instead, due to the occurrence of shear in the radial plane rather than parallel to most of the fibres. As a consequence, the shear stress was determined by the thickness of the cell wall or weight by volume rather than by the percentage of parenchyma fibres;

(e) The percentage of rays was negatively correlated with the shear stress because rays that consist of parenchyma cells are used for food storage and not for strength.

Janssen concluded that the relationship between shear stress and mass per volume was embodied by the formula $\sigma = 0.0212\ G$.

Testing methods for determining the properties of bamboo

This section presents the testing methods used to determine the properties of bamboo in the research project at Gadjah Mada University. Culms should be classified by species and, within the species, by age group. Each culm should then be bucked into three parts of the same length, i.e. butt, middle and top.

Samples for testing should be stored and piled in such a manner that air-drying can proceed evenly throughout the pile. Air-drying should take about three months. In this project, it was conducted in a specially built bamboo shed.

The sampling methods used followed those used by Janssen [16], which were based on both randomness and the single possessive principle, meaning that all specimens were prepared from a certain position in the culm and randomly selected for testing.

Anatomical properties

The anatomical properties that can be assessed included fibre length, the percentage of sclerenchyma fibres, the number of vascular bundles, the starch content and the silica content.

Fibre length

Fibre length measurements can be made on separate macerated material. Maceration was done using a 1:20 solution of glacial acetic acid and hydrogen peroxide. Fibre images were projected on a screen and measured with a mapping wheel.

Percentage of cell elements

The percentage of the different cell elements can be determined using the weighing method [18]:

(a) Prepare photomicrographs of the cross-sections of the outer, central and inner parts of the bamboo culms with a magnification of 50 per cent;

(b) Weigh the paper bearing the image of the cross-section of the bamboo;

(c) Cut out the different cell elements with a pair of scissors and weigh each group of cell elements;

(d) The percentage of cell elements is equal to $W_c/W_a \times 100$, where Wc is the weight of the cell elements and W_a is the weight of the whole image.

Starch content

The starch content can be measured using the method developed by Humphreys and Kelly [19]:

(a) Put 0.4 grams of powdered bamboo (200 mesh) in a 50 ml beaker;

(b) Add 4.7 ml of 7.2M perchloric acid and allow to digest for 10 min with occasional stirring;

(c) Transfer the contents of the beaker to a 50 ml volumetric flask and bring to volume;

(d) After centrifuging, place a 10 ml aliquot in a 50 ml volumetric flask together with a drop of phenolphthalein and make alkaline with 2N sodium hydroxide;

(e) Add 2N acetic acid until the colour is discharged and then add a further 2.5 ml, followed by 0.5 ml 10 per cent w/v potassium iodide and 5 ml 0.01N potassium iodate;

(f) Allow the colour to develop for 15 min, bring to volume and measure the absorption at 650 nm using a blank prepared without starch as zero;

(g) The percentage of starch is calculated as

$$\frac{1{,}839(y + 0.008)}{\text{Moisture-free weight of the sample (mg)}} \times 100$$

where y is the optical density at 650 nm.

Silica content

The silica content is measured using spectro-phatometry. First, the samples are prepared:

(a) Fill some nickel crucibles with 10 ml of 10 per cent sodium hydroxide. Heat the crucibles in a sand bath and finally let it cool in a dessicator;

(b) Fill each crucible with 10 g powdered bamboo and pyrolyse in a muffle furnace at 700° C for 4 hr. After cooling, add 50 ml water;

(c) Pour the residue into a beaker, add 300 ml water and 10 ml 12N hydrochloric acid;

(d) Pour the solution from the beaker into a 1,000 ml volumetric flask and fill with water to the mark.

Then, 2 ml of this solution of the sample is treated with the following reagents: sodium hydroxide solution, 15 per cent; ammonium molybdate solution, 7.5 per cent; tartaric acid, 8 per cent; reducing agent (0.5 g finely ground mixture of sodium sulphite, 0.15 g 4-amino-2-napthol-4-sulphuric acid and 4.5 g sodium metabisulphite and 12N hydrochloric acid. A standard curve may be obtained as follows:

(a) Prepare 11 volumetric flasks of 100 ml each;

(b) Fill the flasks with 200 ppm standard solutions of silicon dioxide. The volumes of these standard solutions are varied: 0.0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5 and 5.0 ml;

(c) To each volumetric flask add 1 ml ammonium molybdate solution (7 per cent), shake and wait for 10 minutes;

(d) To each volumetric flask add 10 ml tartaric acid solution, then add 1 ml reducing agent;

(e) Pour distilled water into each volumetric flask to the 100 ml mark. Let stand for 1 hour;

(f) Observe each absorbance at 650 nm.

The equation of the linear line can be found by linear regression, as outlined in the annex. If the absorbance of the sample is substituted in the equation, the concentration of silicon dioxide in the sample can be determined.

Physical properties

Three physical properties should be measured: moisture content, specific gravity and shrinkage in the radial and tangential directions. The samples should be cut as detailed in figure 7.

For the determination of moisture content and specific gravity, the split-flat-thin specimens should measure 10 cm by 5 cm by the thickness of the culm. For unsplit bamboo, specimens measuring 2.5 cm long by the diameter and thickness of the culm can be used. This method follows the one used by Desh and Dinwoodie and is a modification of ASTM D143-52 [16].

The specimens prepared for moisture content measurements are weighed, dried in a laboratory oven at 103° C + 2° C for 3 h and then weighed again to obtain their constant oven-dry weight. This procedure is in accordance with ASTM D2016-74 for moisture content determination.

The specific gravity measurement is normally only done on split-flat-thin bamboo specimens. Specific gravity is the ratio between the bamboo substance and its maximum volume. The bamboo substance is obtained by oven-drying the specimens until constant weight is determined. The maximum volume of the specimens is then calculated measuring the volume of water displaced. The procedure for this measurement follows ASTM D2395-69.

To measure shrinkage, specimens 10 cm × 2.5 cm the thickness of the culm wall are prepared. The thickness of the culm wall represents the radial direction of shrinkage, while the 2.5 cm width represents its tangential direction. Specimens are steeped in cold water for a few days. This inserts water molecules into the microfibrillar net, thereby expanding the volume of the cellulosic substance to its maximum dimension.

The shrinkage is determined by measuring the maximum dimension of the bamboo specimens and the volume reduction after they have been dried in a laboratory oven at 103° C + 2° C.

Mechanical properties

The mechanical properties normally assessed are as follows:

(a) For unsplit bamboo (green and air-dry): bending, compression parallel to the grain and shear, for samples with and without nodes;

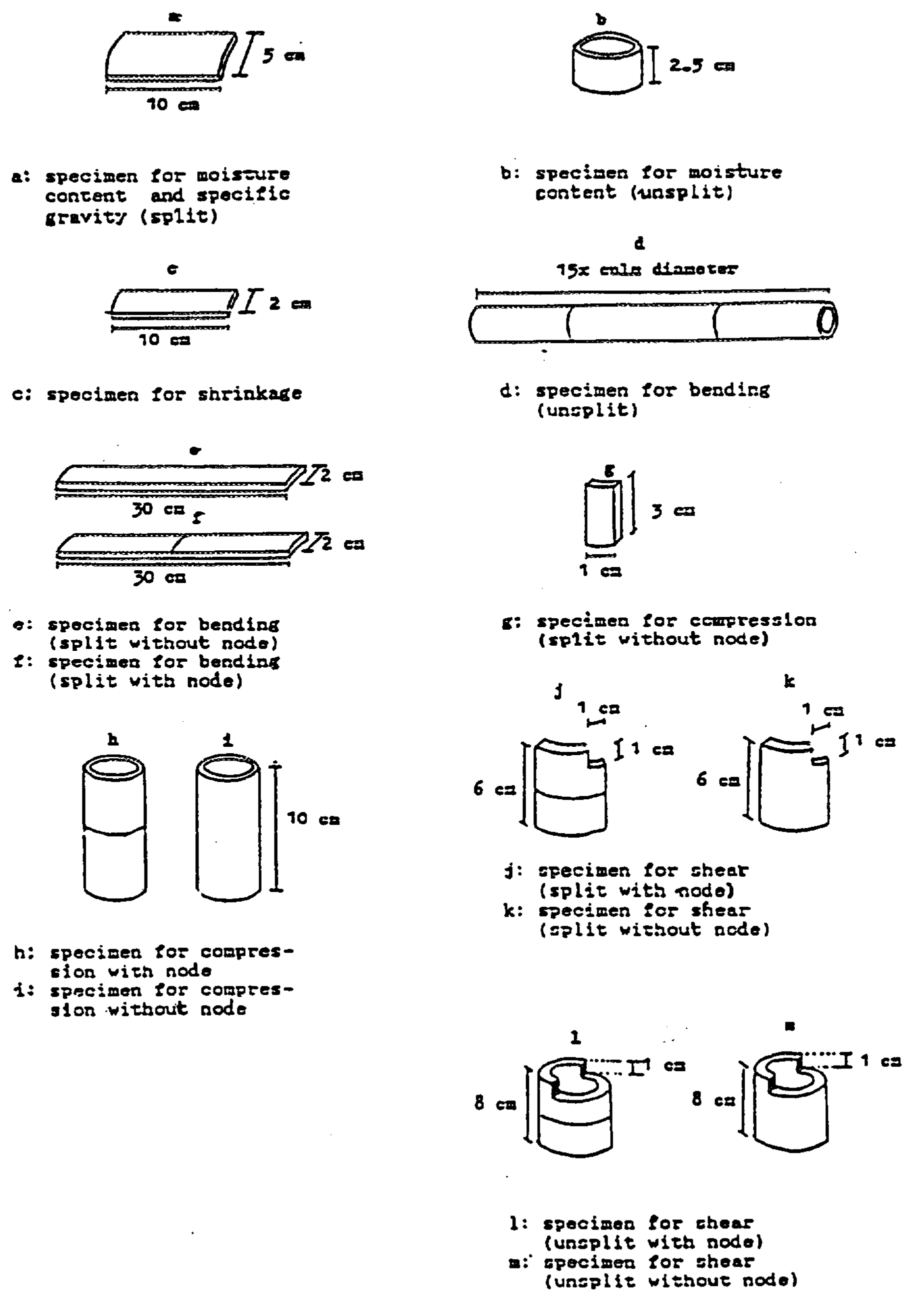
(b) For split bamboo (green and air-dry): bending and compression parallel to the grain, for samples with and without nodes.

The samples and sizes used are as shown in figure 7.

Bending strength

To measure bending, two specimen dimensions can be used, in accordance with ASTM D143-52 and a modified method by Janssen [16]. The length of the unsplit samples should be 15 times the diameter of the culm [20]. Since

Figure 7. Dimensions and shapes of specimens for various mechanical tests



the internodal length is normally less than 15 times the diameter of the culm, no samples can normally be prepared without nodes.

The split specimens can be 30 cm x 2 cm by the thickness of the culm wall, for samples with and without nodes.

An unsplit specimen is mounted on a span length that matches the length of the specimen tested. For the research project, a bearing block that had been standardized for use on the Baldwin universal testing machine, model HP60 was used to apply forces on the centre of the specimen. The load is applied continuously throughout the test at a rate of motion of the movable cross-head of 0.10 in. (2.5 mm) per minute. The forces are stopped when the specimen fails, i.e. when the dial indicator shows no increase in the load. A similar procedure can be used to test the bending strength of the split-flat-thin bamboo specimens.

Compression parallel to the grain

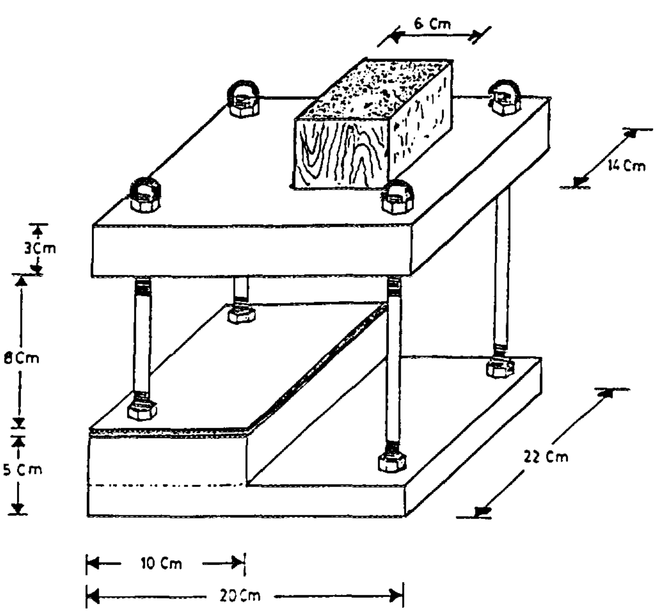
The compression parallel to the grain can be measured for each species and age group on specimens that are 3 cm x 1 cm by the thickness of the bamboo culm for split-flat-thin specimens without nodes. In the research project, this dimension was in accordance with a modified ASTM D143-52 and the method of Janssen [16]. Specimens with nodes could not be prepared because of the small size.

For unsplit bamboo with and without nodes, specimens 10 cm long can be used. In the research project, special care was taken in preparing the specimen for compression parallel to the grain testing to ensure that the end-grain surfaces that were in the load application plane were parallel to each other and at right angles to the longitudinal axis. The specimens were then mounted in the Baldwin universal testing machine. The test was done at a rate of motion of the movable cross-head of 0.18 mm per second. The test was stopped when a complete failure occurred, which was indicated by no further increment in strain.

Shear parallel to the grain

Tests of shear parallel to the grain of split-flat-thin bamboo can be made on specimens 6 cm x 5 cm by the thickness of the bamboo culm, while those of unsplit bamboo can be made on specimens 8 cm by the bamboo diameter by the thickness of the bamboo culm, both of them with and without nodes. In the research project, a special shear tool was designed and built to carry out the test (figure 8). The load was applied from the upper portion, and a metal support held the ore specimen on the end-grain surface of the bottom portion. Care had been taken in placing the specimen in the shear tool to adjust the crossbar so that the edges of the specimen were vertical and the end rested evenly on the metal support over the contact area. The load was applied continuously at a rate of motion of the movable cross-head of 0.12 mm per minute. The applied force was stopped when the maximum strength had been reached.

Figure 8. Specially built apparatus for shear strength testing



Preservation of bamboo

The methods of preserving bamboo can be classified as either chemical or non-chemical.

Chemical treatments

In the chemical treatment of bamboo, preservatives are applied to either dry or green bamboo. Several techniques for chemical preservation have been noted [21]:

Washing and coating

A variety of coatings, such as tar, lime wash, tar and lime wash and tar sprinkled with sand, are used in Indonesia by house-builders. These coatings are successful only when applied at regular intervals to cut surfaces, exposed internodes, abrasions and splits.

Brushing, swabbing, spraying and dipping

These surface treatments are for the temporary protection of bamboo in storage or before it is given impregnation treatments. The various chemicals used include aqueous emulsions of insecticides such as dieldrin 0.03 per cent and aldrin 0.015 per cent, or dichlorodiphenyltrichloroethane (DDT) 7-10 per cent in kerosene oil. In Japan, mercury and tin salts have also been used for protection against borers and fungi, respectively. Other chemicals, such as sodium pentachlorophenate, borax and boric acid, are also used.

Soaking

Air-dried bamboos have only to be submerged in the preservative solution (oil or oil-soluble) for a length of time that depends on the species, age, thickness and absorption required. The penetration is predominantly by capillarity. The soaking method requires little equipment or technical knowledge, provided the schedule of treatment, such as the type of preservative, its concentration and the period of dipping, is worked out. The absorption of preservative is greater in specimens split in two lengthwise (half-split) than in unsplit specimens.

Boucherie process

In the traditional Boucherie process the preservative is applied to green bamboo by the force of gravity, from a container placed at a height. In India this method was later modified to make use of a simple hand pump. By applying air pressure of 1.0-1.4 kg/cm^2 to the container, the preservative is pushed through the tissues of the green bamboo. This modified procedure reduces the period of treatment significantly and, under the pressure, the treating solution forces the sap out of the walls and septa of the bamboo through the openings and in time replaces it.

The penetration and absorption of the preservative depend on several factors, such as concentration, treatment time, the chemical used, the dimensions of the bamboo and its age and moisture content.

Steeping method

The steeping method generally consists of allowing cut culms, with the crown and branches intact, to stand in a container holding the preservative solution to a depth of 30-60 cm. As moisture transpires from the leaves, the solution is drawn up to the stem. The period of treatment depends on the species, the length of the culm, weather conditions, the preservative used etc.

Sap displacement method

Green unsplit or split bamboos are immersed partly in water-borne preservatives. The preservative gradually rises to the top through absorption due to replacement of the sap.

Hot and cold process

When pressure facilities are not available, the hot and cold bath (open tank) process can be used for dry bamboo, just as it is used for timber. Up to 70 kg of creosote per m^3 of bamboo is reported to have been absorbed using this process. When fixed-type i.e. non-leachable, water-borne preservatives are to be used, the bamboo is first boiled in water and then quickly dropped in the cold bath of the preservative.

Research studies at the Forest Research Institute at Dehra Dun (India) indicate that the duration of boiling significantly influences the absorption of preservative. By increasing the heating period from 1 hour to 6 hours, the absorption is more than doubled.

Diffusion process

The diffusion process can be employed using water-soluble preservatives, in solution or paste form, to treat green timber or bamboo. In this process, the toxic chemicals diffuse through the water medium from the place of application, where they are at high concentration, to other zones. If sufficient time is allowed, chemicals spread to almost the entire volume of the green material. The diffusion process appears most suitable for bamboos that are difficult to impregnate under pressure once they have been dried. It requires only simple equipment and is popular in many countries, such as Germany, Canada, the United States, Australia and New Zealand. It appears that the permeability of bamboo to preservatives is significantly increased when it has been kept in a pond.

Although the service life of bamboo treated by the first six of the processes mentioned above may not be equal to that obtained by the pressure or open tank methods, where a greater degree of quality control is possible, the diffusion method is cheap and simple and requires simple equipment. It is applicable even in remote areas and gives reasonably good protection to the treated bamboos.

Pressure processes

Pressure processes are suitable for treating dry bamboos. When the bamboo moisture content is reduced below 20 per cent, satisfactory penetration and absorption are obtained by these processes.

Bamboo is generally air-dried under cover. To prevent deterioration during drying, it is important to impart prophylactic treatment with suitable chemicals.

The installation of conventional pressure treatment plants usually entails heavy investment and operating costs. This makes them unsuitable to the average user of bamboo.

If bamboo is treated under high pressure, cracks can develop that reduce its strength. It has been observed that species having thin walls are susceptible to cracking even when treated at low pressure (5-7 kg/cm^2). Round specimens of *Dendrocalamus strictus* treated at pressures of 14.06 and 28.12 kg/cm^2 absorbed 88.12 and 107.00 kg/m^3 of creosote-fuel oil mixture, respectively, while half-split specimens absorbed 91.54 and 108.81 kg/m^3 of the preservative.

Non-chemical treatment (traditional method)

Insect borers such as the powder post beetle are a serious problem and of economic importance in fabricated bamboo and rattan. Bamboo borers include *Dinoderus minutus* Fab., *D. ocellaris* Steph. and *D. brevis* Horn., which is known as bamboo *ghoon* in India [22, 23] and *bubuk bambu* in Java [24].

In the traditional non-chemical method of preservation used in Asian countries, the cut bamboo culm is soaked under water to protect it from powder post beetle. The method costs almost nothing and can be carried out by the rural people themselves without any special equipment. It is most suitable for reasonably cheap and easily available bamboo raw materials [10].

The susceptibility of bamboo to borer attack depends on the species, its starch content, the age of the culm, the felling season and the physical properties of the bamboo itself [25]. However, further studies indicate that the starch content of the bamboo is the most important factor influencing the susceptibility to borer [25, 26]. Indeed, the damage caused by the borer has been found to be proportional to the starch content of the bamboo [10, 22, 27, 28, 29].

Plank [25] and Beeson [22] observed that during the soaking period, the starch content of the parenchyma cell of the bamboo is reduced. It is then assumed to be less attractive to the borers, and this improves its resistance to borers [10, 28]. This assumption, however, remains to be proved, because not much is known about the real effectiveness of this traditional method of preservation [10].

The rural Javanese have traditionally practised this method of bamboo preservation. Not only do they soak the half-finished bamboo materials in water or muddy water, but they also cut their bamboo culm at a particular time, which they call *mangsa tua*. They believe this to be the most appropriate time for the bamboo species they use, and it is their experience that they will have a better quality bamboo to use for construction if the traditional water soaking preservation method has been followed [29].

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Annex

OBTAINING THE EQUATION OF THE LINEAR LINE BY THE LINEAR REGRESSION OF DATA ON THE ABSORBENCE OF STANDARD SOLUTIONS OF SILICON DIOXIDE

x*	$A = y$**	x^2	$A^2 = y^2$	xy
1	0.114	1	0.013	0.114
2	0.223	4	0.050	0.446
3	0.332	9	0.110	0.996
4	0.456	16	0.208	1.824
5	0.569	25	0.324	2.845
6	0.678	36	0.460	4.068
7	0.814	49	0.663	5.698
8	0.916	64	0.839	7.328
9	1.107	81	1.225	9.963
10	1.248	100	1.558	12.480
$\Sigma x = 55$	$\Sigma y = 6.397$	$\Sigma x^2 = 385$	$\Sigma y^2 = 5.45$	$\Sigma xy = 45.762$

*Concentration in ppm.

**A is average absorbence calculated from nine measurements.

$$y = a_o + a_1 x$$

$$a_o = \frac{(\Sigma y)(\Sigma x)^2 - (\Sigma x)(\Sigma xy)}{N\Sigma\ x^2 - (\Sigma x)^2}$$

$$= \frac{(6.397)(385) - (55)(45.762)}{(10)(385) - (55)^2}$$

$$= \frac{(2485.945) - (2516.91)}{3850 - 3025}$$

$$= \frac{-30.965}{825}$$

$$= -0.0375$$

$$a_1 = \frac{N\Sigma\ xy - (\Sigma x)\ (\Sigma y)}{N\Sigma\ x^2 - (\Sigma x)^2}$$

$$= \frac{10(45.762) - (55)(6397)}{(10)(385) - (55)^2}$$

$$= \frac{457.72 - 355.35}{825}$$

$$= 0.1242$$

$$y = -0.0375 + 0.1242x$$

V. DESIGN OF RATTAN FURNITURE

Pietro Borretti*

Introduction

This chapter outlines and illustrates the elements that are critical to the design of furniture based on rattan:

(a) The distinctive characteristics of rattan as a furniture material;

(b) Appearance elements;
—Form
—Forms reflecting design heritage's (early rattan furniture shown in annex I)
—Textures
—Finish and colour

(c) Structural elements;
—Rigidity methods
—Types of joints
—Cutter to produce exposed cope joints (annex II)

(d) Standardization elements;
—Functionality
—Standardization of parts and structures
—Compliance with performance standards (annex III)
—Standardization of product specification

(e) Value analysis element (annex IV).

The illustrations have been selected to impart a sensitivity for the specific properties of rattan as compared to other materials and to show to what extent these properties can be creatively exploited in product development.

Brief history of rattan furniture

Rattan-type construction is believed to have begun several thousand years ago with the use in Mesopotamia and Egypt of interlaced reeds, grasses, rushes and palms for the production of baskets and stools. A Sumerian stool of woven rush appears in a sculpture dated 2600 B.C.

The Romans utilized willow branches for the manufacture of baskets and chairs, while the Chinese are believed to have widely used rattan in furniture-making early in their civilization. In modern times, rattan furniture has flourished in America and Europe since the early 1800s. However, it was only in the 1950s that highly innovative designs were introduced, using new forms and structures that took advantage of the unique working properties of rattan. Some pieces of early rattan furniture are illustrated in annex I.

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Characteristics of rattan as a raw material

The most distinct working property of rattan as compared with wood is its pliability, i.e. the exceptional ease with which both large- and small-diameter poles can be bent. Moreover, the end grain of rattan possesses an extraordinary screw-holding capability. Because of its resilience, the material can produce a wide variety of decorative surfaces when utilized in the form of flat strips or small-diameter rods. Finally, the extreme lightness of rattan allows the development of complex furniture structures.

Appearance elements

These elements comprise the visual aspects of a product and include form, texture and colour/finish.

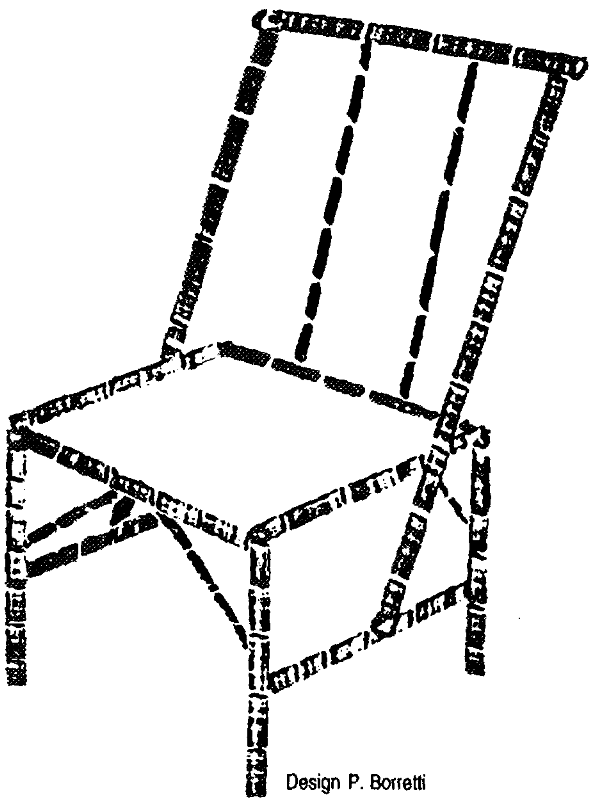
Form

Form is the way in which a product is styled, as a whole as well as in its component parts. Because of its unique properties, rattan lends itself to styling into a great variety of shapes that cannot be achieved using timber. Forms of rattan furniture can be based on visual contrasts, such as straight lines and surfaces, components bent in a single plane, components bent to a compound shape or combinations of flat and compound surfaces. In particular, rattan, unlike wood, allows deep-drawn compound surfaces to be incorporated into the design. Some typical furniture forms are shown in figures 9-15.

Forms reflecting design heritages

Most developing countries have a rich handicraft tradition that can provide a basis for the design of rattan furniture, especially furniture aimed at export markets. Designs that reflect various design heritages are shown in figures 16-20.

Figure 9. Forms based only on straight components (top) and on a combination of straight and bent components (bottom)



Design P. Borretti

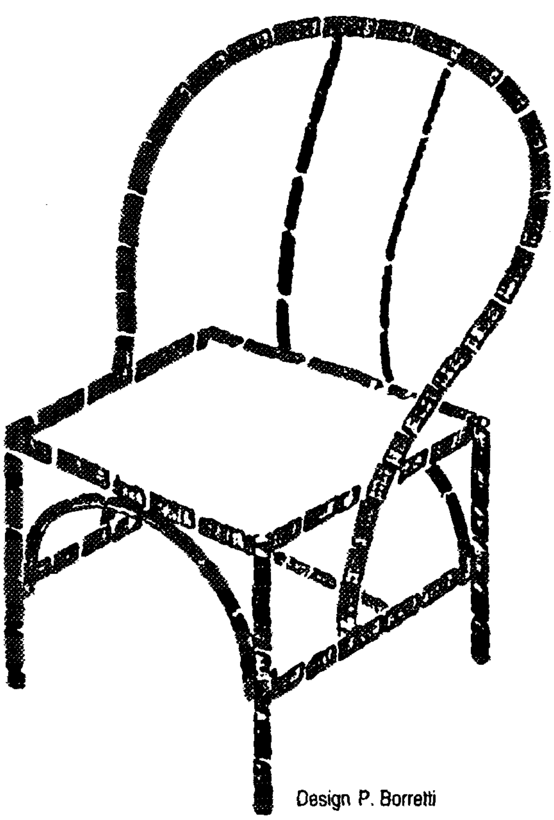


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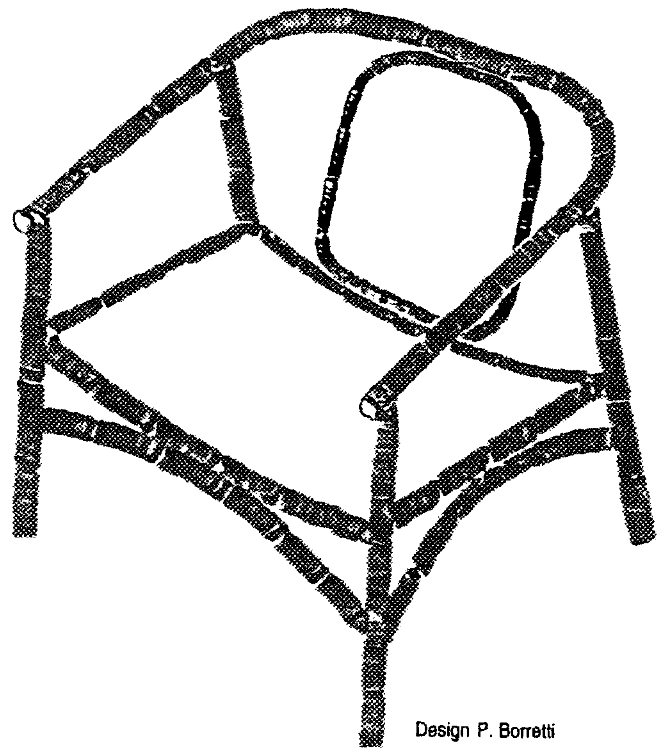
Figure 10. Forms comprising components bent only in one plane



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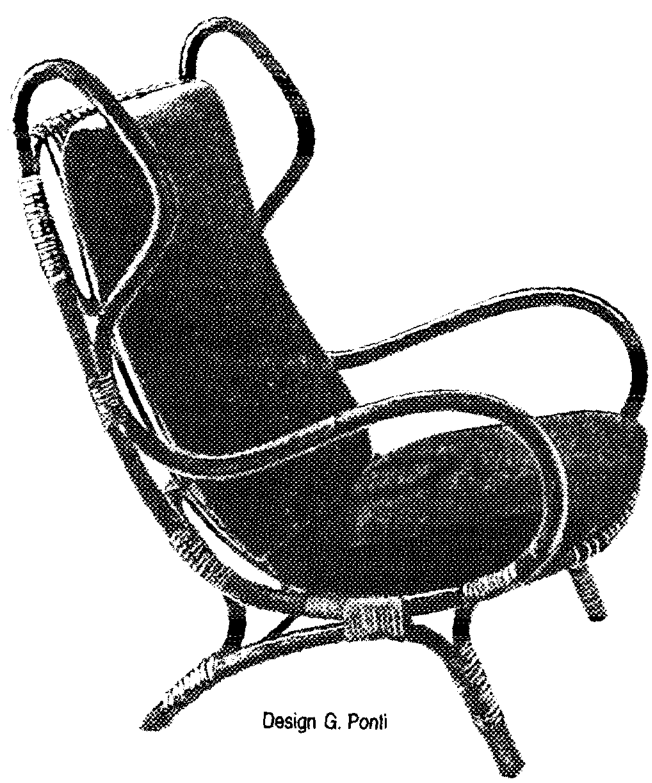


Design G. Ponti

Figure 11. Forms based on components bent to a compound shape

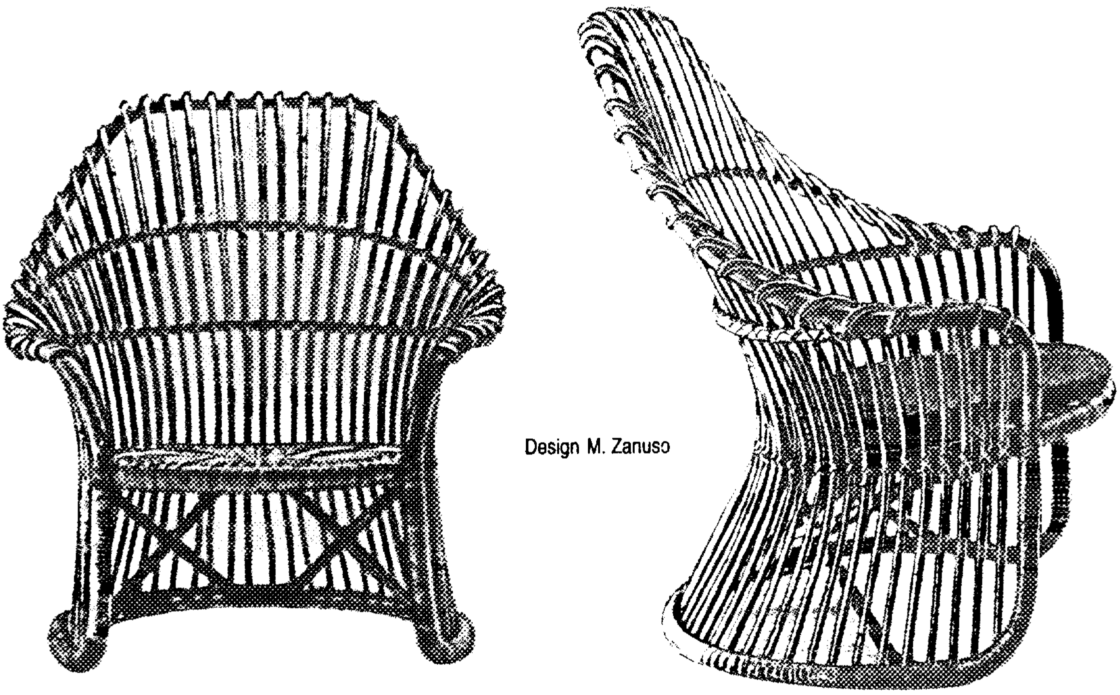


Figure 12. Form based on box-type design

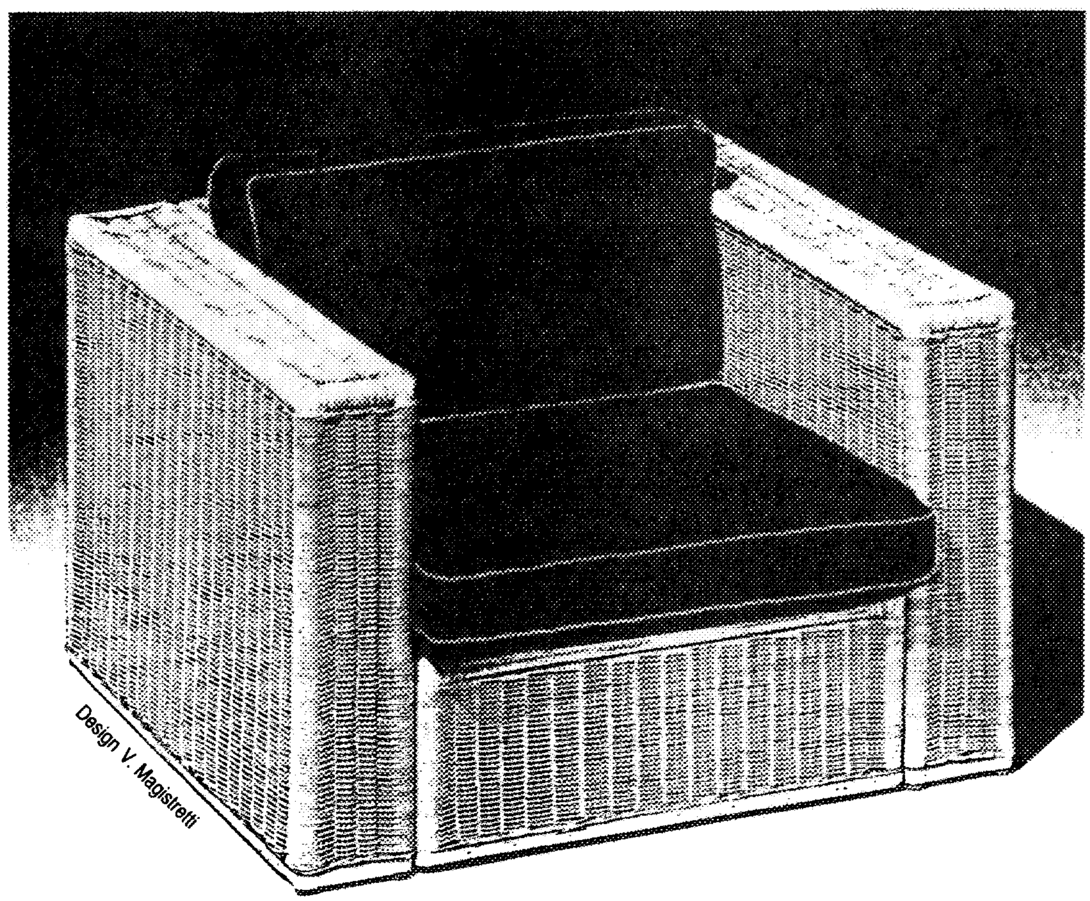
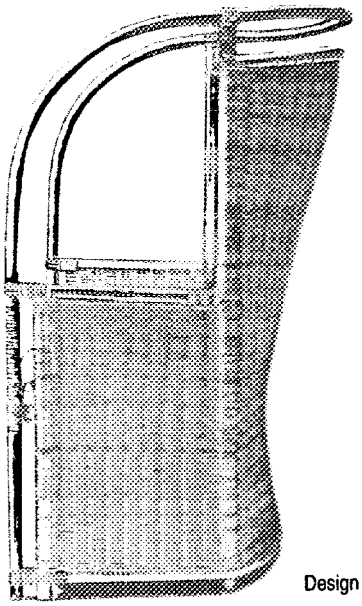


Figure 13. Furniture combining flat and contoured surfaces



Design W. Toffoloni

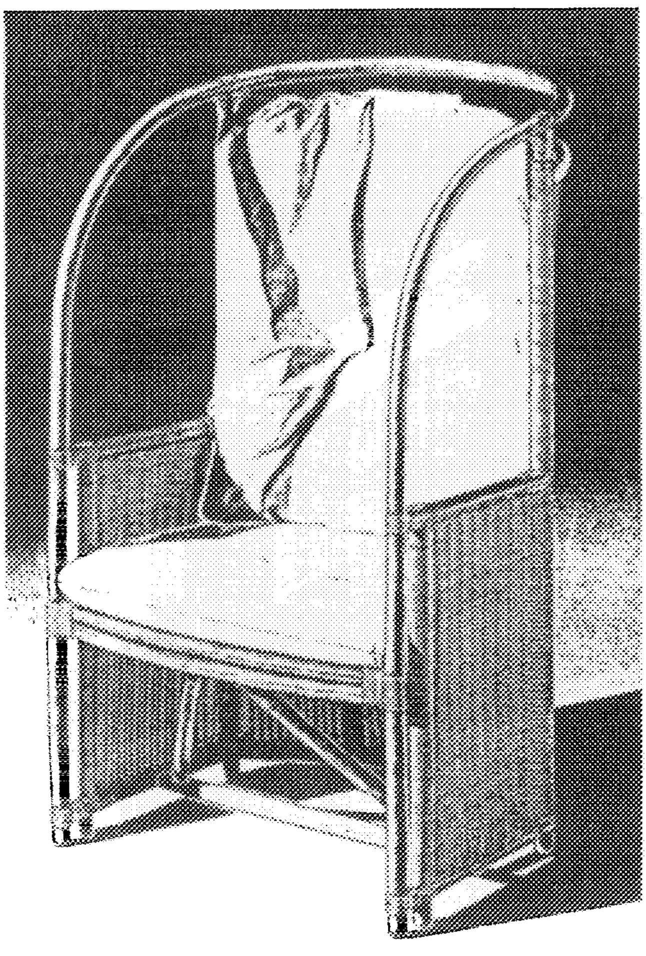
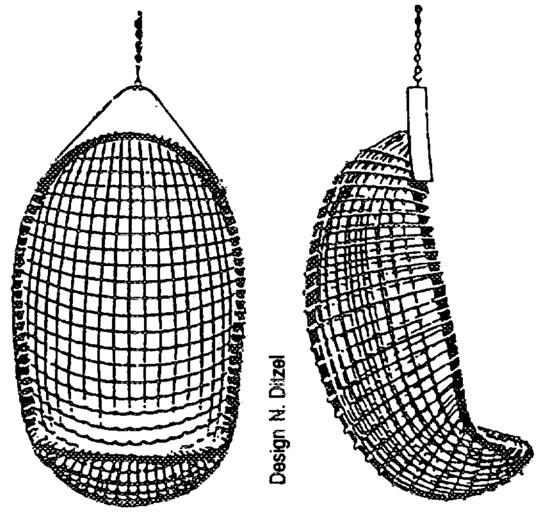


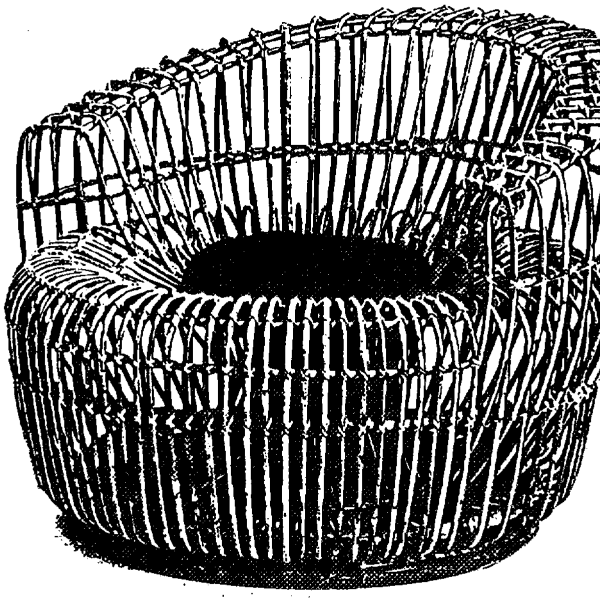
Figure 14. Forms based on open-shell design



Design N. Ditzel

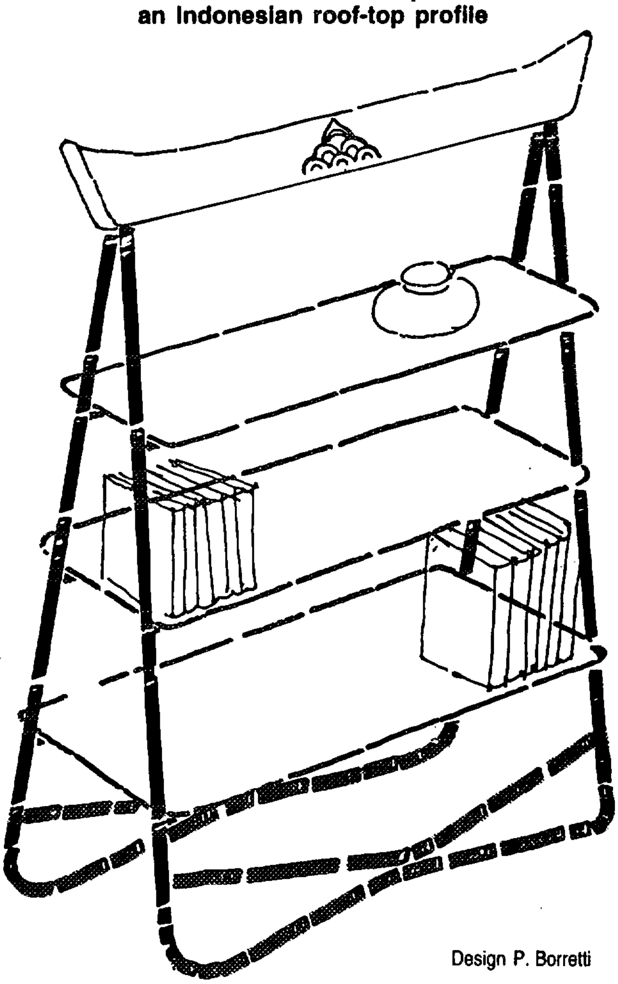
Design G. Gervasoni

Figure 15. Form based on concentric components also having a structural function



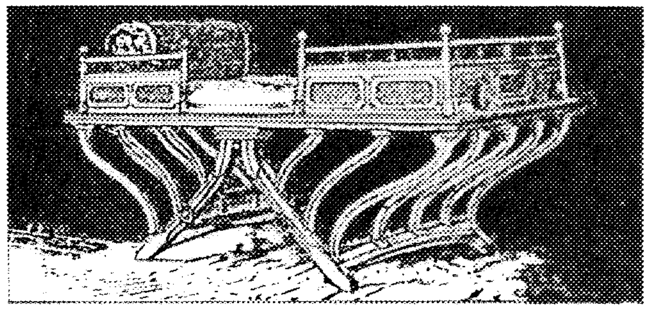
Design W. Toffoloni and P. Palange

Figure 16. Rattan bookshelf with top member of solid timber whose shape recalls an Indonesian roof-top profile

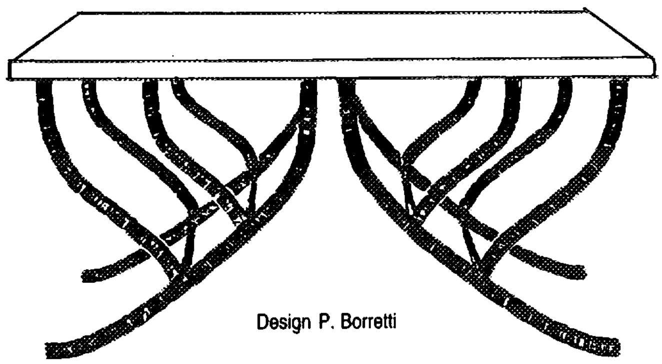


Design P. Borretti

Figure 17. Rattan coffee-table based on traditional Thai elephant seating

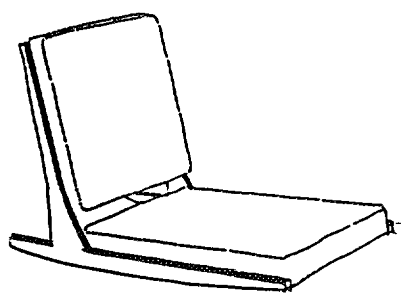


Traditional Thai elephant seating

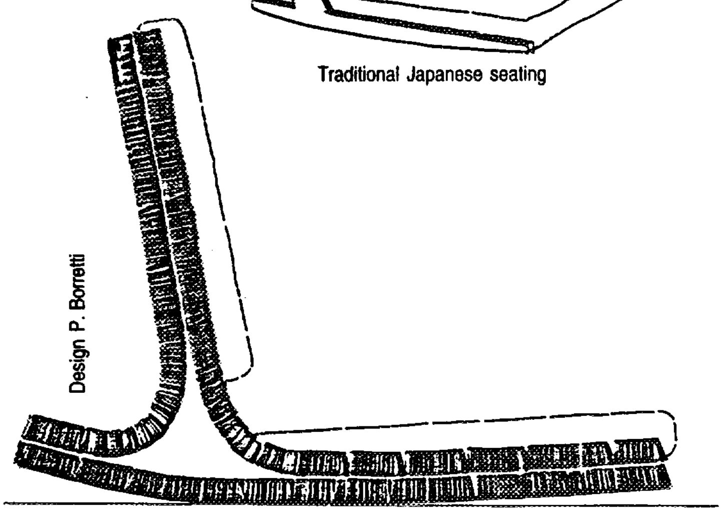


Design P. Borretti

Figure 18. Design for a low seat based on the traditional Japanese chair



Traditional Japanese seating



Design P. Borretti

Figure 19. Rattan chair based on a traditional Chinese design

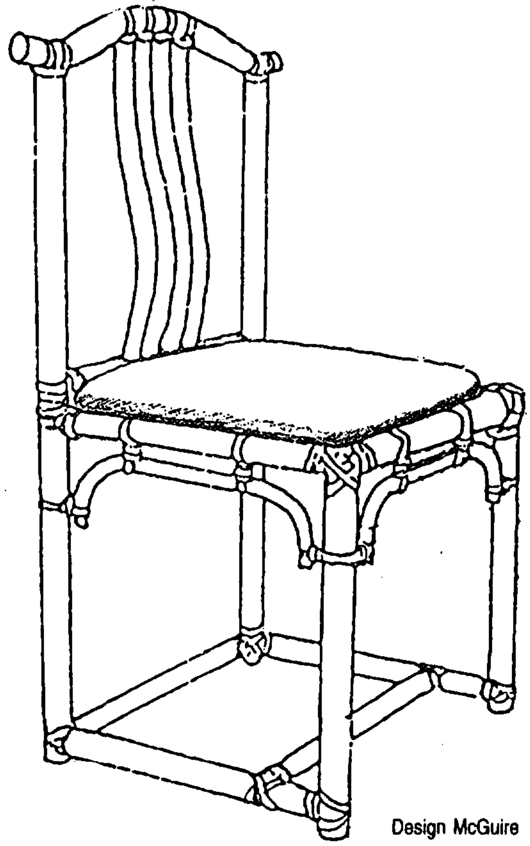
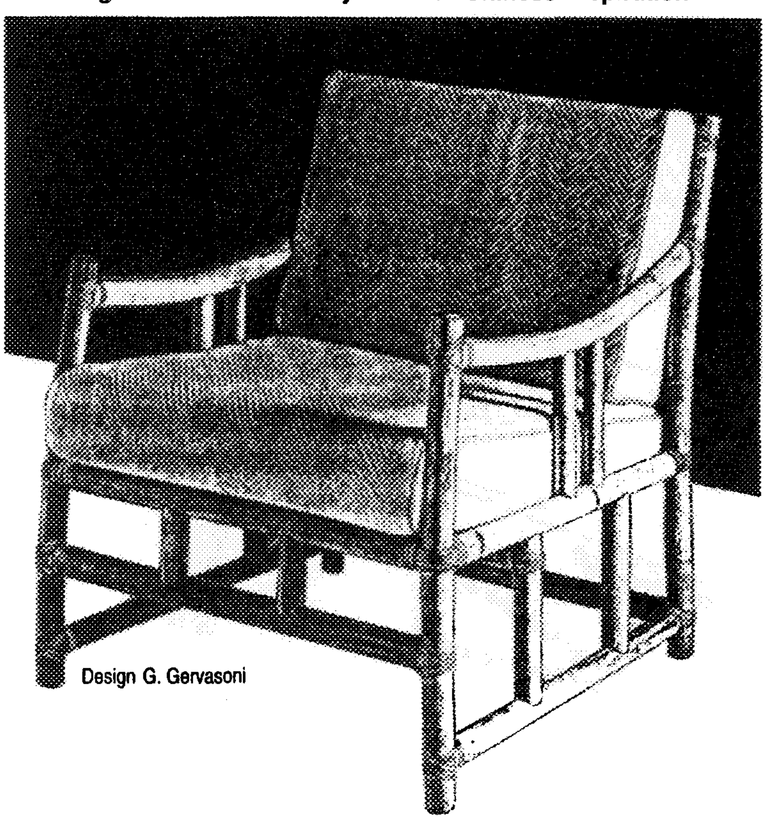


Figure 20. Rattan easy chair of Chinese inspiration



Texture

The wide range of surface patterns that can be achieved with rattan is unparalleled when compared with virtually all other furniture materials. Both closed-grid and open-grid textures and patterns can be obtained by utilizing cane webbing or rattan round core (see figures 21 and 22). The application of various texture patterns in furniture design is shown in figures 23-28. A contemporary texture technique is the wrapping of rattan poles with wicker rods in a cluster or swirl fashion to obtain a decorative surface pattern, as illustrated in figure 28. A similar technique may also be applied to flat surfaces, such as drawer fronts and the edges of wooden panels.

Finish and colour

The choice of finish and colour is an important element in the designer's endeavour to enhance the aesthetic appeal of the product. When the designer chooses the surface finishing characteristics and, in particular, the colour, he or she completes the product design cycle. Rattan lends itself to surface-finishing with most of the materials suitable for wood finishing. The designer can choose to emphasize the natural colour and grain of rattan by utilizing clear finishes; to modify the original appearance by the application of clear or pigmented stains; or to give the surface a glossy, semi-glossy, silk-matt or matt appearance by the application of an appropriate finish.

However, what is distinctive about rattan as far as colour application options are concerned is the possibility of obtaining surfaces with coloured patterns by interweaving cane strips or round core stained in a variety of colours. Figure 29 shows, above, a symmetrical coloured pattern and, below, an irregular pattern with a three-dimensional effect, produced by using cane strips of different widths. Figure 30 shows a chair structure lined with a combination of cane strips and round core stained in a variety of colours.

Structural elements

Structure concerns the way in which a piece of furniture is held together and comprises two main aspects: the method for achieving rigidity and the type of joint.

Methods for achieving rigidity

The most common rigidity methods employed in the design of rattan furniture are based on triangulation bracing (figures 31-34) and pole coupling (figures 35 and 36). A contemporary method uses loop-shaped components (figure 37). Both rattan poles and surfaces made of woven cane and round core can contribute to structural rigidity. Figure 38 shows an easy chair made entirely of rattan poles, and figure 39 shows a design where structural rigidity is provided by hidden rattan poles and a close grid of rattan round core. Figure 40 illustrates the utilization of a close grid of round-core webbing and an open grid of cane webbing in combination with steel and wooden frames, respectively.

Types of joints

A variety of rattan furniture joints and joint binding methods are shown in chapter VII. Shown here in figure 41 is a selection of main joints as well as an exposed mitre joint with a glued-in hardwood spline, which can be used when a decorative appearance is desired without having to apply cane binding.

Exposed cope joints without any binding have been introduced in contemporary rattan furniture designs (figure 20). However, this technique requires that the cope joint be machined with the highest degree of precision and without any splintered edges. To achieve this effect, a special cope cutter with disposable carbide tips should be utilized, as illustrated in annex II. The annex also shows a special type of self-tapping screw, which is recommended for use in structural and knock-down joints, and a circular saw blade required for the splinter-free cross-cutting of rattan poles as it is the case in design details involving exposed pole ends or exposed mitre joints.

Standardization elements

The industrial standardization element of the product development process covers four different aspects:

(*a*) Functionality;

(*b*) The standardization of parts;

(*c*) Compliance with performance standards;

(*d*) The standardization of product specifications.

Functionality

The main functionality requirement concerns appropriate dimensioning of furniture so as to avoid discomfort and minimize the physical effort required for its use. To this end, guidelines have been developed by the United Nations Educational, Scientific and Cultural Organization (UNESCO) in the form of ergonomic parameters based on the body's standing height, as illustrated in figure 42. The correct dimensions are obtained by multiplying the given factors by the given standing height. For instance, the appropriate seat height for a person 1.70 m tall will be 0.25/1.70 = 0.425 m. Details of recommended dimensions of multi-purpose chairs, easy chairs and dining tables are given in figures 43, 44 and 45.

Other functionality considerations include the need for a given piece of furniture to be multifunctional (figure 46) or easy to knock down for shipment (figure 47).

Figure 21. Open-grid textures obtained using cane webbing

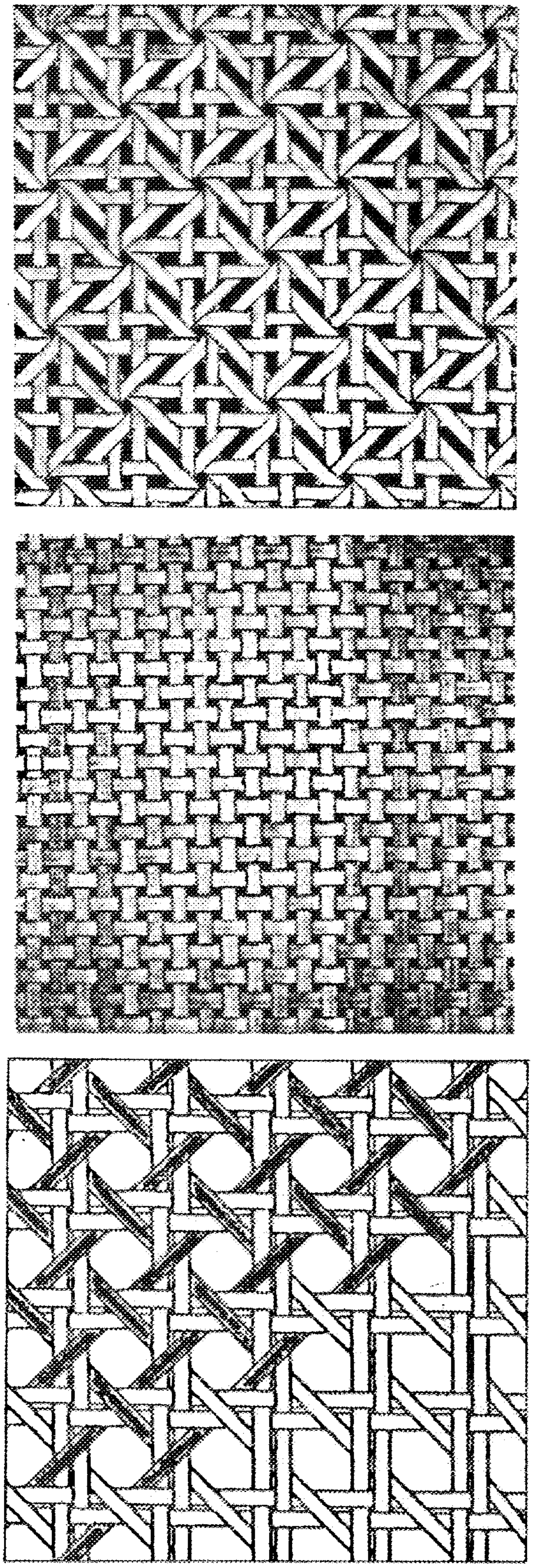


Figure 22. Open-grid and close-grid textures obtained using rattan round core

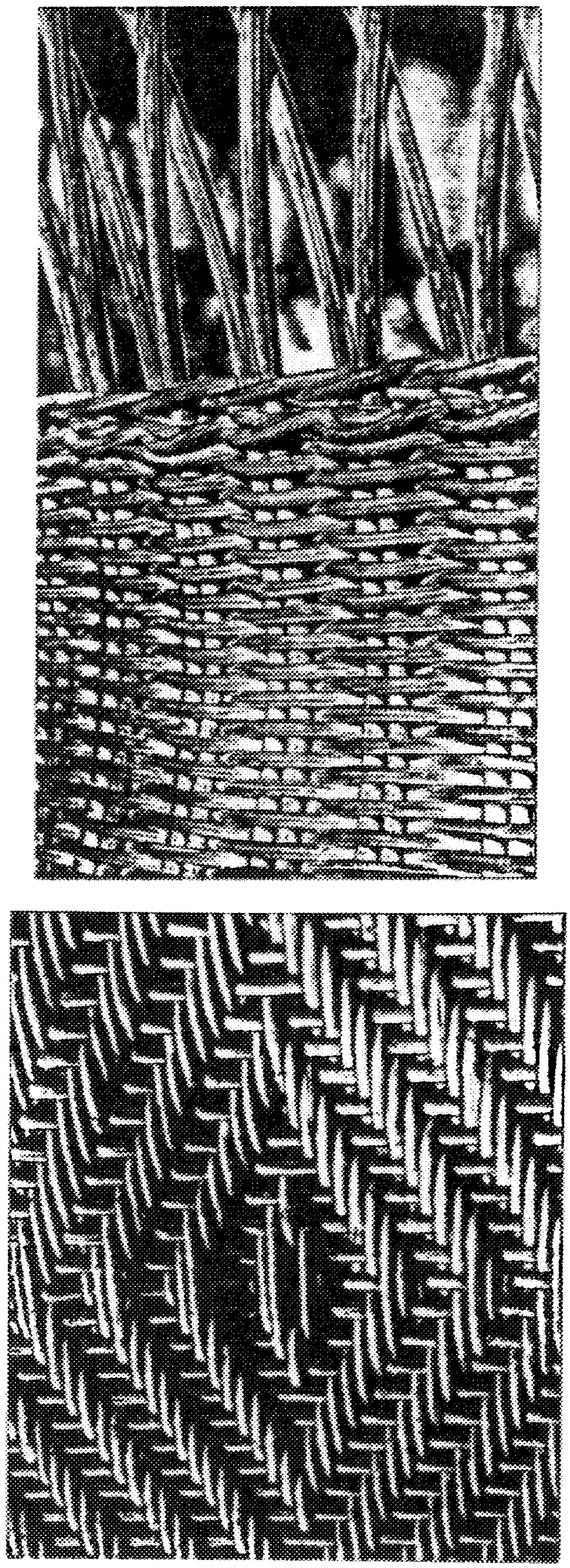
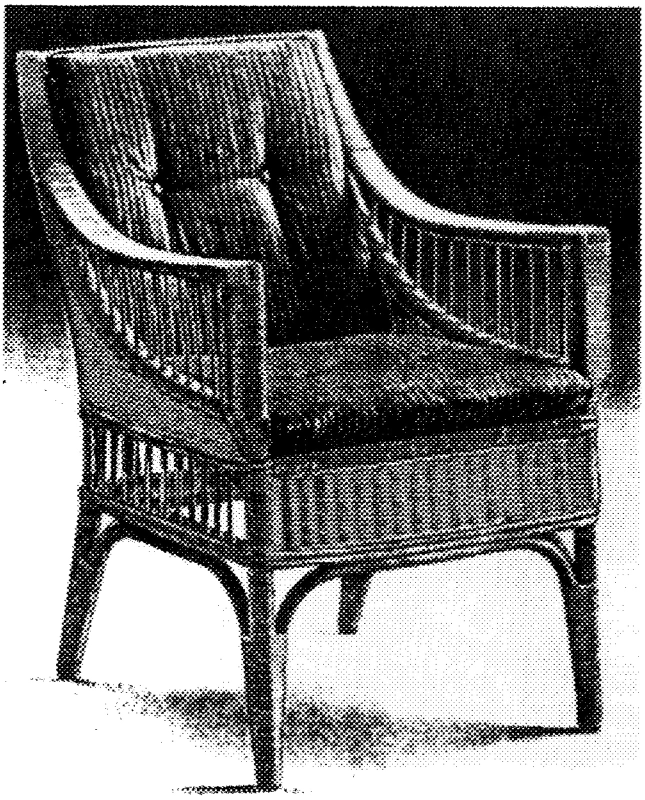


Figure 23. Furniture combining open-grid and close-grid round-core textures



Design M. Bonacina

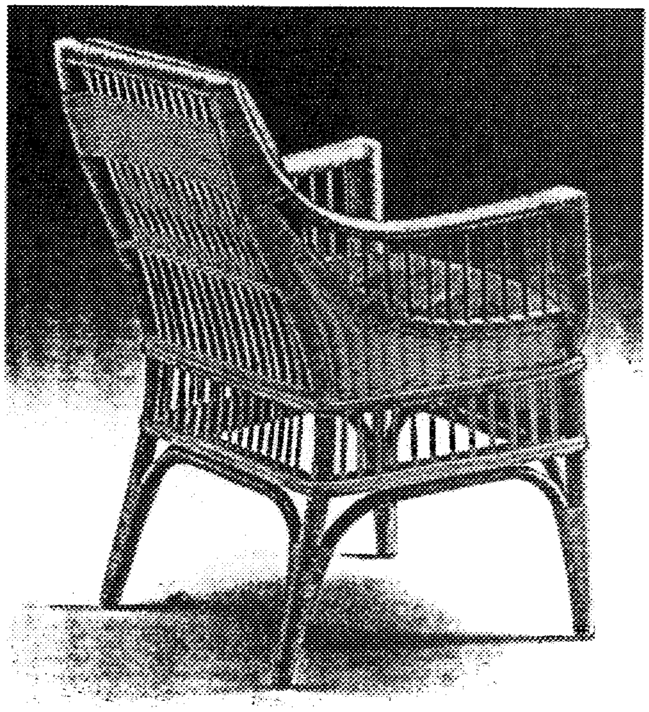
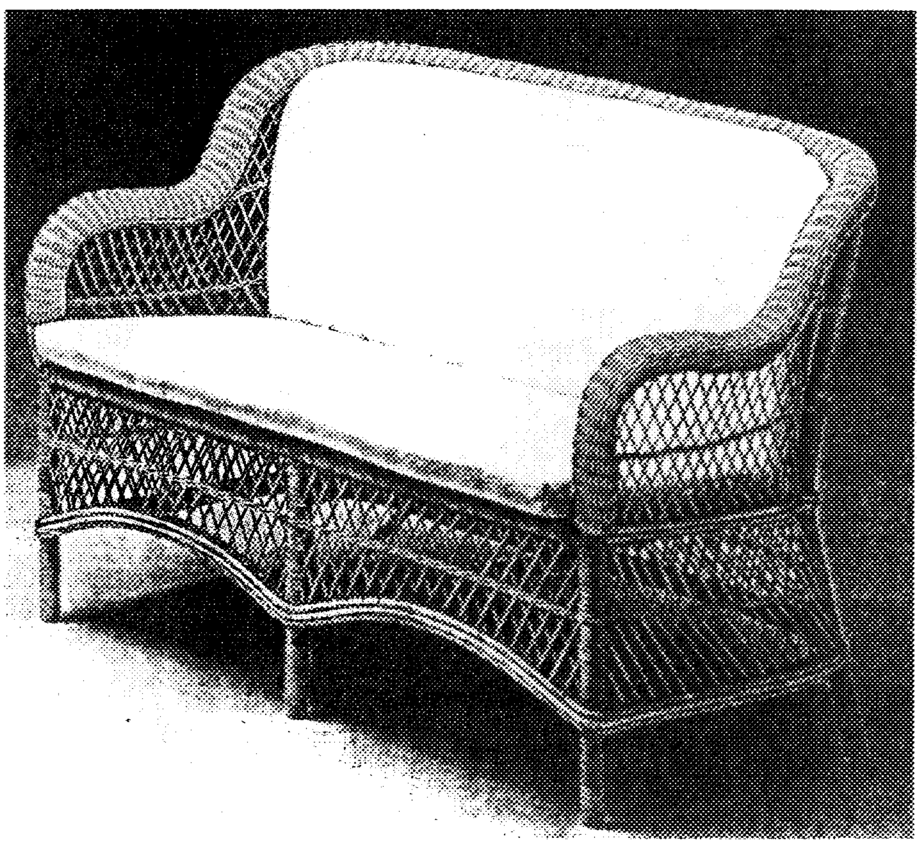
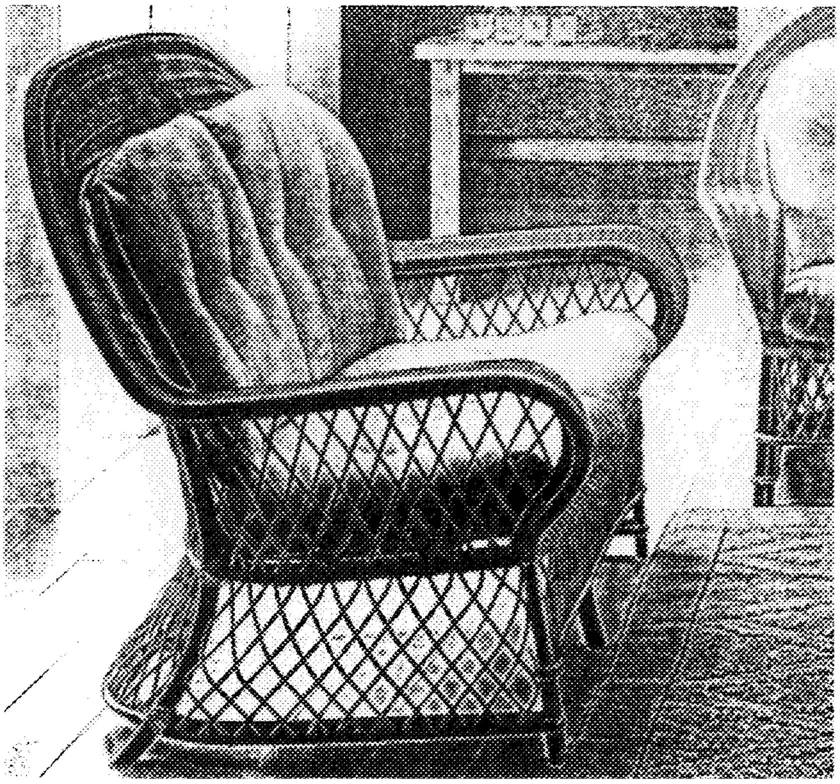


Figure 24. Furniture combining open-grid and close-grid round-core textures



Design G. Aulenti

Figure 25. Furniture combining open-grid and close-grid round-core textures



Design G. Gervasoni

Figure 26. Rattan chair with single lining of open-grid cane-webbing texture

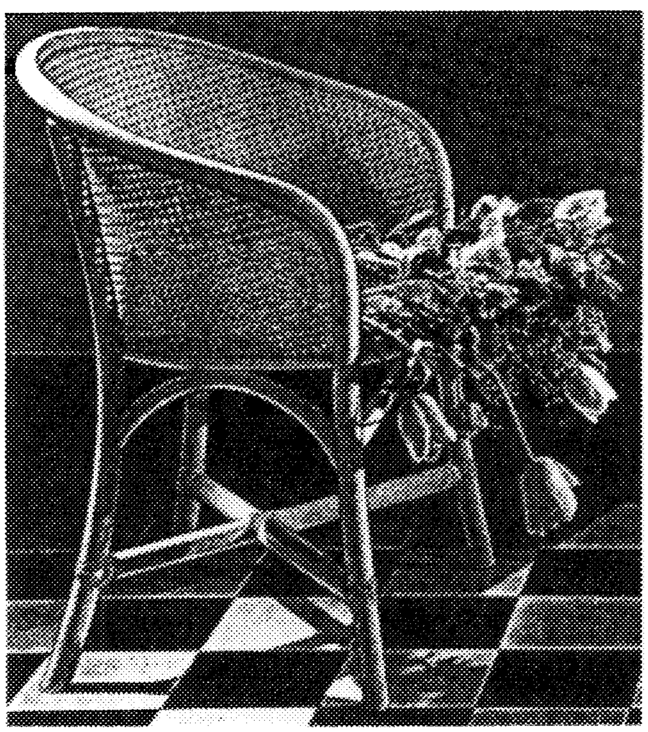
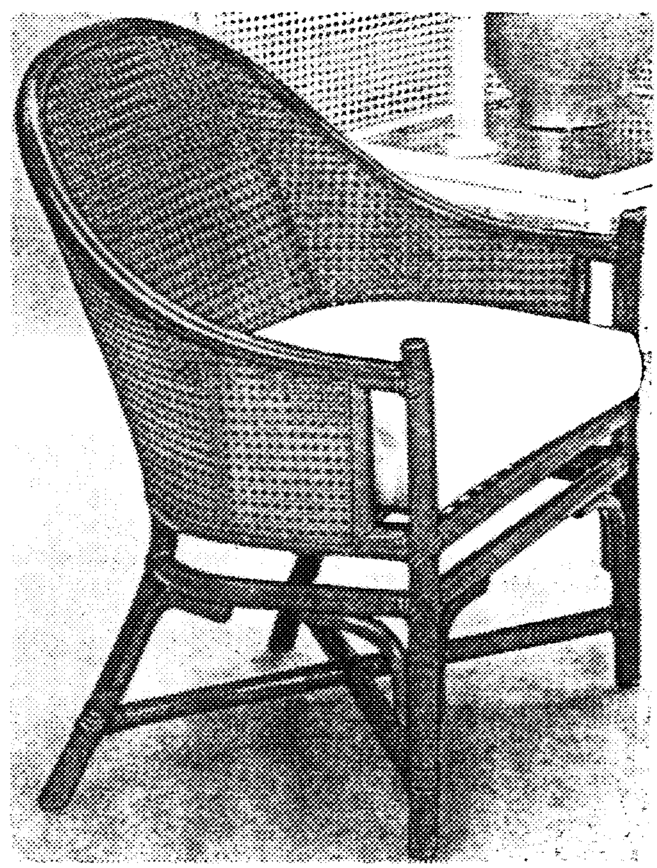


Figure 27. Rattan chair with double lining of open-grid cane-webbing texture



Design Telemaco

Figure 28. Textured surfaces obtained by wrapping rattan poles with round-core; this can also be done with the edges and flat surfaces of wooden panels

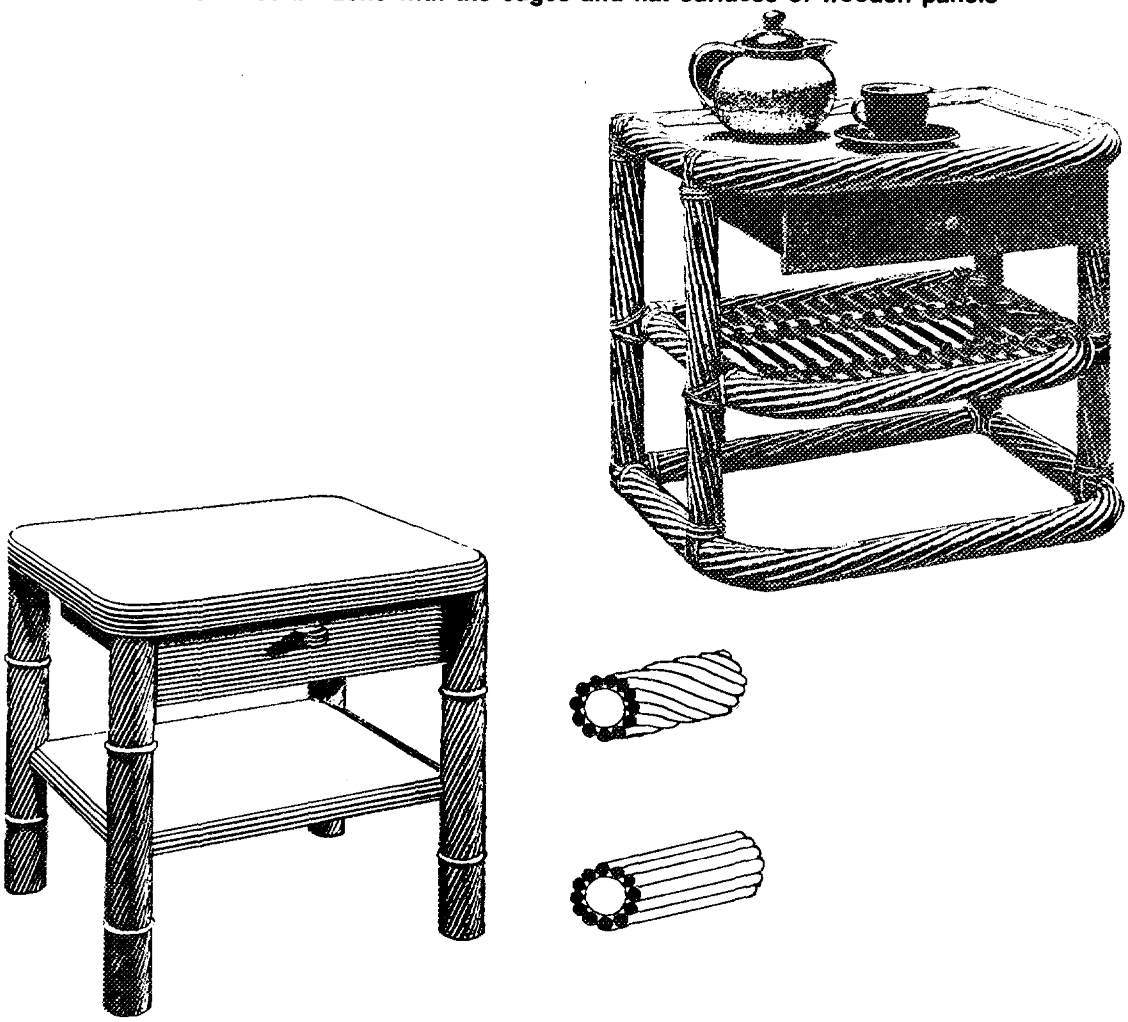


Figure 29. Colour patterns obtained by interlacing cane strips stained in various colours

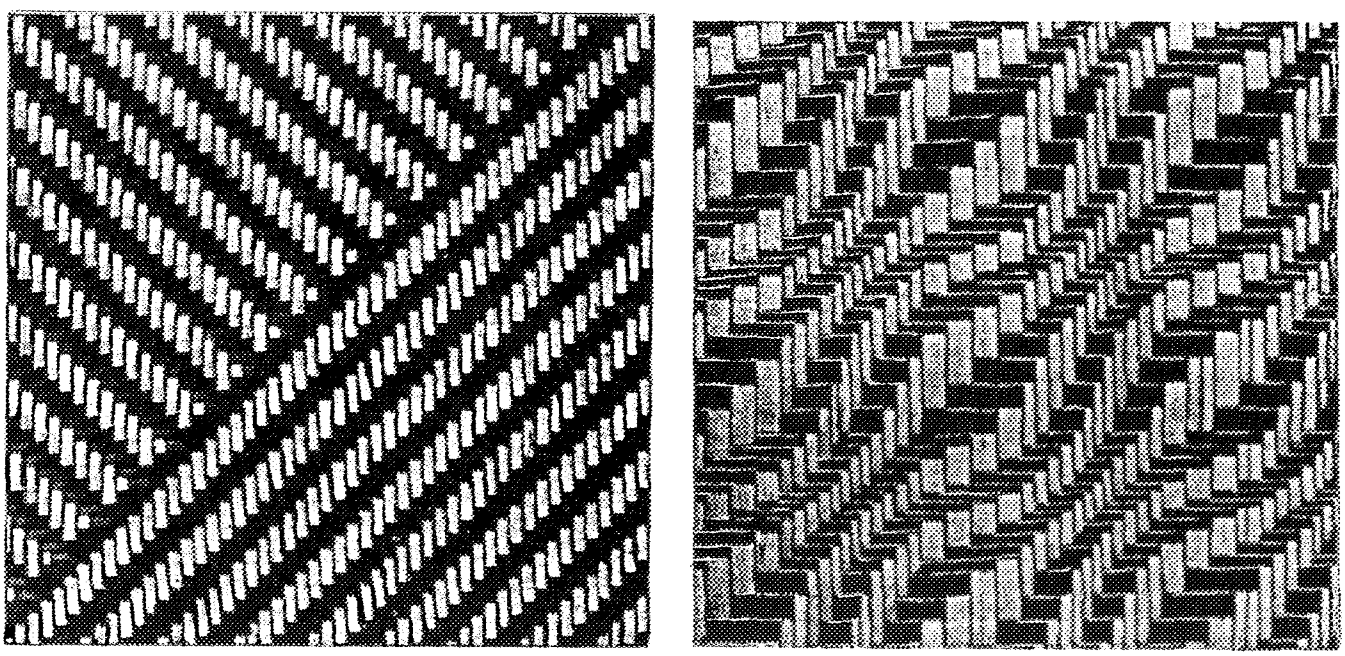


Figure 30. Chair structure wrapped with cane strips and round-core stained in a variety of colours according to a colouring system patented by Eurogroup

Standardization of parts and structures

The standardization of parts of structures within a given product or range of products is a desirable feature in product development when the attainment of low-cost output is a requirement. Unfortunately, this type of standardization is seldom adopted in the design of rattan furniture. Examples of the standardization of parts and structures are shown in figures 47 and 48.

Compliance with performance standards

In developing the structural features of a given furniture item, the designer should endeavour to comply with established standards of good workmanship for rattan furniture. A guideline in this respect is provided by the Philippine Standard Specification for Rattan and Wicker Furniture, given in annex III. The specification also provides details of prescribed performance tests designed to determine, by the application of simulated loads and related stresses, whether the load-bearing joints of a rattan furniture prototype can reasonably withstand normal use. In the Philippines, compliance with this standard allows the granting of the Philippine Standard (PS) Certification Mark.

Standardization of product specification

Lastly, standardization applies to the product engineering drawings and documentation to be elaborated jointly by the designer and the production personnel. Such documentation establishes the quantities and cost of raw materials as well as the production time for a unit of product. Examples of such documentation are the following:

(*a*) Scale drawings (figures 49 and 50);

(*b*) Bill of materials (figure 51);

(*c*) Route sheet (figure 52).

(d) Operation/assembly flow chart (figure 53).

Value analysis element

Beyond the aesthetic, functional and structural aspects of the product development process, the designer ought also to participate in value analysis exercises, i.e. the equating of costs with the functions of new designs, with a view to simplifying the product and increasing the profit without unduly sacrificing quality or reliability. A description of value analysis principles and procedures is given in annex IV to this chapter.

Figure 31. Structure rigidity based on triangulation

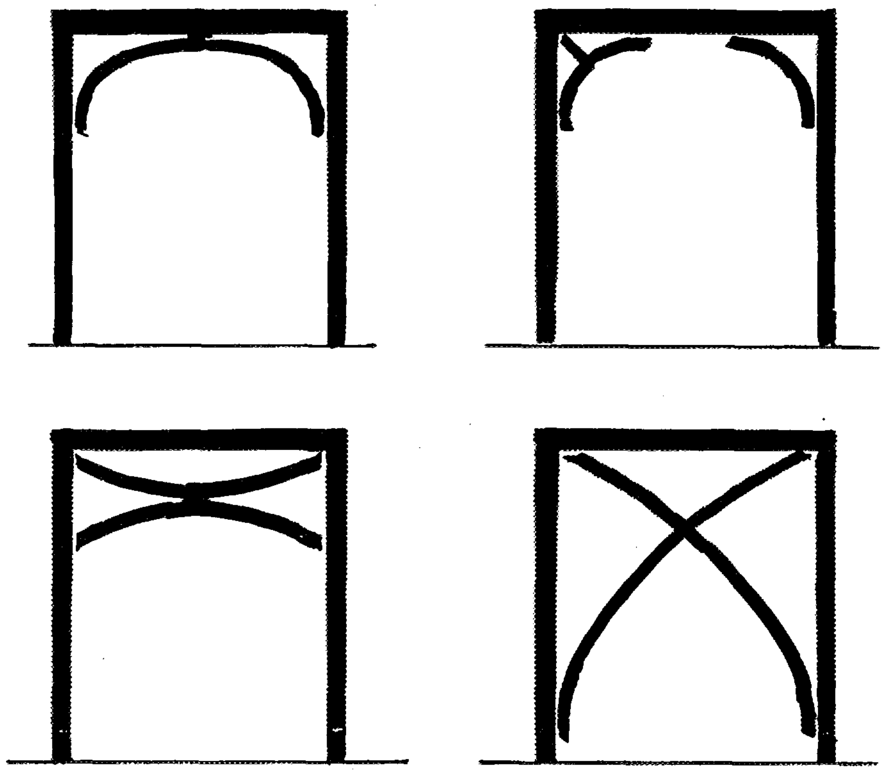
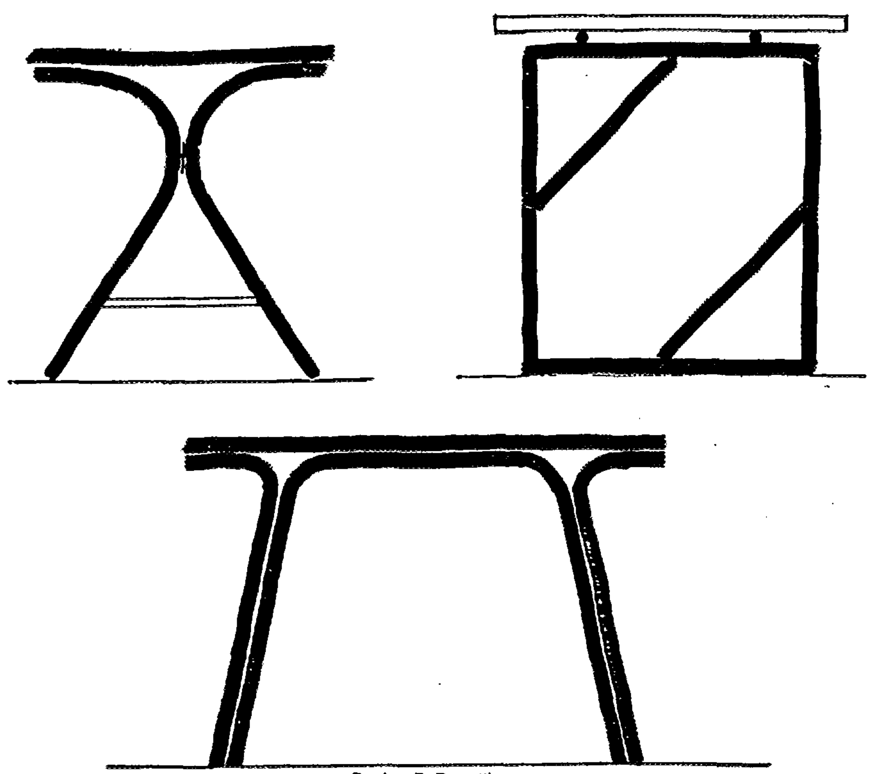
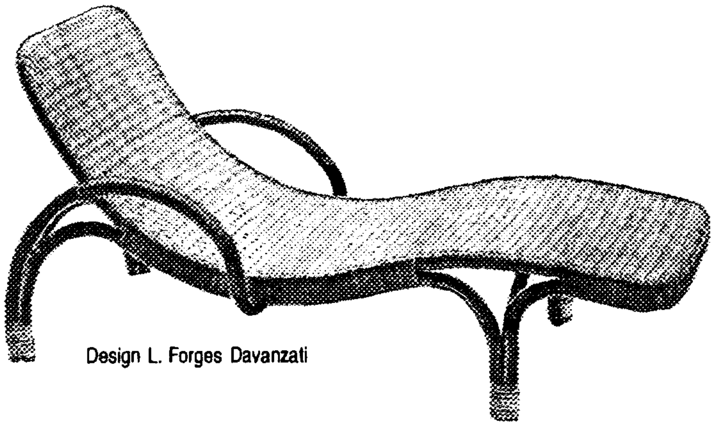


Figure 32. Structure rigidity based on triangulation

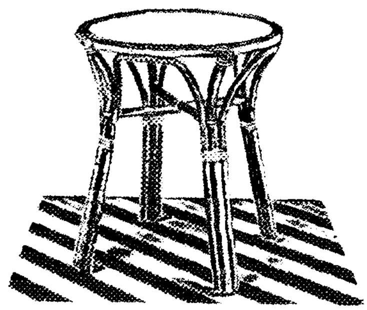


Design P. Borretti

Figure 33. Structure rigidity based on triangulation



Design L. Forges Davanzati



Design A. Casagrande

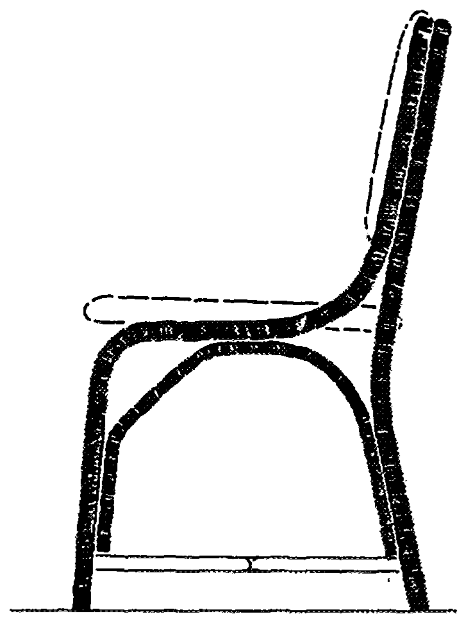
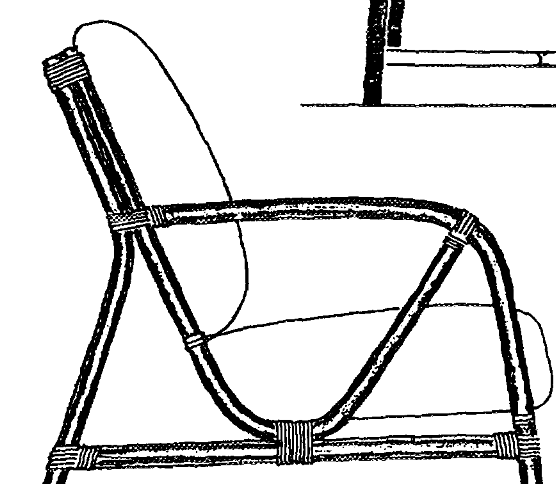
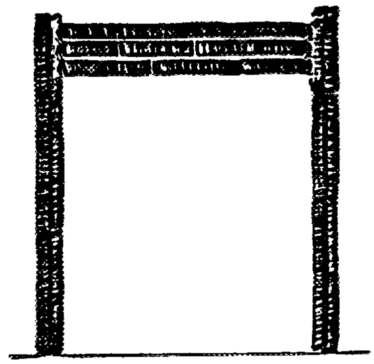


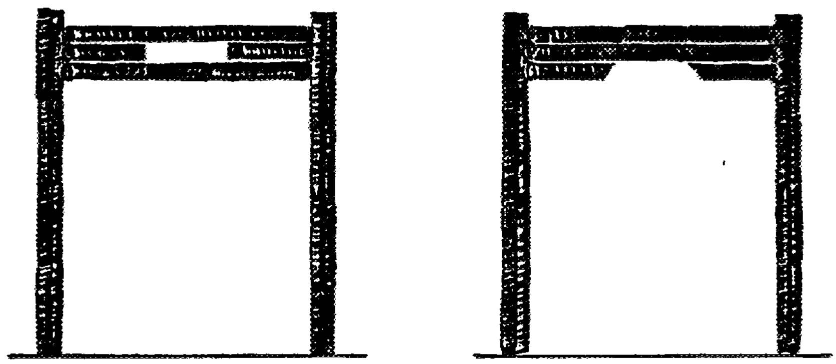
Figure 34. Structure rigidity based on triangulation



Design P. Borretti

Figure 35. Structure rigidity based on the coupling of rattan poles





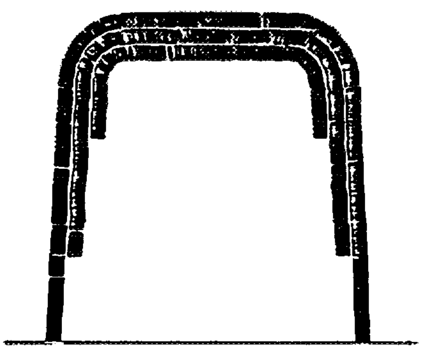
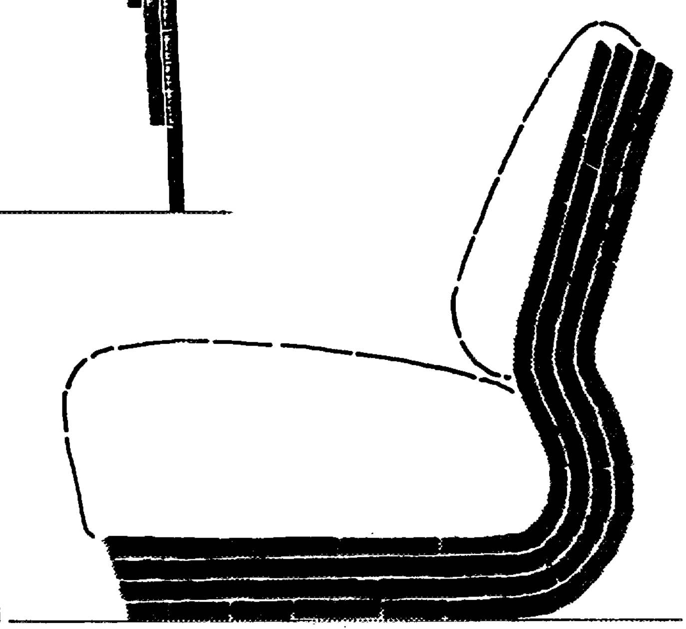


Figure 36. Structure rigidity based on the coupling of rattan poles



Design P. Borretti

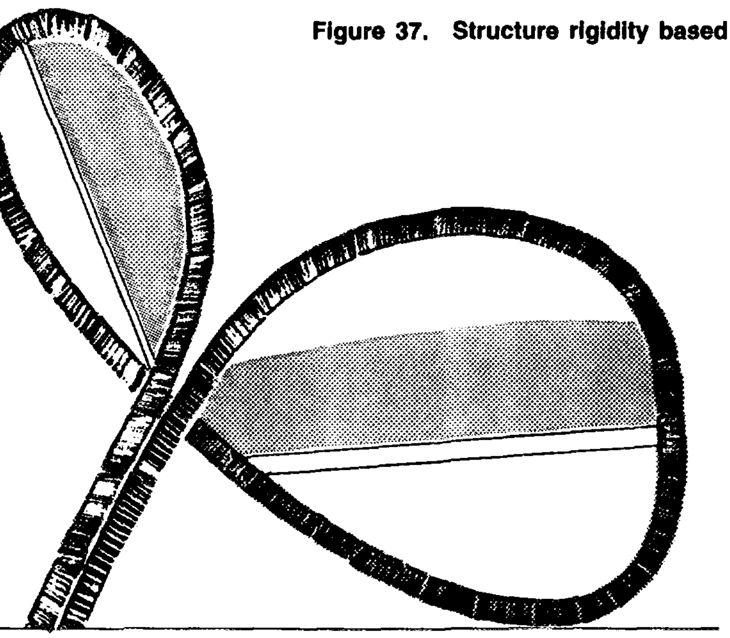


Figure 37. Structure rigidity based on loop-shaped components

Design P. Borrelli

Figure 38. Rattan furniture structured entirely by rattan poles

Design G. Gervasoni

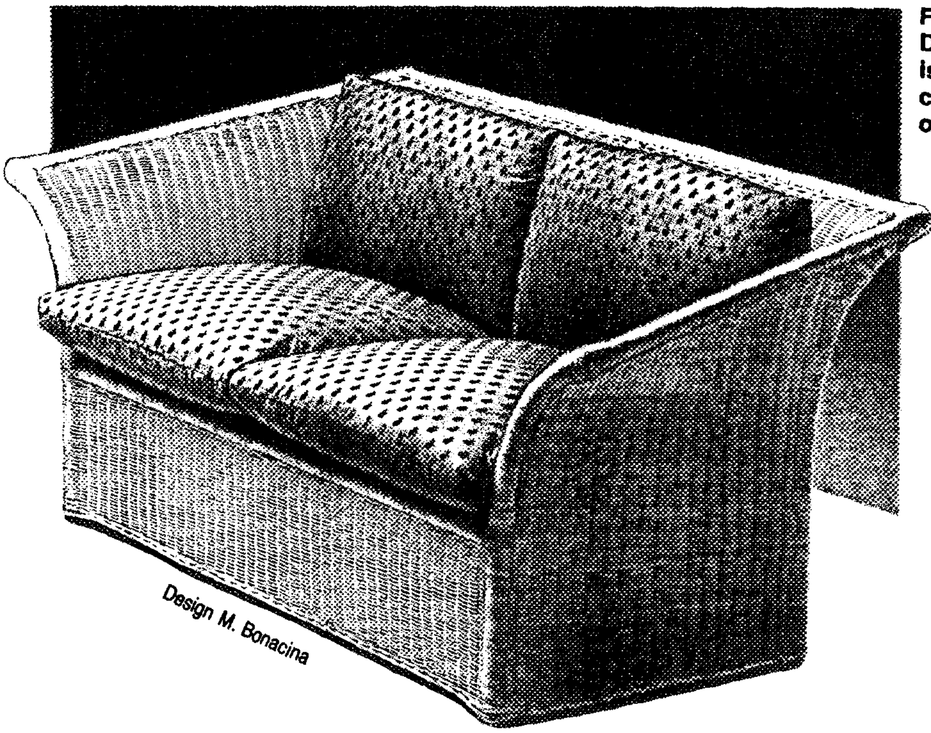
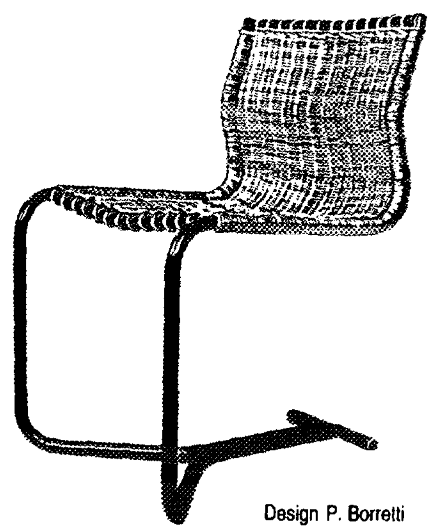


Figure 39.
Design where structural rigidity is shared by hidden rattan poles and close grid of rattan round-core



Design P. Borretti

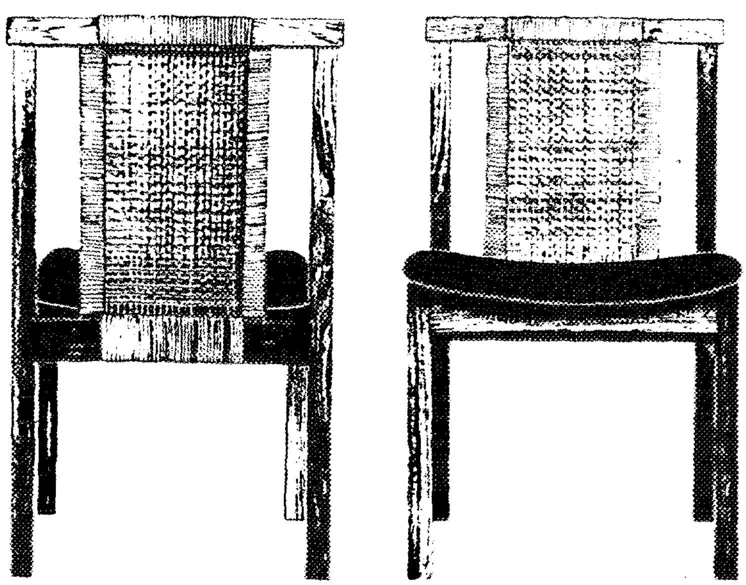


Figure 40. Steel and wooden structures combined with cane webbing and round-core webbing

Figure 41. Main joints typical of rattan furniture construction

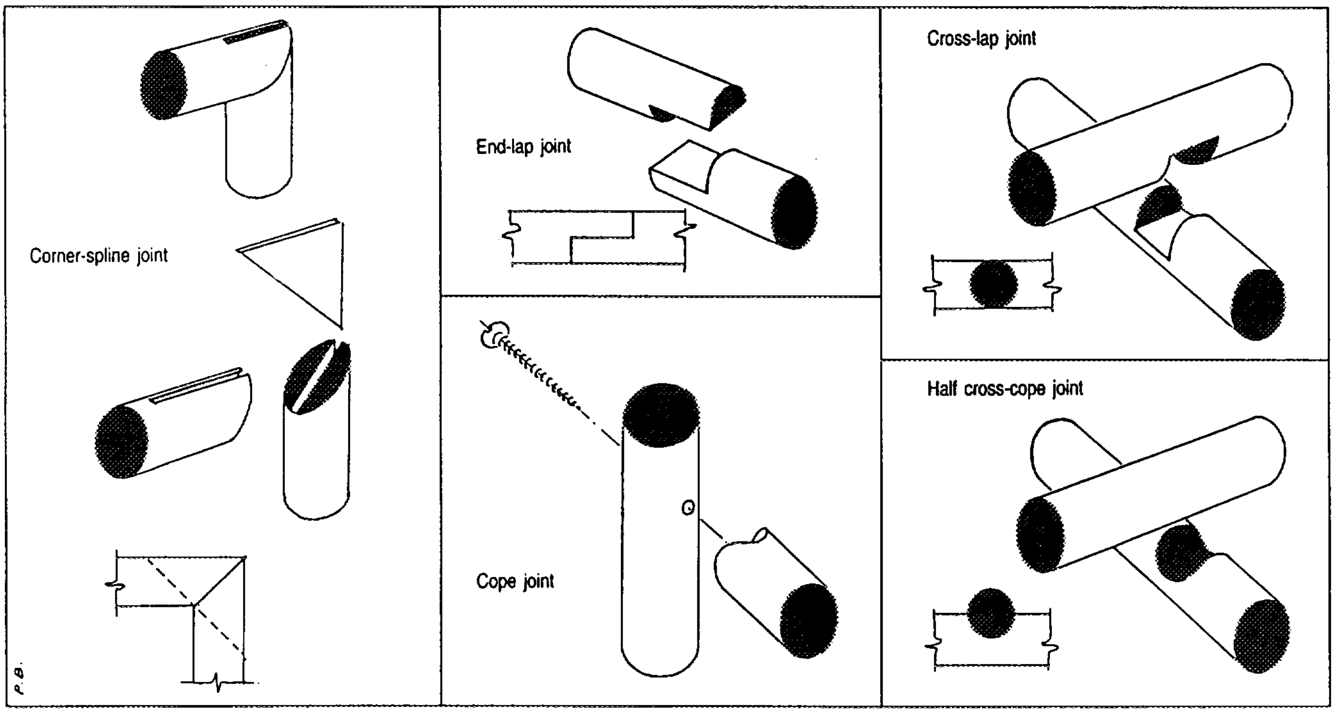


Figure 42. Ergonomic parameters

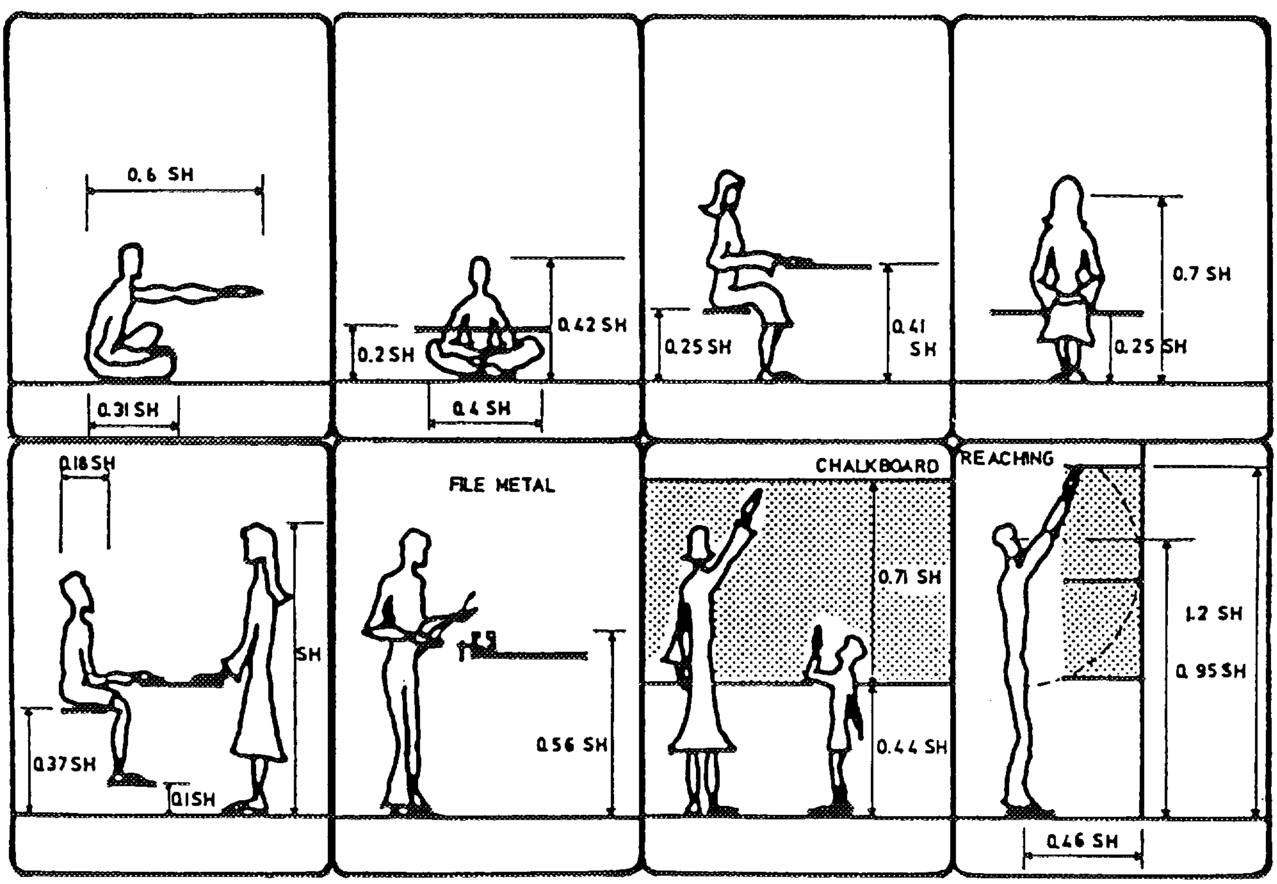
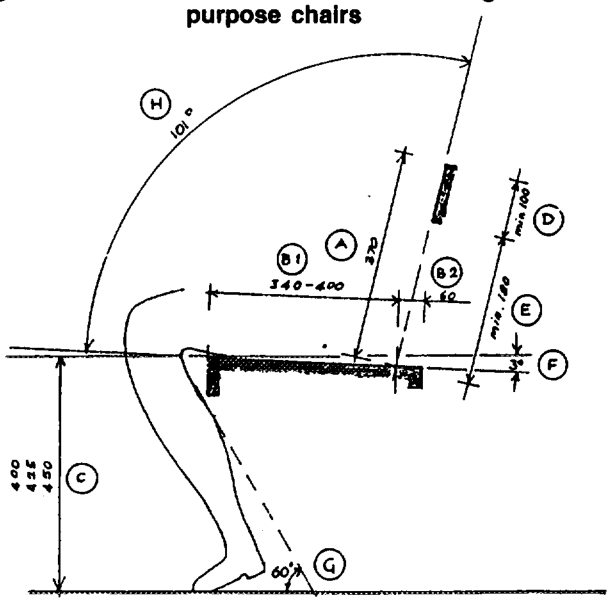


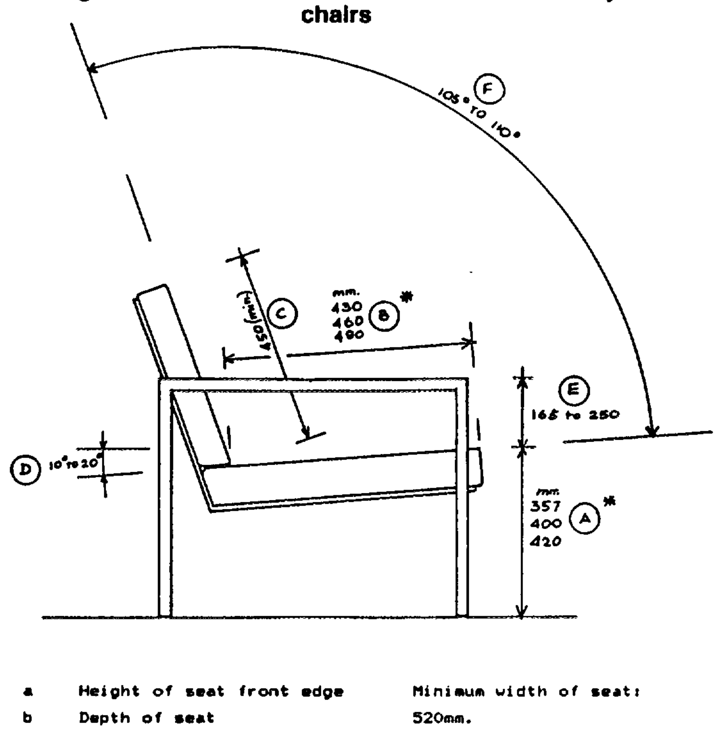
Figure 43. Recommended dimensions for general-purpose chairs



a	Height of backrest above seat
b1	Seat depth to the backrest line
b2	Seat depth behind backrest line
c	Height of seat front edge (based on the standing heights 1.60, 1.70, and 1.80m)
d	Backrest height
e	Height from seat to lower edge of backrest
f	Sitting angle
g	Leg angle
h	Angle between seat and backrest

Minimum width of seat (excluding side frames of chairs): 360mm

Figure 44. Recommended dimensions for easy chairs



a	Height of seat front edge
b	Depth of seat
c	Height of backrest
d	Sitting angle
e	Armchair height
f	Angle between seat and backrest
*	Selection of dimensions based respectively on the following standing heights: 1.60, 1.70 and 1.80m.

Minimum width of seat: 520mm.

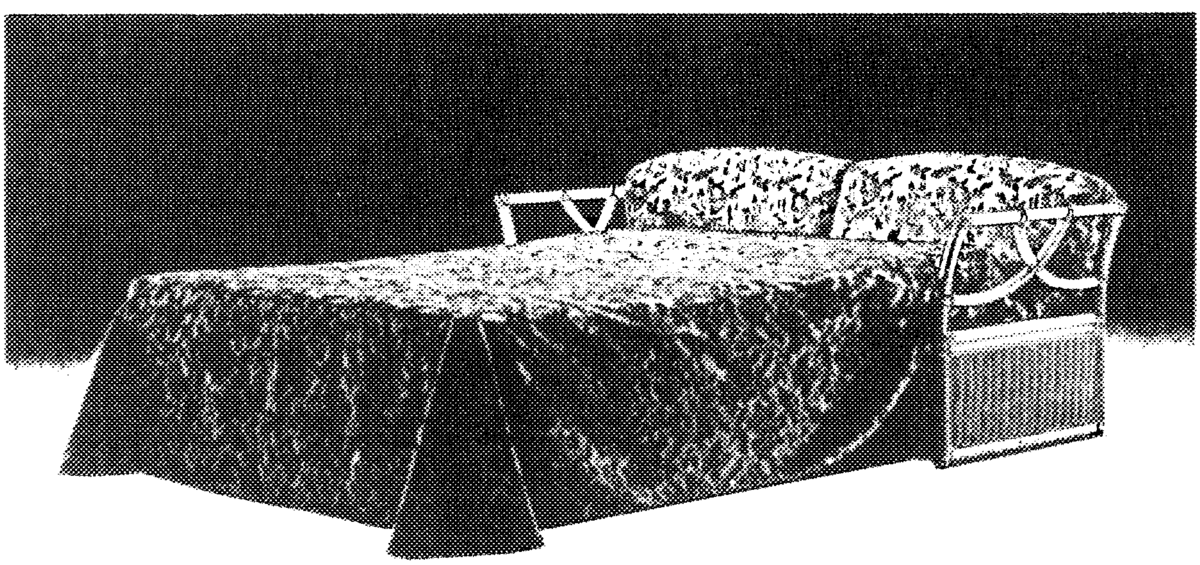
Figure 45. Recommended dimensions for dining tables

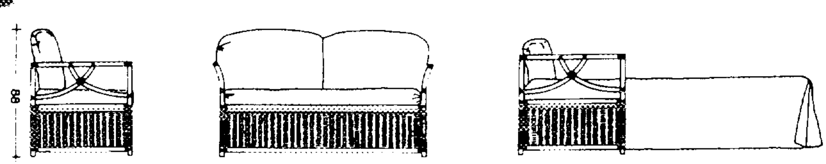
NUMBER OF SEATS	TABLE SIZE DRINKING mm	TABLE SIZE EATING mm
1	450 to 600	600 to 700
2	600 square	750 square
	750 square	900 x 950
	—	1500 x 750
6	—	1400 x 950
	—	1700 x 750
8	—	1750 x 900
	—	2300 x 750

NUMBER OF SEATS mm	TABLE SIZE DRINKING mm	TABLE SIZE EATING mm
1	450 to 600	750
2	600	850
4	900	1050
6	1150	1200
8	1400	1500

Source: Metric Handbook, The Architectural Press

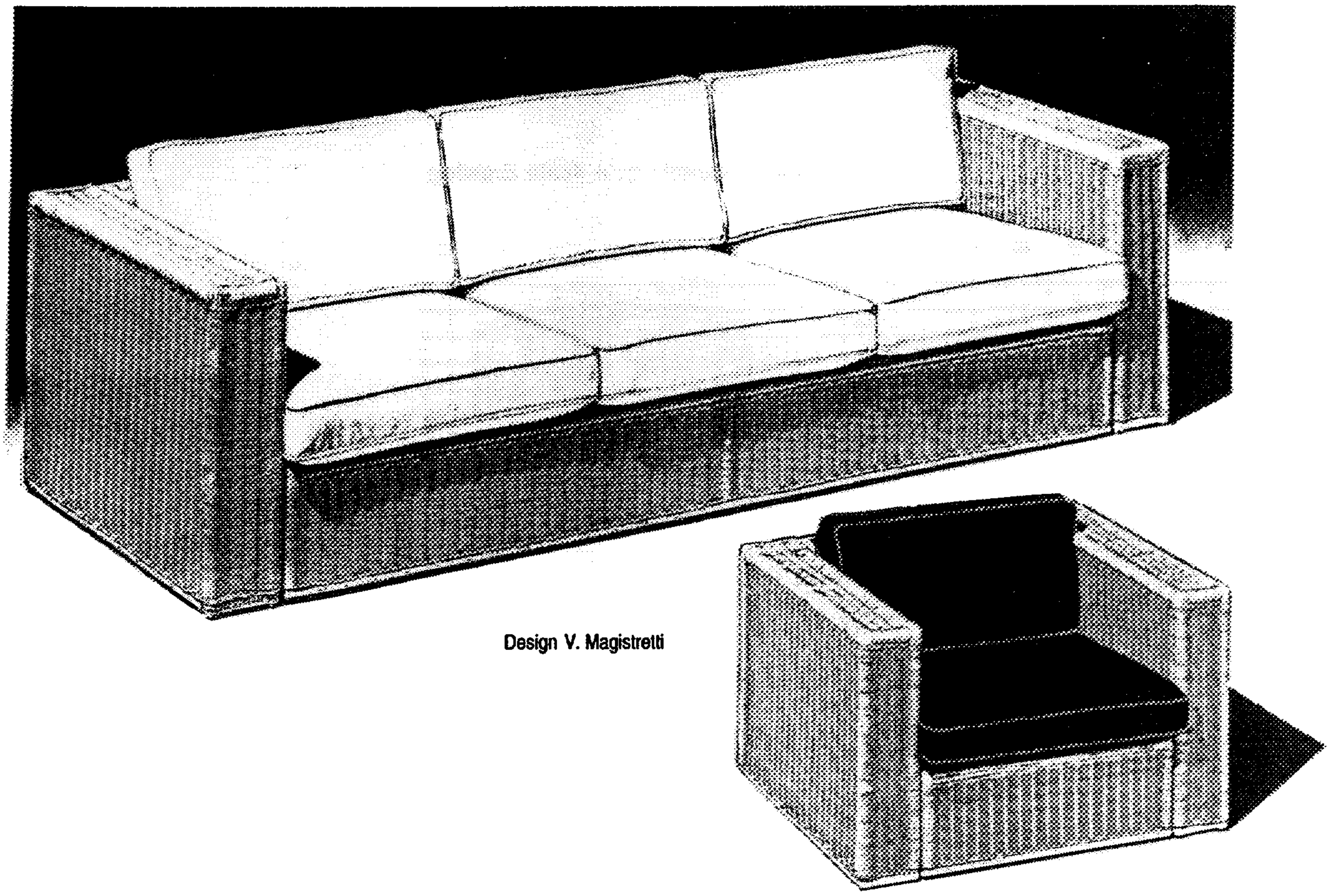
Figure 46. Example of multifunctional furniture: a two-seater settee that converts into a bed





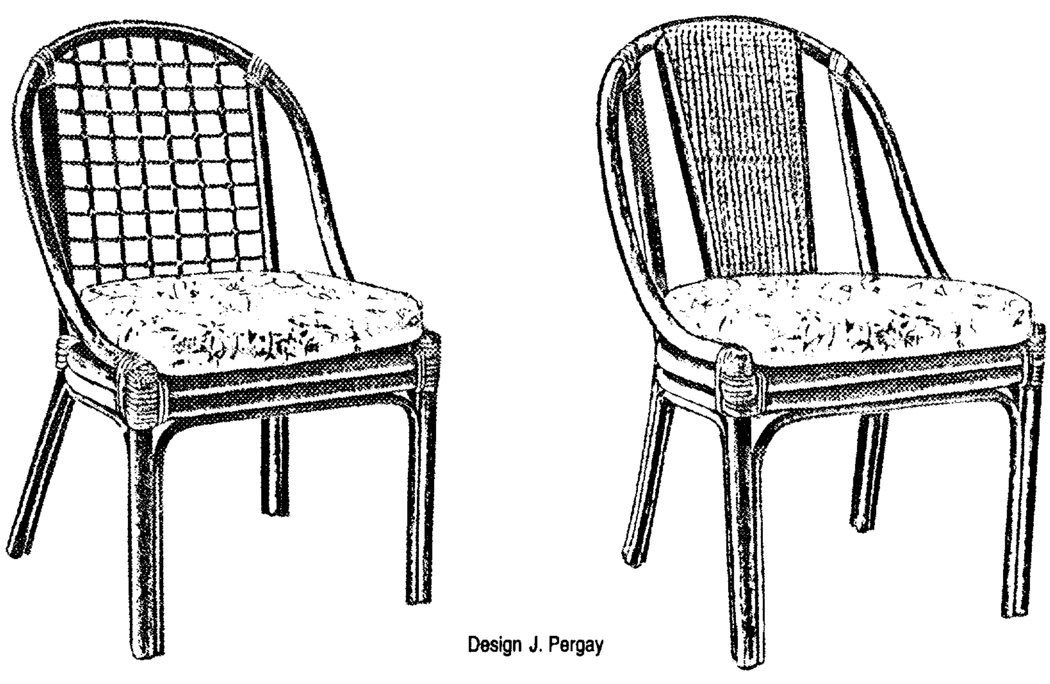
Design A. Pomponio

Figure 47. Example of knock-down rattan furniture with an interchangeable armrest component



Design V. Magistretti

Figure 48. Example of two chairs made of an identical main frame but with backrests of different designs



Design J. Pergay

Figure 49. Example of a scale drawing

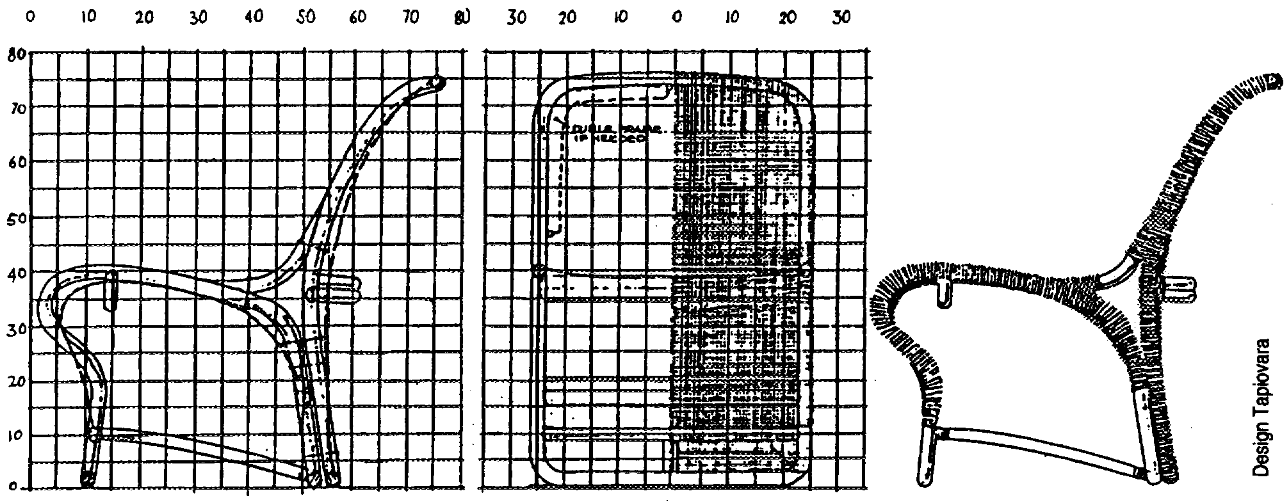


Figure 50. Example of a scale drawing

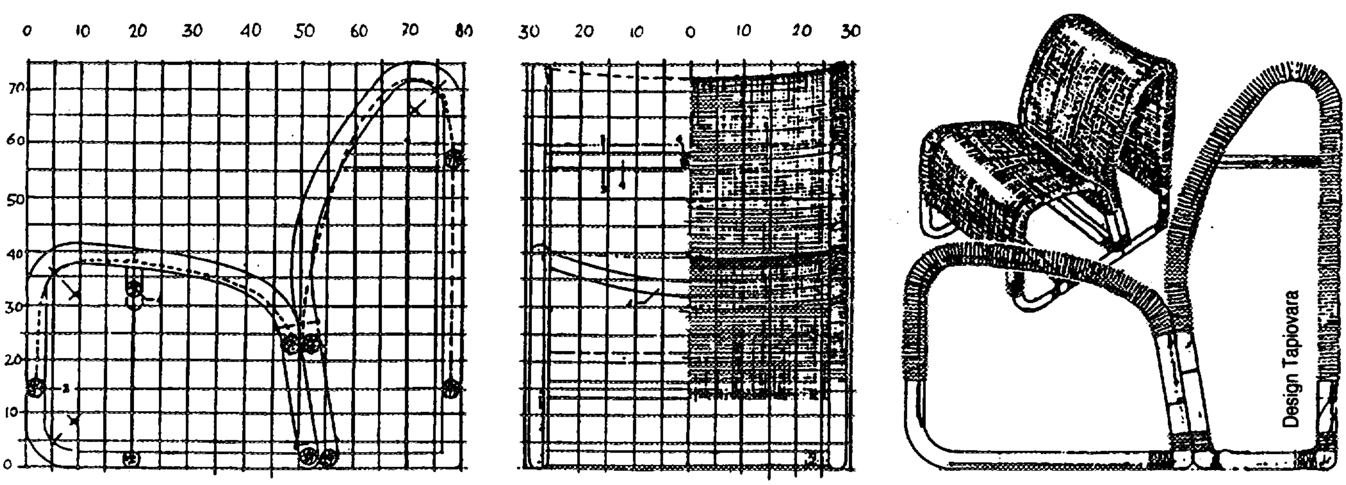


Figure 51. Example of a master bill of materials

MASTER BILL OF MATERIALS
(For wooden and rattan furniture)

Requirements for one unit													Estimated cost of materials for one unit				
Item No.	Sub ass. No.	part no. & name	Mtl. grade	Size and quantity of rough pieces				Size and quantity of finished pieces				Hidden or exposed components	Measure @ rough piece (weight or m3)	Cost @ unit meas. (per kg or m3)	Cost @ rough piece	Waste allowance	Total cost
				T or dia.	W	L	pcs. & weight	T or dia.	W	L	pcs. & weight						

Master Bill of Materials

Product description and code No. | Drawing reference Nos. | Costed by | Total cost

Figure 52. Example of a master route sheet

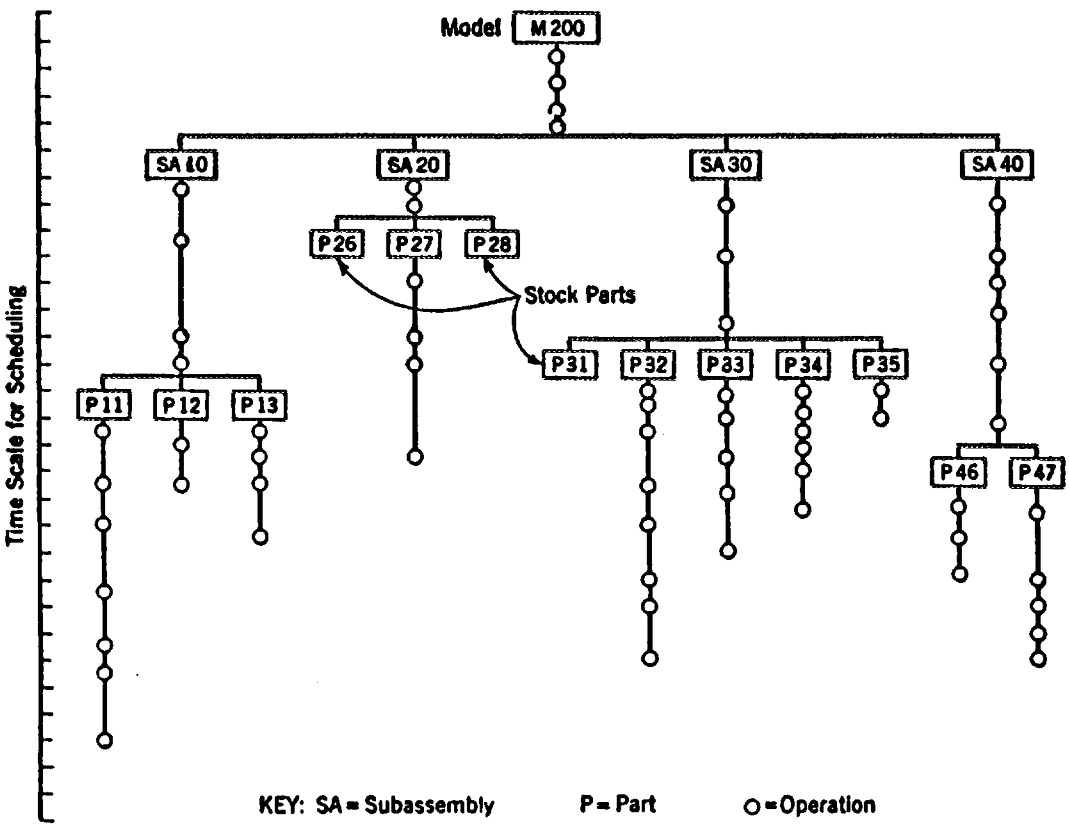
MASTER ROUTE SHEET No.
Date compiled

Model No. | Minimum economical batch size

Dept No.	Oper. No.	Part or Sub-ass. name and process description	Machine type	Templates, Jigs and tools nos.	No. of men	Std. time (min/pc.)	Set-up time	Std. time (min/batch)	Total est. time	NOTES

Master Route Sheet

Figure 53. Operation assembly flow chart



Operation/assembly flow chart

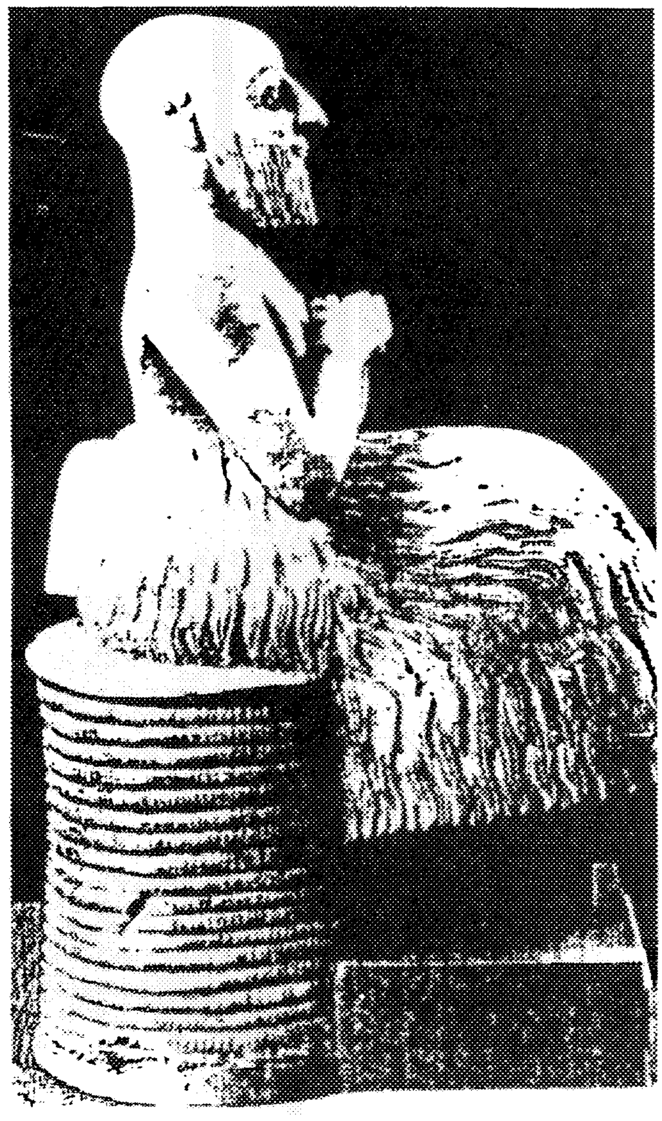
The chart is based on the estimated processing time for each part and subassembly and for the final assembly as applied to a product given batch size. It serves to determine the order of completion and the process scheduling. Parts and subassemblies requiring more processing time are started on an earlier date.

Annex I

ILLUSTRATIONS OF EARLY RATTAN FURNITURE DESIGNS*

Figure A.I.1. Rattan-like chair in a Roman bas-relief

Figure A.I.2. Sumerian stool of woven reeds, 2600 B.C.



Sources: Gabriella Rossi del Lago, *Un materiale nei secoli* (Gervasoni, 1982); *Ottagono* (furniture magazine), May 1987; "Master architects", Data sheet leaflet No. 18, issued by Cassina (furniture manufacturer), 1981.

Figure A.I.3. Chinese rattan chair dated 1870

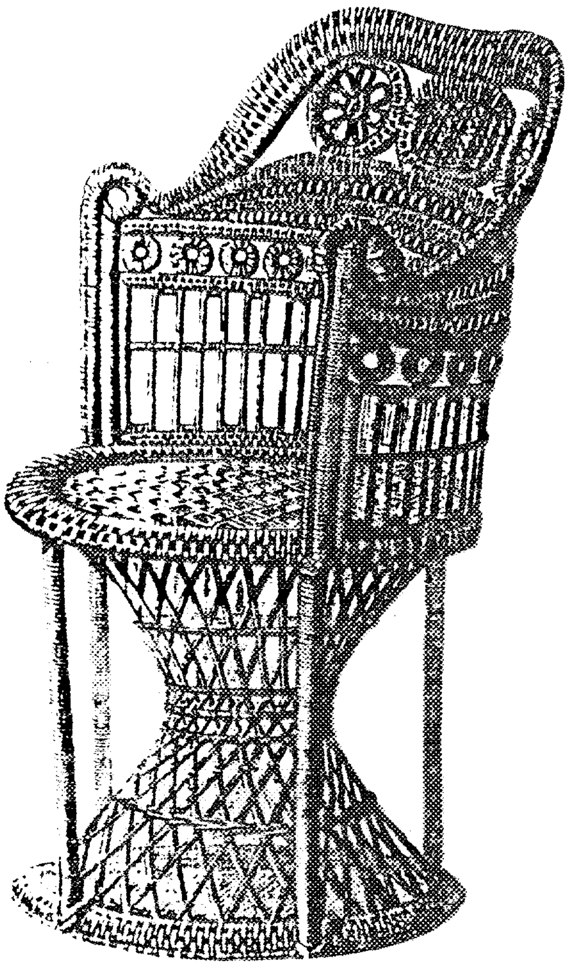


Figure A.I.4. Rattan rocking chair of the mid-1800s

Figure A.I.5. Rattan settee of the Victorian age

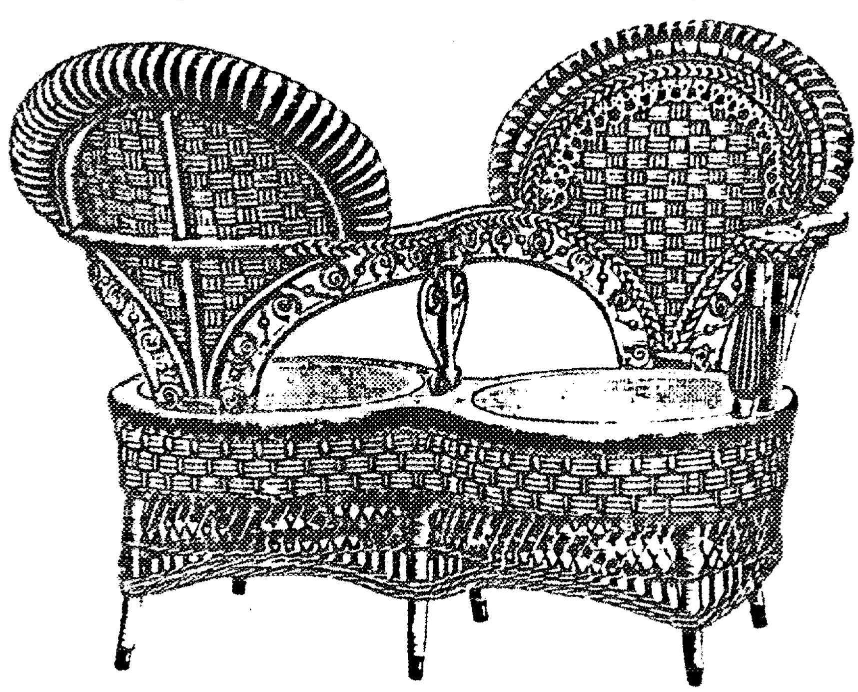
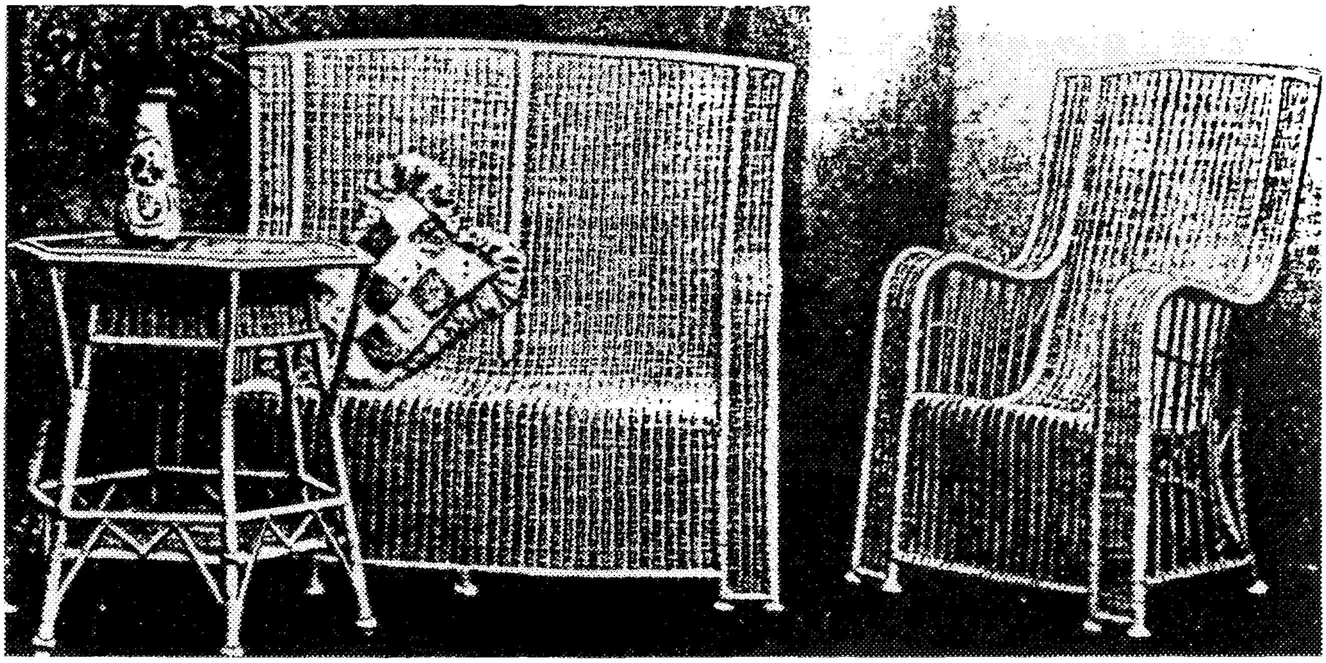


Figure A.I.6. Rattan furniture from the early 1900s



Design G. Gervasoni

Figure A.I.7. Austrian rattan furniture from the early 1900s

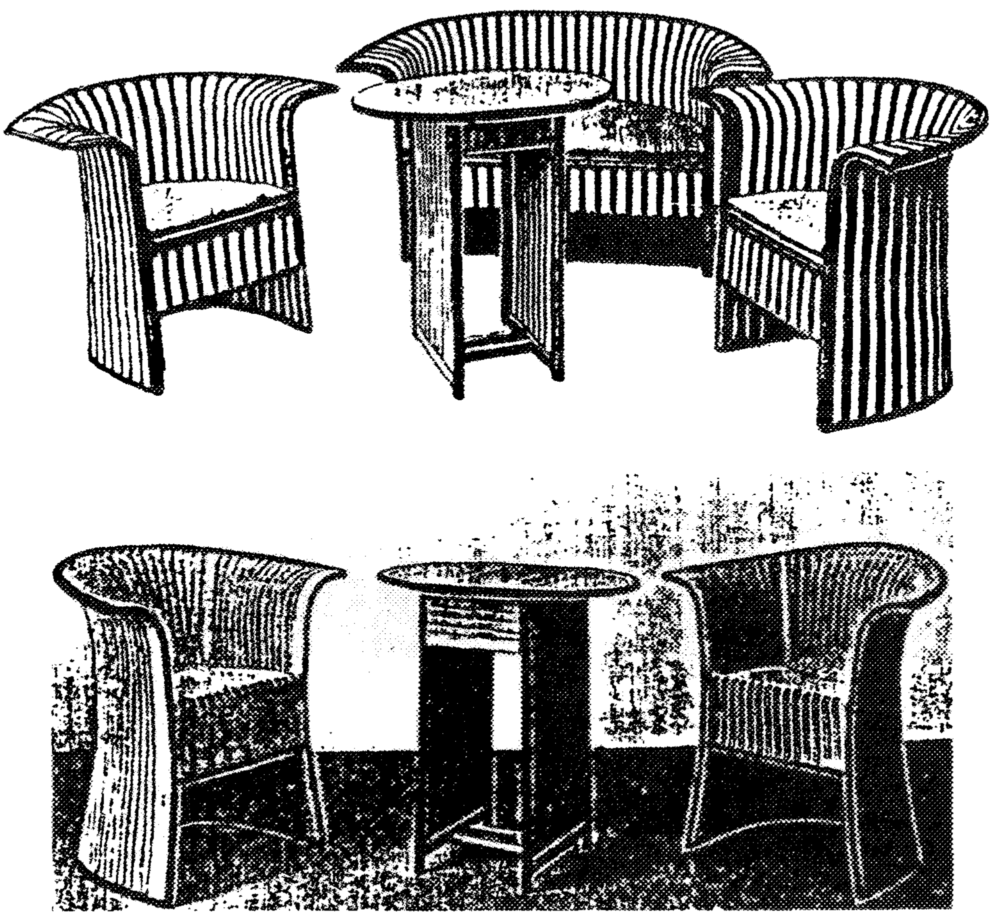
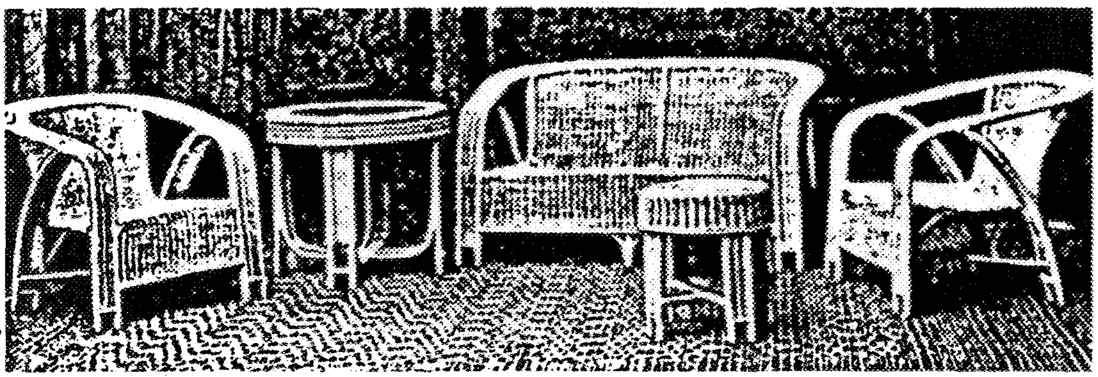
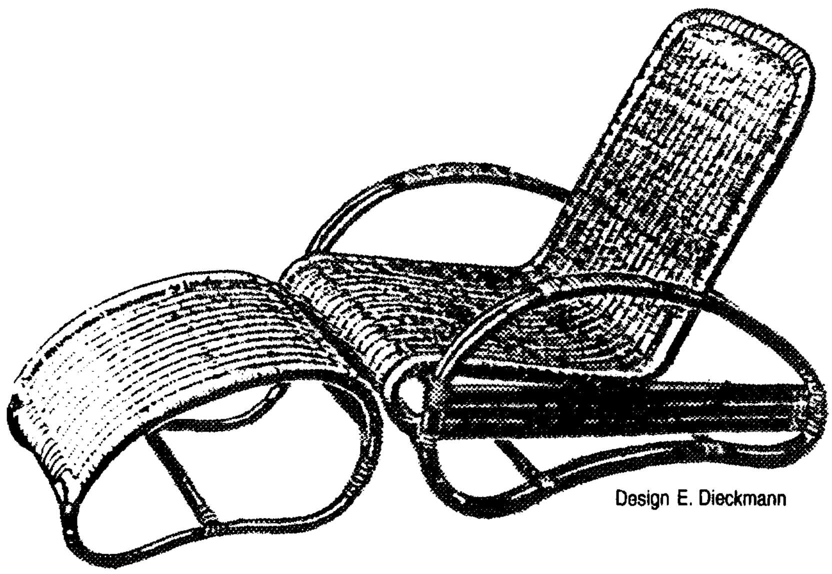


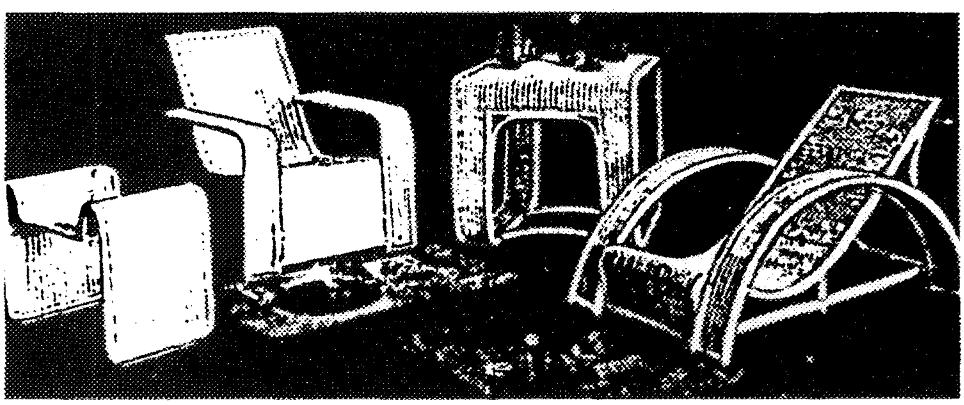
Figure A.I.8. Rattan furniture of the 1920s and 1930s



Design G. Gervasoni



Design E. Dieckmann

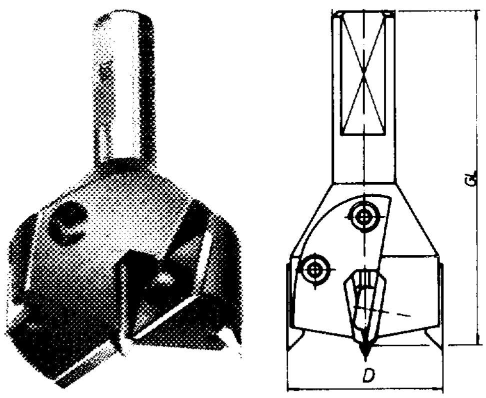


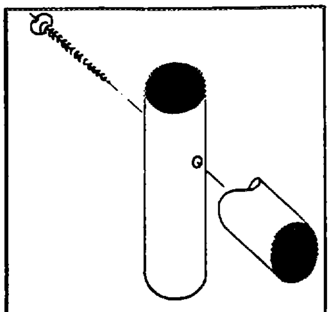
Design A. Zinelli

Annex II

SELECTION OF CUTTING TOOLS AND ASSEMBLY SCREWS

Figure A.II.1. Cope cutter for splinter-free machining of pole ends as required in cope joints not concealed by cane binding





Carbide cope cutter consisting of:

- Two disposable turnblade knives with 4 cutting edges
- 2 regrindable spurs
- Adjustable center point

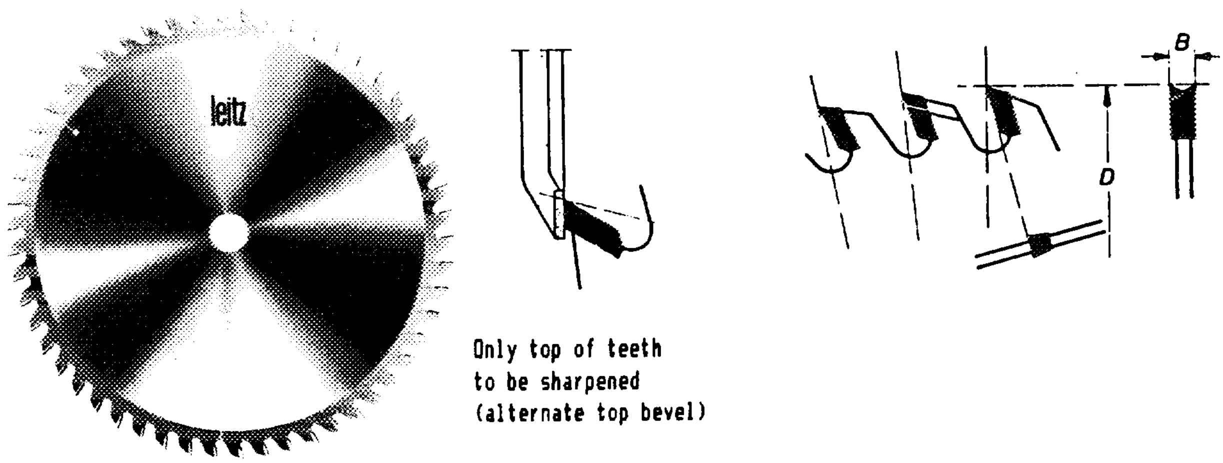
Typical cutter from Leitz (Germany), Type WL-920-0

Dimensions

Diameter	D = mm	25	26	30	35
Total length	GL = mm	54,5	54,5	54,5	54,5

Shank 10 × 26 mm

Figure A.II.2. Saw blades for splinter-free cross-cutting involving exposed rattan pole ends



Saw Type 799

For quality cross cutting of rattan rods, single or in bundles up to 60mm. thick. Also suitable for:

-cross cutting of solid wood, and cutting of
-plain chipboard and hardboard,
-chipboard plastic-laminated on one side.

Diameter	D = mm	200	250	300	350
Max. R. P. M.		9000	8000	6500	5500
Kerf	B = mm	3.2	3.2	3.2	3.2
Standard bore	d = mm	30	30/5/8''	30/5/8''	30/1''
Number of teeth Z =		42	48	60	72

All available with 1 1/4 inch bore, 250 and 300 mm dia.

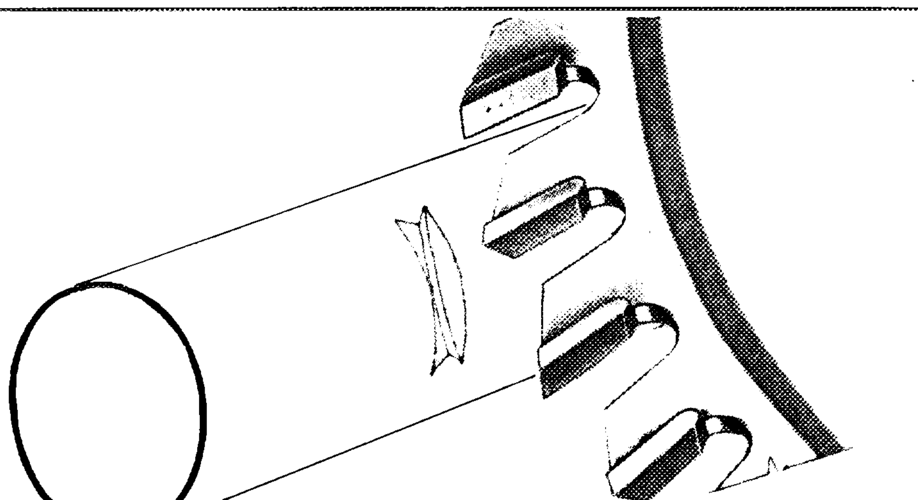
Saw Type 792

Same as saw 799 but with more teeth for higher-quality cross cutting of rattan rods up to 40 mm. thick. Also suitable for:

-cross cutting of solid wood, and cutting of
-veneer(in packs),
-blockboard and plywood,
-veneered chipboard,
-chipboard plastic-laminated on one side.

Diameter	D = mm	200	250	300	350
Max. R. P. M.		9000	8000	6500	5500
Kerf	B = mm	3.2	3.2	3.2	3.2
Standard bore	d = mm	30	30/5/8''	30/5/8''	30/1''
Number of teeth Z =		48	60	72	84

All available with 1 1/4 inch bore, 250 and 300 mm dia. with 5/8, 3/4, and 1 inch bore.



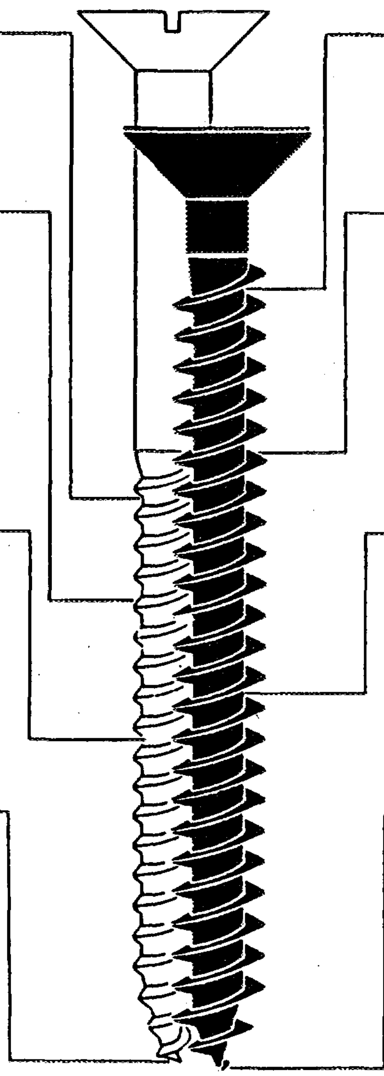
Typical saw blades from Leitz (Germany), Types 799 & 792

Figure A.II.3. Self-tapping chipboard screws suitable for structural joints and knock-down construction of rattan furniture

The comparison with conventional screws

Conventional wood screw:

chipboard screw:



Thicker screw core.
Extensive deformation of the material structure.

Thin screw core.
Low deformation of material.

Lower tear-out resistance.
The lower thread profile and the small space between the individual threads offer only low tear-out resistance.

High tear-out resistance.
High, load bearing thread profile and a lot of space between the threads make for extremely high tear-out resistance.

Higher material risk and troublesome insertion.
The materia is unhardened and the screw has no slide coating. The consequence: Risk of breakage and high screwing torque.

Case-hardened steel with plastic coating.
chipboard screws bore themselves into chipboards and wood. Without pilot-drilling.

First drilling, then screwing.
The tip, a thick screw core and a low thread profile make pilot-drilling necessary for all screw-joints.

Screw insertion without pilot-drilling.
A special tip guarantees exact positioning. A thin screw core and sharp threads make screw-joints without pilot-drilling possible.

Typical self-tapping screws from Wurt UK Ltd, 34 Bowater Rd., Woolwich, London SE 18 5TF, UK

Annex III

PHILIPPINE STANDARD SPECIFICATION FOR RATTAN AND WICKER FURNITURE

This standard specification is hereby promulgated under a fixed designation, PS (Philippine Standard) No. 821-09.03; 1976.

This standard was prepared by the Technical Committee on Furniture and Fixtures with the full cooperation of the Chamber of Furniture Industries of the Philippines.

Suggestions for revision should be addressed to the Philippines Bureau of Standards, P.O. Box 3719, Manila.

1. Scope

1.1 This standard specifies requirements for rattan and wicker furniture.

2. Definition

2.1 For the purpose of this standard, the following definitions shall apply:

(a) Rattan Poles. It is a common term that applies to the various species of tropical climbing palms composing the genera *Calamus* and *Daemonorops* of the family Palmae;

(b) Rattan Round Core. Sometimes called "wicker", refers to round-shaped material, with size ranging from 2 to 10 mm in diameter, processed from the core of the rattan pole, usually used for weaving;

(c) Rattan Flat Core. Refers to the flat-shaped material, with size ranging from 2 to 10 mm in width, processed from the core of a pole and used for weaving and binding;

(d) Rattan Peel. Also "rattan split", refers to flat-shaped material, stripped from the skin of a rattan pole, with size ranging from 2 to 10 mm or wider in width, usually for weaving and binding;

(e) Check. A separation of the fibers along the pole forming a crack or fissure in the rattan, not extending through the piece from one surface to the other;

(f) Shake. A separation of the fibers along the pole, caused by stresses developed in the gathering and cutting, or due to improper processing;

(g) Break. A separation of the fibers which extends through a piece from one surface to the other usually perpendicular or at right angle to the directions of the grains;

(h) Blemishes. Dark spots or discolorations in rattan poles caused by staining fungi or mineral stains.

3. Material Requirements

3.1 Rattan Poles. The rattan used in the construction of furniture shall be the "palasan" or similar variety and shall be of good grade poles: mature, clean, scraped, thoroughly seasoned.

(a) Rattan poles used for local and export market shall be treated against fungi and insect infestations, and thus, free from mineral and fungal blemishes, scar, bruise and specially pinholes;

(b) All poles are to be treated with pentachlorophenol or saline solution to safeguard against insect-borers;

(c) Checks, Shakes and Breaks. Checks and shakes shall be permitted provided that they do not exist in close proximity to holes and grooves as to affect the strength. Breaks, however, shall not be permitted;

3.2 Rattan Core and Peel. The rattan core and peel used for weaving and binding furniture shall be of good quality processed from grade rattan poles preferably of the "sika" variety. Rattan core or peel used shall be of uniform diameter or width respectively.

3.3 Wood. All wood materials used or incorporated into rattan furniture such as seat frames, doors, cabinet, etc. shall conform to PS Specification for Wooden Furniture, Section 3.

4. Construction

4.1 All furniture complying with this standard shall be of good workmanship and all components including those not specifically referred to in this standard such as materials used in constructing the metal and wooden parts, springs, cushions, upholstery shall be of a quality at least equal to that used in recognized good practice in the trade.

(a) Rattan joints for main members and stress joints shall be snugly fitted and secured to adjoin members by nails, screws or bolts, and bound with rattan flat peel or core, or other binding materials glued on to the rattan, so as to withstand normal daily wear and tear;

(b) All main members and stress joints shall be of the concave-cut fitted type or dowelled type of construction;

(c) All joints of rattan rings used for the seats or for support purposes shall be the half-lap type nailed and glued together;

(d) All wood jointings shall follow the PS Specification for Wooden Furniture, Section 4.

5. Finish

5.1 All rattan and wood surfaces shall be sanded smooth and all exposed edges and corners shall be eased. All holes, checks and shakes shall be filled and stained or toned to match color of rattan parts. Exposed nails, screws and bolts shall be countersunk with the holes with plastic wood fillers and/or wooden or rattan plugs flushed and sanded smooth before finishing.

5.2 Furniture finish shall be in accordance with any of the following:

(a) Lacquer or nitro-based clear finishes;

(b) Cellulose acetate butyrate (CAB);

(c) Acid catalyst clear lacquers;

(d) Polyurethane;

(e) Oil or wax;

(f) Polyester.

5.3 All materials used for juvenile furniture shall be of the non-toxic type.

5.4 All polished, painted or otherwise finished surfaces shall be of good workmanship and brought to a durable finish.

5.5 There shall be no excessive stickiness or surface disfigurement of any type such as blistering, marking or change of colour when the furniture is subjected to dry heat. (See Specification for Wooden Furniture PS 821-01.09; 1976).

6. Sampling

6.1 Up to three furniture shall be selected at random for testing. Should one of these fail to pass the tests, the inspector may select as many additional furniture as are necessary within reasonable limits, to satisfy himself of the manufacturer's normal standards of production.

7. Performance Tests

7.1 The main objective of these series of tests is to determine, by the application of simulated loads and related stresses, whether a given manufacturer's products, specifically load-bearing members and joints hereof, can reasonably withstand normal use.

(a) The manner of testing herein described represents the most simple procedure that has been found workable in a majority of furniture, especially chairs. There will, however, be cases in which the design precludes the use of this particular procedure. In such cases, the tests to which the furniture are to be submitted shall be derived from the same principle as the standard test, using other means of applying either the same load or loads that have a similar effect.

7.2 Inspection before Testing

(a) Immediately before testing, each sample shall be inspected and any apparent defects noted, so that they shall not later be recorded as having been caused by the tests. A report on such defects shall accompany the report on the performance tests and these shall be taken into account in assessing whether the article has complied with the requirements of this standard.

7.3 Test Procedure

(a) Each sample shall be subjected to the series of tests specified in Section (4) the tests being carried out in that sequence;

(b) If during or after any of the tests described in 7.4 relative movement is apparent between the members at any joint and it is established that the joint is broken in such a way as to impair its serviceability, the furniture shall be deemed to have failed to pass the performance tests;

(c) If failure of a joint is recorded, or if for any other reason the furniture selected for testing is deemed to have failed to pass the Performance Tests of this standard, the testing of that article shall be discontinued and no further sections of the test procedure shall be applied to it;

(d) If any of the tests specified in 7.4 would cause local damage or is inappropriate for any other reason, it shall be replaced by a test or tests based on the same principle (see 7.1).

7.4 Tests

(a) Test Samples. Samples selected at random in accordance with 6.1 shall be tested as specified herein;

(b) Level Test (all items). Casters or glides shall be removed. Items shall be placed on a flat level surface plate. All legs shall simultaneously rest on the surface plate. Any evidence of rocking when light force is applied at any corner shall be cause for rejection;

(c) Sand Bag Test (chairs and sofa frames). These items shall withstand six impacts of a 29.5 kg (65 pounds) sand bag, 30.48 cm (12 inches) in diameter at dropped end, a distance of 106.68 cm (3.5 feet) in each of the following locations: (a) directly over a leg, (b) midway between the legs on the side frame members and (c) on front frame rail at midpoint;

(d) Impact Test. Chairs shall withstand 12 drops from a height of 91.44 cm (3 feet) above a concrete floor. The chair shall be tilted to an angle of 12 degrees diagonally across the plane of the feet to insure that one leg receives the initial impact;

(e) Diagonal Load Test. Chair shall be laid back in such a way that the front edge of the seat is directly above the feet or the rear legs. Apply a vertical load of 68.04 kg (150 pounds) to the front edge of the seat. The force shall be applied and completely removed steadily during periods of not less than 5 seconds for 20 times;

(f) Static Load Test (chair frame with deck). A static load of 68.04 kg (150 pounds) sand bag shall be applied vertically over a 30.48 cm (12 inches) diameter area in the center of the deck and allowed to remain for 15 minutes. Upon removal of the load, there shall be no evidence of breakage or loosening or separation of frame joints;

(g) Static Load Test (tables). The height of the table shall be measured accurately. A static load of 45.36 kg (100 pounds) shall be applied vertically over a 30.48 cm (12 inches) diameter area in the center of the table top and allowed to remain for 30 minutes. Upon removal of the load, the height shall not have decreased by more than 0.31 cm (1/8 inch) and there shall be no evidence of breakage or separation of joints.

7.5 Criteria for Success

(a) No part of the furniture or its components or fittings shall develop any fracture, or any apparent loosening of a joint intended to be rigid, or any deformation which would adversely affect any of its functions;

(b) Each sample tested shall fulfil the conditions of the test described in 7.3 (b);

(c) Each sample tested shall sustain each of the forces described in 7.4.

8. Marking

8.1 Each furniture complying with this standard shall be marked with the PS Certification Mark.

Note: The use of the PS Certification Mark is governed by the provisions of Standards Administrative Order No. 20, series of 1968, "Rules and Regulations Providing for the Marking of Goods Standardized by the Bureau of Standards and for Other Purposes". This mark on a product/producer is a guarantee that the product is in conformity with the standard. Details of condition under which a license to use the PS Certification Mark may be granted are obtainable from the Bureau of Standards, P.O. Box 3719, Manila.

Annex IV

THE VALUE ANALYSIS CONCEPT

Introduction

Value analysis is a continuing process of equating costs with the function of a product with a view to simplifying the product and improving the profit without unduly sacrificing quality or reliability.

Although value analysis is not a new concept, its application in small-scale furniture manufacturing firms in developing countries has been relatively slow to find acceptance. This hesitancy may not last, because the cost-price squeeze being felt in most developing countries will demand that quality furniture products be delivered at minimum overall cost.

There is a similarity between value analysis and methods engineering or even the work study process, both of which also lead to improved productivity or profit. However, value analysis focuses on functions, while the other two focus on methods. The following may be said of any value analysis initiative taken in a furniture manufacturing operation:

(a) It is a systematic and creative approach to cost reduction;

(b) It pinpoints areas where excessive and unnecessary costs are incurred;

(c) It enriches the value of the product in general as well as the value of each component;

(d) It generates the same, if not better, product performance at a lower cost;

(e) It does not sacrifice quality or reliability.

Value analysis methodology

In conducting a value analysis exercise in a furniture manufacturing firm, a five-step process may be employed. This ought to lead to product improvement, as depicted in figure A.IV.1.

The basis of value analysis is the brainstorming technique, in which members of a group come up with spontaneous ideas for tackling a problem. This technique also affords an opportunity to seek the cooperation of the workforce. For best results, the following sequence should be adopted:

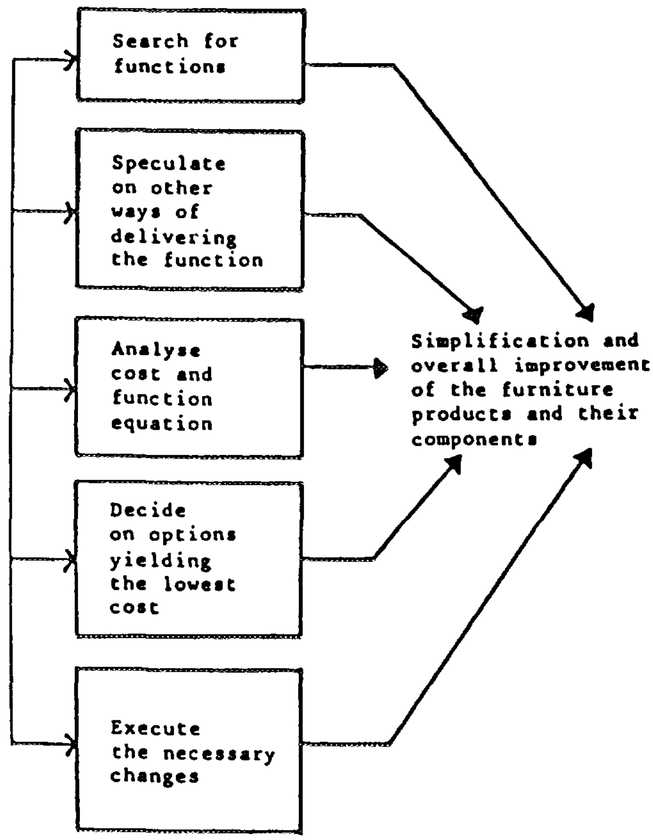
(a) State the problem;

(b) Carefully select members of the brainstorming panel. It should never be assumed that membership must be restricted to the firm. Outsiders such as suppliers or government-sponsored industrial extension officers can be invited to participate;

(c) Give the panel members 10-20 minutes to write down their ideas on the problem;

(d) Encourage the panel members to continue generating ideas while each member in turn presents his own. As the aim is to generate as many ideas as possible, even seemingly unrealistic ones should be welcomed. No idea should be criticized. The combining of ideas should be encouraged;

Figure A.IV.1. Value analysis methodology (brainstorming technique)



(e) Subject the ideas to an initial screening, but only after step *(d)* has been completed. Should the results of the first brainstorming session be unsatisfactory, schedule another session, this time using a more refined formulation of the problem.

Brainstorming aside, it will be recalled that systematic value analysis involves five basic steps, as depicted in the figure: A.IV.1, search, speculate, analyse, decide and execute.

Search

The search step consists of gathering information and defining function. Assuming that a group has already been assembled to apply brainstorming techniques to a particular furniture product, the first stage of the search activity will be to present all the appropriate background information to the panel: the cost of manufacturing, the intended use by the customer, inventory levels, materials billing, flow process charts, flow charts, time studies and the like. After this has been done, the panel prepares for the next stage, function definition. It must be borne in mind that there are four types of function: the utility, or use, function; the aesthetic, or attractiveness, function; the possession (pride in possessing), or esteem, function; and the resale, or trading, function. Small-scale furniture manufacturers will be concerned mainly with the utility and aesthetic functions.

Functions can also be categorized as primary, secondary and tertiary to give an idea of their relative priority. Care should be taken to specify the various functions of the parts of the products and to equate the proper cost estimates for each component with the function of the component.

Figure A.IV.2.illustrates the result of the search step in a value analysis exercise carried out for an ordinary felt blackboard eraser. It will be readily observed that the main function, to erase writing, can be delivered at an estimated cost of 0.30 currency units when performed exclusively by the felt-strip component of the product. This gives ample potential for product simplification and improvement.

The search step is sometimes impeded by one or more of the following: inadequate information; the basing of decisions on beliefs rather than on facts; and an imprecise definition of function.

Figure A.IV.2. Example of search phase; value analysis of a blackboard eraser

Product: Blackboard eraser (felt)

Function: Erase writing

Parts	Functions	Estimated costs (I.C.)
Plywood	Hold felt strips	0.60
Felt	Erase writing (chalk)	0.30
Glue	Hold felt strips / Plywood	0.05
Label	Identify manufacturer	0.20
		1.15

Speculate

This step involves the systematic consideration of the various options open in delivering the function to the customer. Before the panel generates option ideas in a brainstorming session, the following are some of the questions that should be answered: Is this function necessary? How else, other than the way in which it is being done today, can the product deliver this function? Which product components do not make a significant contribution to the main or primary function? The owner-manager, in speculating on alternative ways of delivering the intended product function, should set targets for the brainstorming panel, e.g. reduce the cost of the components by 50 per cent. This may force the panel to enter areas hitherto unexplored. It must be remembered that the aim of the speculation exercise is to find out what else can perform the same function.

Analyse

This step is concerned with the analysis and weighing of all the ideas on cost implications, function and feasibility collected in the previous step. In this step, monetary values are assigned to the ideas, and the value or contribution of the ideas is questioned. At this point, the intention is not to eliminate ideas but to analyse them to determine or enhance their feasibility and workability. If the brainstorming sessions have generated only "conceptual" ideas, the details of these ideas should be worked out before taking the next step.

Decide

This step contains two substeps: additional information and decision/promotion. As was mentioned in the preceding step, the workability of an idea needs to be assured. In the first substep, specialized advice should be sought on those issues that need clarification before deciding to implement an idea. The decision/promotion substep implies exercising judgement in choosing an idea and planning a campaign to enlist the support of those workers who may be affected, directly or indirectly, by the final decision.

Execute

At this step, each promising idea is appraised and evaluated. During the evaluation, additional information may be generated and used to improve on the original idea. The panel can then decide on the appropriate action to be taken for each idea evaluated. Recommendations for action can include dropping the idea; shelving it for a number of years; implementing it in the next batch; or implementing it immediately. The execution step ends when the likely outcome of an idea—better product design, cost reduction, improvement in current practices and methods etc.—has been determined.

Applying value analysis

The application of value analysis in a furniture manufacturing operation calls for five actions:

(a) The setting up of a panel with its own rules of procedure and terms of tenure; this panel will be responsible for the value analysis exercise. Membership may include the staff of the firm and others in a position to contribute to the improvement of the firm's products, practices and methods. As a rule, those selected for the panel should have a questioning attitude and be persistent, imaginative and tenacious in their work;

(b) The establishment of a procedure for the systematic pinpointing and review of high-cost items in the firm. Existing arrangements for cost-reduction programmes, suggestion-gathering and the like can be tied in with the value analysis effort;

(c) The holding of regular panel meetings to evaluate the results of past initiatives, discuss current projects, apply brainstorming techniques to new products or ideas and establish pertinent courses of action;

(d) The conduct of value and function tests on the product and its components to determine the following:

- *(i)* If their cost is proportionate to their value or usefulness;
- *(ii)* If there is anything better available that can be used for the same purposes;

(iii) If they can be produced at a lower cost using improved methods;

(iv) If any other firm is producing the same product or component for less;

(v) If standardized, marketable products can be produced;

(e) The keeping of thorough and accurate records of all the ideas put forward, the deliberations on them, suggestions for their improvement etc. Reports on all projects, successful or not, should be filed. The record of a project that has failed to generate usable results can be kept to forestall future similar ventures or to start a new project at the point where the previous attempt began to fail.

Value analysis and cost reduction

When value analysis is first introduced, the panel members may suggest that the exercise has been carried out before, but in the context of cost reduction. And, indeed, there would appear to be no significant difference between the two. Yet a difference does exist: it lies in the fact that value analysis means sustained, planned change, while cost reduction means intermittent, partially sustained change. Value analysis can also lead to benefits other than cost reduction. The most important of these is product standardization and simplification.

Case study of a safari chair

The case study is for a light chair called "Safari". Made of white pine and canvas, the chair was exported in knock-down form, in a carry-away package. The company producing it felt that there was a market niche for that type of a chair, but retailers suggested that the price was a bit too high, that the design could be slightly changed and that the chair was not very comfortable.

The marketing manager wanted to improve the value of the product and suggested to management that the chair be given a value analysis. Figures A.IV.3 through A.IV.11 reveal how value analysis was able to modify the chair to meet these identified concerns.

Figure A.IV.3. Job definition and basic information form

JOB DEFINITION AND BASIC INFORMATION (form No. 1) 82-03-31

Product SAFARI

Project No. 82-07

Part

Drawings No. 78-52

Price/pcs about 140 FIM

Pcs/year about 2000

Cost/year 90.5 × 2'000 = 181 000

Goal savings 10 per cent = 18 100 FIM/year

Estimated costs 25h × 50 + 1000 2 250 FIM

Savings/first year 15 850 FIM

Time reserved TWO MONTHS, 25 man-hours

Project team Co-ordinator: A.J.

Members K.E, HL, PH, JP

Time and place of meeting TUESDAYS 9 a.m. to 11. a.m

Definition of the depth of the analysis and parts and properties that have to be retained

- A SAME KIND OF PRODUCT FOR THE SAME MARKET, EVEN ABOUT THE SAME PRICE RANGE ?, OR A LITTLE LESS EXPENSIVE
- CHANGES IN DESIGN ACCEPTABLE
- RAW MATERIALS : WOOD & CANVAS

Appendices DRAWINGS

PRODUCT CALCULATIONS

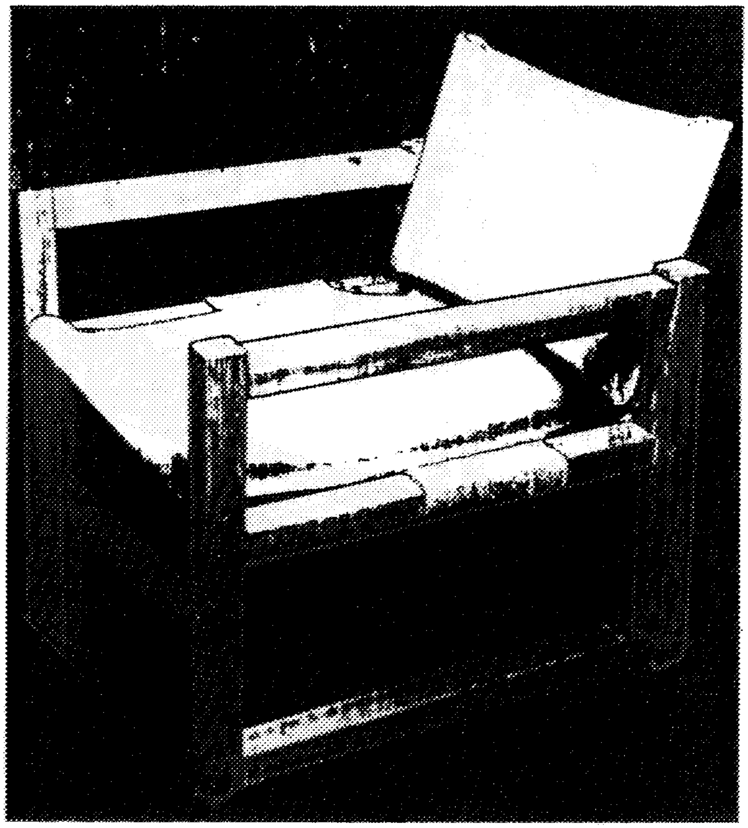


Figure A.IV.4. Safari chair before value analysis

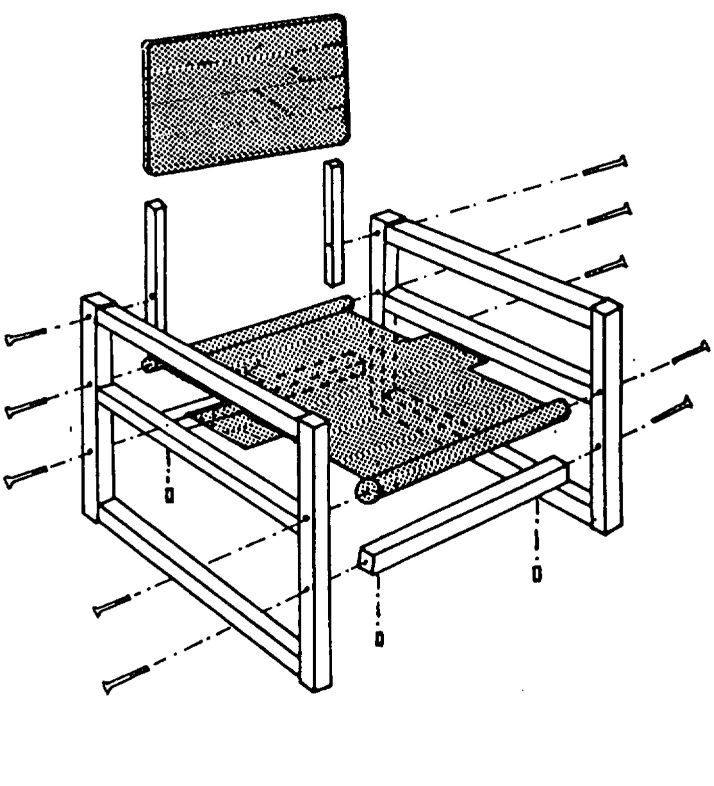


Figure A.IV.5. Safari chair to be analysed

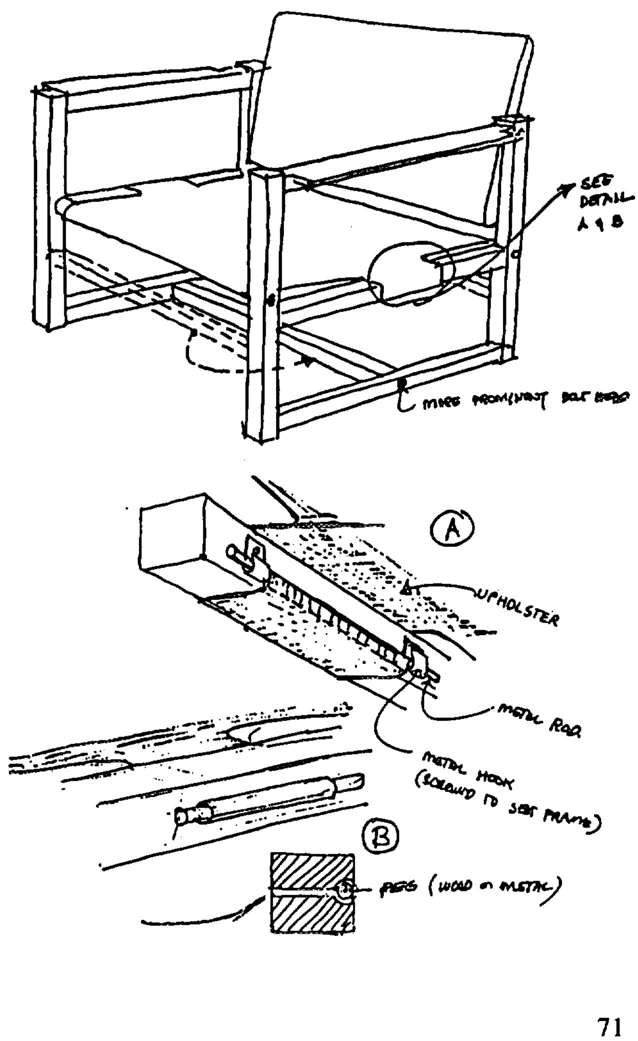
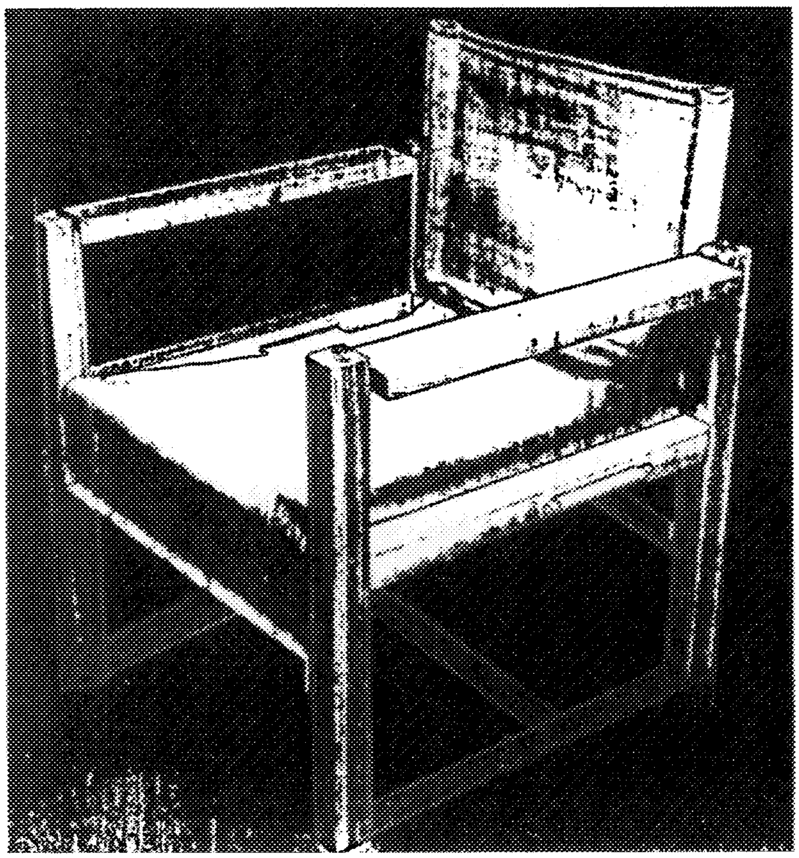


Figure A.IV.6. Sketches the designer made in the creative phase

Figure A.IV.7. The new safari chair



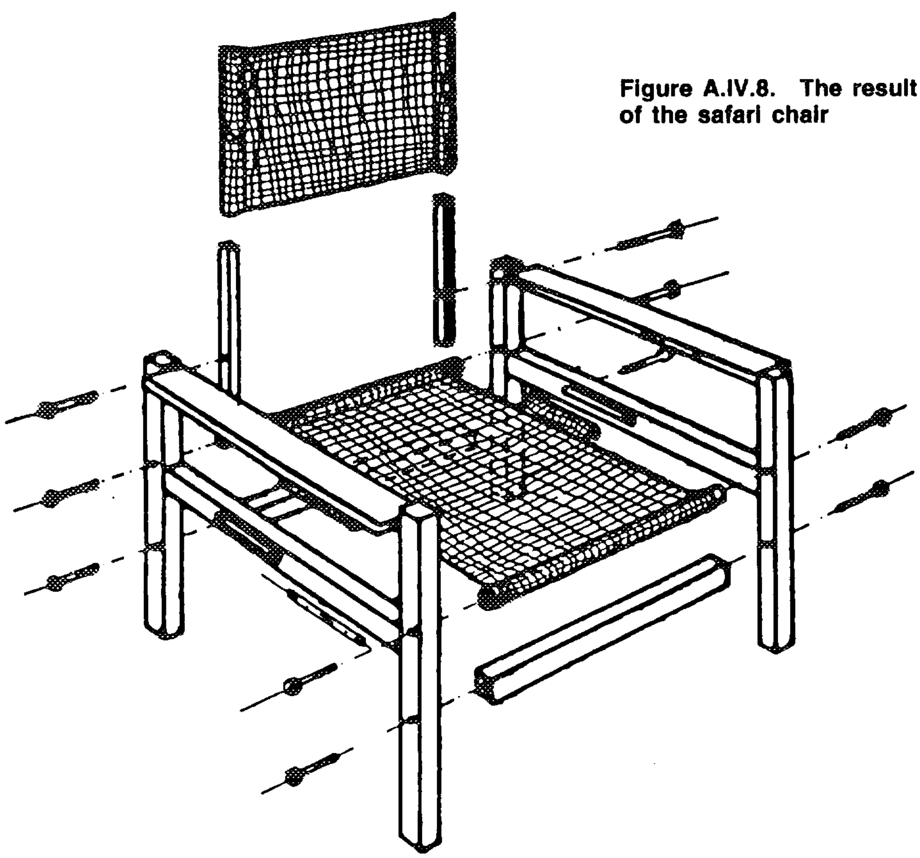


Figure A.IV.8. The result of a case-study analysis of the safari chair

Figure A.IV.9. Function analysis on form No. 2

FUNCTION ANALYSIS (form No. 2) Page 1

Product SAFARI | Project No. 82-07 | Date 82-04-06

Part	Main function	Other functions
The CHAIR	To allowe siting - for one person - comfortably ? In second living room or at country side house	Functions as part of pine furniture set
SIDE - upper part	As armrest	Construction Strength
- middle part	Construction	Strength Allowes otaching of canvas
- lower part	Design	Construction ?
LEGS - front	Construction	
- back	Constr.	Design ? All. attaching of the Back
FRONT CROSS BAR	Strength	
BACK CROSS BAR	—"—	
SEA - Canvas	allowes sitting	Design
- Side part of canvas	gives strength	Design

FUNCTION ANALYSIS Page 2

Product SAFARI | Project No. 82-07 | Date 82-04-06

Part	Main function	Other functions
SEAT cont'd - wood pcs	Joints	
- round sup-ports	Construction Strength	Roundness gives comfort
	Joints (canvas)	
- screws	Joints	
- thread-seams	Joints	
BACK - wood pcs	Joints	
- thread seams	Joints	
- canvas	Construction i.e functions as back	Design the seat
	Tilts = comfort	
- fittings	Tilts = Comfort	
KD-Fittings		
PACKAGE (carry-away)	Protects = Package Saves clients trouble, acts as sales promoter	
Surface Finish	Design, out look	Cost value, easy to clean
Filling (putty)	Design, out look	Cost value easy to clean

Figure A.IV.10. Creative phase on form No. 3

CREATIVE PHASE (form No. 3) Page 1

Product SAFARI | Project No. 82-07 | Date 82-04-06

Part	Ideas		Cost effect
THE	1 ROUND PARTS	R	
CHAIR	2 USE LEATHER	R	
AS SUCH	3 COMBINE THE BACK & SEAT	To idea bank	
	4		
SIDES	1 ELIMINATE LOWEST B.	A	
	2 ELIMINATE MIDDLE B	R	
	3 ELIMINATE UPPER BAR	R	
	X AND USE CANVAS INSTEAD		
	5 MAKE UPPER BAR WIDER	A	
	X TO FUNCTION AS REAL ARM-		
	X REST.		
	8 SHORTEN DIMENSIONS OF	A	
	X BARS		
	10 USE THINNER MATERIAL IN	R	
	X THE MIDDLE AND IN THE		
	X LOWER BAR		
	13		
LEGS	1 BACK LEG HIGHER + 30cm	R	
	2 ROUND MATERIAL	R	
	3 SHORTEN LEGS AND LET	R	
	X THE ARMREST TO COME OVER		
	5 PUT WHEELS	R	
	6		
SEAT	1 ELIMINATE ATTACHMENT OF CANVAS	R	
	X TO SIDES		
	3 USE SINGLE PLY FABRIC	A	
	4 USE THICKER BUT CHEAPER FABRIC	A	
	5 SEAT & BACK TO BE ONE PIECE	R	
	6 ATTACH CANVAS TO UPPER SIDE	R	

CREATIVE PHASE Page 2

Product SAFARI | Project No. 82-07 | Date 82-04-06

Part	Ideas		Cost effect
	X RAILS = ARMREST		
	8 ATTACH CANVAS WITH PRESS	R	
	X BUTTONS		
	10 USE DARK SEWING THREAD TO	R	
	X GIVE DESIGN		
	12 FRONT SUPPORT HIGHER TO	R	
	X GIVE BETTER SITTING POSITION		
	14 ATTACH. SEAT TO SIDES ONLY	R	
	15 ATTACHMENT WITH DOWEL STICK	A	
	X		
	17		
BACK	1 ELIMINATE TILTING (EXCESSIVE)	R	
	2 COMBINE SEAT AND BACK	To idea bank	
	3 HIGHER BACK LEGS, ATTACH	R	
	X BACK TO LEGS		
	5 USE SINGLE-PLY CANVAS	A	
	6 LOWER TO SAVE MATERIAL	R	
	7 RESERVE AN EMPTY SPACE	A	
	X BETWEEN BACK AND SEAT		
	9		
	10		
	11		
	12		
	13		

Figure A.IV.10. *(continued)*

CREATIVE PHASE — Page 3

Product SAFARI — Project No. 82-07 — Date 82-04-06

Part	Ideas		Cost effect
KD-FITTINGS	1 USE SIMPLIFIED CONSTRUCTION	A	
	2 AS IN PICTURE		
	3		
	4		
	5		
	6		
	7		
	8		
	9		
	10 MAKE A STANDARD VERSION	R	
	11 FOR HOME MARKE WITHOUT		
	12 KD CONSTRUCTION		
	13		
HEXAG.	14 ELIMINATE IF KD ELIMINATED	R	
WRENCH	15		
	16		
SCREW	17 ELIMINATE	A	
DRIVER	18		
	19		
	20		
	21		
CARRY-	22 PRINT IMPROVED INFORMATION	A	
AWAY	23 ON TOP		
PACKAGE	24 SAVE MATERIAL IF DIMENSIONS	A	
	25 ARE REDUCED		
	26 USE SILK-SHRINCK METHOD	R	
	27		
	28		
	29		
	30		

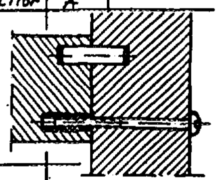


Figure A.IV.11. Project summary on form No. 4

PROJECT SUMMARY (form No. 4) — 82-04-20

Product NEW SAFARI — Project No. 82-07

Part — Drawings No. 82-09

New price/piece 120

Pieces/year 2 000 or more

Cost/year

Goal savings	percent =	18 100 FIM/year
Previous costs	2000 × 90.50 =	181 000 FIM/year
New costs	2000 × 76.00 =	152 000 FIM/year
Savings	2000 × 14.50 =	29 000 FIM/year
Percentage-savings =	16	
Cost of analysis	22 manhours × 50 Fim	1 100 FIM
Other costs	drawings + proto	2 000 FIM
First-year savings		25 900 FIM/year

Comments Because of lower price and improved functions the value is now higher and so higher sales figures are expected

Ideas to be further developed

THE CHAIR WITH COMBINED CANVAS SEAT AND BACK IS TO BE DEVELOPED

VI. FACTORY/WORKSHOP PLANNING AND MANAGEMENT IN THE RATTAN/ BAMBOO FURNITURE INDUSTRY

Desmond Cody*

Planning a rattan furniture factory

Introduction

The characteristics of an efficient rattan furniture factory are as follows:

(a) A product range that responds to market requirements of design, quality and price and is compatible with the available manufacturing capabilities;

(b) A degree of rationalization within the product range that reflects a limited number of models and component/ element interchangeability;

(c) Series production and minimum batch sizes;

(d) Appropriate manufacturing facilities, i.e. purpose-designed buildings, services, machinery and other equipment, which conform to the requirements of rattan manufacturing technology;

(e) Factory layout that reflects the efficient use of space, enables the free flow of raw materials, work-in-progress and finished goods and is conducive to a good working environment;

(f) Suitable production planning and control systems, including prototyping, product development, work study (methods and time study), costing and quality control;

(g) Effective raw materials management, including supply, storage and efficient utilization;

(h) Sufficient separation of production from sales in order that an acceptable productivity level is maintained at all times;

(i) Informed management capable of establishing and maintaining all management systems and procedures;

(j) Effective supervision in all departments and in all key areas of production;

(k) A well-trained and motivated workforce capable of carrying out the tasks allotted to it within specified time limits and in accordance with quality standard requirements;

(l) A delivery time not exceeding four weeks;

(m) Adherence to delivery dates with a tolerance of two days;

(n) A return on investment of at least 20 per cent;

(o) A capital turnover factor of not less than 2.5;

(p) A production staff:management staff ratio of 10:1;

(q) The company's own capital funds accounting for not less than 45 per cent of the total capital.

General

Although any general-purpose factory would be suitable for the manufacture of rattan furniture, the bulky nature of the product and its susceptibility to damage in handling make it necessary for the factory premises to be relatively spacious and free from obstructions and to have level floors. Furthermore, single-storeyed buildings are highly desirable since multi-storeyed buildings would necessitate the introduction of expensive, and often unsatisfactory, lifts and hoists.

Because the quality of the finish often greatly affects the saleability of the product, separate and enclosed surface-finishing rooms and/or booths with air-conditioning, dust extraction and temperature control equipment appropriate to the finish are of considerable importance. Only a very small proportion of the rattan furniture factories visited by the consultant had any of these desiderata.

Whether spacious, modern, single-storeyed premises, designed and laid out for flow production with comprehensive dust exhaust and compressed air systems, are envisaged or an existing building is to be revamped, the principles of plant design described in this chapter should be adhered to as closely as possible. These refer in particular to site development and the building of the factory, the selection and location of appropriate processing machinery and equipment and the provision of factory services, including dust exhaust and compressed air systems, internal transport and other facilities.

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Other important factors must be taken into consideration during the planning stage:

(a) The projected annual output and therefore the plant size;

(b) Provision for future expansion;

(c) A good working environment, achieved, for example, through proper ventilation, especially in tropical climates;

(d) Storage for raw materials, work-in-progress and finished goods;

(e) Internal transport and materials handling;

(f) Building and equipment maintenance;

(g) Offices for administration and production management;

(h) Product development facilities;

(i) Personnel facilities, including canteen and toilets;

(j) Future product design diversification, e.g. the production of woven rattan or case-goods.

Table 7 lists the functions for which space must be set aside in a rattan plant.

Project output

The factory planning described in this instance is based on a projected output of three 40-foot containers per week. Assuming a capacity of 300 units per container and a six-day working week, this means an output of 150 units per day. Further assuming 300 working days per year, this means an annual output of 45,000 units, or 150 containers.

An occasional armchair, which is likely to be representative of the rattan furniture to be manufactured, is illustrated in figure 54. Such a chair has the following parts:

Structural components	20
Bracing and decorative components	8
Total, excluding the wooden seat frame	28

This means, an average, annual production of 1,260,000 components, a monthly production of 105,000 components, and a weekly production of 26,250 components.

The projected capacity should not preclude the possibility of increasing output, and provision should be made for this eventuality in terms of space utilization and processing machinery capacity.

Site

The area required is 1.5 hectares (15,000 m^2). This would allow for eventual expansion of the factory in three phases to over twice the initial size, permitting production to increase as and when required. Figure 55 shows, in outline, how this expansion should take place.

Development of the site may include levelling, excavation, roadways, drainage and foundations, and these tasks should be borne in mind during site selection. In addition, pile-driving may be necessary on marshy sites. Where there is no nearby existing development to indicate the load-bearing properties of the soil, the only certain way to assess the type of foundation required is to obtain samples from bore-holes.

Depending on the site, either a loading platform or a ramp will be needed to bring the floor of the dispatch department and the floor of the container to a common level. If a ramp is needed, adequate drainage must be provided.

Factory buildings

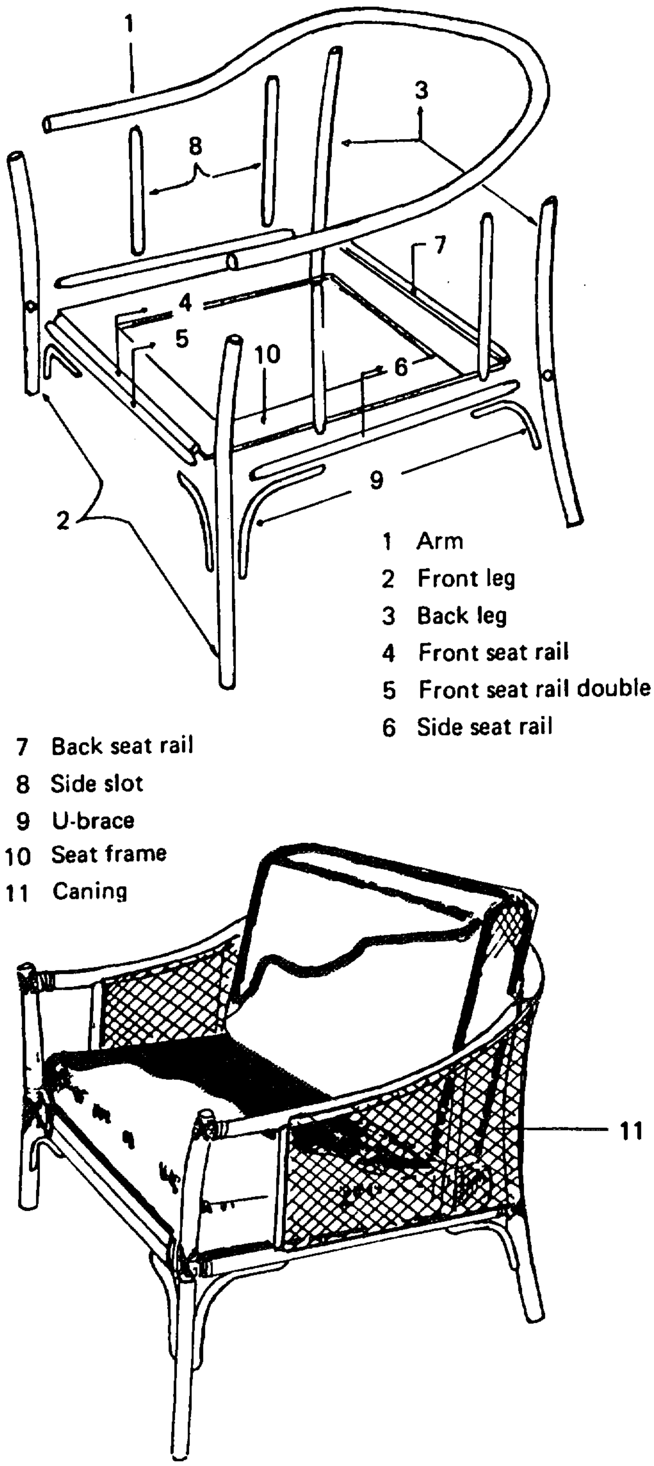
The main building envisaged is rectangular, single-storeyed and steel-framed and has a total floor area of 4,512 m^2. Elevation drawings for it are presented in figures 56-59. It should conform to the following typical outline specification, which in turn should be adapted to local building requirements:

(a) General. Building should be single-storeyed and single-span construction. Clear span, full width;

Table 7. Functions for which space is needed in a rattan factory

Production	*Ancillary services*	*Production management*	*Other*
Inspection, grading, dipping, storage	Product development workshop	Production director	Canteens
Cross-cutting and storage	Metalworking and machine maintenance	Production manager	Toilets and washrooms
Moulding and storage	Design studio	Production engineering and works study	Reception and showroom
Rattan machining, including before/after storage	Lacquer storage (external)	Production administration	
Wood machining, including before/after storage	Hardware storage	Supervisors' office/ meeting room	
Drying room for moulds (including boiler house) (external)	Compressor room		
Framing and checking specials	Jig library		
Main framing and storage			
First sanding and storage			
Binding and storage			
Second sanding and de-webbing			
Staining, lacquering and accelerated drying			
Intermediate storage after spraying			
Upholstery			
Finished goods storage/dispatch			

Figure 54. Typical rattan armchair



(*b*) *Floor levels.* All materials used should conform to appropriate local standard specifications. All building techniques should conform to local building regulations and factories acts. Extra fire escape doors may be necessary;

(*c*) *Dimensions.* Width 23.5 m clear span; length 96.0 m (16 bays of 6 m), height at eaves 6 m and roof pitch approximately 15 per cent;

(*d*) *Structural steelwork.* Portal frames, mild steel single span. Haunching and jointing arrangement to manufacturers' specifications and in accordance with British Standard 449 or the local equivalent;

(*e*) *Roof construction.* Single-skin, galvanized, corrugated iron sheeting incorporating 20 per cent fibreglass (or equivalent translucent material) to provide roof lighting. All on steel purlins at appropriate centres. All external laps to be sealed with appropriate sealing compound and sheeting to be rustproof-coated;

Figure 55. Schematic layout for rattan furniture production

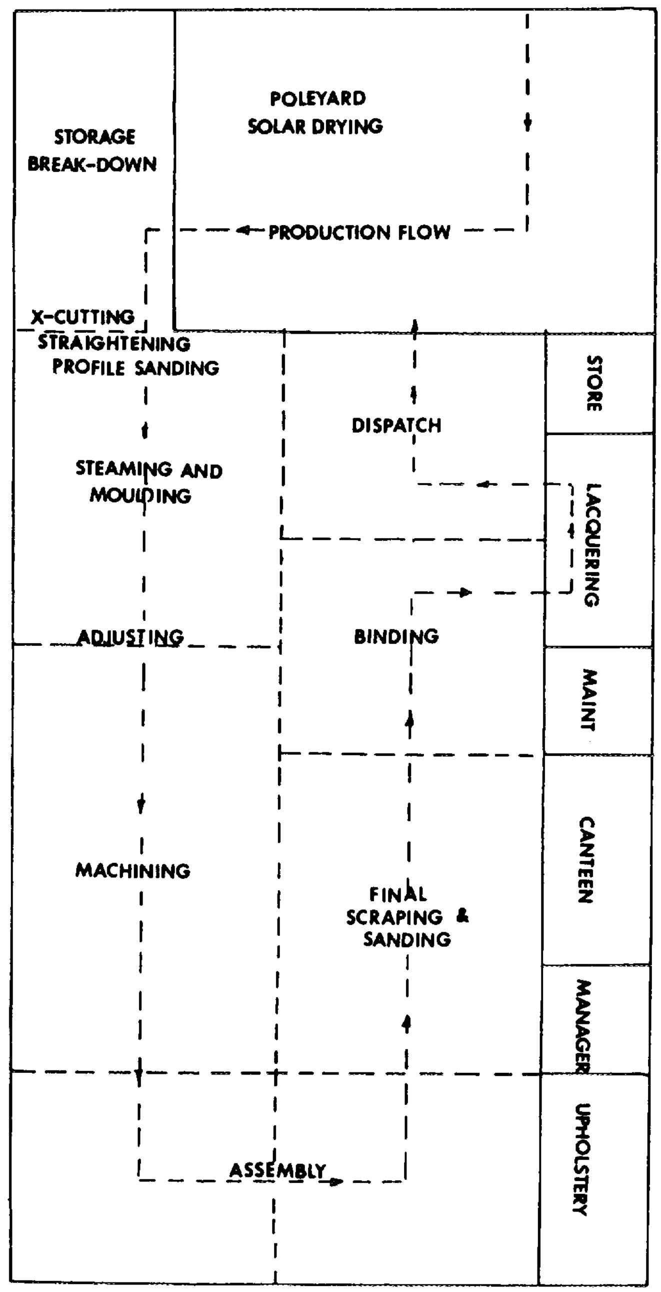


Figure 56. Factory front and rear elevation

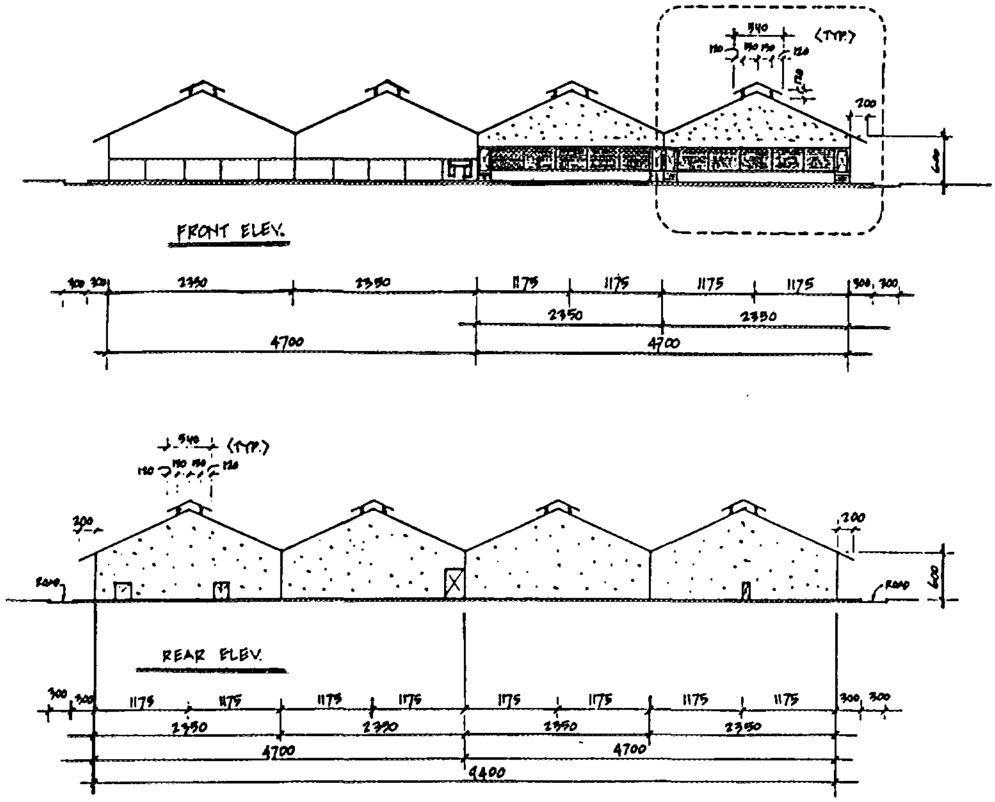


Figure 57. Factory side elevations

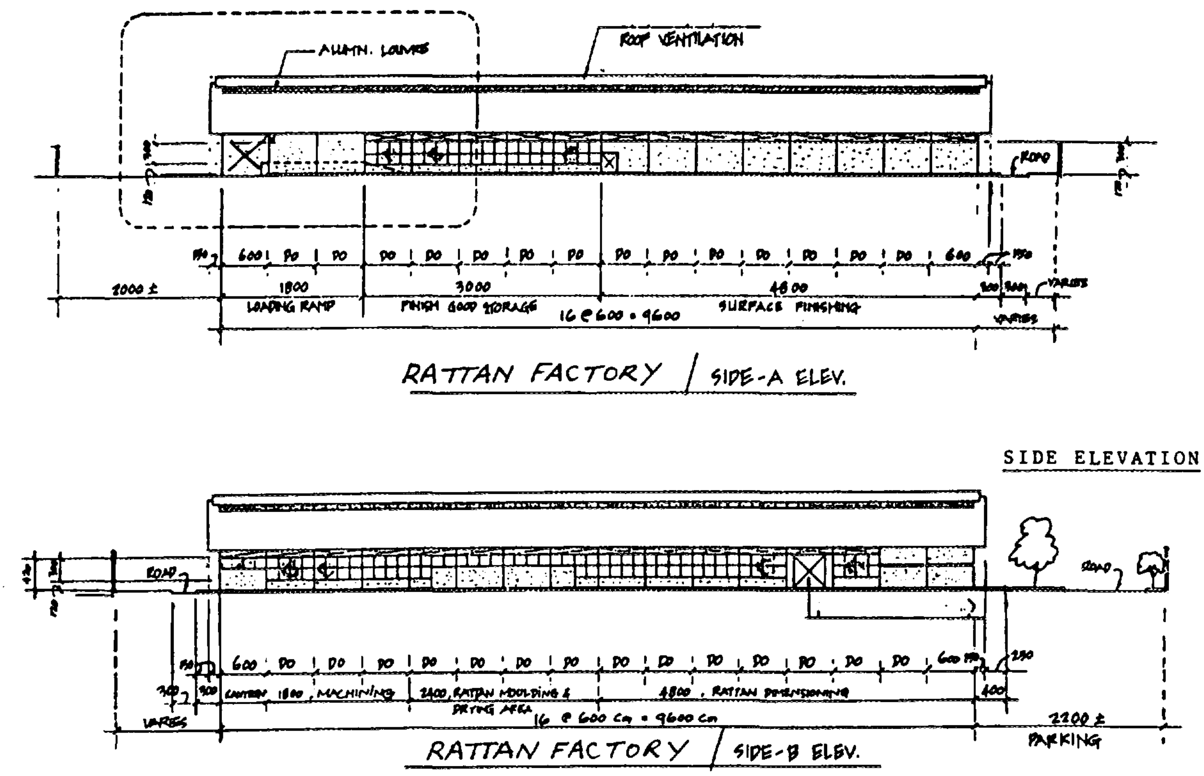


Figure 58. Front view of loading section

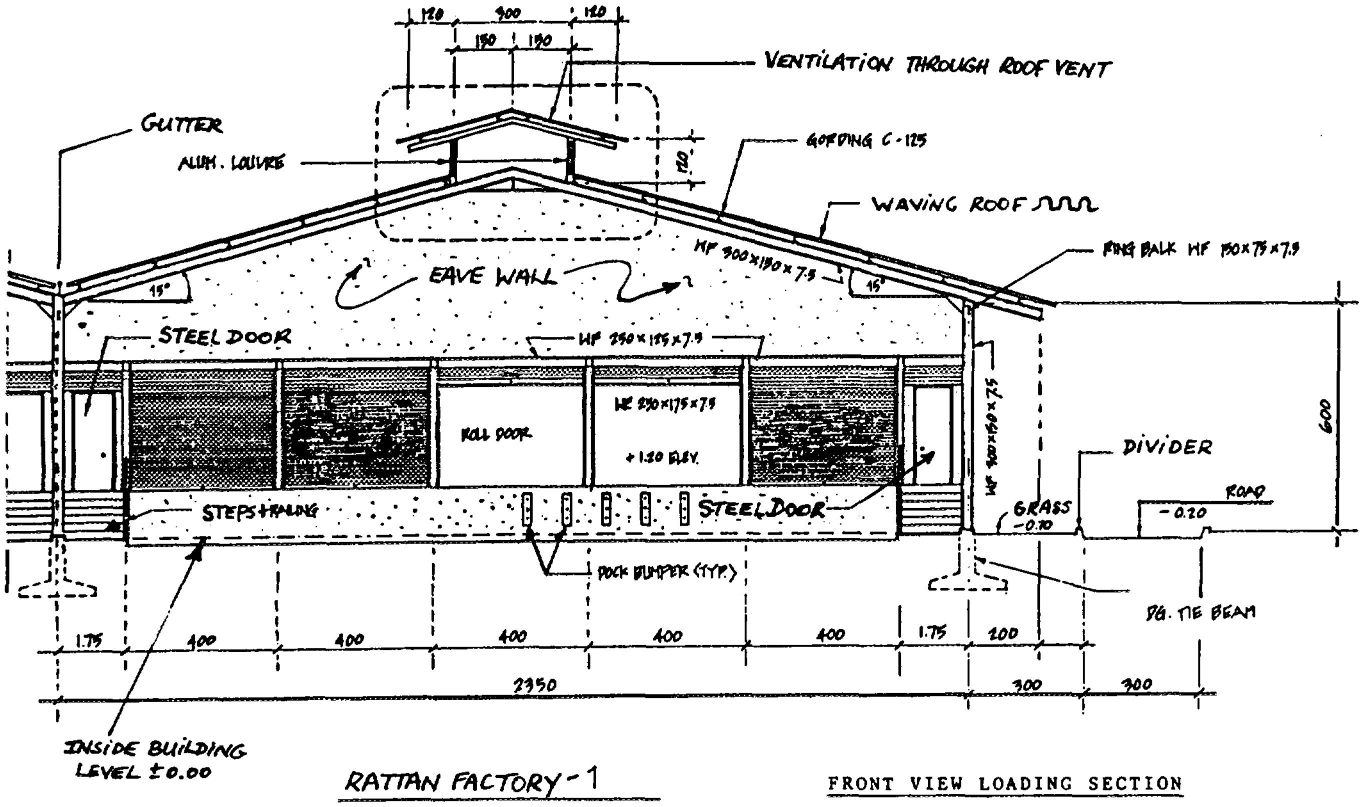
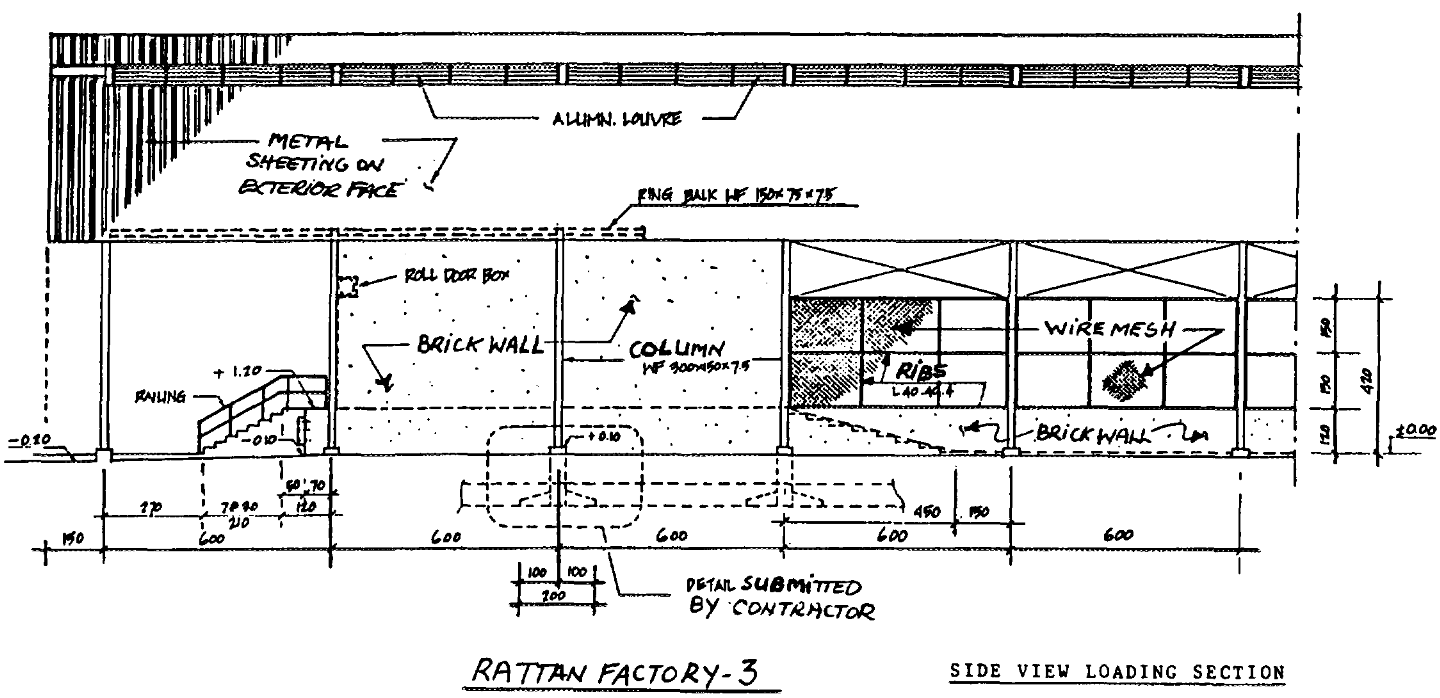


Figure 59. Side view of loading section



(f) *Walls.*

- (i) Solid concrete block wall, 15 cm thick and 1.2 m high;
- (ii) Approximately 3 m of wire mesh to provide light and ventilation;
- (iii) Reinforced-concrete beam (50 mm) between staunchions;
- (iv) Appropriate piers and door openings;
- (v) Appropriate concrete 1:2:3 block foundations;
- (vi) Solid blockwork plastered externally and neatly pointed internally;

(g) Rainwater disposal. Gutters and rainwater pipes, complete as required for the roof slopes and adjacent areas. Best quality galvanized fittings throughout. All gutter joints to be sealed with an appropriate sealing compound;

(h) Floor. Smooth-finished concrete slab, 10 cm thick on 15 cm well-compacted hard core. Slab reinforced with mild steel mesh (4.5 kg/m^2). Floor slab to have appropriate expansion and contraction joints and the finished surface to be treated with an approved dust-proofer;

(i) Road. Layer of hot-mix (5 cm thick) on 15 cm well-compacted macadam hard core;

(j) Concrete foundations. Concrete for all foundations to be 1:2:3. All foundations to be designed for bearing on well-drained boulder clay, pending examination of the excavated trenches. Foundations to be reinforced with mild steel bars as required by conditions and to bear a minimum of 1 m below finished floor level;

(k) Lighting. Lighting to be twin fluorescent fittings to give a minimum level of illumination in the factory area of 300 lm/m^2;

(l) Production facilities. In-house fabrication of the benches and working tables is suggested as the best course of action. The figures that accompany the discussion in the following section on plant layout and the organization of production provide information that could be useful in this regard. Equipment such as spray booths, drying tunnels and sanding machines are best purchased and installed under contract by the suppliers. Feed-in and storage tables or other service facilities can then be set up around these machines. Trolleys for moving goods could be manufactured in-house or could be built under contract.

Rattan plant layout and the organization of production

Rattan production flow

Attention is drawn to details of the manufacturing process described in the UNIDO publication *Manual on the Production of Rattan Furniture* (ID/299), chapter V.

The sections on drying, selection and classification; piece parts preparation (cross-cutting and storage); sub-assembly and final assembly; and surface finishing are elaborated below. Figure 60 shows the process flow for rattan production.

Rattan processing

The various components are produced in large series in the machining and moulding departments and then put into an intermediate component storage area to await assembly in accordance with order levels and specific customer requirements. The large reduction in setting up and moulding times results in optimum machinery utilization.

Rattan pole stacks

Minimum quantities consistent with the supply situation and the need to air-dry require the storage in open, covered piles of 100,000-125,000 rattan poles at any given time. Normal consumption would be approximately 27,500 poles per month. Handling is manual and transport is by means of specially designed bogeys (figure 61).

Drying, selection and classification

After delivery, the poles are inspected and checked for size, i.e. diameter, and quality. They are then classified as follows: first class, no brown spots; second class, intermittent brown spots; and third class, continuous brown spots. The supplier's classifications for three classes are, respectively, Blue Tie and Red A; Red B; and White.

The number of poles in each class is then counted, the usual stock of poles ready for production being approximately 55,000. The diameters of the poles vary from 6 mm to 42 mm, with a breakdown as follows:

Pole diameter (mm)	*No. of poles*	*Distribution (% of total)*
40-42	1 650	3
36-38	7 700	14
34-36	11 000	20
30-32	7 700	14
26-28	5 500	10
22-24	5 500	10
18-20	4 950	9
14-16	3 850	7
12-14	3 850	7
6-8	3 850	7
	55 550	

If it is found necessary to treat the poles against insect and fungi attack, special arrangements for dipping in an appropriate solution should be made before stacking in the storage areas.

The poles are then straightened and stored vertically in bundles of 100, according to size and classification (figure 62). Vertical storage allows any residue of moisture to flow to the bottom of the pole and ultimately to evaporate. Aisles are maintained between the different pole classifications to provide easy access and to ensure usage in accordance with the normal storage period. There is a permanent staff of six in the pole storage area; this may be augmented if large quantities of poles are delivered simultaneously.

Figure 60. Flow chart for the rattan production process

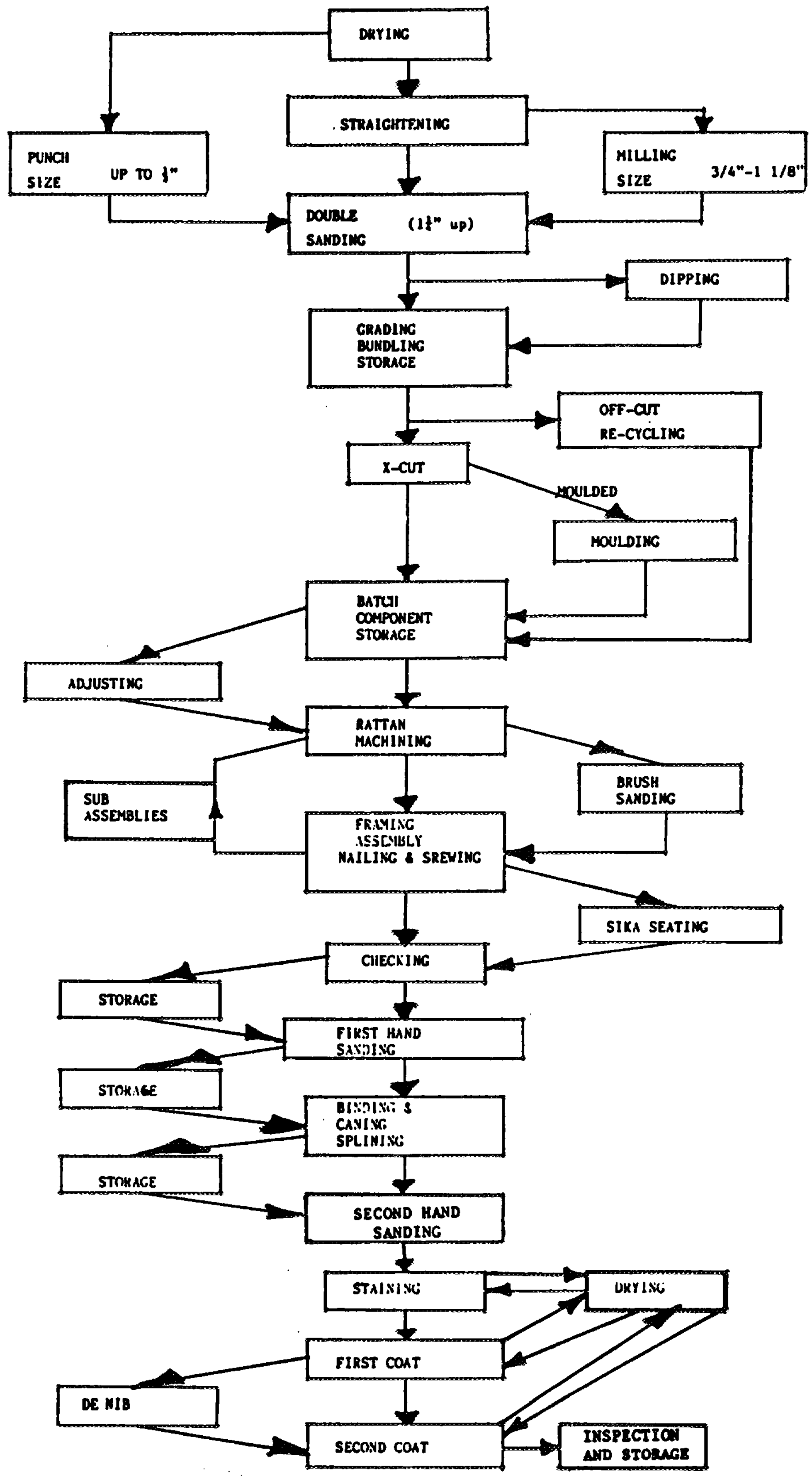


Figure 61. A rattan pole transporter

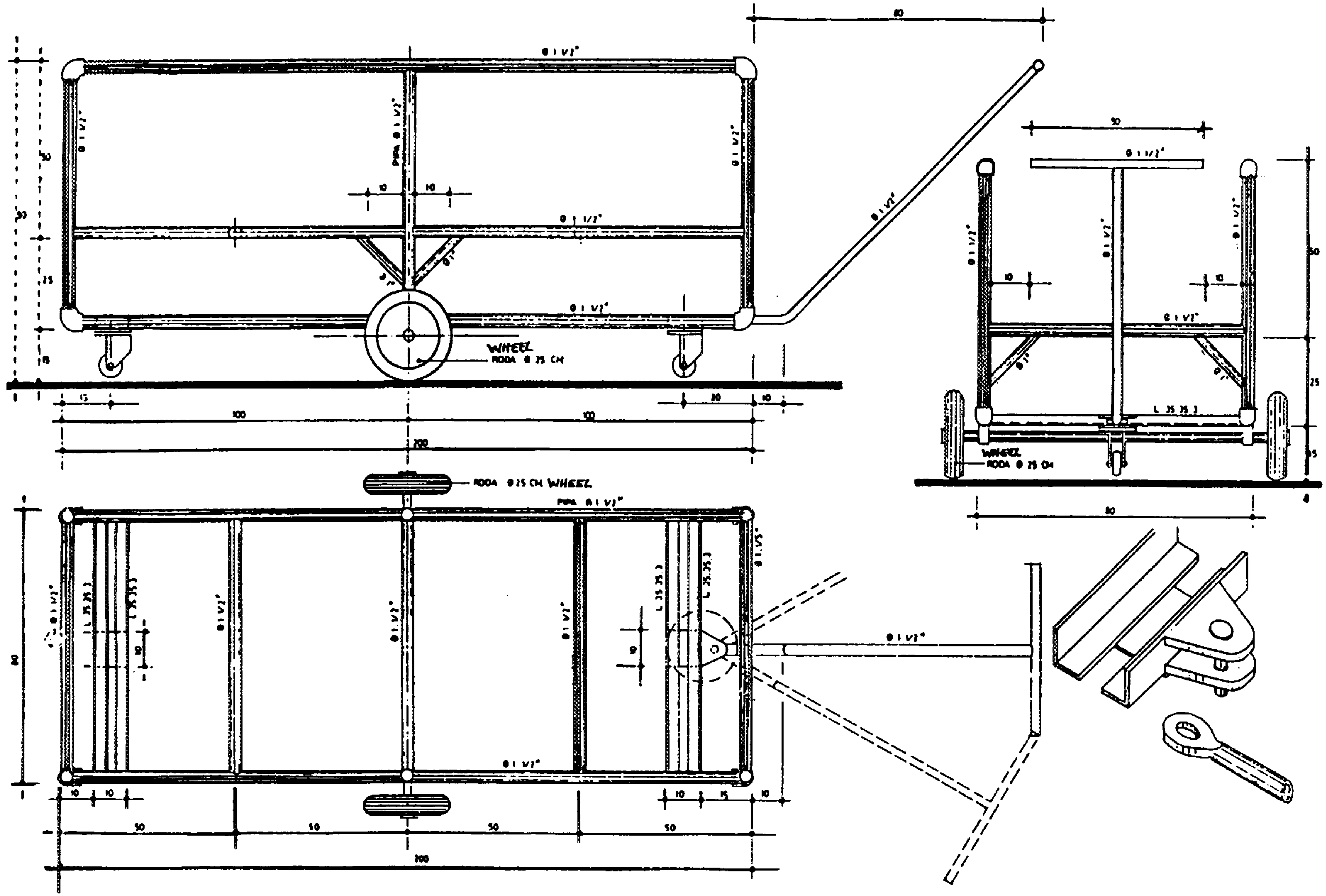
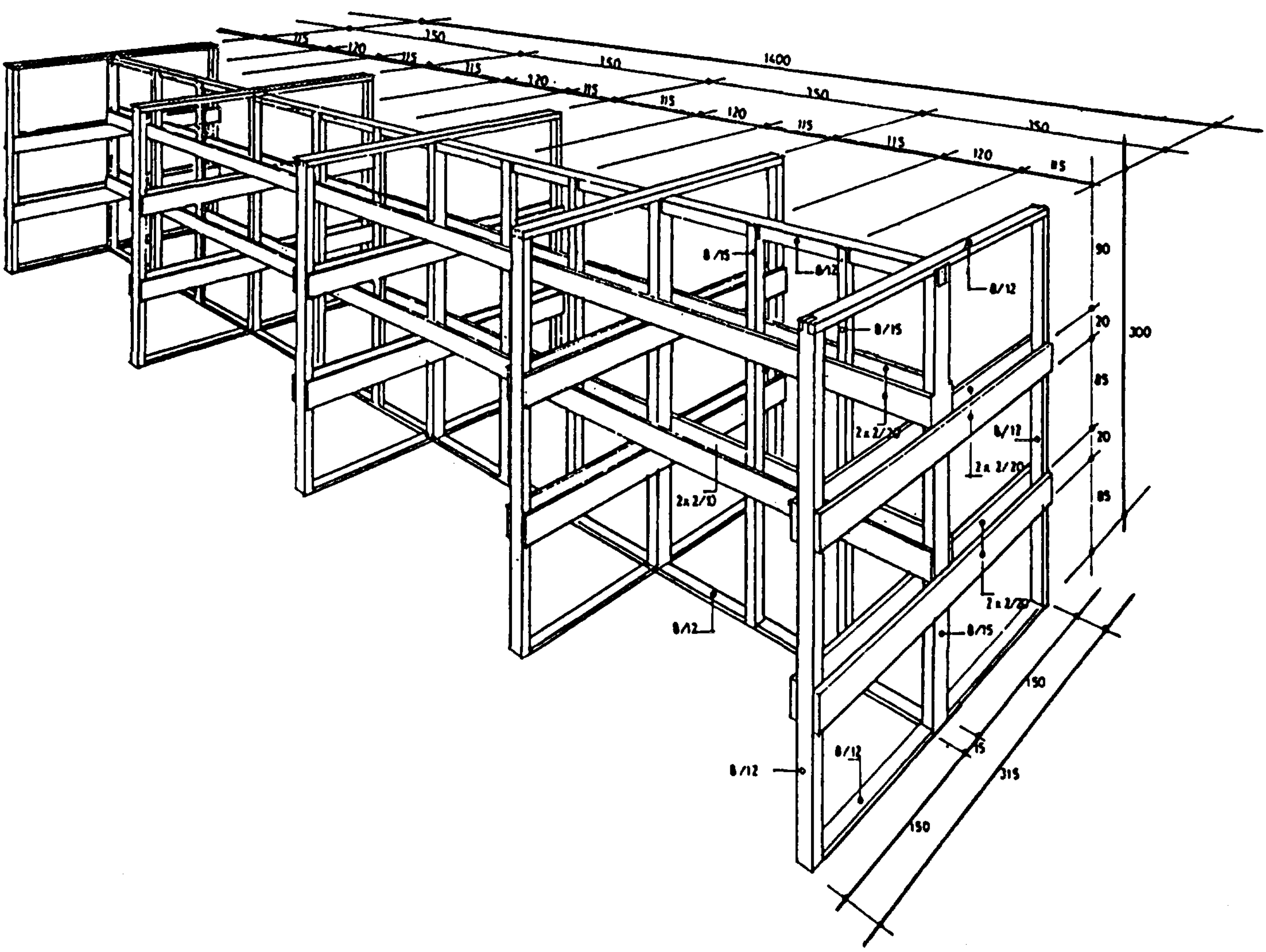


Figure 62. Storage arrangement for rattan poles



Piece parts preparation (cross-cutting and storage)

Poles that have been dried and are ready for production are delivered to the cross-cutting area. Here a buffer stock of all required sizes is maintained, each size being located conveniently behind a cross-cutting saw. Two saws operate in this section: one for standard cutting and one for dimensioning random-length off-cuts. A daily cutting order, which is prepared in the production planning department, goes first to the sawyer responsible for recycling off-cuts. He will extract whatever cut components are available from his stock. The order for the remainder then goes to one or another of the sawyers, each of whom is responsible for cutting poles of particular diameters, usually four diameters for each sawyer. In cutting the poles, the sawyer must use his discretion in following the cutting order so as to ensure maximum pole utilization. The cut poles are subsequently bundled according to length and diameter and are stacked in trolleys (figure 63) to await delivery to the moulding department or, if they will remain straight components, to the batch component storage department. There they will later be joined by the moulded components. To reduce handling to a minimum and to speed up delivery, special castorized bins are used at this stage. The cross-cutting saws are fitted with left and right extensions on which all required cutting dimensions are marked.

A reduction in the variety of models and, therefore, an increase in the number of standardized parts will enable a more comprehensive list of blank sizes to be produced for stock.

Bending and moulding

The equipment in this department includes three steaming ovens for components of varying lengths and universal pneumatic moulding benches with fixed moulds for various types of bend (figure 64). The components usually moulded include back legs, front legs, seat bows, arms, side braces, back braces, seat braces; back decoration and arm decoration. The wide variety of models currently being produced, in which there are few standardized parts, makes

Figure 63. A trolley

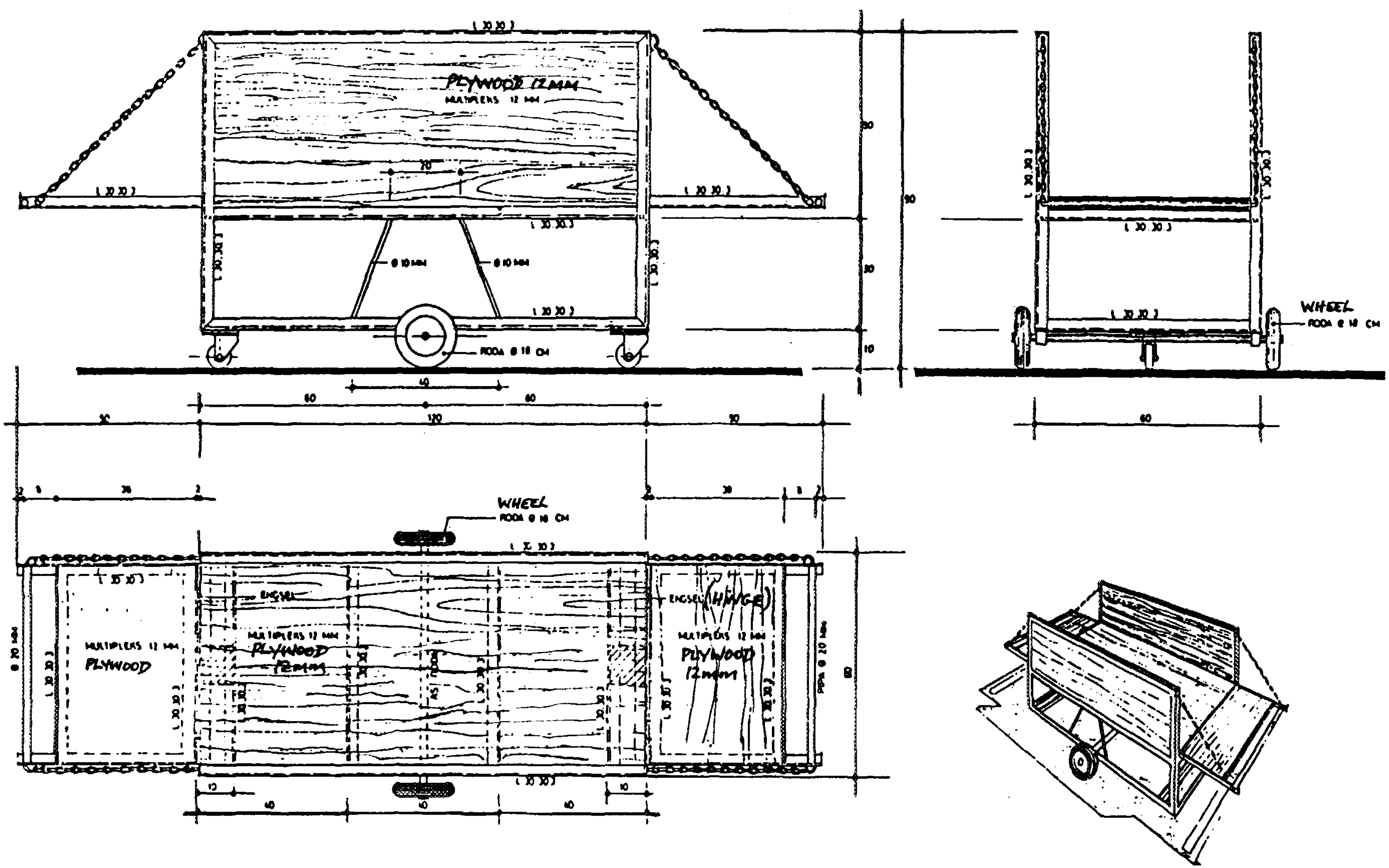
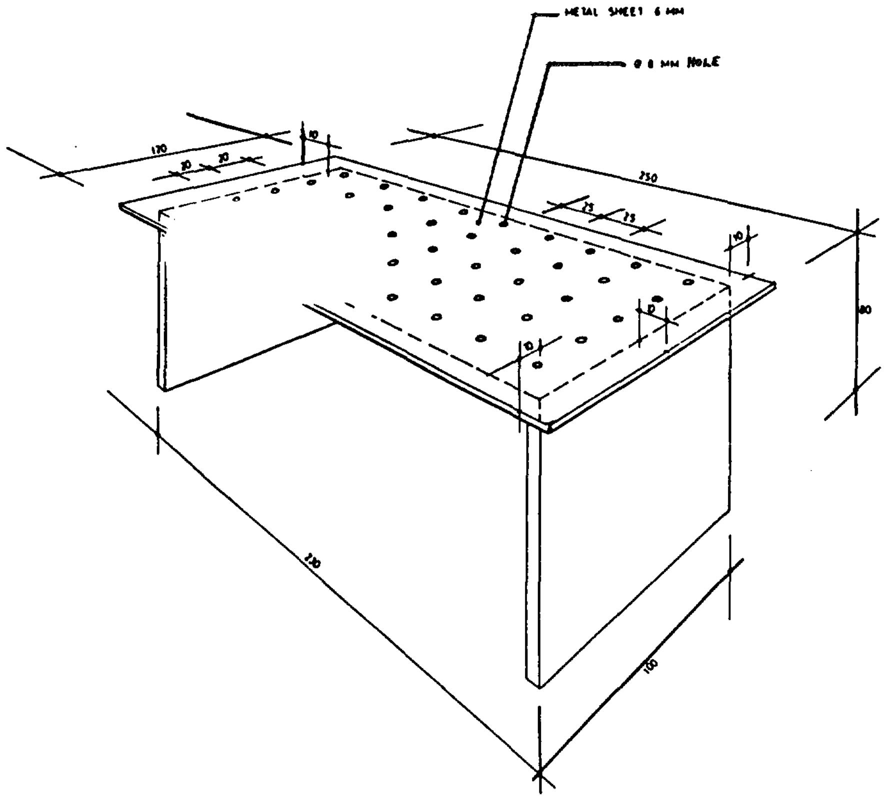


Figure 64. Jig moulding and bending bench



it almost impossible to introduce any degree of moulding specialization or to designate specific workers of equipment for standardized and highly repetitive production.

Since the factory should aim to reduce this variety considerably and at the same time to increase the batch sizes per model to a level consistent with a high volume of production, the opportunity will arise for the use of more accurate jigs and the manufacture of moulded parts that match as closely as possible the final shape required. This will have the added advantage of speeding up the framing of sub-assemblies and final assemblies, since at this stage less time will be required for final adjustment of the part.

The setting time is about four hours for simple bends and moulds but much longer for compound shapes. It can, however, be speeded up by providing additional storage in the boiler area. "Loaded" moulds will be detached from the moulding benches, placed on specially designed trolleys and then stored in the drying room for the required drying period.

Adjusting

Because of the resilience of the material, moulded components tend to lose their shape somewhat and may need further adjustment before machining. An area near the batch component storage is therefore set up for this purpose, and all compound shapes are finally checked and, if necessary, adjusted to conform to the required shape.

Sanding and buffing

Straight components may need further sanding at this stage, and for this purpose a double-belt (fine and coarse) sanding machine is used (figure 65). Shaped components, i.e. moulded and bent, are sanded on six buffing sanding machines, which are fitted with brush heads or cylindrical heads according to requirements.

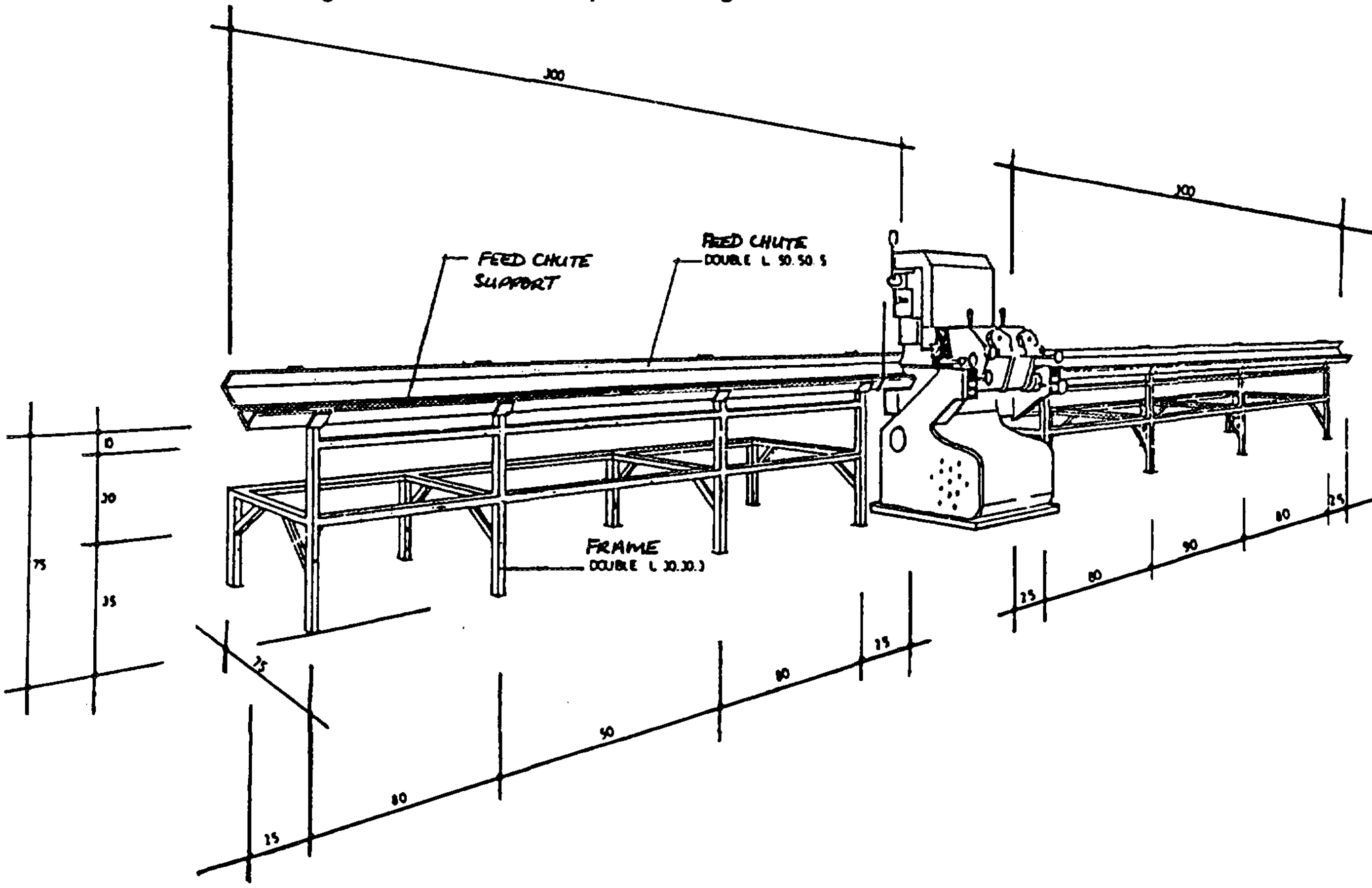
Rattan machining

The machining of rattan includes grooving, rebating, finger-jointing, shaping, boring (figure 66), coping, chucking, splitting, dimensioning, mitre-cutting, surface planing and dowel boring. All these processes are carried out on a variety of rattan and woodworking machines that have been selected for these purposes. They are located near the framing department so that certain sub-assemblies can be returned from the framers for further machining. (For further information, see the *Manual on the Production of Rattan Furniture*, pp. 23-25.)

Dowelling

This is an important construction technique and is used extensively in rattan production to connect, where possible, all the components, e.g. the front legs, the side rails and the

Figure 65. Feed and disposal arrangements for double-belt sander



back legs, to the rails. Dowel holes are drilled by pneumatic or electro-pneumatic, self-feed spindle heads, which are adjustable and can be arranged to suit the profile or shape of the component being drilled. The dowels, or spigots, are turned on a specially designed chucking machine that will turn them to match the diameter of the drilled holes into which they are expected to fit.

Coping and scribing

Since all rattan sections are round, it is necessary to scribe some components at the fitting stage, e.g. rails to legs or arms to legs, so that a perfectly fitting joint is obtained after assembly. This is particularly necessary for knock-down furniture where the joint is not subsequently bound and any defects would be very evident. It is done by fitting a specially designed cutting bit to the self-feed drills, already referred to. The bit bores and scribes at the same time. It should have a diameter equivalent to that of the rattan section being used. The feather edge produced on the scribe should be carefully sanded off to avoid "spawling". This scribed joint, which is especially suitable for knock-down furniture, is subsequently screwed through the leg and into the rail. Boring and scribing may also be carried out on a router. The process is carried out in conjunction with carefully designed and accurately manufactured location and holding jigs.

Grooving

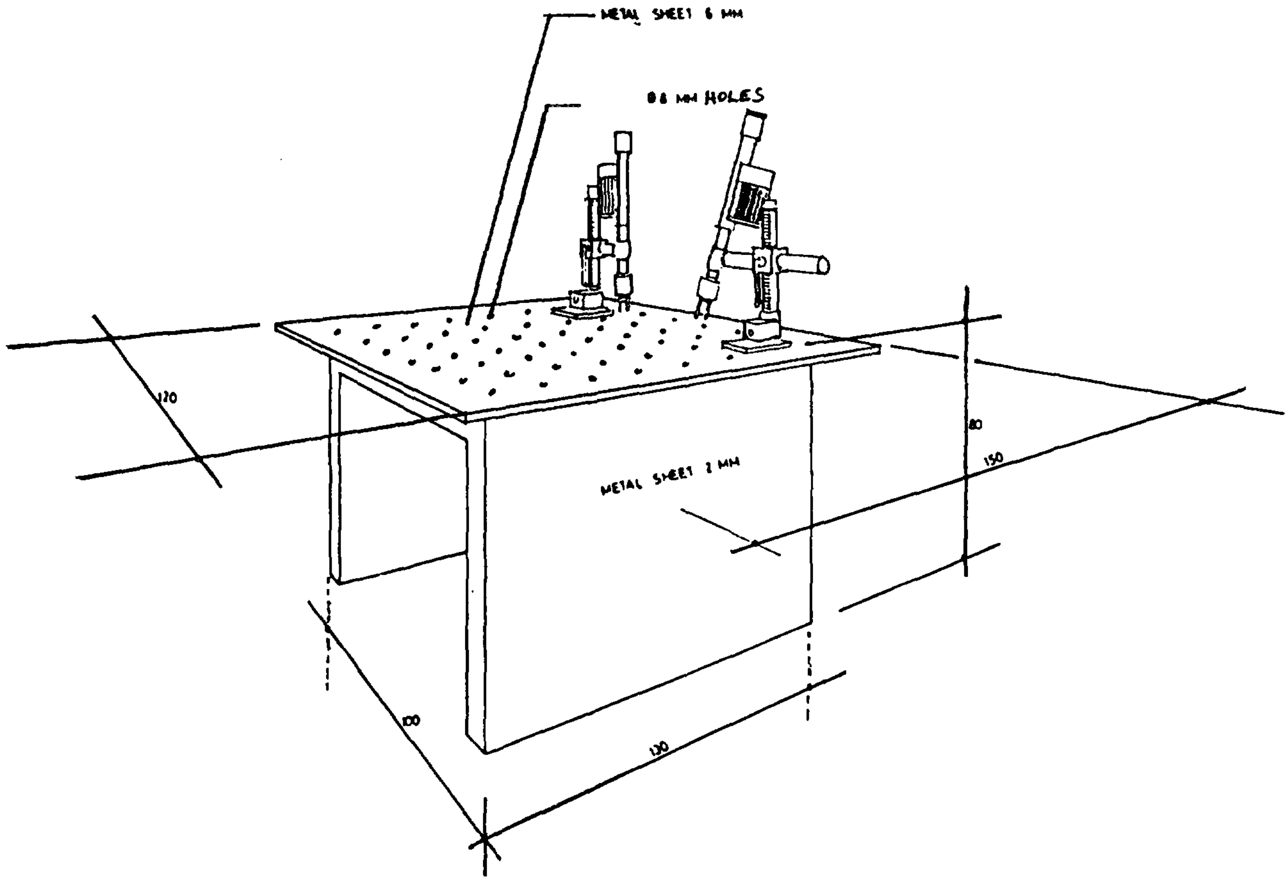
Grooving is necessary for frames into which woven cane is being incorporated. It is done with either a router or a drilling machine to which a special grooving bit has been fitted. Often caning cannot be done until the full frame has been assembled.

Sub-framing and final framing

The pre-assembly of rattan components

Back, front and other sub-assemblies of chairs and frames may be assembled in pneumatic or manual cramping jigs or tables. These are then stacked in an intermediate storage area to await final assembly. During sub-assembly it may be found necessary to adjust some of the moulds in order to achieve the exact contour required: the bend is softened by the application of heat to make it more malleable. This procedure should be avoided if at all possible since the heating process, usually done with a blowlamp, tends to char and discolour the surface of the mould to

Figure 66. Multiple boring bench with self feed unit



which it has been applied. Additional time is then needed to remove the discoloration.

The moulding of shaped parts (ply seats)

Shaped parts may be moulded in multiple widths either in a simple spiral press with a pressing matrix or in a moulding press with resistance heating. Suitable adhesives for cold gluing are polyvinyl acetate (PVA) and for hot gluing, urea-formaldehyde (UF). Cold gluing is preferable since it allows parts to be stacked.

Framing

Framing is the most time-consuming and labour-intensive activity in the whole plant, and the opportunity for reducing the time spent on the various framing activities depends in very large measure on the quality of the previous moulding and machining processes as well as the suitability of the different framing aids, such as jigs and formers.

The most effective and time-saving method of framing is to do as much accurate machining of the components as possible, have efficient assembly aids and arrange the framing on the basis of teamwork, with about eight framers and a supervisor to each team, which will specialize and therefore become accustomed to a limited number of models. It is anticipated that in full production, about 60 framers would be employed. Thus, seven or eight groups of, say, eight framers each will share the framing activities between them to the best advantage. This arrangement would allow the introduction of an incentive bonus scheme based on individual group performance.

To reduce further the time elements, each group should be provided with suitable framing tables (figure 67), a bandsaw, a mitre saw, a coping machine, pneumatic drills, staplers and screwdrivers.

Sika seating

For so-called sika seating, mainly dining room chairs and easy chairs, rails are drilled into which sika, or small-diameter rattan, is inserted to support the seat. The support consists of a series of parallel canes at about 25 mm centres that cover the whole of the seat frame. This process cannot be carried out until the chair frame has been fully assembled and is therefore done by a special group trained for this purpose.

Checking

This, in effect, may be regarded as an intermediate inspection checkpoint to make sure the item being

Figure 67. Rattan framing bench

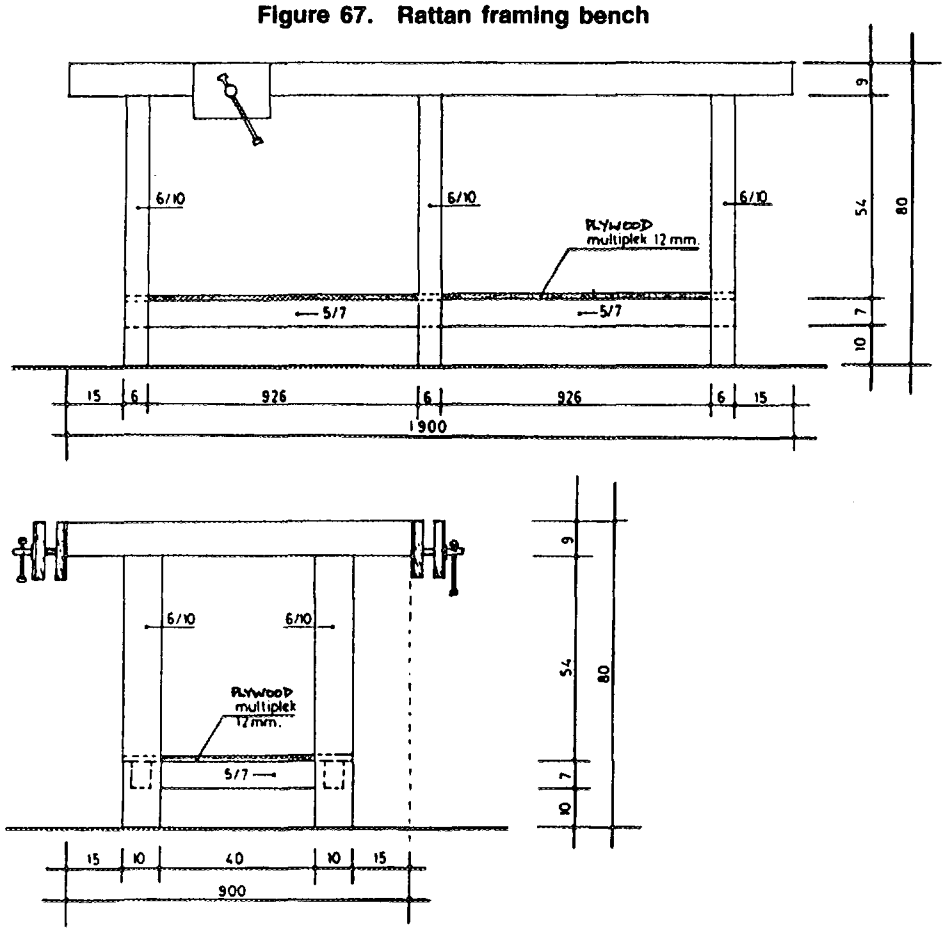
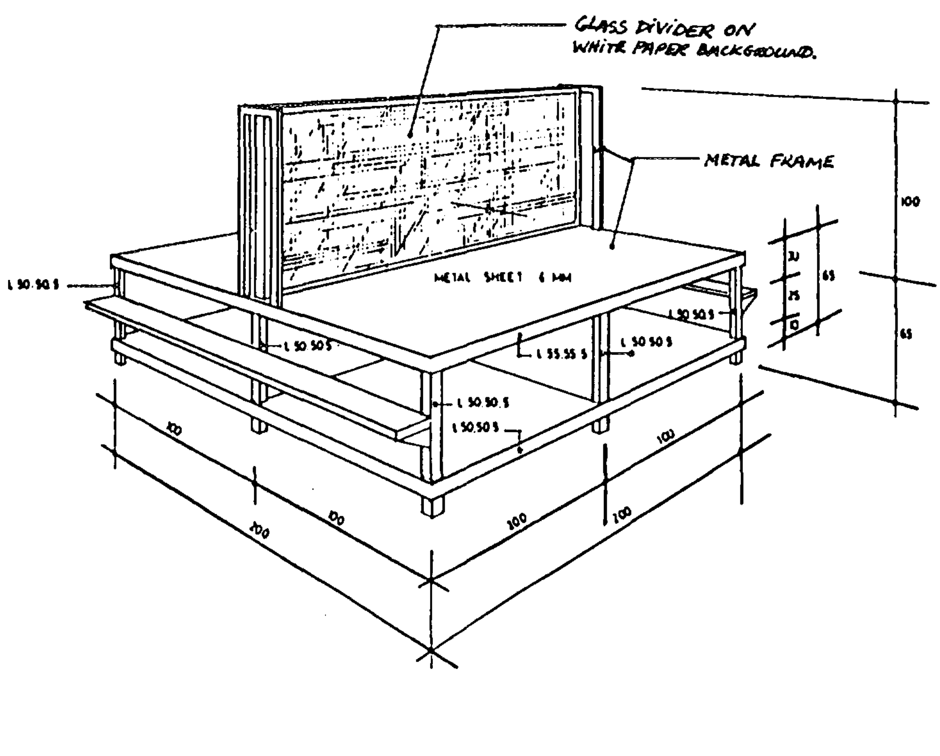


Figure 68. Double-sided inspection bench



inspected conforms fully to the original specification. Special inspection tables (figure 68) and other quality control aids ensure that the standard is maintained. Rejects at this stage are returned to the framers for adjustment and are then permitted to proceed to the next stage.

Scraping and sanding

Although components will have been sanded prior to sub-assembly and final assembly, some additional cleaning up is necessary at this stage and before binding. It can be kept to a minimum by good initial sanding before assembly and careful handling subsequently. For example, only staples and pneumatic stapling guns should be used, and arrangements for transport should take into account the need for as little damage as possible in transit and storage. At most, no more than one hour, and preferably less, should be devoted to this procedure.

The binding of joints

Various materials are used for this purpose, including leather, rawhide, parchment and, more popularly, rattan splits. The last-named must be scraped prior to use so that subsequent staining and lacquering will adhere properly to the material. Some binders prefer to sit on low stools or even on the floor to do this work; others like to work at a low bench on which the frame is placed. In either event, it is important to ensure good working conditions and that materials are readily available and preferably pre-scraped and sanded so that the actual binding time is reduced to a minimum.

Solid wood and plywood processing

Wood processing for both solid and sheet material is confined initially to the production of the wooden seat frames that are sometimes incorporated into rattan seating and plywood, which is used mainly for table tops (both dining and occasional). Later, it will form the basis for the production of case-goods for the living room, dining room and bedroom. These will be decorated with rattan trim, i.e. small-diameter canes, split cane, woven rattan and mouldings.

An additional machining department has been provided for wood and plywood processing. It will also cater for machining operations that cannot be done in the rattan machining department.

Kiln-dried timber

Only kiln-dried timber that has been dried down to a moisture content of 6-8 per cent should be used in furniture that is destined for export, especially to a drier climate than in Indonesia. Assuming a good supply situation, it will not be necessary to carry large stocks (in storage, the kiln-dried timber reabsorbs moisture).

Cross-cutting

Short components are cut in multiples to the required length. A manually operated overhead cross-cut saw with roller tables is sufficient for this purpose. The capacity of this saw is about 13 components per minute.

Surfacing and thicknessing

Standard surface and thickness planers are recommended because most components are flat on two sides. Tapered parts may be planed with the assistance of a counterjig; turned parts are not planed.

Surface sanding

For the sanding of all flat surfaces a wide-belt sander is recommended. The sander is fitted with two motors, one for a sanding drum and the other for a sanding pad.

Sanding curves and edges

Edges and curves are sanded on manually operated bobbin sanders, open-belt sanders and pneumatic drum sanders.

The pre-assembly of solid wood components

Back and front sub-assemblies of chair seats are assembled in pneumatic cramping tables and cleaned off. They are then stocked in an intermediate storage area. In this way, the bending and twisting of small single components is avoided.

Panel processing

Panel material may be classified as follows:

Material for table tops	Veneered particleboard or plywood
Material for chairs	Plywood 10 mm
Moulded parts	Plywood 6 mm thick, made up of two 3 mm plywood sheets glued and moulded together

Chair seats and plywood for moulded parts are cut on a dimension saw with a moving table.

Moulding of shaped parts

Shaped parts may be moulded in multiple widths either in a simple spiral press with a pressing matrix or in a moulding press with resistance heating. Suitable adhesives for cold gluing are polyvinyl acetates; for hot gluing, urea-formaldehydes are used. The cold method is preferable since parts can be stacked on top of one another and pressed in a single form.

Curving, profiling and boring

After pressing, moulded components are shaped on a bandsaw and then profiled on a spindle moulder with a jig. Dowel holes (for fixing) are bored with a vertical multi-spindle boring machine, and the edges are rounded off on a curve sander.

Edge gluing, profiling and sanding

Solid edges are glued to table tops using a tongue-and-groove joint if a solid edge banding machine is not available. The edges are then equalized on a flat belt sander and are, if necessary, moulded on a spindle moulder and then sanded.

Storage of intermediate components

The backs and fronts of chairs are assembled in the pre-assembly department. The advantage of this organizational feature is that there is no distortion of components, fewer single parts and better storage. Daily requirements are taken from intermediate storage, with small series being assembled in accordance with orders. A good assortment of stock in component storage increases the preparedness for delivery. Also, the assembly of similar models in small series shortens the setting-up times at the assembly clamps.

Frames for chairs and tables are assembled on a pneumatic frame press, and the joints are cleaned off and sanded by hand.

Surface finishing (staining and lacquering)

Surface treatment typically requires a number of procedures.

Staining and drying

Glued assemblies are sprayed or dip-stained manually, softened and equalized by means of brush and sponge and put on pallets and roller conveyors. They are pushed manually to the flash-off, or drying, area.

Base coat spraying and drying

This is done at a series of dry spray booths on turntables (figures 69 and 70). The frames are put on pallets and conveyed through a factory-made drying tunnel. Table tops are placed on castorized drying racks, which are also fed into the tunnel.

Intermediate (de-nibbing) sanding

After the base coat has dried, components, sub-assemblies and fully assembled frames are sanded to smoothen the surface and prepare it for the top coat (figures 71, 72 and 73). If suitable, hand sanders may be used.

Final coat spraying and drying

The final coat is applied in the same manner as the base coat.

Drying plant

The drying plant is built up around a tunnel oven through which the stained and lacquered items are pulled on trolleys by a conveyor at floor level (figures 74 and 75). The trolleys accommodate two chairs or one settee. The drying rate, including passing through evaporation and cooling zones, is 40 chairs per hour.

The throughput can later be doubled by providing enough space in the drying plant to accommodate four chairs in two tiers on the trolley.

Final assembly

Final assembly is carried out in accordance with orders and forwarding instructions. Upholstered seats and backs are fixed to the polished frames. Table tops are fixed to table frames. This is done at workbenches using hand tools and pneumatic/electric tools.

Inspection

Quality control is achieved by a final inspection to ensure compliance with standard specifications and conformity to colour and surface requirements.

Finished goods storage

All merchandise ready for packing and dispatch is sent to finished goods storage.

Upholstery department

The upholstery department carries out the following tasks:

(a) Covering materials and foam cushioning are cut by a straight-knife cutting machine;

(b) The foam is glued using a neoprene adhesive, which is sprayed onto the foam with a spray gun. This should be done only in a special spray booth in which an exhaust fan has been fitted;

Figure 69. Spray booth

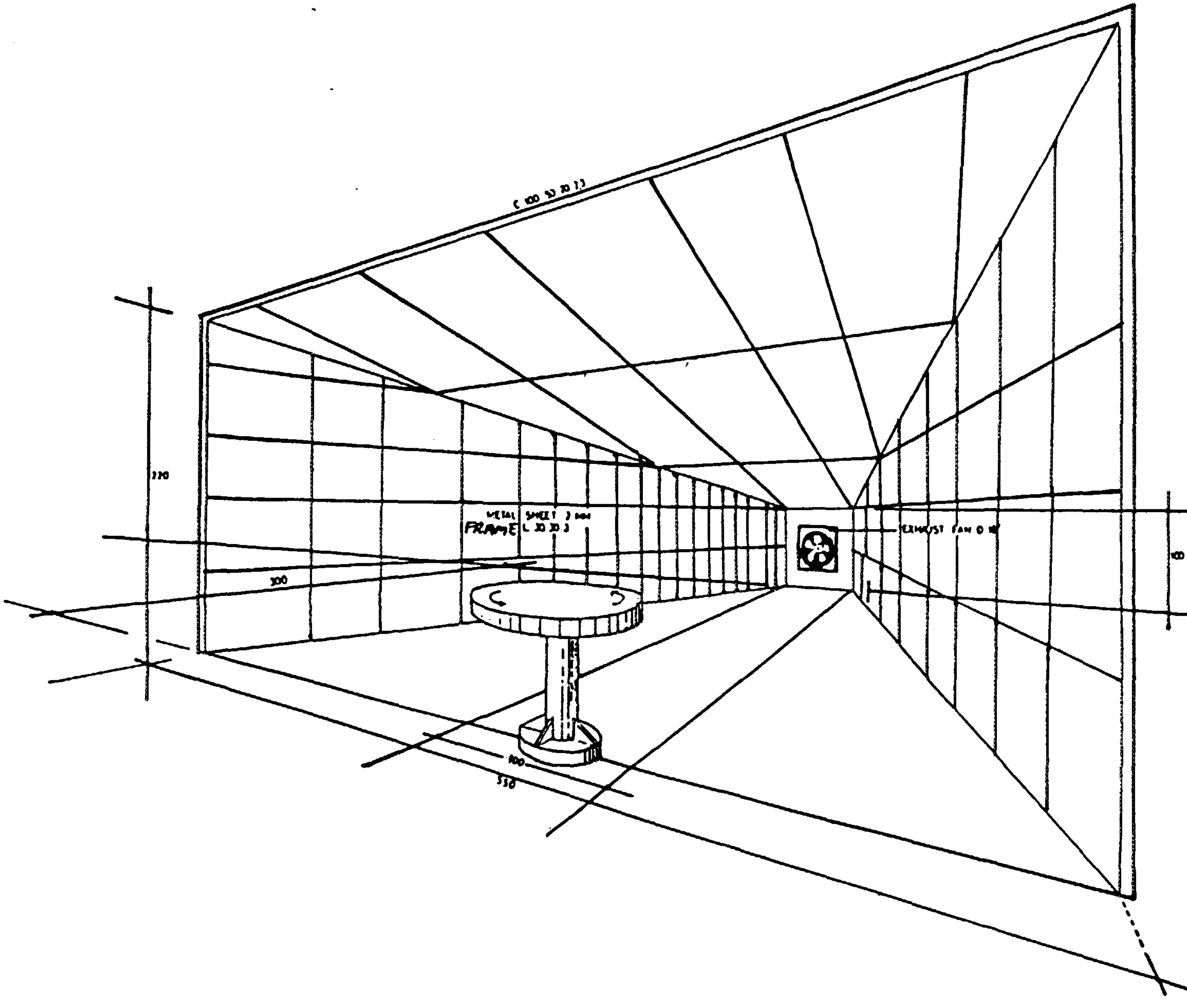


Figure 70. Spray booth details

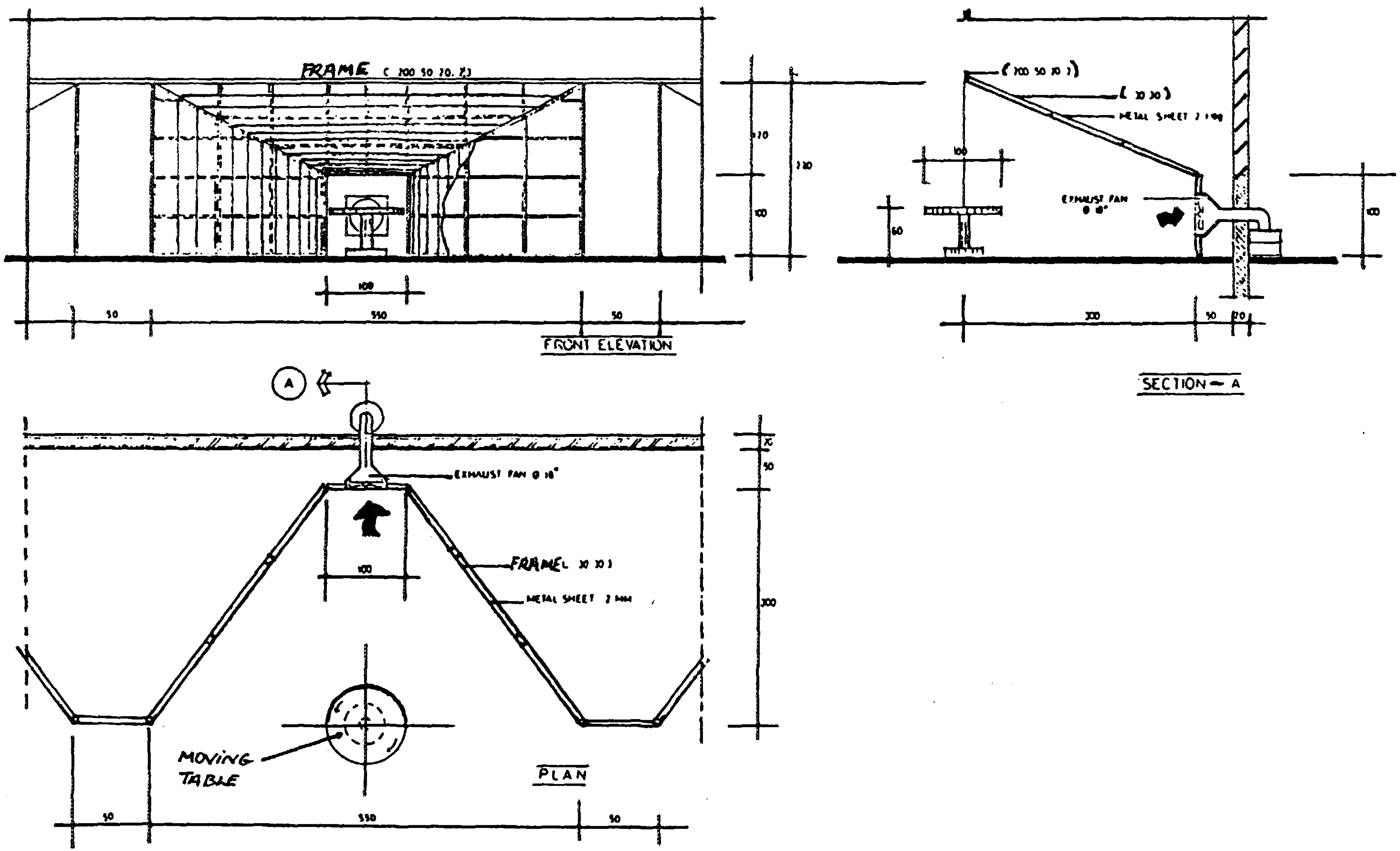


Figure 71. De-nibbling and sanding table

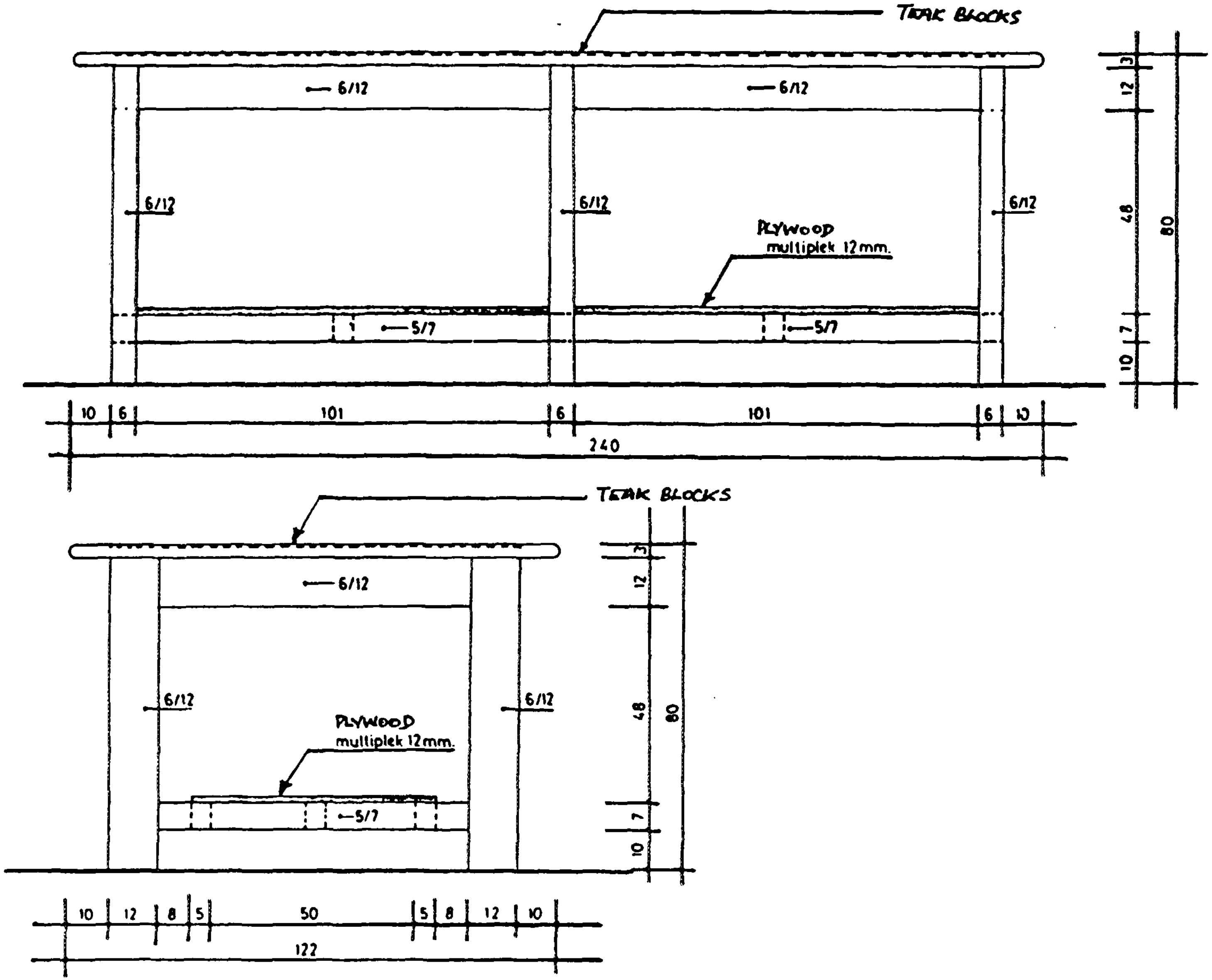


Figure 72. Buffer/sander dust control booth

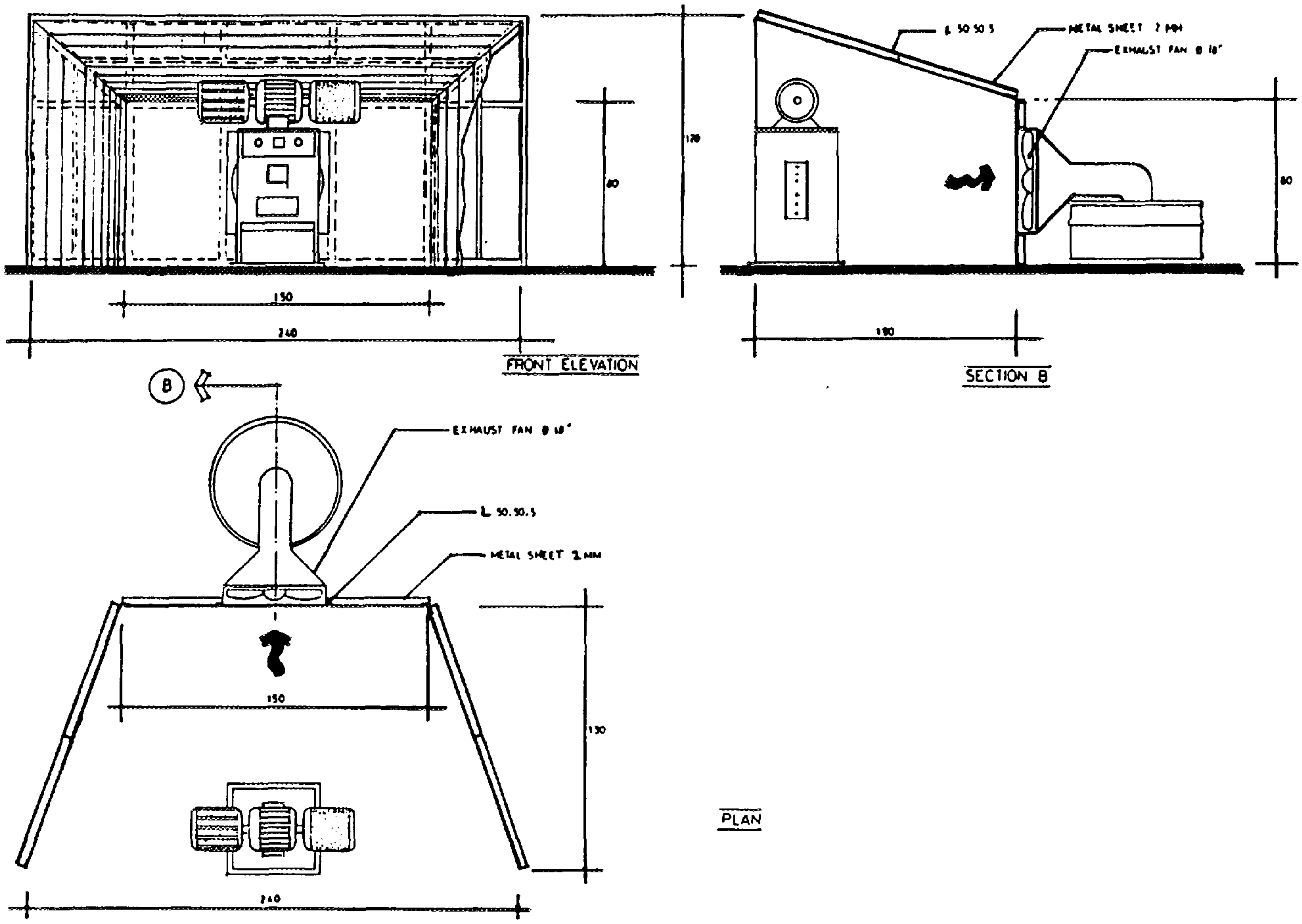


Figure 73. Buffer/sander dust control booth

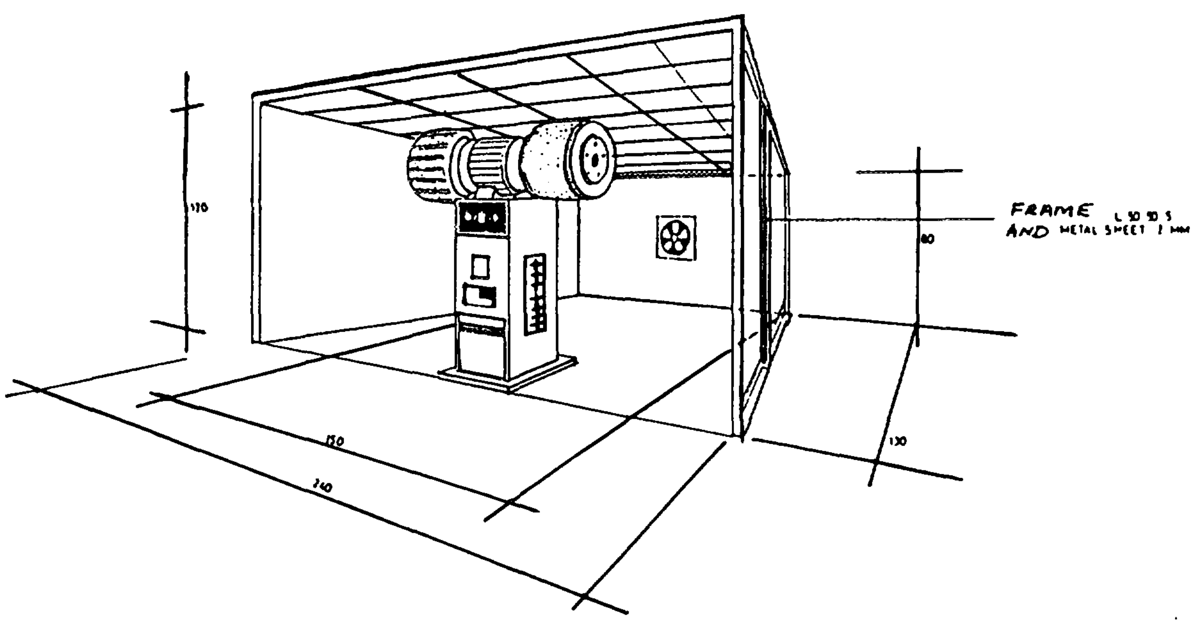


Figure 74. Accelerated lacquer drying tunnel

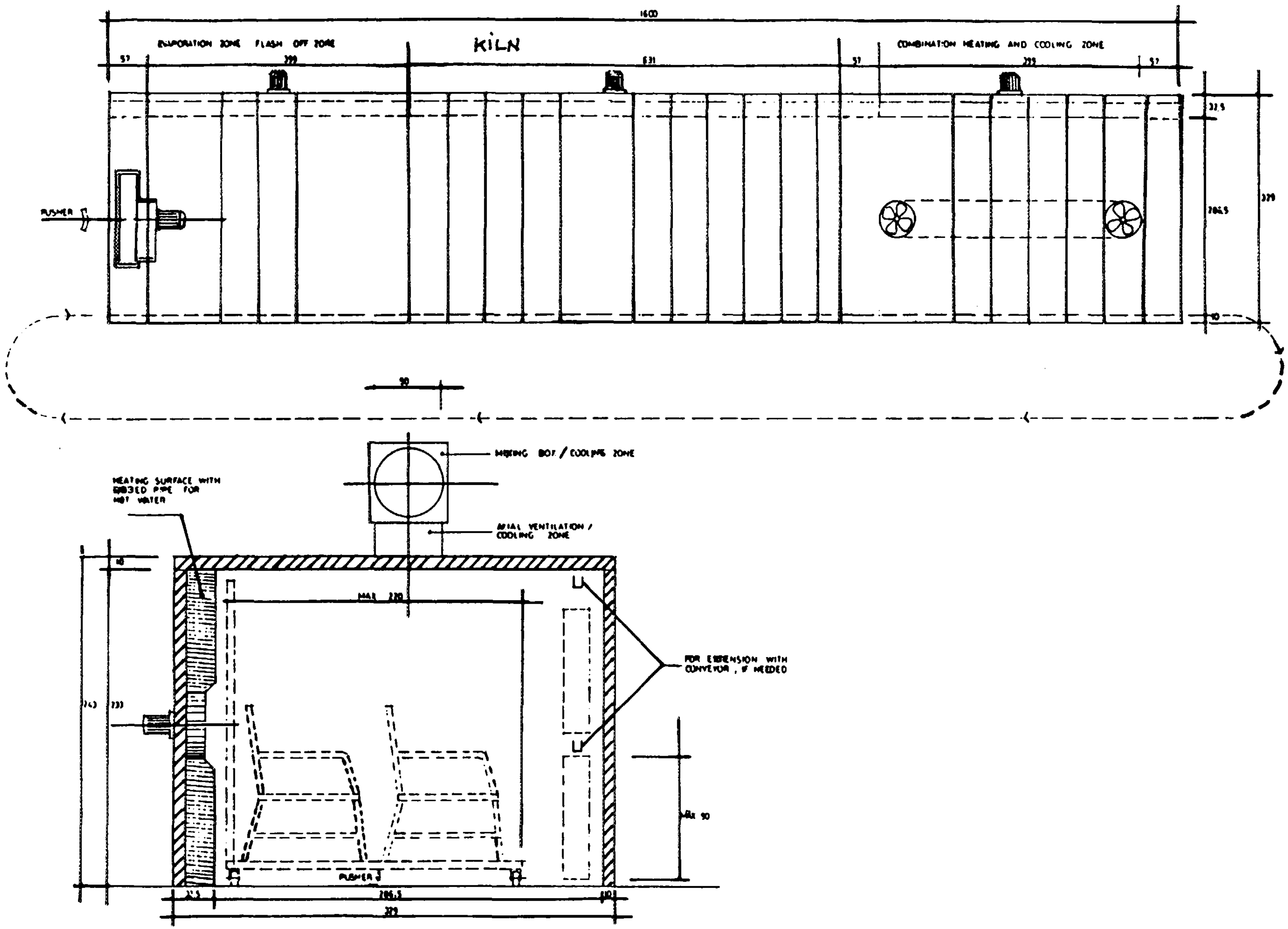
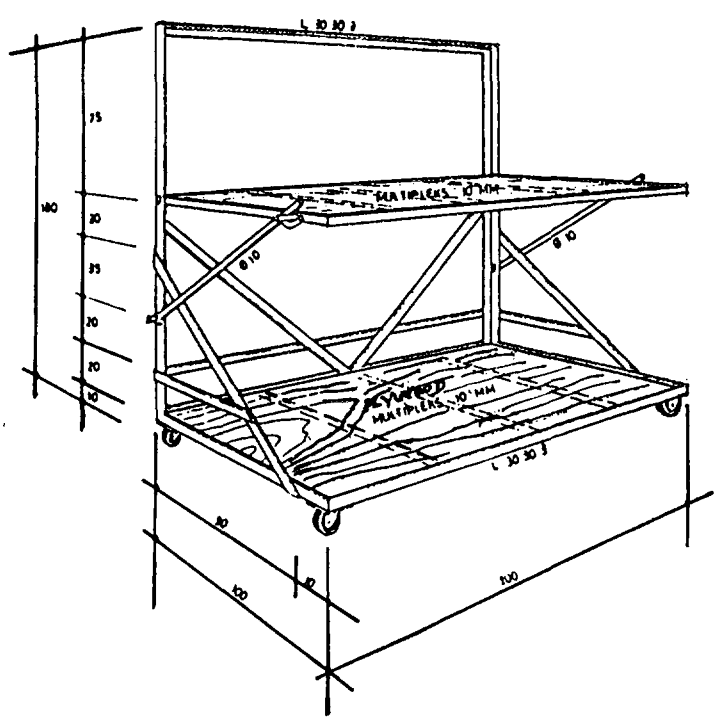


Figure 75. Frame transporters for drying tunnel



(*c*) The edges of the cushions are profiled, or rounded, using a special profiling attachment on the spindle moulder.

(*d*) Loose sets are assembled using a purpose-made pneumatic jig. Some cushions are cut square and others are made up from a combination of urethane foam and polyester fibre fill.

(*e*) Cushion covers are made up, closed and fitted with zippers on an industrial sewing machine.

Plant and machinery details and costs

Table 8 lists equipment and costs; table 9 summarizes these.

Table 8. Plant and machinery details and costs, 1988

Equipment	*Power (hp)*	*Units required*	*Unit cost ($US)*	*Total cost ($US)*
Pole preparation				
Pole straightener	4.0	1	1 830	1 830
Pole double sander	5.5	1	2 777	2 777
Brush profile sander	1.5	2	5 171	10 342
Disc sander	4.0	4	702	2 808
Total	15.0			17 757
Pole dimensioning				
Cross-cut saw	14.0	2	1 587	3 174
Total	14.0			3 174
Rattan machining				
Bandsaw	4.0	2	1 888	3 776
Grooving machine	4.0	1	2 500	2 500
Single-column drills	1.0	2	1 000	2 000
Mounted adjustable drills	1.0	2 prs	1 200	2 400
Mitre saw	2.5	5	700	3 500
Chucking machine	1.0	1	2 000	2 000
Total	13.5			16 176
Wood/rattan machining				
Cross-cut saw	7.5	1	1 587	1 587
Bandsaw	2.0	1	1 888	1 888
Tilting arbor saw	2.0	1	1 725	1 725
Surface planer	3.0	1	1 703	1 703
Spindle moulder	2.0	1	1 610	1 610
Route	2.0	1	1 777	1 777
Dowel boring machine	2.0	1	2 787	2 787
Thickness planer	2.0	1	1 392	1 392
Wide-belt sander	20.0	1	20 700	20 700
Dowel milling machine	1.0	1	1 175	1 175
Dowel cutting machine	1.0	1	1 941	1 941
Dovetail machine	2.0	1	5 361	5 361
Multiple boring machine	6.0	1	4 500	4 500
Laminating press	–	1	6 000	6 000
Dimension saw	3.0	1	1 531	1 531
Dust collectors	8.0	4	350	1 400
Dust collection unit	3.0	1	558	558
Total	66.5			57 635
Rattan surface coating				
Spray booths	3.0	3	1 000	3 000
Drying tunnel	4.0	1	2 500	2 500
Airless pump, hose, spray guns etc.	–	–	10 150	10 150
Miscellaneous finishing equipment	–		500	500
Total	7.0			16 150
Engineering				
Bench grinder	2.0	2	400	800
Universal sharpener[a]	0.5	1	2 825	2 825
Bandsaw grinder	1.0	1	2 400	2 400
Bandsaw welder	–	1	2 500	2 500
Arc welder (optional)	–	1	1 440	1 440
Gas welder (optional)	–	1	1 600	1 600
Hacksaw (optional)	2.0	1	3 600	3 600
Metal bandsaw (optional)	1.0	1	3 600	3 600
Total	6.5			18 765
Miscellaneous				
Compressor	30.0	2	5 400	10 800
Air dryer	–	2	4 000	8 000
Pre-filter	1.0	2	360	720
After-filter	1.0	2	360	720
Steaming ovens	–	6	100	600
Electric wiring, insulators, starters				30 000
Pallet truck	–	1	500	500
Rattan transporter	–	4	100	400
Rattan trolley	–	20	100	2 000
Machine tools, power tools and hand tools	–	–	–	10 000
Draughting equipment	–	–	–	1 000
Compressed air system	–	–	–	2 000
Total	32.0			66 740

[a]For tungsten-carbide-tipped tools.

Table 9. Summary of plant and machinery costs, 1988

Production department	Power chip	Cost ($US)
Pole preparation	15.0	17 757
Pole dimensioning	14.0	3 174
Rattan machining	13.5	16 176
Wood/rattan machining	66.5	57 635
Rattan surface finishing	7.0	16 150
Engineering	6.5	18 765
Miscellaneous	32.0	66 740
Total	154.5	196 397

Specification for the compressed air system

Compressed air requirement

Approximately 1,000 l/min of compressed air with an air pressure approximately 6 kg/cm^2 is required. This amount will vary according to usage and general working conditions. It is therefore prudent to install two compressor units, each with an effective capacity of 1,000 l/min, or a total effective capacity of 2,000 l/min. This would allow for contingency capacity.

Assuming additional compressed-air requirements later on, a compressor with a working pressure of 10 kg/cm^2 is recommended.

Compressor specifications

The compressor should be of the reciprocating type and have an effective capacity of 1,000 l/min and a maximum working pressure of 10 kg/cm^2. It should be double-stage-working and have an electric motor. It should also be equipped with an intercooler (air- or water-cooled) and an after-cooler (air- or water-cooled) with an automatic steam separator. There should be automatic electric control for alternating or intermittent operations, adjustable to the required pressure values.

The air-compressor unit should be installed in a separate room, and special care should be taken to ensure that the air taken in is as cool and dry as possible and substantially free of dust. The pressure chamber should have a capacity of about 2 m^3 and be rated for a maximum pressure of 10 kg/cm^2, and it should have all the necessary auxiliary fittings.

Additional equipment

The compressed air system also requires air pipes, valves and traps, pressure-reducing valves and gauges, service units with water/oil separator, a quick-action coupling valve, reducing nipples and branches.

Installation of the compressed air system

The overall requirement for compressed air must be established before installing the air piping system, considering all of the pneumatic units and devices that are to be operated from the system. Allowance must also be made for reserve capacity, so as to ensure that the system will not be overloaded by any minor addition to the number or size of pneumatic units working on the one air supply.

Regardless of its type and size, the air distribution system should be installed in the form of a ring main. Depending on the number of take-off points, i.e. pneumatic units, and the extent, i.e. the volume, of piping, the ring main should be fitted with branch mains or cross-lines.

Rigid lines are used for air distribution. They are normally 2 in. diameter galvanized threaded pipes with appropriate connections. Three-quarter-inch pipes take off from the grid to the points of consumption. Plastic hose in various sizes, from 3 to 19 mm inside diameter, fits connectors and unions in the size range from M3 to 3/4 in. and links them to the pneumatic tools.

The pipes should be installed so that they are inclined about 1 per cent from the horizontal and lead to a trap. Pressure-reducing valves should also be installed on the cross-connecting pipes.

Each air station should be equipped with an attendance device consisting of a water/oil separator and a pressure-reducing valve with gauge and an oiling device.

Internal transport system

The factory has been planned to give a free flow of men and materials throughout. Thus, 2 m wide clearways have been included so that there is immediate access to every department and to every workstation within each department. These clearways must be kept clear at all times so that the movement of work-in-progress remains unimpeded.

Raw materials, machined or moulded components, sub-assemblies and final assemblies are moved by bogey, trolley and live or dead pallets, depending on the nature and volume of the material in question (figure 76). Generally, solid wood components and sub-assemblies are transported on dead pallets with the aid of a manually operated hand-lift truck, while rattan components are transported on specially designed trolleys.

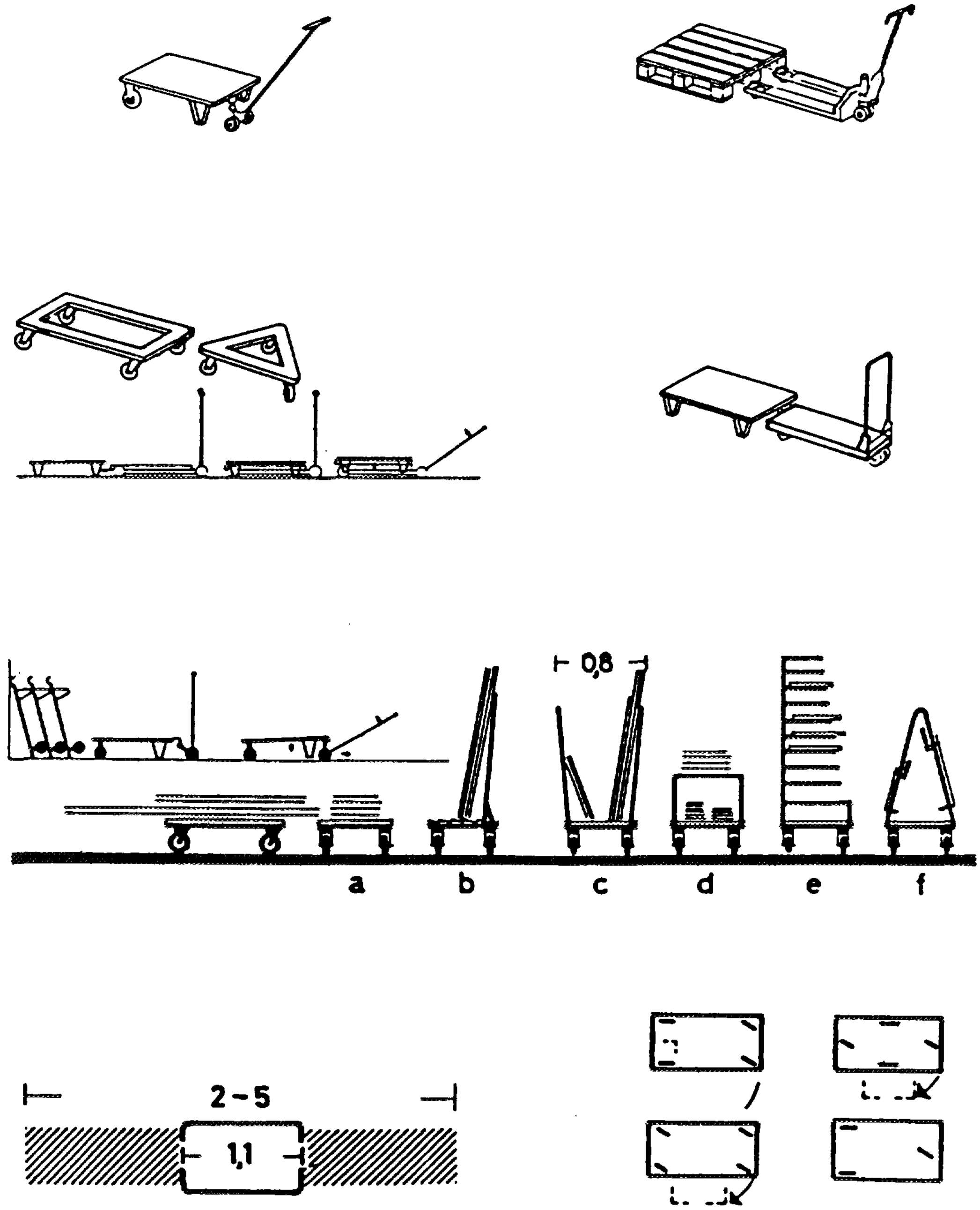
The aim should be to keep the factory mobile by ensuring that raw materials etc. are never placed on the floor but always on either a trolley or pallet.

Management of a rattan furniture plant

Management organization

The management organization presented in figure 77 is typical of that which applies in a well-organized, medium-to-large, export-oriented rattan furniture plant. If the plant is much smaller than the one described in the previous sections, all the management functions referred to must still be exercised, even if by fewer people. It is therefore impor-

Figure 76. Manual internal transport system



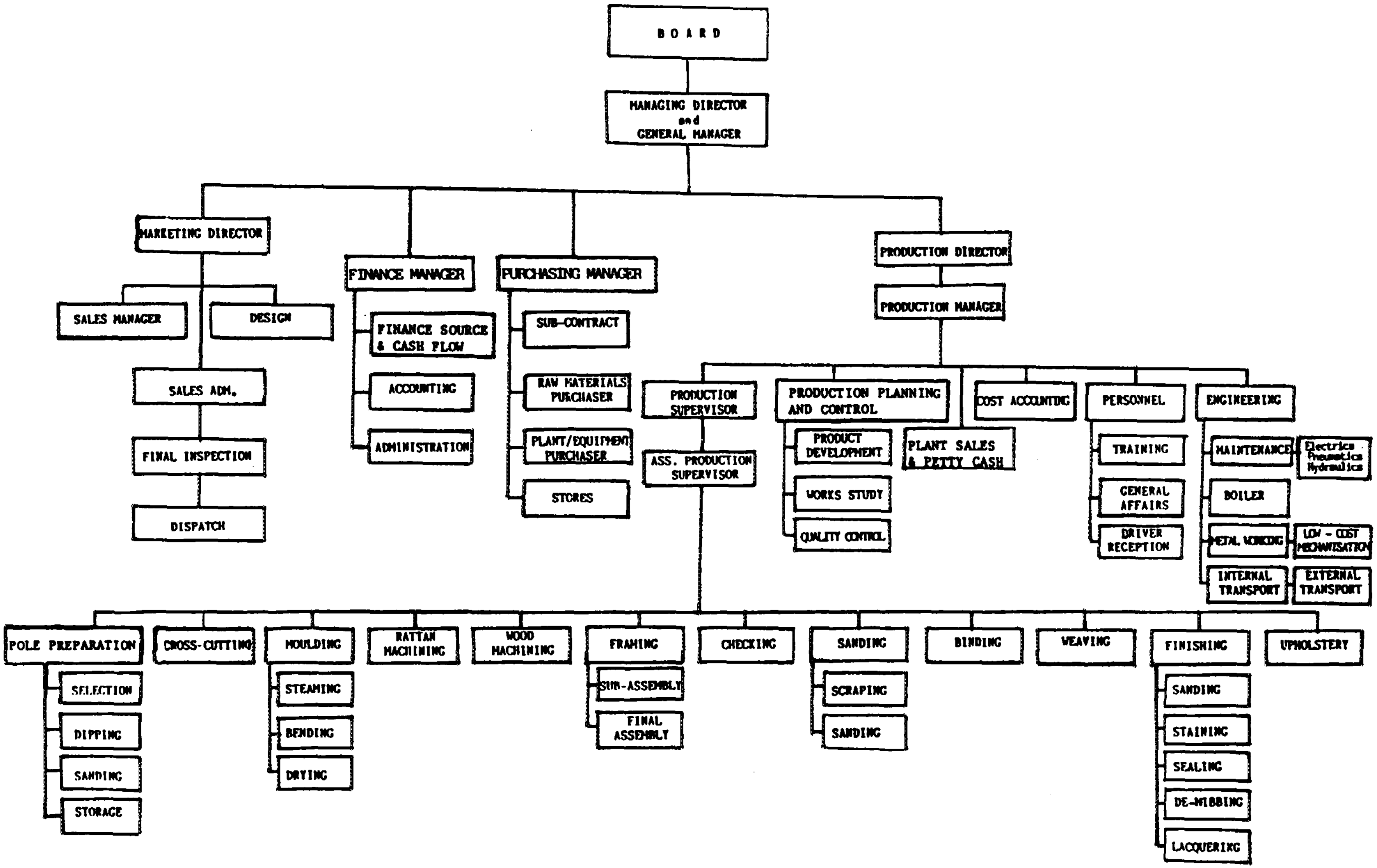
tant to understand each of these functions, all of which contribute directly or indirectly to the main objective of the organization, namely, the making of money.

In the case of a rattan furniture plant, the management is in business to make furniture and to sell that furniture at home and abroad to people wanting furniture and prepared to choose the plant's products, in the qualities and styles offered, at the prices quoted and with the service facilities offered. If any one of these conditions does not suit, the consumer will not take the furniture offered but will choose that of another plant. The plant will be successful and will realize profits only if its management has correctly diagnosed market requirements and has adequately met them.

Department functions and job descriptions

The functions of the various departments in a rattan plant are listed in the *Manual on the Production of Rattan Fur-*

Figure 77. Management organization chart



niture, on pages 73-75. The middle and lower management job descriptions should evolve from these functions, which are reflected in figure 77.

A job description should be prepared for each management and/or supervisory post in each department, setting out responsibilities and providing details of all jobs undertaken. These responsibilities are frequently used as a basis for grading jobs in respect of importance and monetary value. If so used, the job specifications should contain details of special qualities required for the job, the range and number of internal and external contacts and expected performance standards. Typical job descriptions that specify the level of responsibility are provided below.

Production management

The most important determinant of plant efficiency and profitability is the calibre, style and method of management. A high level of technical and professional knowledge is required at all levels if the manufacturing organization is to operate successfully and produce furniture of the kind and quality demanded by the market and at a cost that allows for an acceptable profit.

At the managerial level, the basic skill required is the ability to organize, control and make decisions without undue delay. This involves matters of product policy, finance and marketing as they are applied to routine matters of administration and production. Technical knowledge is also essential at this level to ensure that problems are thoroughly understood and dealt with in a practical manner. Production managers need not be experienced in financial management, but they should have a working knowledge of the financial implications of operating a business of this nature, especially costing and cost control, so that they can correctly judge the efficiency and economies of methods, materials and products.

Finally, the style of management should be cooperative. This style of management attempts to master the tasks set through mutual efforts by all employees, bearing in mind their different levels of responsibility. It acknowledges that each worker is an independent, grown-up individual.

Management controls

It may be said that pride in maintaining a standard is the hallmark of good management. But before the standard can be maintained, it must be set, and to know whether it is maintained, performance must be measured. Where the performance of a collection of people, an organization, is involved with standards of behaviour are also involved. In all manifestations of management, whether it is one's own private affairs, a foreman managing a department or a manager running a large organization—this need to set standards (aims, policies, targets, etc.) and to measure performance is inherent. Standards of design, quality, output, financial results can be set down and measured quantitatively. Although this cannot be done for such activities as general behaviour, motivation, coordination, consultation and cooperation, it is just as necessary to make a deliberate attempt to set a high standard here, too, and this standard must be maintained—and must be seen by all to be maintained—by the manager.

Simply stated, the process of management involves establishing an aim or object, setting standards (as high as practicable), revealing discrepancies and taking steps to correct such discrepancies and to improve performance. When this is carried out deliberately, continuously and successfully, a manager can be said to be in control, the organization will be in harmony, and the "captain" will have a "happy ship".

In many ways, the chief executive of a business is becoming more and more a coordinator, and to coordinate effectively, he must understand the principles that govern the working of the business in all its aspects. In practical terms this means that he can no longer confine his knowledge and experience to technical and specialized operations. He must understand how the operating plans for marketing, production and distribution interlink, what effect a change in volume will have on overall profits and so on. Such coordination is based effectively on control, and this presupposes the existence of planning in association with control. A framework for planning that is based largely on the financial implications of running a business is shown in figure 78.

Control can be defined as guiding and regulating the activities of a business by means of management judgement, decision and action for the purpose of obtaining agreed objectives. The various stages of control, in order of time, can be expressed in diagram form, as is shown in figure 79.

Budgeting

Most firms undertake some sort of annual policy planning, but there is considerable variation in the extent to which operations are planned. Some are content to draw up a sales forecast and an estimate of profits, combined perhaps with a budget for capital expenditure and a forecast of cash movements. However, more and more firms are coming to appreciate the need for more detailed planning, which can form the basis for motivation at the departmental or supervisory level and can be used for subsequent control. The overall planning is then supplemented with detailed budgeting covering overall and departmental objectives, activities and resources.

In practical terms, the budget for an enterprise or a particular department of that enterprise will specify the quantity of output the department will be expected to produce during the year ahead and the resources that management will need to produce this output, e.g. materials, man-hours, machine-hours, power, supervision and so on. To enable this departmental budget to be fitted into the overall picture, each of these resources is costed out at the price or rate expected to be paid during the period.

The interrelationship of the principal budgets is shown in figure 80.

Figure 78. Framework of financial control

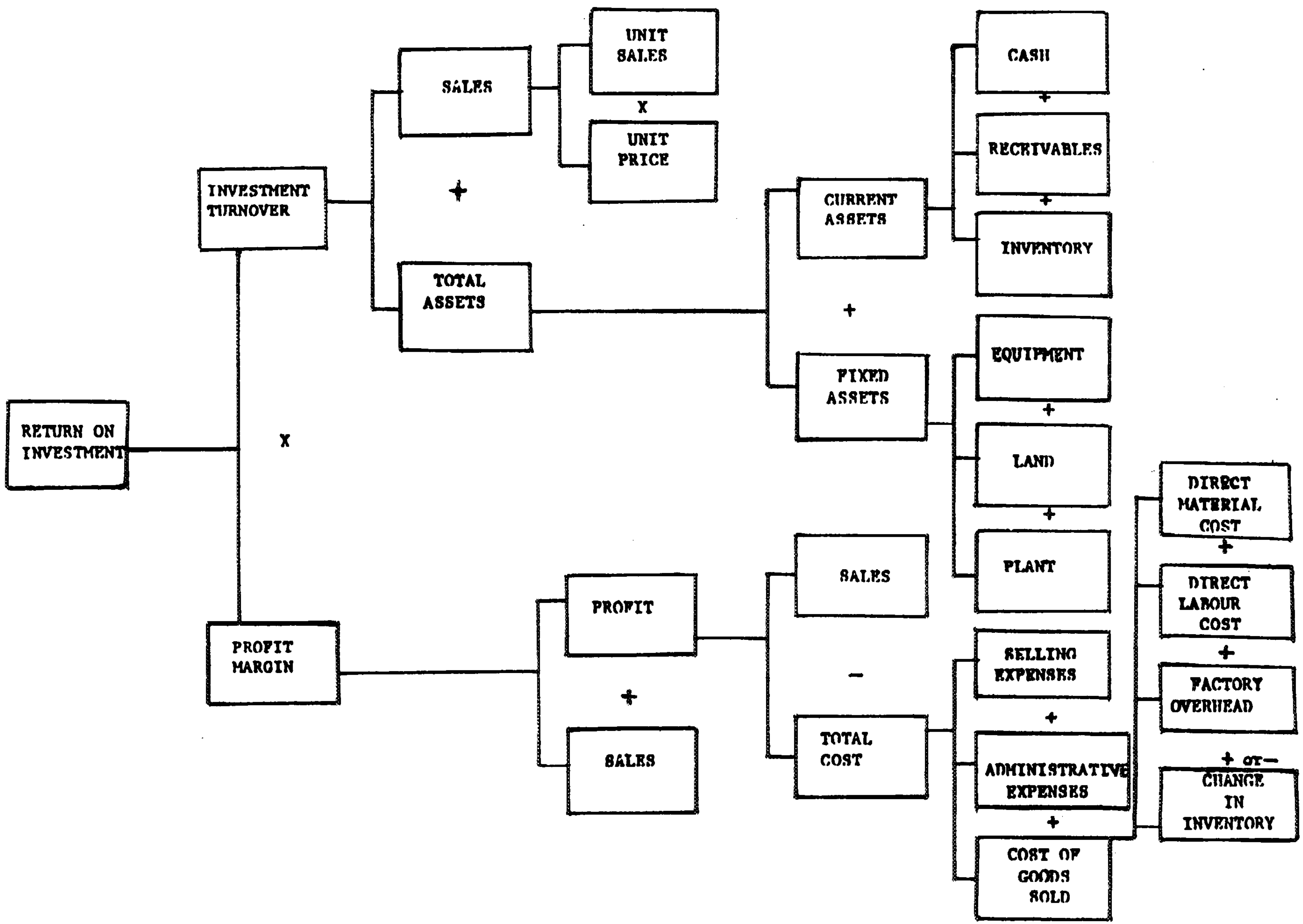


Figure 79. The control cycle

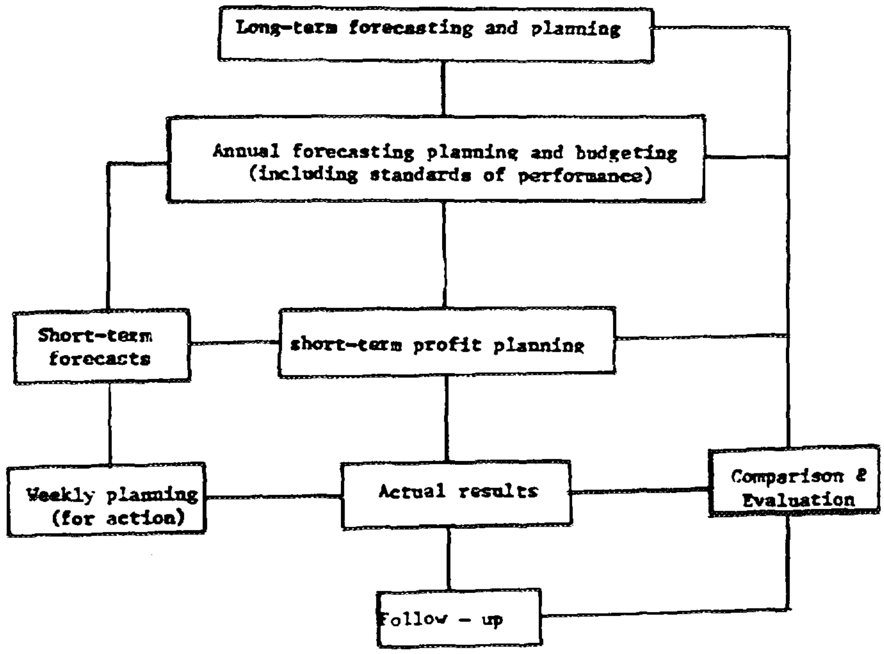
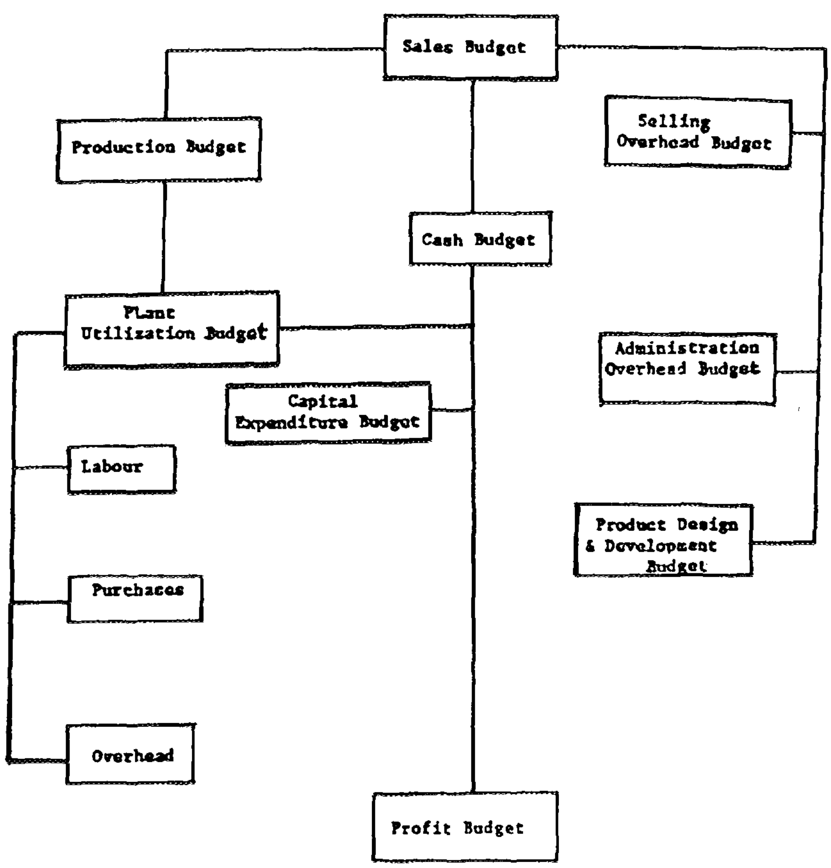


Figure 80. Interrelationships of budgets



In any manufacturing business, the following budget items are usually necessary:

Budget item	*Prepared by*
Sales	Sales manager
Production, based on:	Production manager
Plant utilization	Production manager
Labour budget	Production manager
Purchasing	Production manager
Product development	Production manager
Overhead, based on:	Accountant
Production	Accountant
Administration	Accountant
Selling	Accountant
Cash	Accountant
Capital expenditure	Owner/managing director
Design	Marketing manager

Sales budget

The sales budget is the most important budget and is usually the most difficult to forecast. It is based on a knowledge of customers, competitors, new designs and trade conditions, both general and specific to the furniture industry.

Production and plant utilization budgets

The production and plant utilization budgets express the figures in the sales budget in terms of factory capacity, machine loading, tooling, maintenance and repairs.

Labour budget

The man-hours required for the planned production are based on the expectation that output will conform to predetermined standards for output per hour. The budget therefore discloses the following information:

(a) The number of workers of each class or grade required to achieve the output in each period into which the output budget is divided;

(b) The anticipated cost of each type of labour in each period;

(c) Special training requirements.

Purchasing budget

Sales projections must be converted into raw materials requirements and components so that decisions can be made about purchasing. If semi-manufactured components are "bought in", they must be ordered in good time so that they are available when necessary. Consideration must be given to the limiting effect on production of any materials that are, or are likely to be, in short supply. The budget must show the quantities of materials required, taking into account:

(a) Quantities that must be in stock during the budget period;

(b) Sales for which materials required must be available, taking into account the forecast rate of output;

(c) The anticipated cost of the materials;

(d) The period of credit allowed and the amount that will fall due for payment during any budget period.

The information thus disclosed will enable purchasing to be carried out under the best possible conditions.

Overhead budgets

These will include factory overhead, administration, sales and distribution, product design and development.

Financial budgets

The most carefully prepared manufacturing plans are incapable of fulfilment if adequate cash is not available at the right time. The preparation of a cash budget or forecast is therefore of the utmost importance, both for the short-term budget period and, especially, for the longer term. The aim of most businesses is a planned and constant expansion, and unless a long-term cash forecast is made, progress may be frustrated by an unanticipated lack of funds.

Increasing sales usually imply a need for increased investment in raw materials, work-in-progress, finished stocks and debtors, so that additional financing may have to be obtained.

The whole exercise will of course be useless unless the budgets are soundly based. This means that full use must be made of forecasts of external conditions such as the economic climate, consumer demand, consumer preferences, price trends and wage rates. In cases where production engineers/managers have been able to arrive at suitable standards of performance for factory operations, these will be built into the budgets; in other cases, they will have to rely on managers' own estimates.

Control

Having agreed on long-term and short-term plans, management needs to exercise control in order to ensure either that the plans are carried out or that they are appropriately modified where circumstances so warrant. If it becomes apparant that the original objectives cannot be carried out in their entirety during the period under review, then it is the job of the control function to establish the extent of the deficit at the earliest possible moment. A person looking forward to a hot bath does not want to wait until the bath is full before discovering that the hot water supply has run cold.

Visual control

There are two types of visual control: the supervision of operator performance by foremen and supervisors and the control of mechanized operations by frequent observation of a control panel. Both are strengthened by control reports in which actual performance is evaluated and compared with a standard. Control by instrumentation usually entails technical or quality matters.

Control by exception

Control by exception means comparing actual performance with expected performance and actual costs with target costs, in such a way that suitable corrective action can be taken if things go wrong. It depends for its effectiveness upon such factors as the following:

(a) The validity of the target figures;

(b) The linking of targets and actual results with specific management or supervisory responsibilities;

(c) Speedy corrective action.

Pre-control

Pre-control is a term for control exercised at the budgeting stage. For example, the best opportunity for reducing maintenance costs may come at the time the maintenance budget is prepared rather than later.

Control by motivation

Motivation is usually encouraged by giving everyone concerned with management the opportunity to take part in deciding target levels and by informing them frequently and promptly of results.

Overall control

Bureau control describes the job of coordinating all the activities carried out in the day-to-day running of the business:

Activity	*Nature of the activity*
Management of disposable funds	Technical/financial
Plant management	Financial
Production	Technical/financial
Marketing and sales	Technical/financial
Product management	Technical/financial

It is also concerned with reconciling conflicting interests. Production and marketing management may, for example, have incompatible aims. One may want to reduce the variety of models produced, while the other may want a wider variety in order to capture more of the market.

Typical job descriptions

Rattan Furniture Design Consultant

The Rattan Furniture Design Consultant is responsible to the Managing Director. He is responsible for establishing a product design policy for the rattan furniture factory and advising on the design and development of an integrated range of retail and contract furniture for selected export markets.

The Consultant will be attached to the furniture factory and will identify, design and develop ranges of period and modern rattan-based furniture that are consistent with specific market requirements and that can be produced efficiently and profitably in large volume by the factory. In particular, he will be expected to do the following:

(a) In coordination with the marketing and design departments of the factory, review and assess current design programmes;

(b) Advise on a new integrated product mix based on target market and production requirements. This product mix should have an image that is identified with the enterprise;

(c) Eliminate unsuitable and unprofitable models;

(d) Redesign existing models where appropriate and/or introduce new ones on the following basis:

- (i) To cover the chosen sectors of the relevant export markets;
- (ii) To include living-room, dining-room, bedroom, office and occasional furniture requirements, both upholstered and non-upholstered;
- (iii) To use, where possible, indigenous raw materials and advise on the selection and sourcing of materials that have to be imported;
- (iv) To exploit fully the special skills and equipment available;
- (v) To design on a modular basis, with a high degree of rationalization and interchangeability of components;
- (vi) To incorporate, where appropriate, knock-down and self-assembly techniques;
- (vii) To ensure that the furniture can be produced and sold within the stated price ranges;
- (viii) To establish product continuity so that customers can add to the pieces they have already purchased;
- (ix) To ensure acceptable quality standards and specifications, in accordance with functional and ergonomic requirements;
- (x) To design, where appropriate, packaging for the products.

(e) Establish correct procedures for design management, from the design briefing through prototyping to the stage where a model is developed for serial production;

(f) Advise on graphics generally and, specifically, the design and preparation of sales catalogues and other point-of-sale and promotional literature;

(g) Participate in trade fairs and assist in establishing and maintaining contacts with trade and institutional buyers, especially for exports.

The Rattan Furniture Design Consultant should possess the following qualifications: internationally established as a furniture designer, with considerable experience in the design and marketing of a wide range of rattan-based furniture for large-scale, serial production and suitable for contract and retail export markets. Designing experience and a knowledge of the European, Japanese and United States of America furniture market requirements is essential.

Product Development Engineer

The Product Development Engineer is responsible to the Production Manager. He is responsible for all aspects of product development, from the preparation of working drawings to the stage when a model is ready for full production. In particular, he will be expected to do the following:

(a) In coordination with the Design Consultant and the production team, supervise the work carried out by the product development workshop;

(b) Make prototype models in accordance with the full-size detailed drawings of each model prepared in the design drawing office;

(c) Develop each model in terms of components, sub-assemblies and assemblies, so that it can be produced efficiently in series;

(d) Produce master parts and master sub-assemblies of each model. These are for use throughout the factory as production and quality guides;

(e) Prepare measuring gauges to ensure dimensional accuracy and the accurate setting-up of machines. They would include length and width gauges, thickness gauges, boring pitch gauges, joint gauges and profile gauges (templates);

(f) Design and supervise the production of accurate moulding and framing jigs, in which the guiding surfaces correspond exactly to the primary measurement and shape of the finished product;

(g) Prepare production planning and control documentation, including process flow charts and route cards, and assist in the compilation of costing data;

The Product Development Engineer should be a qualified industrial designer and/or production architect/engineer, with considerable experience in planning, programming and product development for the large-scale production of rattan and panel-based furniture. Familiarity with the technology and operation of a wide range of woodworking machinery and equipment is essential.

Production Supervisor for Wood and Rattan Machining

The Production Supervisor for Wood and Rattan Machining is responsible to the Production Manager. He is responsible for the overall direction and supervision of all technical and production aspects of the machining of wood and rattan components for furniture and the achievement of output targets, with particular emphasis on the following:

(a) Machine selection and utilization for a wide variety of production purposes;

(b) Machine set-up, operation and maintenance;

(c) Adaptation of machines for specific purposes;

(d) Design of machine production aids such as jigs and formers;

(e) Achievement of close machine tolerances;

(f) Training and supervision of machine operators;

(g) Establishment of machine safety standards and procedures;

(h) Saw sharpening, cutter grinding and sharpening;

(i) Establishment and maintenance of quality control;

(j) Large series production.

The Production Supervisor for Wood and Rattan Machining should be a wood-cutting machinist with considerable experience in the series production of wood and rattan furniture. Familiarity with the wide range of machinery used by the rattan and wood furniture industry is essential, as is the ability to supervise and train machine operators.

Rattan Technician and Production Supervisor

The Rattan Technician and Production Supervisor is responsible to the Production Manager. He is responsible for work planning, the supervision of all production activities and the achievement of the production targets set by the Production Manager. Particular emphasis is laid on the following:

(a) Work planning, allocation and supervision;

(b) Making prototype models in accordance with the designers' full-size drawings;

(c) Designing and making appropriate jigs, formers, fixtures etc. for component machining, moulding and framing processes;

(d) Progress chasing via internal transport;

(e) Raw materials control;

(f) Devising low-cost mechanized systems for processes;

(g) Maintaining quality standards;

(h) Maintaining good housekeeping throughout the plant;

(i) Training rattan workers in all aspects of production;

(j) Ensuring that production targets are achieved and maintained.

The Rattan Technician and Production Supervisor should be a rattan processing technician with considerable experience in the manufacturing processes of rattan furniture. A period of hands-on involvement with rattan furniture production, as well as industrial woodworking training, would be advantageous. Detailed knowledge of rattan furniture manufacturing processes is required.

Rattan Surface Finishing (Lacquering) Technician

The Rattan Surface Finishing (Lacquering) Technician is responsible to the Production Manager. He is responsible for all aspects of rattan and wood furniture finishing, from final sanding to final lacquering. His duties include the following:

(a) Selection and application of the most suitable staining and lacquering system;

(b) Work planning and allocation;

(c) Operator training and supervision;

(d) Attainment of production targets;

(e) Maintenance of spray and ancillary equipment;

(f) Safety procedures;

(g) Good housekeeping;

(h) Establishment and maintenance of quality standards;

(i) Progress chasing.

The Rattan Surface Finishing (Lacquering) Technician should be a rattan and wood surface finishing technician with considerable experience in the staining and lacquering of a wide variety of rattan/wood furniture. Detailed knowledge of surface coating and ancillary equipment is essential. If possible, he should have English language ability for customer contact purposes.

Rattan Production Technician for Pole Dressing, Dimensioning, Moulding and Adjusting

The Rattan Production Technician for Pole Dressing, Dimensioning, Moulding and Adjusting is responsible to the Production Manager. He is responsible for all aspects of pole preparation and moulding, including inspection, initial classification, straightening, sanding, cross-cutting, steaming, bending, drying, adjusting and straight and profile sanding. His duties include:

(a) Work planning and allocation;

(b) Operator training;

(c) Operator supervision;

(d) Attainment of production targets;

(e) Tool and equipment maintenance;

(f) Safety procedures;

(g) Good housekeeping;

(h) Maintenance of quality standards;

(i) Progress chasing;

(j) Design, manufacture and use of a wide variety of moulding jigs and formers suitable for efficient rattan bending and moulding.

The Rattan Production Technician for Pole Dressing, Dimensioning, Moulding and Adjusting should be a rattan industry technician with considerable experience in the series production of rattan furniture. Familiarity with rattan moulding and the preparation of moulding jigs is essential. He should have English language ability for customer contact and discussion purposes.

Rattan Production Engineer/Technician

The Rattan Production Engineer/Technician is responsible to the Production Manager. He is responsible for all technical aspects of rattan and wood furniture production and achievement of output targets with particular emphasis on the following:

(a) Organization and works study;

(b) Establishment and maintenance of production planning systems and procedures, including quality control;

(c) Prototyping, product development and technical preparation for large series production;

(d) Design of a wide variety of close-tolerance production aids for all machining, moulding, sub-assembly and final assembly procedures;

(e) Increasing mechanization of production and improving individual machine utilization;

(f) Use of hydraulics, electrics and pneumatics and all aspects of production;

(g) Assembly fixtures and auxiliary devices;

(h) Machine set-up and maintenance;

(i) Establishment of safety procedures, especially in wood machining.

The Rattan Production Engineer/Technician should be an industrial engineer, preferably with experience in the rattan and/or woodworking industries. Detailed knowledge of work study and its application to rattan/wood furniture manufacturing is essential. He should have English language ability to deal with customers who visit the factory.

Production management and supervision

Job of the Production Supervisor

The supervisor's job consists mainly of creating—by word and action, by decision and example, by orders and organization—an atmosphere in which people are motivated to work willingly, effectively and with continuous high effort. It is a job of leadership. Although a new type of leadership must permeate management from top to bottom (no section, department, works or organization can be better than the man at the top), it is at the lower level of management, the level of "supervision", as exercised by the foreman, that a lack of leadership causes the most unrest and reduces individual effectiveness. The foreman or supervisor is in constant daily touch with operatives, frequently giving direct orders and making personal decisions. He is often the weakest or the strongest link in the chain of command.

During the past few decades, the responsibilities of managers of all grades, including supervisors, have been steadily reduced or changed. Certainly their freedom to be domineering has been reduced, even if their effective power is more. Specialists are now employed to do much of the work that, in the earlier days of the industrial era, occupied a foreman's time. Processes and methods are laid down by technicians and production engineers; the order of production is decided by planning engineers; costs and performances are calculated by accountants; and the whole employee/employment function is often the responsibility solely of the personnel function.

Instead of selecting supervisors only for their operating or technical skill and then training them specifically for the job of supervision, they should be selected mainly for their abilities, even if latent, as leaders. In addition to knowing the technical work being done by subordinates and associated specialists, the supervisory role consists of putting the right man in the right place, seeing that he is suitably rewarded for his efforts, giving him all the information he needs, making decisions on the innumerable occasions that are not covered by standard practice, instructions and procedures, and continuously inspiring his team to work willingly and well.

The aspects of supervision that most immediately apply include motivation, discipline, communication, consultation, decision and cooperation, coordination and integration.

Motivation

Inspiring leadership in everyday work can have astonishing results in raising workers efforts much above the ordinary level. To attain this, managers must show by their enthusiasm and example that they have faith in the purpose of the job in hand and in the company's product or business and that they are loyal to the company's policies, to their own seniors and to all their subordinates. It is not enough to show this on important occasions, it must be shown in every small decision and action, in giving orders and receiving unpleasant ones, in reprimands and in commendation, in attempting the impossible and carrying out the routine jobs, in dealing with disputes and correcting or reporting grievances, in setting tasks and ensuring rewards. To inspire his team and maintain a high morale, the manager must set himself a high standard and live up to it. Inspiration, then, is the essence of leadership. Loyalty is a principal ingredient—loyalty to subordinates, to management and to the purpose of the enterprise. Other ingredients are keenness, which is infectious; absolute honesty in all things, but especially in discussions; an interest in and a liking for people, leading to personal sympathy and understanding; readiness to face awkward situations and to accept responsibility, but unwillingness to ask others to do anything one would not do oneself; an ability to make prompt and resolute decisions, however unpleasant; and, finally, a sense of humour.

Discipline

Discipline on the shop floor and adherence to rules and regulations are vital, not only to prevent chaos from developing but to maintain safety. In addition to organizational rules, such as starting and finishing times and so forth, there must be rules defining where people may and may not go, where and how materials must and must not be stored and handled, how certain machines must be guarded and when goggles must be worn. The most effective precursor to good discipline is the example of the supervisor. Discipline based on "don't as I do, do as I say" will soon lead to chaos and may well lead to serious injury. Most people respect a strict but fair disciplinarian, but very few are really happy under a lax management, for laxness in administrative rules is usually matched by laxness in safety rules, and someone eventually gets hurt.

Communication

Communication is a vital tool of management, probably more so today than ever. There are two aspects of communication. The first is the manager's expertise in transmitting ideas or instructions to another person or group of persons in such a way as to ensure that the recipient of the information knows exactly what is happening or what he is intended to do.

Not everyone in a supervisory position is necessarily good at expressing himself orally or in writing, so it is important to make sure by checking. Random checks can be undertaken by asking the recipient of the information to repeat the instructions in detail or asking someone on the shop floor his understanding of the information.

The second aspect of communication that management must take positive steps to achieve is communication instead of secrecy. Often secrecy is unintentional; busy managers intent on their immediate problems may not find time to stop the department, call everyone together and pass on the latest information about what is happening and why. One solution to this problem is briefing groups.

A briefing group is the periodic assembly of the whole department with the department head, be he foreman, manager or director, to enable the head to tell his subordinates what is happening and why and to give an opportunity for general discussion on what needs to be done and how everyone can best contribute. To be effective, briefing groups must be held at regular intervals, not only when there is some bad news to impart or a rush job to get out. At departmental head level, once a month, following publication of the monthly statistics, is a good time; then, everyone can be kept abreast of the fortunes and prospects of the company and so identify with its continued success.

Finally, as communication is between people, it is essential to present facts and get reactions, as personally as possible. A few minutes' talk is worth more than pages of notices, and even in the talking, warmth and a sense of humour are more effective than a cold, impersonal speech, however perfectly phrased.

Joint consultation

Much of a manager's time is necessarily spent in dealing with people, but little of it should be spent in actually giving instructions. For most of the time, a manager should be passing or receiving information as a result of which subordinates take action, if action is necessary. In doing so, he should provide a reasonable opportunity for the other people to express their opinions, even if they have to be corrected or rejected. In this way all subordinates, and the rank and file, are made to feel that their opinions count and that they matter. The larger an organization becomes, the more difficult it is to do this; information does not move very freely along the channels of communication, and decisions made high up may appear arbitrary.

Sometimes, there is resistance instead of ready cooperation. For that case, a more formal means of ensuring the flow of information becomes necessary, and the so-called "joint consultation" approach comes into play.

Decision

Decision is another important element of leadership. Here, both the impetuous, hasty decision and the hesitant or procrastinating one are out of place. Some people find it very difficult to make up their minds and stick to a decision. For this reason, highly skilled technical people and those trained in research often do not make successful managers: they have been so used to looking at details that they are unable to make a decision rapidly. Although it is essential to be able to take a decision, it must not be thought that it is possible to do so without a knowledge of the facts and without a good deal of thought. A manager must not always be forcing his ideas; he must be a good listener as well as a good talker. Above all, he must be able to get others to contribute their ideas and facts and, as far as possible, to share, or feel they share, in the decision.

When all the facts of a situation are disclosed, everyone concerned, supervisors and operators alike, forms the consensus. There is not the same feeling as when orders must be obeyed. Authority can still be exercised, but it is authority backed by the facts of a situation.

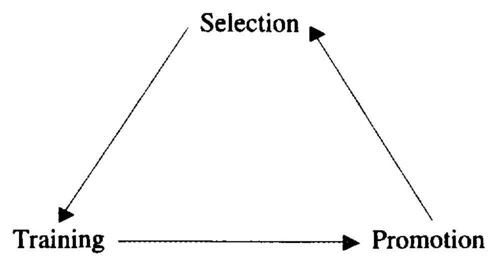
Cooperation, coordination and integration

Cooperation, coordination and integration are elements of the technique for organizing action. Cooperation is a state of mind that is based on the knowledge and appreciation of a common purpose that is understood by all. Likewise, coordination requires that all concerned have the information necessary at the time the common effort is required. Integration requires the pooling of all the facts and ideas in order to arrive at the best solution to a problem, one that is likely to be better than any other solution. In each case, the sharing of information is required. This means that there must be frequent meetings between those concerned, not necessarily large or formal meetings but at least an exchange of views, ideas and facts. Under wise leaders, cooperation, coordination and integration ensure the harmony, progress and effectiveness of the whole team.

Selection and development of supervisors

Because selection and training schemes are matters in which the Personnel Manager advises and does a good deal of the work does not mean that these schemes are no longer the line executive's responsibility. Ultimately, the head of a department is responsible for the people he has working for him, and he must retain the final right of decision about people added to his staff, retained or promoted. He has the duty of requesting and considering the advice of the Personnel Manager, but he himself must make the final decision.

The skill of choosing subordinates is one which the young or newly promoted manager must learn if he is to be successful. Many reorganizations would not have been necessary, and many unhappy organizations would not be unhappy, had the executive at the head been skilled in his choice of men. Few persons remain what they were when they were young. All are susceptible to training, particularly good and stimulating training. So training is equally important, and it makes for more stability and loyalty than introducing outside persons into an organization at a high level. To choose good people at an early age and then train them means that each promotion is also a selection. Thus, selection, training and promotion, all vital elements in management, form, as it were, a triangle:



When selecting staff, managers must be good listeners and better observers. Dominant men usually get "yes-men" round them. To gauge a man's abilities and potentialities a manager must draw him out and encourage him to express his views and talk of his abilities; this can only be done by giving him his head in so far as possible. Although interview and test techniques have been imposed, they are not sufficient by themselves, and personal evaluation, particularly of character and personality, has still to be relied on. Such evaluation should be continually practised if it is to be reliable. For it to be practised only in the case of important appointments and for the inevitable mistakes to be made is expensive and wasteful. A manager can practise it without actually making appointments, by studying the behaviour of the people he meets and checking his judgement later. It will be found, except in rare cases, that a conscious effort must be made to evaluate. Otherwise the decision will be affected too much by emotional reactions and personal likes and dislikes.

It is a good idea for a manager to have a list of all his immediate subordinates who would be contenders for his position if he himself were promoted. Against each name he should record proficiency in the technical skills required for his job and should also rate him on the personal qualities required. Analysis of the chart will frequently show a few contenders, each with various shortcomings in technical knowledge, experience or personal qualities. The manager should then take steps to initiate a training programme to make good those weaknesses. To do this it is not always necessary to let the men concerned know that they are in the running. The manager should know his subordinates well enough to know which will get the best results, silence or knowledge.

Performance

Most people like to know how well they are doing. In industrial activity this knowledge is essential. A company must render an account at least once a year of its financial results. However, the trading account is the result of the individual and collective actions of all employees from day to day, and it is equally necessary for an account to be rendered of the results of their work, that is, of their performance. This is done for piecework operators, since their output is measured. One of the advantages of measuring piecework on a time basis is that the percentage bonus is a measure of performance that can be used for comparing individual and collective, or departmental, results.

A manager is responsible for the work, and hence the performance, individual and collective, of all employees under his authority. The total bonus percentage of a department is obviously one measure of departmental performance for which the foreman can be held responsible. But there are other kinds of performance, often not measured or not measured accurately. Perhaps the most important of these are total overall costs per unit output and excess costs. In some cases such as furniture component processing, machine utilization is equally important. Although the quality of the product is usually checked, if not controlled, by the inspector, the Production Manager is responsible for results. A manager must see to it that he has accurate reports of all such measures of performance relating to his department and must take energetic steps to improve performance continually.

A supervisor should scrutinize the figures weekly; in particular, good performance should be complimented: "an ounce of appreciation is worth a ton of reprimand". This also applies to good departmental performance. Poor performance, particularly when out of character, should be investigated, not so much to administer a reprimand, although this may sometimes be necessary, but to determine whether it indicates a training need, equipment shortcomings or perhaps personal worries about a situation outside the workplace. In this case, the Personnel Department may have to help. With labour performance figures it is the significant change rather than the general level that is important.

A supervisor should also be trained to understand and take action on the labour cost return for his department. The most important measure is the cost per unit of output, a significant rise in this figure being cause for immediate investigation. The form for reporting labour cost return should be set up so as to reveal areas requiring investigation, e.g. waiting time, rectification time and so on.

The performance, or quality, of the finished parts is another aspect of performance. It is often thought that this is the responsibility of the Inspector. It is not. The quality of product is a supervisor's (manager's or foreman's) responsibility. The Inspector is really the representative of the customer in the Assembly Department or Sales Department. He is employed as a guardian of quality, and it is his job to obtain and use reports on the performance, or quality, of the product. Just as a supervisor analyses labour costs, the Inspector must look for incidence of cause and follow up by trying to cure the cause. Nor is it right to assume that there must always be some waste, or that a normal figure needs no further efforts to reduce it. It is surprising to see how an already low rate of waste or faulty work can be further reduced if an effort is made.

Productivity

In the past 10-15 years much stress has been laid on productivity. It is, of course, a very important index, but it is not easy to measure. Output per man-hour is an index of productivity that can be measured for a given factory in a given year, using the value of sales and the number of man-hours. This will give a false picture of productivity improvement if, for instance, selling prices are increased and labour hours remain the same. One index of productivity that enables these points to be taken into account is value added per employee in relation to the company's capital intensity. The concept of value added is now familiar to most people, but its relation to hours worked, number of employees, or capital employed has not been widely recognized as a productivity index.

Control in action

A manager of a production unit, whatever his title, must spend a large part of his time controlling the activities for which he is responsible, that is, checking performance against the plan or standards and taking action to correct errors or undesirable trends. The higher a manager's position in the organization, the more he will have to judge results on the basis of reports and other documents. Such documents should therefore be designed to make deviations, shortages, excess costs, overdue items etc. stand out from the mass of figures.

Cost control reports presenting performance figures and analysing excess costs according to cause should be used down to the level of supervisor. The Production Manager will scrutinize them first, then discuss significant items with his subordinates. They, in turn, will discuss the reports in more detail with their assistants.

The Production Manager will examine other manufacturing expenditures by comparing them with his budget. He will have discussed the budget with his managers before it was agreed and will likewise discuss results with them when they are known, usually at monthly intervals. Time should not be wasted in going through every item, but thought should be given to excess expenditures about which something can be done. The Production Manager will also need to check output, preferably weekly, against delivery requirements, and take action to prevent overdue deliveries. Failures here may necessitate the rearrangement of production facilities, overtime, extra shifts or the hiring of additional labour, as well as discussions with the managers concerned. He will also watch earnings as an index of performance. Stock levels and out-of-stock items will need to be discussed with the Purchasing Manager and the Storekeeper; again, production plans or purchasing programmes may have to be adjusted to bring them in line with changes in material supply. Likewise, reports from the Personnel Department on absenteeism and turnover may call for action, either by reassigning existing labour or recruiting new labour.

There will be other control reports used by a particular company. The important thing is that the Production Manager should not just receive, read and file these reports but should, at least frequently if not regularly, discuss doubtful or unsatisfactory, as well as good, results with the persons responsible. In this way the reports are kept alive, and those responsible for the results are motivated to do something about them: production is under control. This concept is the background and basis of management-by-objectives, in which a three-stage process—determine targets; operate; check performance—is subject to regular, say six-monthly, review. The principles of management by objectives are not new; indeed they are just good management in action. However, in many organizations and for many people good management does not happen unless it is programmed, introduced by an expert or given a fancy name. But whether it is done formally or informally, it must be done. Then the Production Manager will be managing, and he will be achieving the objectives of his position.

Guidelines for rattan production supervisors, technicians and other technical personnel

General

General guidelines are as follows:

(a) The best kind of supervision comes as a result of training. Workers must be properly trained to do the job. This applies particularly to newcomers to a section;

(b) There is no substitute for direct and full-time supervision. A supervisor must be with his section all day, every day, and must ensure that in his unavoidable absence, someone else takes over;

(c) A worker has no business being in any other part of the factory, apart from the toilet, without permission. If he comes into another department, he should be instructed to leave immediately;

(d) Punctuality is an important contributor to productivity; even minutes count. There must always be someone else capable of taking over the job if a worker is absent from his post, and a supervisor's stand-in must be briefed on this arrangement;

(e) In the case of absence, including his own, a supervisor must always make sure there is someone else capable of taking over the job and that his stand-in is well briefed before departure;

(f) Workers must come to their supervisor and no one else for all permissions, and they must never be allowed to leave their workplaces without his permission. They should also report to him on their return;

(g) No worker should be permitted to leave his workplace without permission, and this must not be given except for genuine need. In that event, a supervisor must make sure that the absence does not disrupt work elsewhere;

(h) When giving instructions to his workers, a supervisor must make sure that he is fully understood. Often, a simple sketch can be worth a thousand words;

(i) Instructions and corrections should be given firmly but tactfully;

(j) A supervisor must consult with his fellow supervisors in other departments daily, if not hourly, so that there is complete harmony throughout the plant. This applies in particular to those departments that are interdependent, e.g. machining, sanding, assembly and finishing. A supervisor must never discuss another colleague on the supervisory staff with any of the workers;

(k) Toilets should be hosed out and disinfected daily;

(l) No materials are permitted on the floor; pallets must always be used;

(m) Clearways must always be kept clear;

(n) When a pallet or trolley load has completed one process, it should be immediately removed to the next machine or intermediate storage waiting area;

(o) A supervisor's most important job is to ensure that his men:

- (i) Never have to leave their machines or benches except for personal reasons;
- (ii) Always have plenty of work in front of them;
- (iii) Always have the means to do the job satisfactorily, i.e. machines set up, all the right materials available etc.;
- (iv) Always have the work moved on to the next station when completed;

(p) Waste bins must be provided for every machine and should be emptied daily;

(q) Waste occurs mainly at the break-down stages, i.e. at the cross-cut and circular saws. Ensure that it does not move further in the factory;

(r) Space is very valuable. If there is not a good reason for material occupying space, then it must be got rid of whatever it is;

(s) Under no circumstances should a job be started until everything needed to complete the job is available;

(t) A supervisor must ensure that the instructions he gives his men are fully understood by them. If they have never done a particular job before, then he must instruct them clearly on how to do it;

(u) A supervisor must try to anticipate difficulties and problems that might arise, e.g. cutters needing to be sharpened, sanding belts needing to be replaced, one of the men about to run out of work;

(v) When issuing instructions to his men, a supervisor should do so firmly but tactfully, otherwise he may get their backs up and their output down;

(w) If a man is appointed to operate a machine or work at a bench, then all of his time should be spent on that work

and not on fetching and carrying. There should be others to do that, and it is part of a supervisor's job to see that his production men remain fully productive;

(x) A supervisor should be quality conscious himself and make sure his men are also. Defective materials must not be used;

(y) The time to discover a mistake is not at the final stage of production, but when it occurs;

(z) A new man coming into a section has to be specially trained and instructed. A supervisor should think back on his own first day at work;

(aa) The successful factory is the one where there is cooperation between people. Cooperation is ensured by keeping people informed. A supervisor should confer daily or even hourly with his fellow supervisors in each department;

(bb) All work areas, assembly benches etc. must be kept clean and tidy at all times;

(cc) Daily production programmes should be prepared at least one day in advance;

(dd) Daily production reports should be completed at the end of each day's production.

Stage I

Guidelines for stage I, pole delivery, inspection, classification, drying and storage, are as follows:

(a) Since rattan poles account for such a high proportion of the total cost of manufacturing, great care should be taken in their inspection, classification and storage;

(b) It is also this department's responsibility to ensure that adequate stocks of all types of poles required for production are maintained in the cross-cutting area;

(c) It should be noted that the pole storage area in the cross-cutting department has been so arranged that each type of pole classification and diameter is stored separately and can be retrieved without difficulty;

(d) If a first scraping has to be done on newly delivered poles, this should be carried out as soon after drying as possible;

(e) The scraping must be done quickly and efficiently. The scraping tools must be checked;

(f) When a concrete pathway from the pole storage to the cross-cutting area has been completed, all poles should be transported on carts and should not be carried;

(g) Poles that are rejected should be returned to the shipper immediately;

(h) Initial storage of dried and straightened poles is in the storage shed. This should be in accordance with classification and size;

(i) Minimum stock levels of poles should be maintained at all times, and management should be warned well in advance of possible shortages;

(j) It is the responsibility of this department to ensure that adequate stocks of various diameter dried and straightened poles are maintained in the storage area of the cross-cutting mill.

Stage II

Guidelines for stage II, cross-cutting and storage, are as follows:

(a) A daily production programme should be prepared by the supervisor, and cutting instructions should be issued to the sawyers;

(b) Each sawyer should, as far as possible, deal with the batch cutting of only one model at a time and should complete this before commencing another model;

(c) Generally speaking, each sawyer will concentrate on the cutting of a particular pole diameter;

(d) The sawyers should remain at their saws and should always be handed the appropriate raw material by a helper;

(e) The poles should be delivered to the saws on trolleys and after cutting be placed in another trolley for delivery to the straightening machines;

(f) There should always be a buffer stock of cut poles awaiting delivery by cart to the straightening and sanding area;

(g) Unusable off-cuts should be put in waste bins located beside the cross-cut saws;

(h) Delivery of cut poles to the straightening and moulding department should always be in accordance with immediate production requirements.

Stage III

Guidelines for stage III, straightening and sanding, are as follows:

(a) The straightening machines and profile sanders should operate without stopping (except for power failures) throughout each day;

(b) The supervisor must ensure that there is always an adequate supply of poles awaiting these operations in the immediate storage area close to the machines;

(c) The machines have been so arranged that it is possible for an operator to take each component from one cart, pass it through his machine and load it on to a second cart without difficulty;

(d) The operator must therefore be continually serviced with loaded and empty carts, and processed poles must immediately be moved to the next storage, or waiting, area;

(e) Down times on these machines can be reduced by ensuring that sanding belts and other requirements are always quickly and easily available;

(f) The dust exhaust system at each machine must be checked periodically to ensure that it is operating effectively;

(g) After straightening and sanding, the poles are transferred to a storage area to await moulding and bending. Some pole components are not moulded and should therefore be transferred directly to storage to await machining;

(h) A special storage area close to the rear entrance should be kept for cut poles that are being sent to subcontractors;

(i) The clearway surrounding the sanding and straightening machines should always be kept clear so that there is a free flow of carts and pallets in this area;

(j) Transport carts should be used and material should not be thrown on the floor;

(k) Special castorized pallets should be used for the splitter and sizer machines.

Stage IV

Guidelines for stage IV, bending and moulding, are as follows:

(a) The layout in this department is particularly important since it is necessary for all benders to have easy access to the steaming ovens. Therefore, moulding benches and moulding activities should be located as close to the steaming ovens as possible;

(b) At all times there should be clear access to the steaming ovens, and work-in-progress should not be allowed to accumulate around them;

(c) To improve and speed up the flow of work through this department, the following moulding equipment should be used:

- (i) Special motorized jig with detachable cylinders for moulding all rings. Four cylinder diameters will be required: 15, 12, 10 and 7 in.;
- (ii) Adjustable holders fitted to each cylinder that will hold the rattan during the moulding stage without the use of nails;
- (iii) Detachable moulding bench tops fitted with appropriate bending jigs. When the jigs are loaded, the whole bench top is removed and placed on a tiered trolley until the setting period has run its course. Meanwhile, the same bench may be used to mould a further series of bends;
- (iv) Vertical posts should be used only for rings requiring small-diameter rattan;

(d) A clearway should be marked around the steaming ovens and kept clear at all times;

(e) Additional pallets should be used to transport moulded parts to the next intermediate storage area. Some of these should be of the bin type, especially for small moulded components. All should be used in conjunction with a pallet truck;

(f) Holding cleats should preferably be stapled to the moulded parts, not nailed;

(g) It is necessary to build up buffer stocks of standard-type moulds, and arrangements should be made for the continuous production of these;

(h) All waste materials should be stored in bins especially provided for this purpose and should be emptied periodically.

Stage V

Guidelines for stage V, wood and rattan machining and machine sanding, are as follows:

Wood and rattan machining

(a) This is the key area in any rattan furniture factory. If machining is done properly, there are few, if any, problems in assembly and finishing;

(b) Each worker must be carefully instructed in the purpose and safe operation of each machine he uses;

(c) The lighting over each machine must be adequate for the accurate use of the machine. No operator may suffer from defective eyesight;

(d) The best kind of machine maintenance is preventive maintenance: this will avert unexpected breakdowns and shortages of parts or tools;

(e) Bottlenecks in machining can be avoided by balancing the work flow and ensuring an even distribution of work to the various machines. Where a machine is overloaded, some of the work can be done elsewhere;

(f) After a machine has been set up, it should be checked, preferably with a gauge, before commencing batch production. It should subsequently be checked again at intervals to ensure there is no departure from the standard;

(g) The correct sharpening of cutters and cutting tools will ensure accuracy and better performance;

(h) Measurement gauges should be used for setting up and checking the accuracy of machining. The use of tapes and rulers is to be avoided, as their accurate use depends on individual eyesight and judgement;

(i) Few machines require more than one helper;

(j) Woodworking machines operating at high speed require the full-time attention of the operator. He must not be distracted in any way;

(k) The dust extraction system at each machine must be operating satisfactorily. Even a partial failure of the system can have serious effects on the efficiency of the machines;

(l) All dust etc. should be blown off the machine each evening before shut-down;

(m) Jigs and formers that are used in conjunction with a particular machine should be kept on a rack close to that machine;

(n) All jigs and formers should be made from plywood, and wearing surfaces should be protected by a hard-wearing material like metal or plastic laminate;

(*o*) Master parts, painted a vivid orange, should also be available where necessary at the machine for checking purposes;

(*p*) When a batch of components has been processed at a machine, it should be immediately moved to the waiting area of the next machine;

(*q*) Stacking on pallets should always be done carefully. This makes it easy to count the number of components at any stage;

(*r*) Where two machines are used in conjunction with each other, e.g. bandsaw and router for shaped components, they should be located close to each other;

(*s*) Records should be kept on each day's production and explanations should be given for variations from standard production times. It is easy to monitor and measure output per machine;

(*t*) In no circumstance should waste or rejects be allowed to accumulate around any machine. The factory floor is for work-in-progress only;

(*u*) As much work as possible should be done at the machining stage. This includes provision for handles, locks, hinges, movements, shelves etc.;

(*v*) The machining section should always be at least one week ahead of sanding and assembly. There should always be a buffer stock of machined components equivalent to one week's output;

(*w*) Since there is sometimes absenteeism in the plant, make sure there is always at least one stand-by machinist capable of operating the machine in the absence of the usual operator;

(*x*) Particular care should be taken to ensure that the setting-up of a machine is checked before the machine is set in motion. Many serious accidents can be avoided in this way. Also, guards and other protective devices must be used on all occasions.

Machine sanding

(*a*) Operators of sanding machines should be reminded that the quality of the lacquering system is totally dependent on the quality of the sanding;

(*b*) The lighting in the sanding area should be of sufficient intensity to allow for accurate checking of the sanding process;

(*c*) Operators should be familiar with the following:

- (i) The use and maintenance of conventional belt sanders;
- (ii) Types of abrasive belt: sizes (length, width and thickness), different grades/grits, backing and resistance to clogging;

(*d*) When operating sanding machines, operators should be familiar with the following:

- (i) The operation of insulating/master switches;
- (ii) The warning light system (where fitted);
- (iii) Safety precautions:
  - — Correct adjustment of guards;
  - — Risk of injury from the sharp edges of belts;
  - — Avoiding trapping anything between the rollers and the belts or between the belts and the materials;
  - — Avoiding contact, especially of loose clothing, with moving parts;
  - — Careful handling of belts;
- (iv) Tensioning and centring of belts;
- (v) Adjusting the bed height;
- (vi) General adjustment, e.g. of the rollers that maintain pressure, sanding widths, downward movement of pressure pads;

(*e*) The following are daily operator maintenance tasks:

- (i) Safety precautions, including:
  - — Isolating the machine;
  - — Ensuring that all parts are stationary;
- (ii) Preventing the accumulation of dust in the machinery by blowing out frequently;
- (iii) Avoiding dust accumulation;
- (iv) Checking the sanding belt for wear and replacing when necessary;

(*f*) A sanding operator must recognize, appreciate the possible causes of and take appropriate action to remedy faults such as indentations, bruises, scratches, uneven sanding and oversanding;

(*g*) A sanding operator should be encouraged to check his finished work not only visually but also by touch;

(*h*) There should always be one helper for the sanding area;

(*i*) The operators must keep, or have kept for them, a strict account of their daily production, and this must relate to standards set;

(*j*) Workers are permitted to sit at their sanding machines.

Stage VI

Guidelines for stage VI, framing, sub-assembly and final assembly, are as follows:

(*a*) The main work of a framer may be summarized as follows:

- (i) Identifying piece parts with work instructions;
- (ii) Inspecting parts, correcting faults and fitting;
- (iii) Making up sub-assemblies;
- (iv) Constructing the main assembly;
- (v) Preparing the assembled item for the finishing process;

(*b*) A framer should be capable of using and maintaining all the basic hand- and power-operated hand tools;

(c) A framer should be familiar with all clamping and framing procedures, both mechanical and manual, including the special pneumatic equipment used for the assembly of all types of frames;

(d) A framer should be reminded that his is the last stage before finishing and that the success of the finishing, i.e. sanding and lacquering, depends on large measure on the quality of his work;

(e) A framer should have the ability to select the most appropriate of his skills for any given task. This means a capacity to plan his work and to decide for himself the following:

- (i) The most economic use of materials;
- (ii) The tools best suited for the job;
- (iii) A logical sequence of operations;
- (iv) The best layout of his workplace;

(f) In the preparation stages of his work, a framer should be capable of:

- (i) Identifying the material;
- (ii) Verifying that the shape, e.g. of joints and mouldings is correct;
- (iii) Checking that the dimensions are within the required tolerance;
- (iv) Inspecting quality, i.e. freedom from unacceptable flaws;
- (v) Where necessary, pairing and matching such items as doors, stiles, arms, etc.;

(g) He should be able to recognize and understand the cause of basic faults:

- (i) Material quality faults, such as distortion, cracks, shakes and stain marks;
- (ii) Machining quality faults, such as cutter marks, snaking and burn marks;
- (iii) Inaccurate dimensioning (it will be necessary to know and apply the acceptable tolerance);
- (iv) Out-of-true faults or shape faults;

(h) He should be familiar with all holding devices, such as vices and clamps, including:

- (i) Use of packing or protective pieces;
- (ii) Risk of damage or distortions from over-tightening and hammer marks;
- (iii) Methods of checking for true and squaring where necessary;

(i) He should be familiar with the use of jigs, fixtures and locating devices. These should be periodically checked for trueness and accuracy of dimensioning and should be maintained in that condition;

(j) A framer should invariably observe the following sequence for all assembly procedures:

- (i) Trial fitting of basic components;
- (ii) Laying out components in the correct sequence for assembly;
- (iii) Applying adhesive where necessary;
- (iv) Assembling, starting with base components, e.g. bottom rails and stiles;
- (v) Locating joints correctly and seeing that all gaps are closed and that the work is square;
- (vi) Securing joints, e.g. dowelling, wedging, pinning, screwing and nailing;
- (vii) Removing surplus adhesive;
- (viii) Checking the reverse side and removing surplus adhesive;
- (ix) Handling the assembly while the adhesive is still wet;
- (x) Laying aside, in stacks, for adhesive to set;

(k) In carrying out the sub-assembly and assembly work a framer should understand the purpose of and know when to use the following: dowels, wedges, staples, screws and fasteners. This understanding should allow:

- (i) Knowing why a particular fastener or combination of fasteners is used;
- (ii) Selecting the appropriate size;
- (iii) Setting them out, i.e. correct positioning;
- (iv) Correct securing, punching, countersinking or trimming as necessary;

(l) He should also be able to do the following:

- (i) Recognize well-fitted joints and make adjustments where necessary;
- (ii) In making up frames, have an understanding of the construction principles;
- (iii) Know how to secure cladding to frames;

(m) Line production requires a knowledge of the following:

- (i) Methods of controlling the supply of materials:
  - — Calculating correct quantities from a list of parts per batch;
  - — Stacking and transporting machined parts on pallets;
  - — Matching ironmongery to machined parts;
  - — Checking components against the job by the framer;
- (ii) The machining of parts to allow the immediate fitting of ironmongery, e.g. handles and castors;
- (iii) Plant layout:
  - — Pallets/stacks placed to facilitate assembly operations;
  - — Economic use of floor space. It may be appropriate to mention the cost of floor space;
  - — Maintenance of clear aisles;
  - — Contribution of maintained, methodical layout to safety and productivity;
- (iv) Workplace layout:
  - — Tools and materials to hand;
  - — Adhesive in correct containers, ready for use;
  - — Ironmongery such as staples and screws in separate container/ compartments;

(v) The logical sequence of assembly procedures:
- — The order in which assembly is carried out, e.g. ends to cross-rails/ties, top and bottom, back, plinth/legs and doors and drawers;
- — Planning the production of sub-assemblies to coincide with the main assembly operations;
- — Avoiding ineffective work by, for example, careful handling to eliminate damage, moving and handling material as little as possible and carrying out, at a given stage, only the essential surface preparation;

(vi) Provision for the maintenance of quality, e.g. defined standards and inspection;

(vii) The role of work study in providing an analytical approach to the development of layout and methods of work;

(n) For final assembly and fitting, a framer should have a thorough understanding of the standard of finish necessary before the final lacquering process can be carried out. He should know how faults at this stage can be exaggerated by the finishing process;

(o) He should know the correct fit for doors and drawers and how to adjust them so that they operate smoothly;

(p) Where hardware fittings are used during the assembly stage, a framer should know how to mark, remove and store them before the work goes for polishing and refit them without damage;

(q) With regard to repair work, he should be capable of stopping, cutting out damage or defects and fitting matching inserts/plugs;

(r) Strict supervision of framing, sub-assembly and final assembly is essential at all times, and particular care should be taken to ensure the following:

(i) That each framer has plenty of work ahead of him and that all his completed work is checked and removed immediately to a storage area to await finishing;

(ii) That he makes proper use of his bench and assembly platform;

(iii) That strict account is kept of each man's daily output and that basic times are established, and adhered to, for each process;

(iv) That each completed item is immediately placed on a live pallet for removal to the finishing area;

(v) That a buffer stock of machined and sanded components is maintained so that work in this area never slackens;

(vi) That no assembly work is begun until all components have been thoroughly sanded.

Stage VII

Guidelines for stage VII, scraping and sanding, are as follows:

(a) The less damage done during the assembly stage (especially from wedging and nailing), the faster and easier it will be to complete final sanding and scraping;

(b) It takes from three to six hours to scrape and sand the average chair frame, and any reduction in this time represents a considerable saving;

(c) It is important to ensure that workers in this section spend all their time on production and none on fetching and carrying;

(d) Make sure that one person is given the job of transporting frames to and from his area and that there is always a satisfactory accumulation of work waiting to be done;

(e) Even though some sanding and scraping is done after binding, this should be minimal and should be related only to final inspection;

(f) Always set a daily target of frames to be completed and record the number actually finished. If there is a wide discrepancy between the two, give the reasons so that remedial action may be taken.

Stage VIII

Guidelines for stage VIII, binding, are as follows:

(a) Binding is a manual operation, so it is important that the skills for it are both fast and fully developed. This is achieved by training and careful supervision;

(b) For good productivity, i.e. bound frames per man per day, a binder must always have available to him both the binding material (leather or rattan) and the frame, as well as a comfortable position in which to work;

(c) When the frame is completed it should immediately be transported to final inspection and touching up;

(d) When the frames reach the binders, they have already been scraped and sanded. It is important, therefore, to handle them carefully so that there is minimum touching up during final inspection;

(e) Binders should be given sandpaper to sand off any surface marks occurring during binding;

(f) Binders should prepare their own binding material. This is time-consuming, so it may be advantageous for them to do this in batches that will keep them supplied for, say, a day at a time;

(g) A production target for bound frames should be set daily and reasons for not achieving it noted in the daily production report.

Stage IX

Guidelines for stage IX, final inspection and touching up, are as follows:

(a) A supervisor must be completely familiar with all the specifications and quality requirements for each model. These do not change from one design to another but are uniform throughout the whole range;

(b) The task is to ensure that the quality standards applied at every stage of production, from pole drying to the binding of the finished product, are done consistently and well;

(c) Apart from that, whatever final adjustments and touching up are deemed necessary are made, so that the product leaves the factory in accordance with the high standards and good reputation expected by the customer;

(d) At the same time this function must not be overdone; rather, there must be a careful balance between the cost of final finishing and the standard to which the customer is normally entitled;

(e) On the other hand if a serious fault or defect is detected that was caused by carelessness at some stage of production, then the fault must be traced to its source so that it will not occur again;

(f) Only when the required standard has been reached should the approval stamp be applied to the product.

Stage X

Guidelines for stage X, lacquering and polishing, are as follows:

(a) Finishing operators should be made aware that finishing materials and solvents are expensive and that a considerable loss of material can occur through bad working practices. An example is the wastage due to fog loss when unnecessarily high pressure is used on a spray gun;

(b) Operators should also be made aware that finishing must be done only in a clean, dust-free area, where daily sweeping after work has ended ensures the right working conditions;

(c) Doors leading into and out of the spray area should always be kept closed, and only finishing personnel should be allowed to enter the finishing area;

(d) Operators should fully understand the nature of the materials they are using, with particular reference to the following:

- (i) Shelf life;
- (ii) Pot/working life;
- (iii) Curing times, including accelerating/retarding agents;
- (iv) Working temperature;
- (v) Flash point;
- (vi) Compatibility with other materials;
- (vii) Relative costs;

(e) They should also know the characteristics of the finished coat and their effect on the use of the lacquer, e.g. resistance to damage, hardness, durability, texture, clarity, the effects of ageing or sunlight and methods of application;

(f) The finishing systems normally used are a two-pack polyurethane lacquer and an acid-catalyzed lacquer. They have a high resistance to heat, moisture and chemicals such as nail varnish remover. They are, however, relatively expensive;

(g) It is essential that the finish be applied to a sanded surface free from grit;

(h) An operator should be as familiar with sanding techniques and sand finishing standards as a sanding operator;

(i) An operator should know the characteristics of the stains used and understand the reasons for using them, including:

- (i) When a natural (unstained) finish can be used;
- (ii) Staining to enhance colour;
- (iii) Achieving a "toning" effect without concealing the grain or colour;
- (iv) Varying the intensity of the base stain to "match" grains;

(j) When fillers are used, an operator should understand the following:

- (i) The characteristics of paste fillers;
- (ii) Accelerating or retarding drying times;
- (iii) Staining filler to match the base stain or to create an effect;

(k) The purpose of the sealing coat should be understood, as should the use of flatting agents and the effects of sanding sealing coats;

(l) It must be ensured that stains are selected to match the base colour and that the matching stain incorporates a binding agent to bond with the sealer coat;

(m) Spray gun operators in particular should be instructed in the following:

- (i) Health and safety, including:
  - — Toxicity of fumes;
  - — The use of protective gloves, a mask and barrier creams;
  - — Fire precautions;
  - — Action in case of fire;
  - — Dangers associated with compressed air;
- (ii) Equipment and the principles of their operation: motor and compressor, receiver, air regulator and compressor air supply;
- (iii) The spray booth: its proper operation and cleaning extraction equipment, risk of fire or explosion from sparks and the hazards presented by an accumulation of waste material;
- (iv) The spray gun: its components, types of gun and feed, air and lacquer flow and control, air and fluid lines, operating the gun and adjusting the spray pattern.

Stage XI

Guidelines for stage XI, prototyping and product development, are as follows:

(a) The prototyping and product development workshop is devoted exclusively to the translation of all new

designs from the drawing-board to the stage when each can be put fully into production;

(b) It therefore needs to make prototypes, patterns, jigs, moulds and anything else required to produce the model on a batch basis efficiently and profitably;

(c) The prototype and product development workshop liaises very closely with the designers, the drawing office, the factory and the costing and estimating department;

(d) Since the two are very closely connected, it also works very closely with the engineering workshop and therefore needs to be sited near both the machining and engineering departments;

(e) The procedure to be adopted for prototyping and product development is as follows:

- (i) Making of the prototype exactly in accordance with designers' instructions;
- (ii) Preparation of a materials requisition sheet detailing all cutting and other requirements;
- (iii) Preparation of a route card indicating the various stages in the manufacture of the new model. This varies little from model to model;
- (iv) Preparation of master parts for quality and accuracy guidance during the various stages of production. All master parts should be painted a vivid colour;
- (v) Preparation of all production aids, including accurate cutting lists, bending moulds, boring and coping jigs, and any other guidance that will enable trouble-free production of each component;
- (vi) Introduction of a trial batch into production, during which the problems encountered are ironed out;
- (vii) Preparation of a cost estimate as guidance to administration;
- (viii) Full batch production and an accurate costing of the model;

(f) Since this department sets the quality and performance standards for the whole factory, its work must be very efficient and accurate;

(g) The department must therefore be well equipped with machines (it is located close to the machine shop) and hand tools, and the persons working in it must be experienced in every aspect of rattan production;

(h) All jigs, moulds and bending aids must be carefully and accurately made, tabulated and stored in a proper jig library when not in use. Their subsequent maintenance is also the responsibility of this department;

(i) Other tasks to be carried out by this department include collaborating with the engineering workshop in adapting machines for specific purposes, making special fixtures, guides and formers to be used in conjunction with certain machines and improving and maintaining technical systems and procedures such as internal transport and storage.

Stage XII

Stage XII, engineering, is carried out by the engineering department, which is responsible for the following:

(a) Preventive maintenance and good working order of all machinery, equipment and tools;

(b) All electric, pneumatic and hydraulic work;

(c) The compressed air and dust/waste extraction systems;

(d) All cutter and saw grinding and sharpening;

(e) The fabrication of all metal parts for machine jigs, fixtures and formers;

(f) The fabrication, where possible, of machine spares;

(g) The maintenance of all vehicles and internal transport systems;

(h) The fabrication of special fittings and tools when required;

(i) General building maintenance;

(j) The maintenance of a machinery and equipment logbook containing full details of every machine in use, including its purchase date and the name and address of the supplier; the date and nature of overhaul, servicing and repair; and the availability, source and supply of spares and accessories;

(k) Close cooperation with the prototyping and product development workshop in the technical aspects of production planning.

Factory management, production planning and control

Production objectives

The objectives of production planning can be stated as follows:

(a) To relate orders and delivery promises or plans to the capacities available or, conversely, to provide the capacity and production to meet agreed or accepted demand;

(b) To ensure that materials and components are available where and when required;

(c) To produce a steady flow of work through all departments;

(d) To preserve a balance of work between the various departments;

(e) To preserve adequate manufacturing instructions, enabling management and supervisors to concentrate on supervision and production techniques and relieving them of detailed clerical work;

(f) To provide management with information to correct for possible delays and difficulties.

Organization of the Production Planning Department

The work of the Production Planning Department generally falls into three stages:

(a) Compiling and recording facts;

(b) Developing plans;

(c) Putting plans into operation and controlling results.

The stages and the tools used in each are shown diagrammatically in figure 81. The production process data are outlined in figure 82.

The Production Manager will have his own specific objectives, such as getting a product of an agreed quality produced on time at minimum cost. Other influences, such as the continuity of employment, fluctuations in demand and the utilization of equipment, will also be considered.

A manager is someone who gets work done by people in order to achieve particular targets. This involves planning, organizing, implementing, motivating, controlling and making decisions. He may also carry out individual tasks peculiar to his own training, e.g. preparing accounts, adjusting engineering processes, electrical testing and designing. This is known as individual or operating work.

He will have to organize production so that provision is made for direct line guidance and supervision, maintenance, work study, production engineering, quality control and production planning and control. Whereas all of these functions may in fact be carried out by one man in a small organization, it is the function of production planning and control that will be discussed here.

General considerations

Production planning and control is defined by the British Standards Institute as "the means by which a manufacturing plan is determined, information issued for its execution and data collected which will enable the plan to be controlled through all its stages".

In all manufacturing organizations, some form of production planning and control exists. It may be very rudimentary, as, perhaps, in the case of the owner-manager who carries most of the data in his head, but as an organization grows in size, such informal control becomes impossible, and an organized, formal system must be developed to assist in drawing up the plan and to ensure its proper execution.

The notion of control implies the existence of a target or plan, deviations from which are measured. The amount of the deviation indicates the degree of control existing in the system. In order to be meaningful, the target must be realistic and attainable. In the context of production planning and control, therefore, the plan must take into account the resources available in terms of men, machines and capital. The way in which the utilization of resources is planned will vary in detail from industry to industry and from firm to firm, but the basic format is the same for similar types of production systems, such as jobbing production systems, batch production systems and mass production systems.

Types of production

There are two main types of production systems, namely jobbing (or make-to-order) systems and mass (or flow) production systems. All other systems fall between these two extremes.

Jobbing production

In jobbing production, the customer generally specifies what he requires, and manufacturing quantities tend to be very small or one-off. Special-purpose furniture and items such as large furniture contracts for hotels and similar institutions fall into this category. Because of the individual nature of the order, the work tends to be identified with the customer. The variable nature of the work frequently calls for skilled labour and general-purpose machinery. Machine utilization tends to be low and the volume of work-in-progress tends to be high. The order book constitutes the manufacturing programme.

Mass production

Mass production refers to the large-scale manufacture of a standard product. Special-purpose machines and semi-skilled or unskilled operatives are normally used, and machine utilization is very high. The manufacturing programme is obtained from a sales forecast. This type of manufacturing is very unusual in the furniture industry.

Batch production

Batch production is the term applied to the broad category between jobbing and mass production. The products are processed in batches, the sizes of which may vary considerably, and manufacture may be done to order or to satisfy a sales forecast or both. Most types of manufacture fall into this category, for example, office machines, furniture and footwear. The operatives tend to be skilled or semi-skilled, and machine utilization can vary considerably according to the product mix. The volume of work-in-progress tends to be high, and the operating time tends to be less than the process queueing time.

Production planning and control systems for each of these types of production are similar in principle but different in detail, and it is helpful when developing a system to first analyse the type(s) of production existing.

The influence of production planning and control on return on investment

Effective production control can greatly reduce inventories of finished goods, raw materials and work-in-progress. This has the effect of reducing assets and increasing investment turnover if sales are held steady.

Effective production control reduces labour costs (less down time waiting for materials and instructions) and

Figure 81. Production administration, showing stages and tools used

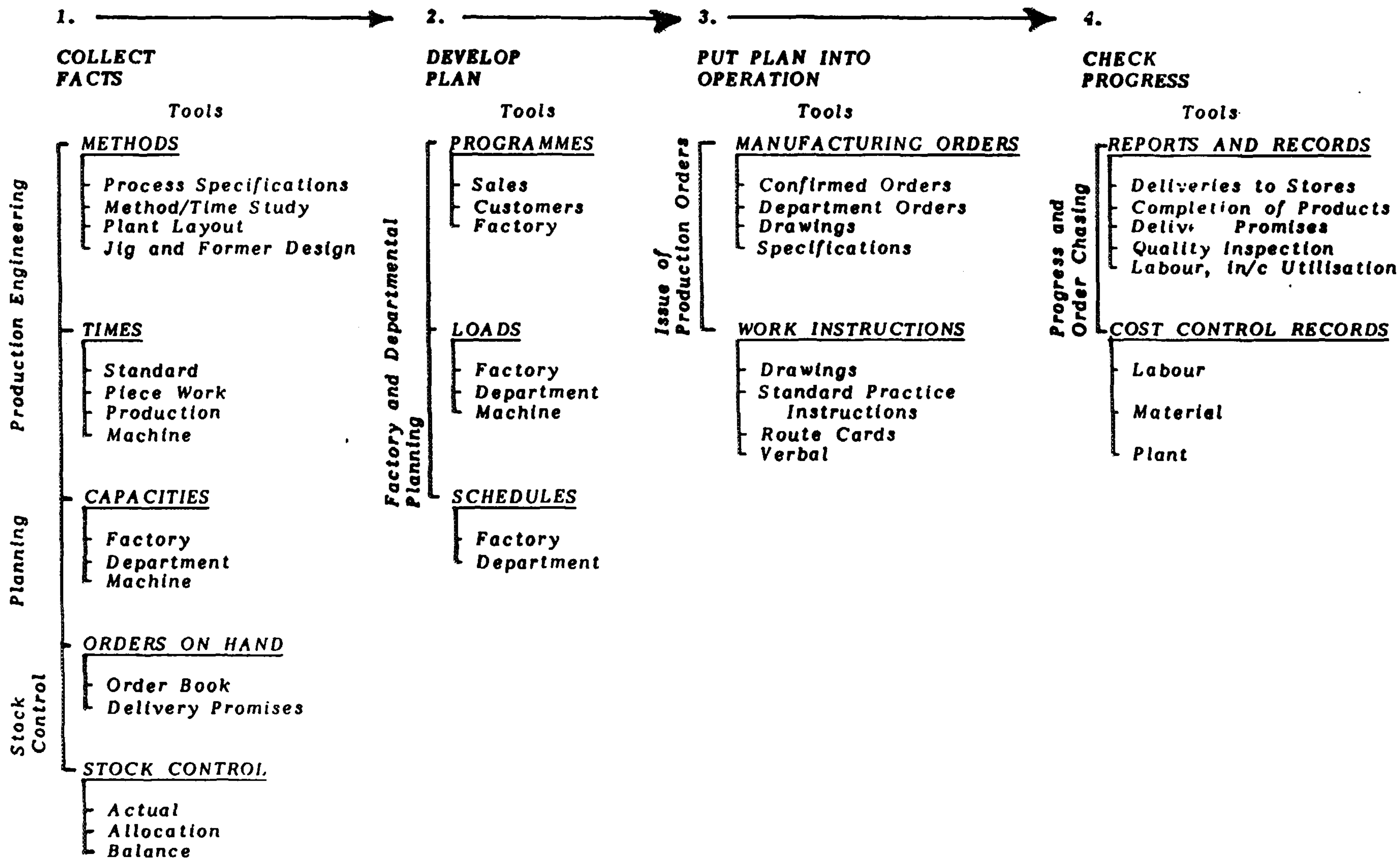
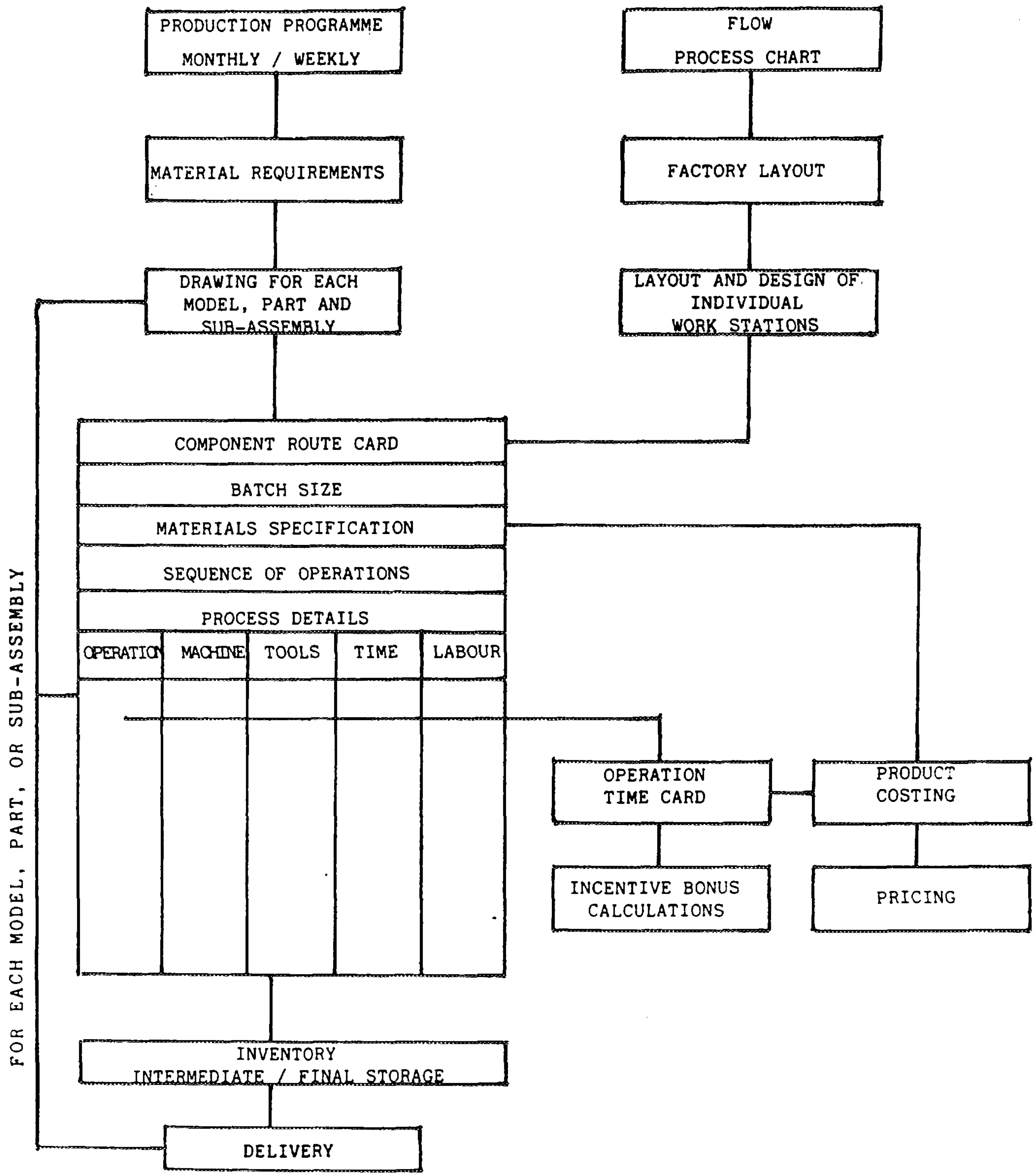


Figure 82. Production process data



increases machine utilization by accurate plant loading. The reduced labour cost will increase the profit margin and increased sales will increase investment turnover.

The overall effect of increasing investment turnover and profit margin is to considerably increase the return on investment. It will be seen, however, that the levels of sales and profitability, the product mix, the amount of working capital available for investment in inventory, and new equipment purchases will all have an influence on the decisions of the planner.

Location of the production planning and control function within organizations

Production planning and control is a service to the Production Management Department and in many cases acts as a liaison between the Production and Sales departments. In a very small organization the function may be introduced in the form of a progress clerk responsible to the Production Manager, but as the organization expands, the increasing importance of production planning often causes the function to be removed from the Production Department and to be made responsible to the General Manager. The case for such a structure would have to be argued in the context of a particular company, but there are many points in favour of placing responsibility for the procurement and control of all materials under one senior executive.

Status of production planning and control practices today

A book on management principles and practices [1] has examined production management in large firms (over 500 employees), medium-sized firms (100-500 employees) and small firms (20-99 employees). It was found that 13 per cent, 29 per cent and 44 per cent of large, medium and small firms, respectively, had no work documentation, i.e. no requisition forms, work orders or stock records. Furthermore, 21 per cent, 65 per cent and 85 per cent of large, medium and small firms, respectively, had never applied work study, and 39 per cent, 85 per cent and 93 per cent, respectively, did not keep machine loading records. There were very few attempts to order in economical quantites, and 43 per cent, 81 per cent and 95 per cent of large, medium and small firms had no separate production planning and control department.

Functions involved in production planning and control

The particular functions involved in production planning and control must be considered in the light of overall company policy on customer service, labour recruitment and inventory levels. Following clarification of that policy, the basic production planning and control functions may then be considered as follows:

(a) Development of the manufacturing programme;

(b) Pre-production planning: product specification, process planning, materials planning, purchasing and stock control;

(c) Planning and control of manufacture: input control involves selecting, scheduling and loading, while output control involves expediting;

(d) Inventory control.

Development of the manufacturing programme

In practice, every organization has some form of manufacturing programme, either as an order backlog or as a development of a projected sales forecast or as a combination of both. Without a programme it is impossible to estimate immediate and future requirements in terms of men, machines and capital. Lead times tend to get longer and invite unfavourable comparison with competitors.

Because of customer complaints, which are commonly due to large order backlogs, there has been great interest in forecasting systems in recent years. While techniques in this area are becoming more sophisticated, there is no perfect forecasting system, and a successful system must be capable of dealing with an inaccurate forecast.

When the manufacturing programme is drawn up from a sales forecast, there are three major points to be considered:

(a) The accuracy of a forecast is a function of time. Longer-term forecasts tend to be less accurate;

(b) Accuracy is also a function of the number of items in the product group being forecast. The larger the number of items, the more accurate the forecast;

(c) The forecasting groups selected must be meaningful in terms of the demand on manufacturing facilities, e.g. machine or labour hours.

The steps taken to draw up the manufacturing programme are as follows:

(a) Define the time-span of the plan;

(b) Define the minimum inventory level to be maintained;

(c) Spread the sales forecast over the time-span of the plan. The forecast units should cover groups that are processed by common manufacturing facilities;

(d) Set opening and closing inventories for the period;

(e) Calculate total production as the sales forecast plus inventory change;

(f) Spread the total production over the planning period;

(g) Compare requirements with available capacity;

(h) Finalize the programme.

It should be noted that when the manufacturing programme is drawn up, sales, production and inventory requirements are integrated. This is a fundamental step in developing an effective programme.

It should be remembered that manufacturing programmes are only approximations. There is little chance that a sales forecast will be totally correct, as indeed there is little chance that the plant will exactly meet its budgeted performance level. There is, therefore, a point of diminishing returns at which greater refinement of the manufacturing programme becomes meaningless.

Pre-production planning

Product specification

All products should be specified as regards content, form and quality. For a new product, the specification should be drawn up before manufacturing is begun, and for standard products, specifications should be kept on file.

In the case of rattan and bamboo furniture, product specifications will take the form of full-size, detailed working drawings.

Process planning

Process planning is concerned with deciding where and how each item should be manufactured. It may be performed by the Technical Department, but the information is subsequently used by the Production Planning Department.

Materials planning

The requirements scheduling part of materials planning breaks down the manufacturing programme for the period into progressive stages of completion and lists all components required for the completion of each stage, together with the date by which they are required. For example, in the production of a batch of rattan host chairs (dining-room chairs with arms), as many as 10 drawings may be necessary to describe each of the invididual components or elements and to indicate the material and processing requirements. In complex applications, computers are frequently used.

If some of the materials required are not kept in stock or if stocks are low, the materials planning function helps to give advance warning of requirements to the purchasing, internal ordering and inventory control sections. Orders may be collated at this point so as to take advantage of bulk purchases.

Production control during manufacture

Controlling input

To control work-in-progress, work backlog and lead time, the issue of orders to the manufacturing system must be related both to inventory and to available capacity. The chief areas of control in order issue are as follows:

(a) The selection of orders for issue;

(b) The scheduling of order priorities;

(c) The loading of each operation centre to the desired level of capacity.

In selecting the appropriate orders for issue, cognizance is taken of the inventory situation and of any major over- or undercapacities. The scheduling of order priorities provides a basis for order expediting by providing a start and completion date for each operation. Loading provides a detailed analysis of the capacity/load situation on a short-term basis and provides a basis for action to smooth temporary production bottlenecks.

Selection

The selection of orders for issue is aimed at meeting the planned production rate while keeping the backlog of work on the shop floor to a minimum. Large backlogs of issued orders create problems in expediting, location and general control. The place for an order backlog to be kept is at the Production Manager's desk, ready for issue at the appropriate time. From the manufacturing programme, the planned production rate is shown, and orders should only be issued to fill the capacity available at the planned rate. On the order issues form there should, however, be a note of the total estimated hours of work backlog, so that the people concerned are aware of the overall situation for each department or machine centre. The Production Manager must also concern himself with overloads or underloads at each operation caused by the product mix. He may decide to schedule an order in advance of the requirement if such an order, by virtue of its process requirement, will balance the capacities of the various operations. If no such balancing order is available, management has a basis for generating a suitable stock order to fill the requirement.

Scheduling

The scheduling of orders by operation is necessary if production control personnel are to be kept aware of impending shipping delays as soon as they become likely. This means that if the completion date has been agreed with the customer, there are critical dates for each operation, and any overshoot in these dates is likely to cause the order to be overdue.

This information enables the Production Control Department to revise its priorities, if necessary, and reschedule the remaining processes on that order or, if this is impossible, to inform the customer, through the Sales Department, of the impending delay. The latter is a very important aspect of customer service.

Scheduling should be kept to as short a cycle as possible, weekly or even daily. Scheduling may be "forward", by working from the date of proposed commencement to arrive at a completion date, or "backward", by starting with the date by which the order is required and working back through the intermediate processes to a start date. Backward scheduling is commonly used for products requiring bought-in components for assembly, but frequently a combination of backward and forward scheduling is used.

Before scheduling can begin, a system of scheduling rules must be drawn up. This will normally be in the form of a table giving average processing times per unit, together with queueing, transit and inspection times.

Loading

Loading is concerned with identifying immediate under- or overcapacity at each process centre. Where there are dissimilar machines, as in wood/rattan processing, and orders requiring processing on particular machines, then loading must be done on a machine basis.

Controlling output

Output control is concerned chiefly with finding and expediting urgent orders through the system by moving them ahead of other orders competing for the same facilities. In this way the expediter (usually the Assistant Production Manager) is the liaison with the input function when priority changes occur or component supply delays threaten to result in a particular order not meeting a scheduled due date. Most expediting is the result of poor initial planning and overrigid scheduling, and while some expediting is necessary, the need for it can be kept to a minimum by ensuring that the expediting is carried out on a planned basis. This requires defining clearly the duties and responsibilities of the expediter and his relationship with the production function in general and with foremen in particular.

In general, the expediter is responsible for maintaining order progress records and for ensuring that orders are processed in the correct sequence and at the planned time and rate. He is also responsible for implementing priority changes and splitting batches. If there are a number of expediters, he is generally responsible only for the progress of all work through his own section, although in some instances there are advantages in making an expediter responsible for the progress of a number of orders through various sections and stages of manufacture.

A good system of expediting will improve shop efficiency and customer service and will reduce delays.

Reference

1. E. F. L. Brech, ed., *The Principles and Practice of Management* (Harlow, United Kingdom, Longman, 1975).

VII. PRODUCTION TECHNOLOGY*

Sean O'Driscoll**

Introduction

In the production of rattan furniture, four inputs are of importance: machines, manpower, methods and materials. While everything relevant to production is covered by these headings, a fifth element—good management—is crucial for success.

Interrelationship of production facilities and product

The equipment and materials available have a bearing on what products can be made and, conversely, particular products call for particular equipment and materials. Four factors are relevant: range of items produced, production philosophy, factory capacity and manufacturing activities.

Range of items produced

The products may be classified as to end user and type of product.

End-user

Designs for contract furniture are often provided in the specification. Domestic furniture is usually designed in-house.

Type of product

Panel products, such as cabinets (often called case-goods), typically use cane-faced panels and wood or rattan mouldings.

Leg products, such as chairs, can be of large- or small-pole construction or woven roundcore; milled or unmilled structural pole assembly, with or without skin finish.

Production philosophy

The extent to which a factory produces furniture on its own varies widely. Four types of arrangement can be distinguished:

(a) All production done in-factory;

(b) Limited external subcontracting;

(c) Many suppliers bought in;

(d) Spraying capacity for subcontract suppliers.

Factory capacity

Although the goal of a factory, whether large or small, is to achieve a balanced production with respect to labour, equipment and spraying capacity, in fact such an equilibrium state is achieved only at fleeting points in time. As soon as it is achieved it is lost, owing to either the expansion of production, in which case the labour force and/or the level of mechanization must be increased, or the consolidation of production by improving technology, rationalizing production, increasing productivity or introducing new techniques.

Manufacturing activities

A factory making rattan and bamboo furniture usually carries out the following activities:

(a) Pole preparation, classification, storage;

(b) Cross-cutting, off-cut recycling;

(c) Steam-moulding, straightening;

(d) Adjusting;

(e) Machining, machine sanding;

(f) Subassembly, machining (if required);

(g) Final assembly, checking;

(h) Sanding;

(i) Binding, caning;

(j) Final sanding;

(k) Staining, lacquering;

(l) Protection packing;

(m) Loading.

*The material in annexes V-VIII is reproduced directly from *Furniture and Joinery Industries for Developing Countries* (UNIDO publication, Sales No. E.88.III.E.7) and the original figure and table numbers have been retained.

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Personnel

An important task of production management is identifying tasks, selecting staff with suitable qualification and allocating them efficiently.

Qualifications required

Office of the Production Manager

Office personnel should be able to take on the following responsibilities:

(*a*) Drawing office: the maintenance of design and production archives, new model interpretation, cutting list preparation;

(*b*) Production planning, work allocation;

(*c*) Materials supply and control;

(*d*) Production scheduling;

(*e*) Progress monitoring;

(*f*) Coordination with the sales section;

(*g*) Work study, time-keeping;

(*h*) Bonus monitoring and calculation.

Factory floor

Factory floor staff should be capable in the following areas:

(*a*) Prototyping;

(*b*) Making and maintenance of jigs;

(*c*) Coordination of activities;

(*d*) Development of new manufacturing techniques;

(*e*) Quality control;

(*f*) Discipline and motivation;

(*g*) Electrical and mechanical maintenance and development of simple production machines and jigs.

With regard to prototyping, a buyer usually arrives with his own designs and asks the factory to produce a prototype to determine the quality of production. Since this is a costly proposition and frequently involves making special jigs, the enterprise should not be afraid to charge for it. In such cases the buyer should be told that he will have to pay for the production of the prototype, and the charge should be about 400 per cent of the actual cost. If the buyer accepts this condition, it can be assumed that the enquiry is serious; if he refuses, a lot of effort with no rewards can be avoided.

Organization of the workforce

The principle is to have autonomous groups of workers, carrying out easily quantifiable activities such as framing, sanding or binding. They should be divided into groups of eight workers each, supervised by a group leader. Such a group system allows the following:

(*a*) The easy recording of output;

(*b*) Group/product specialization;

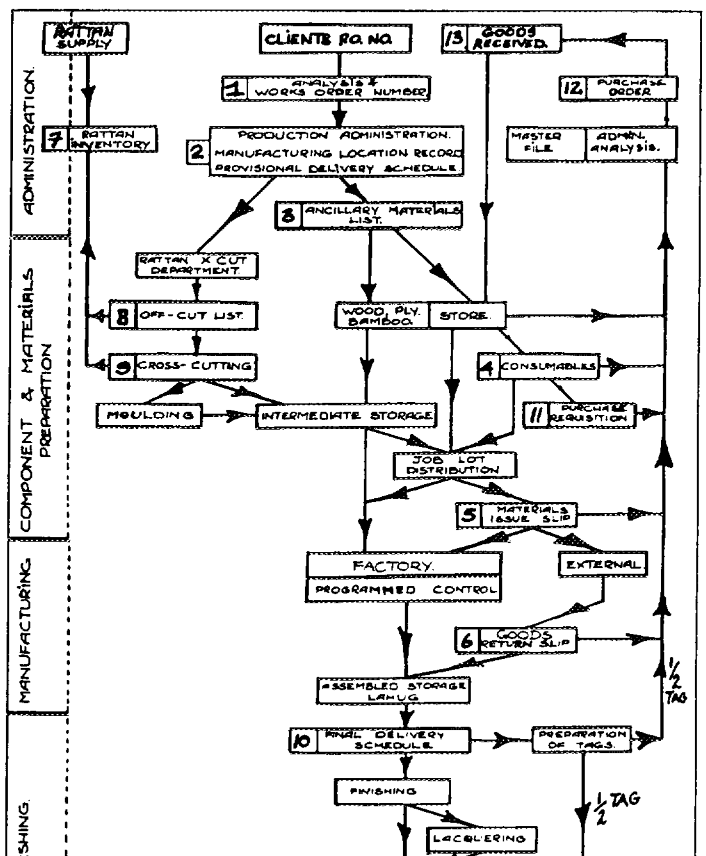
(*c*) The possibility of establishing balanced activity groups, e.g. 16 groups of framers, 5 groups of sanders, 6 groups of binders;

(*d*) A basis for a group bonus scheme.

Materials

A typical materials and production control documentation programme for a medium to large rattan furniture manufacturing plant is provided in figure 83. Usually the product range covers a large number of individual items, each of which uses a large number of components. In addition, some items may have to be specially ordered. Because so many items are involved, most modern rattan furniture factories now control all their materials demand and stock situation by simple computer programs.

Figure 83. Materials and production control documentation



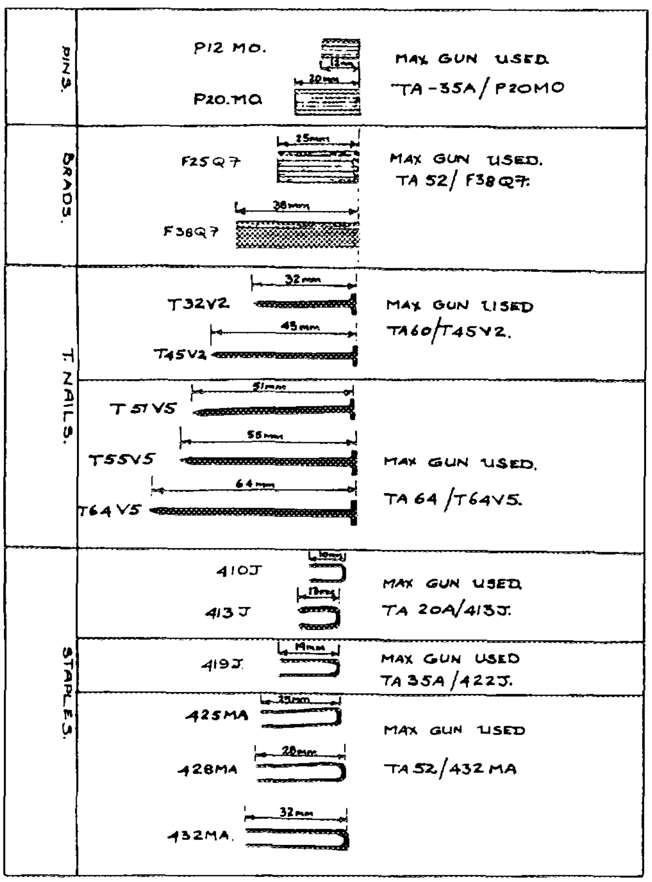
Typical materials

The most commonly used materials are listed in table 10.

Table 10. Materials most commonly used

Material	*Unit*
Rattan poles, sanded and natural, round core, structural, bracing, decor, seat	kg
Rattan splits, binding	kg
Cane webbing, closed and honeycomb	m^2
Leather, binding	kg
Bamboo, round, split, treatment, Tanalized	kg
Screws, particle-board-type preferred to normal wood type	Box (of 100 or 144)
Nails, pins, brads (figure 84)	kg
Staples, T-nails (figure 84)	Box
Glue: PVAc, UF resin, neoprene contact	kg
Wood-based panels: plywood, block board, particle board, MDF	Sheet
Fittings: hinges, drawer runners, stays, handles, shelf studs	Piece
Wood: seat frames, mouldings	ft^3, board ft or m^3
Stain, sealer, lacquer, thinner	Litre
Glass	Component
Filler (compatible with stain)	Box
Kerosene	Litre
Sandpaper, 180 and 240 grit	Sheet
Sanding belts, 60 and 120 grit	Piece

Figure 84. Typical fastenings used in the manufacture of rattan furniture; numbers and staples refer to products of Max (Japan)

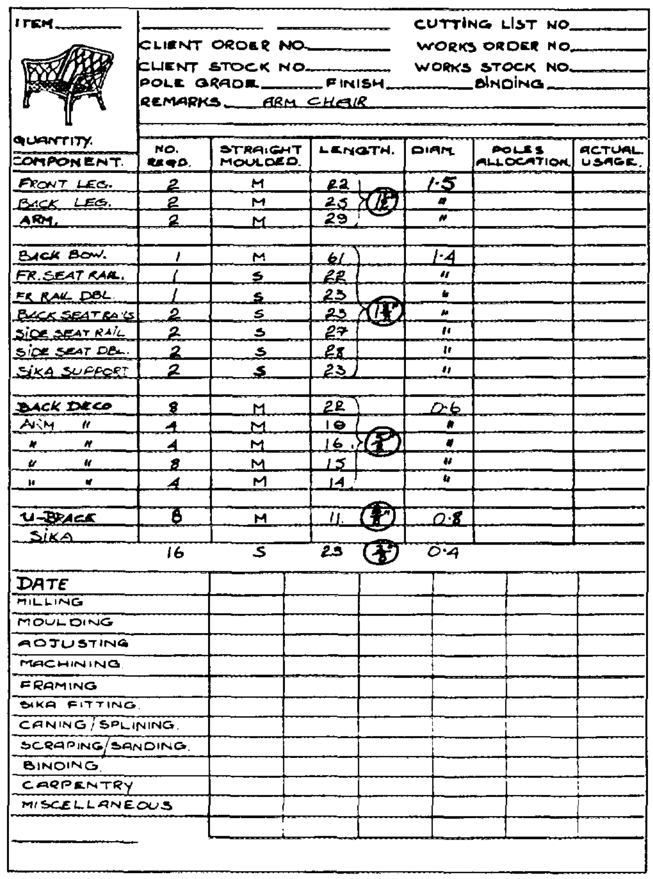


Control of material characteristics and usage

The normal usage of each material in terms of issue amounts can be inserted into table 10, allowing it to serve as a basis for ordering. It is important to use quality materials, and an essential function of production management is to verify that the materials purchased perform satisfactorily and comply with the methods and modes of operation for which they were specified.

Furthermore, a master list (figure 85) should be elaborated for each product. As can be seen, each individual chair or other item of furniture is broken down into the number of components needed for it. Such a master list, which can be used for the scheduling of cutting orders and for stock control, lends itself to computerization. Before a production run is started, the prototype department should prepare a master list for every new piece of furniture.

Figure 85. Master list for a given item



ITEM ______ CUTTING LIST NO ______
CLIENT ORDER NO ______ WORKS ORDER NO ______
CLIENT STOCK NO ______ WORKS STOCK NO ______
POLE GRADE ______ FINISH ______ BINDING ______
REMARKS ARM CHAIR

QUANTITY.

COMPONENT.	NO. REQD.	STRAIGHT MOULDED.	LENGTH.	DIAM.	POLES ALLOCATION.	ACTUAL USAGE.
FRONT LEG.	2	M	22	1·5		
BACK LEG.	2	M	25 (12')	"		
ARM.	2	M	29	"		
BACK BOW.	1	M	61	1·4		
FR. SEAT RAIL.	1	S	22	"		
FR RAIL DBL.	1	S	23	"		
BACK SEAT RAILS	2	S	23 (14')	"		
SIDE SEAT RAIL	2	S	27	"		
SIDE SEAT DBL.	2	S	28	"		
SIKA SUPPORT	2	S	23	"		
BACK DECO	8	M	22	0·6		
ARM "	4	M	10	"		
" "	4	M	16 (7')	"		
" "	8	M	15	"		
" "	4	M	14	"		
U-BRACE	8	M	11 (7')	0·8		
SIKA						
	16	S	23 (3')	0·4		

DATE						
MILLING						
MOULDING						
ADJUSTING						
MACHINING						
FRAMING						
SIKA FITTING.						
CANING/SPLINING.						
SCRAPING/SANDING.						
BINDING.						
CARPENTRY						
MISCELLANEOUS						

Productivity control

Productivity incentive schemes traditionally operate well in the rattan and bamboo furniture industry. Hence, good management includes not only the control of materials and labour but also the assessment of productivity.

As the quantity of different materials required for a given operation is known, the materials can be issued to the operating group upon presentation of their production slips, which indicate how many items have been made.

Normally, a perforated sheet is used on which the production stages/group are listed. As the item progresses through the factory, each group, after having completed the job, tears off the part relating to its activity. At the same time the production slips, which are submitted by and collected for each group of workers, serve as a control on productivity and as a basis for the payment of incentives.

Since each group receives items from a previous group, it exercises *de facto* quality control. If an item is faulty, the next group will have to rectify this, which would affect its overall productivity. Therefore, if something is wrong, the item will not be accepted and will be returned to the previous group for reworking. Annex I outlines a typical productivity incentive scheme.

Combined use of wooden and rattan components and the replacement of wood by rattan

The combined use of wood and rattan is illustrated in annex II. Annex III shows examples of rattan furniture made of large- and small-diameter poles. The trend is away from large-diameter poles because of their high price and relative scarcity.

Storage and protection

Customers do not like to see their furniture fall apart or become a breeding ground for beetles. It is therefore necessary to preserve the rattan and to protect the raw rattan during storage before manufacturing. The recommendations made in earlier chapters on rattan preservation should be followed, keeping in mind visual appeal when choosing the finish for a piece of furniture. Large-diameter rattan, for instance, should be used for lighter lacquered furniture, which is more likely to have a high export value. Examples are shown in annex III.

Waste control and recycling of rattan off-cuts

In rattan factories producing batches of assorted products, there is always extra material left over after an order has been completed, as well as off-cuts. Thus, it would be beneficial to set up a separate cutting section. Rather than allowing components to occupy storage space in production sections in anticipation of a repeat order, all surplus or waste that is recoverable should be sent to an off-cut recovery operation for storage. Cutting lists for new orders should go first to the off-cut section to see what can be provided and only then should fresh rattan poles be given out. Annex IV contains some guidelines on this recovery operation.

Construction details

Over many years of experience in the use of rattan, a specific technology evolved, based on the material's elasticity and ease of bending, its resistance to splitting during nailing and its exceptionally strong end-grain-holding properties, as well as on the possibility of triangulating the braces and even the structural components and of using wrappings and bindings either to add strength to the joints or for decorative purposes.

Originally, no two chairs were alike, and each required an inordinate amount of time during assembly, owing to length corrections etc. Thus, all joints were butted, nailed and bound as there were no fixed jointing positions. Later, machines were developed specifically for rattan, such as hydraulic straightening machines, round pole sanders, round pole milling machines and die sizing machines.

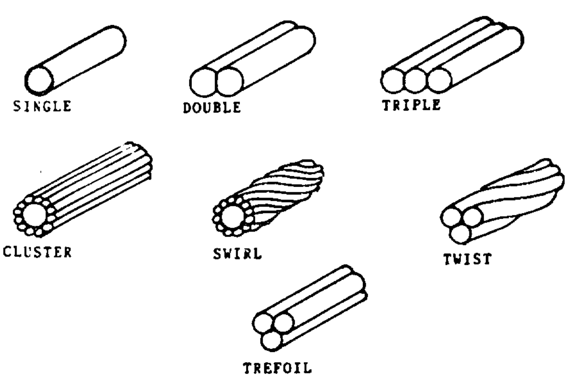
Rattan also benefited from its association with its more established counterpart, wood. Many of the production techniques, much of the equipment and many of the new materials and fittings developed by the wood industry can, with appropriate modifications where necessary, be used to great advantage in the production of rattan furniture. At the same time, the inherent characteristics of rattan—especially its lightness, flexibility, strength, durability and nailing and screwing properties—allow the production of furniture incorporating shapes and forms impossible to obtain with wood.

Construction details are outlined in figures 86 and 87. Single, double and triple sections may be sanded or milled. To ensure close joints, others should be milled or sized sections. It is generally accepted that for top quality rat-

Figure 86. Furniture construction details; sections generally used for arms, backrails, backbow, legs, seat-rails

CONSTRUCTION DETAILS.

1. STRUCTURAL POLE SECTIONS:



SECTIONS GENERALLY USED FOR ARMS-BACKRAIL-ARMS/BACKBOW, LEGS-SEATRAILS.

(a) Single, Double and Triple Sections may be sanded or Milled.

(b) To ensure Close Joints others should be Milled or Sized Sections.

(c) It is generally accepted, for top Quality Rattan Furniture Large Diameter Structural Poles (28mm - 40mm) should have a Sanded - Unmilled Finish to enhance the appearance of the Nodes in the finished Product.

(d) Deco. and Bracing Poles may be milled to obtain uniform Diameter and so simplify subsequent Machining Operations.

Figure 87. Leg-rail joints

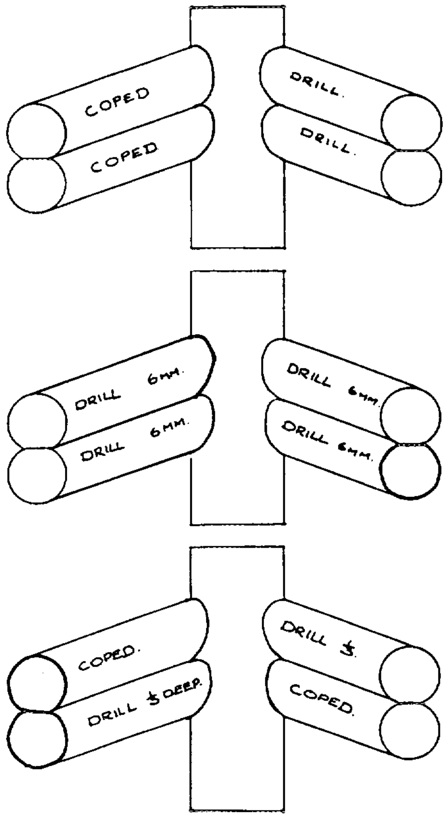


Figure 88. Examples of rattan applications

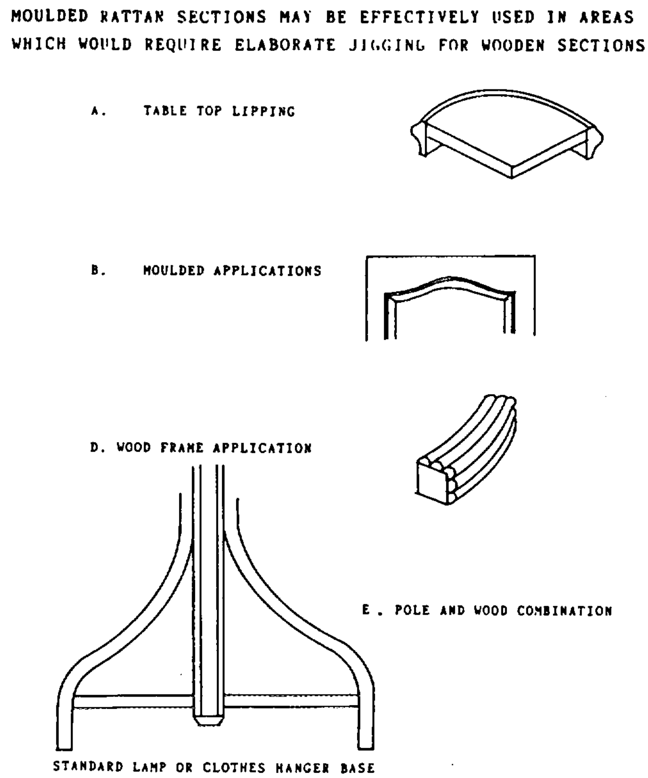
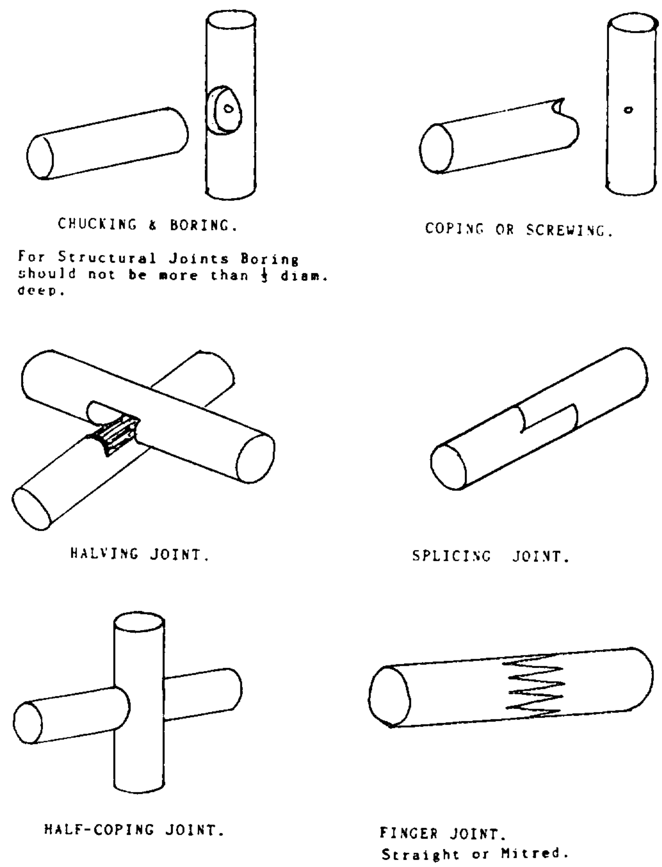


Figure 89. Structural joints



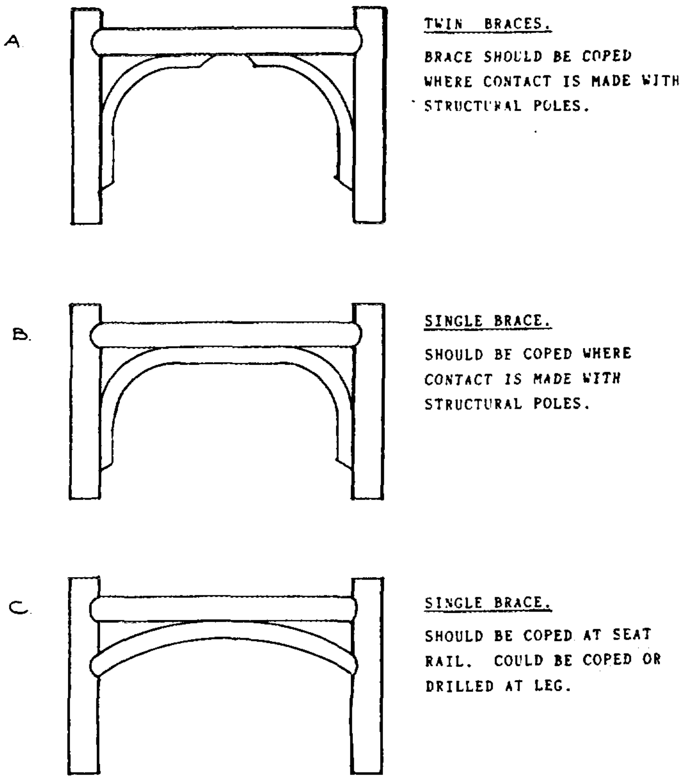
tan furniture, large-diameter structural poles (28-40 mm) should have a sanded but unmilled finish to enhance the appearance of the nodes in the finished product. Decorative and bracing poles may be milled to obtain uniform diameter and so simplify subsequent machining operations. Rattan applications are shown in figure 88. Moulded rattan sections may be effectively used in areas that would require elaborate jigging for wooden section. Structural joints are shown in figure 89 and bracing assemblies in figure 90.

Before beginning any mechanization process, it is imperative that the components have all been adjusted to and remain secured, if necessary, in their final shape. This presumes the use of accurate and stable adjusting jigs. As most machining jigs incorporate the final shape of the component, these parts must be accurate. In some instances, it is possible to use the final adjusting jig itself as a holding element for machining, i.e. for drilling the arm bow. Jigs will be discussed in more detail in the next section.

As far as possible, all joints and assemblies should be positively located. This can be achieved by *(a)* using jointing techniques that automatically position the parts to be jointed, i.e. drilled and dowelled joints, or *(b)* using accurate subassembly and assembly jigs that automatically position and hold the components to be jointed. It goes without saying that the components must be accurate, the jointing techniques must be appropriate, the joints must be machined and the jigging must be accurate.

If all that is done correctly, manual corrections and adjustments to structural members and most adjustments to

Figure 90. Common bracing assemblies



decorative components can be eliminated at the assembly stage. As a result, assembly will be considerably faster and overall productivity will increase.

Figures 91 and 92, which are taken from the *Manual on the production of rattan furniture* (ID/299), show the manufacture of typical components, using jigs designed to ensure the accuracy needed for interchangeability, which in turn is necessary for high output and quality in the final assembly.

Jigging

The main concern of furniture-making in developing countries as it becomes an industry rather than a craft is to increase productivity and profitability at minimum cost. All societies produce furniture at the craft level. The industrial production of furniture, however, demands serial production, labour specialization and standard, interchangeable components. A prerequisite for the interchangeability of parts is accurate, jigged machining. Simple jigs greatly increase the versatility and productivity of the basic machines used in the production of rattan furniture.

If accurate jigs are used at all stages of the process, it is possible to produce standard, interchangeable components: each batch is considered as a final product, and at the assembly stage, where the components are combined, no manual alterations or corrections should be necessary. Because curved components are common in rattan furniture, and because the material is elastic, the jigs tend to be more complicated than those used in similar operations in woodworking.

Figure 91. Shaping legs and top back-rail for a period dining-room chair

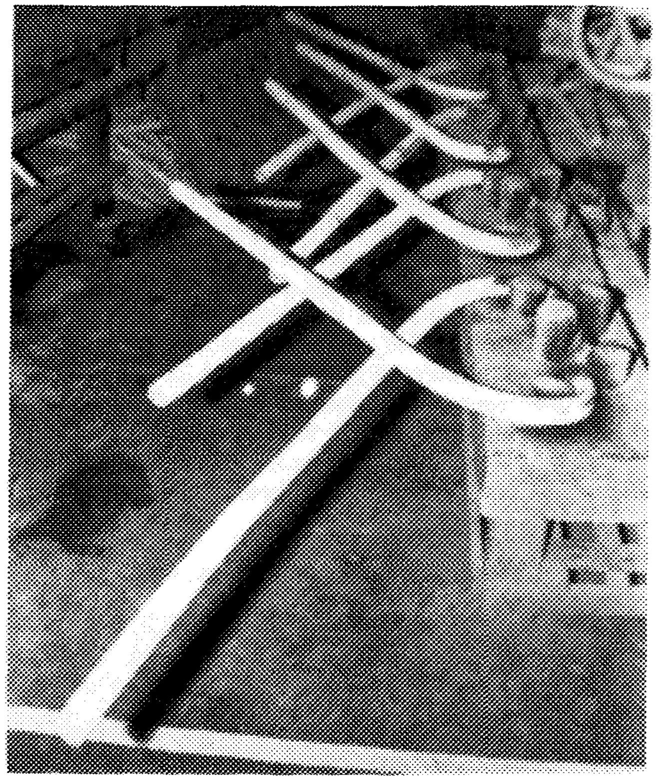
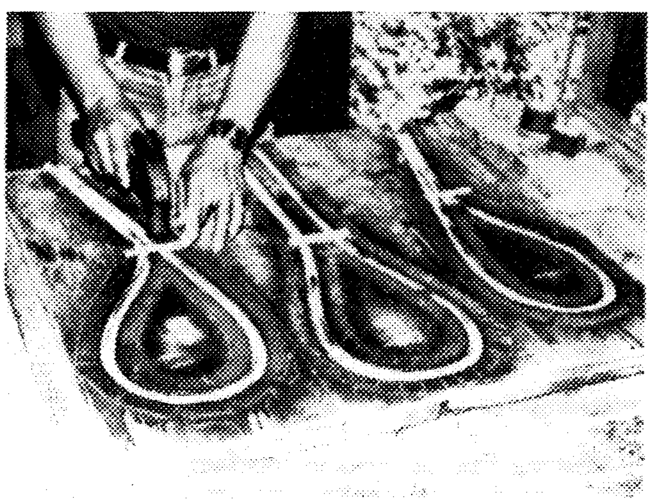


Figure 92. Moulding chair splatts



Types of jig

In general, all production jigs in the rattan industry can be divided into the following categories:

(a) Bending or moulding jigs;

(*b*) Adjusting jigs;

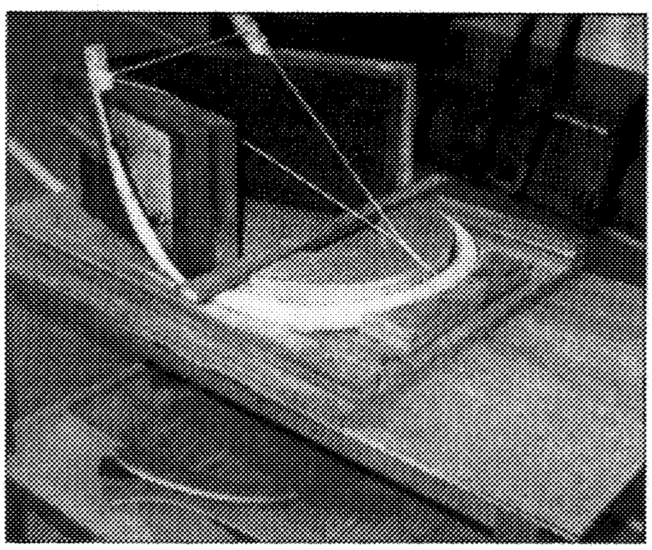
(*c*) Machining jigs;

(*d*) Assembly jigs (including subassembly).

Bending jigs

Great attention should be given to the design and construction of bending jigs. This requires an accurate knowledge of the amount of springback, which normally depends on the diameter of the pole used, the species, the preparation (e.g. steaming), the method of restraining moulded components and the length of time the mould must remain "loaded" in a jig until it obtains its final shape. Too often, multi-purpose jigs are used at this stage, resulting in unacceptable correction or an excessive amount of time spent adjusting the jigs to make them fit the whole assembly. A typical bending jig is illustrated in figure 93 (figures 91 and 92 also showed bending jigs).

Figure 93. A typical bending jig



Adjusting jigs

Adjusting jigs are used to transform moulded components into accurate standard furniture parts, suitable for sizing and machining in the next stage on machining jigs. Typical adjusting jigs, as used for drilling purposes, are shown in figures 94, 95 and 96.

Depending on the diameter of the pole being used and the complexity of the bend required, most adjusting at this stage is done with the aid of a blowtorch or a liquid gas gun. Small-diameter poles may be adjusted manually without heat assistance, using a bench-mounted bending aid.

Accuracy at this stage eliminates time lost in machining and assembly operations and also minimizes the number of parts that are later rejected. On occasion these jigs may be used to hold components for boring, coping or additional machining. The latest technology incorporates the use of radio-frequency heating to cure steamed components into their final shape in one operation and without the use of manual adjusting procedures.

Figure 94. Arm adjusting jig

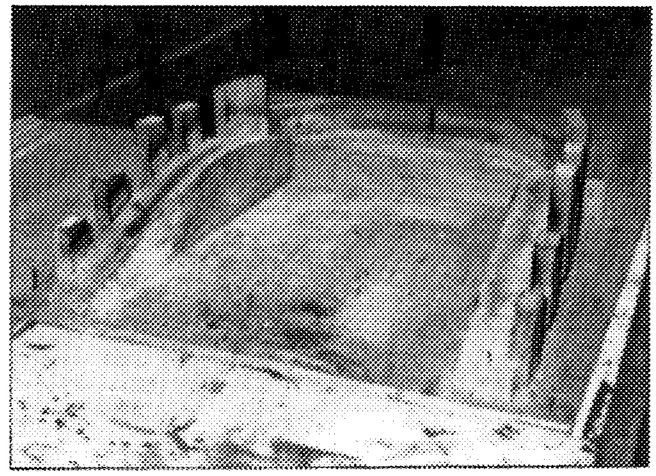


Figure 95. Holding in jig for back leg boring

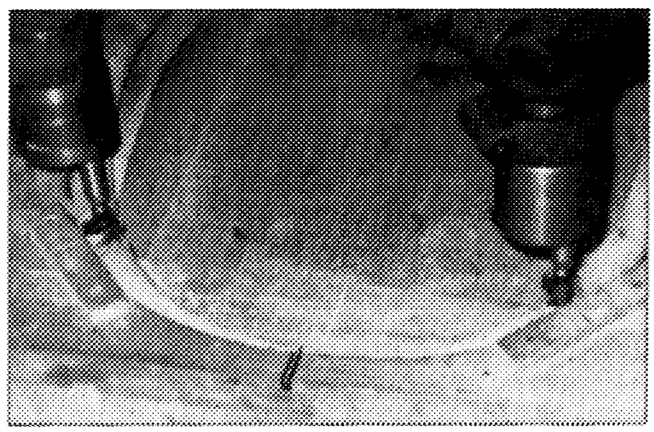
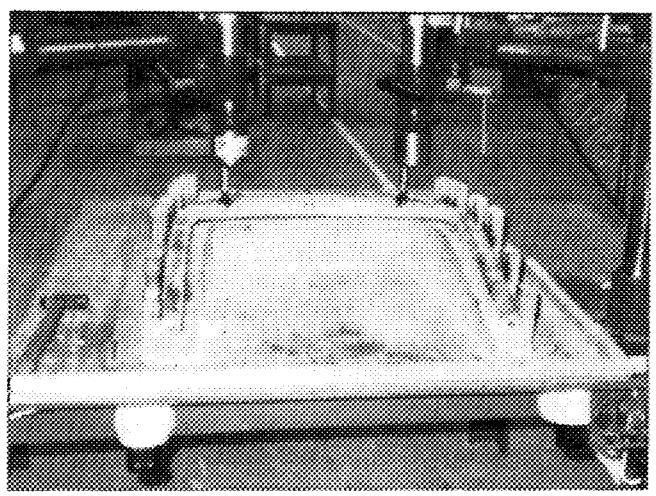


Figure 96. Front view of holding jig for back leg boring



Machining jigs

Machining jigs are appliances used in the machining department to accurately guide or locate tools or workpieces during the operations required to produce standard parts. Simple jigs can be constructed at practically no cost and greatly increase the productivity and versatility of basic machines.

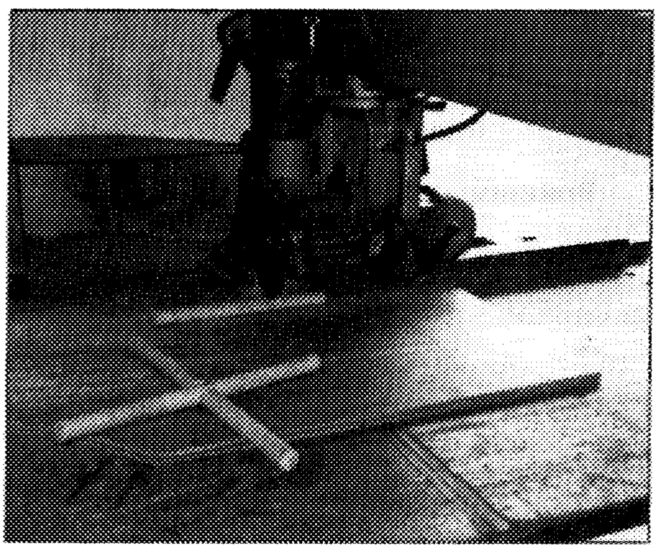
One positive consequence of the higher manufacturing accuracy achieved by the use of jigs is a reduction in the number of faulty parts and, hence, a savings in raw material and labour.

Machine jigs can also be designed to function as safety devices. They should be provided with handles for safe machine feeding and with splinter guards to protect the eyes.

When properly set up jigs are used to machine components, the operators need not be as highly skilled as operators for direct machining.

A typical machining jig is illustrated in figure 97, where a wobble saw is set up to half-cut cross lateral braces for jointing purposes.

Figure 97. Cross-halving with wobble saw (guard removed for illustration)



Assembly jigs

The dimensional accuracy of a finished product depends on the accuracy with which previous operations, i.e. adjusting and machining, have been carried out. If the components are accurate and suitable, then the assembly can be performed with great accuracy and precision.

Assembly jigs, especially when used for final assembly, can be equipped with holding devices such as eccentrics, screws, clamps, springs or pneumatic rams. Often these can be recycled when the jig is no longer required and used again on other new jigs.

Figure 98. Subassembly jigs for chair fronts and backs

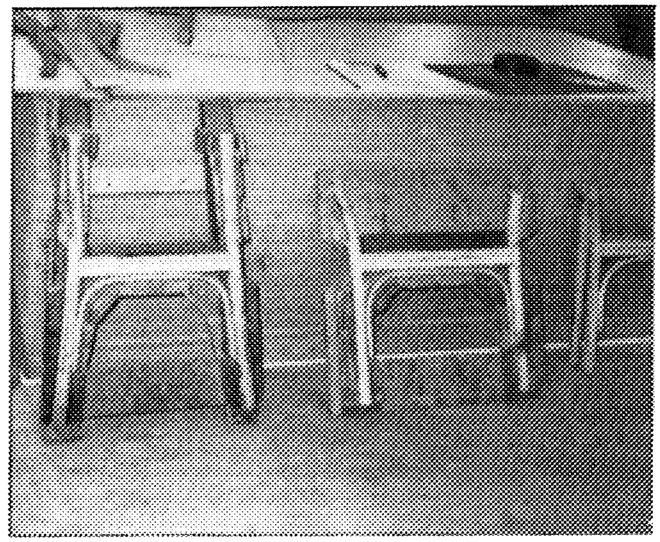


Figure 99. Jigs for subassembly of chair sides

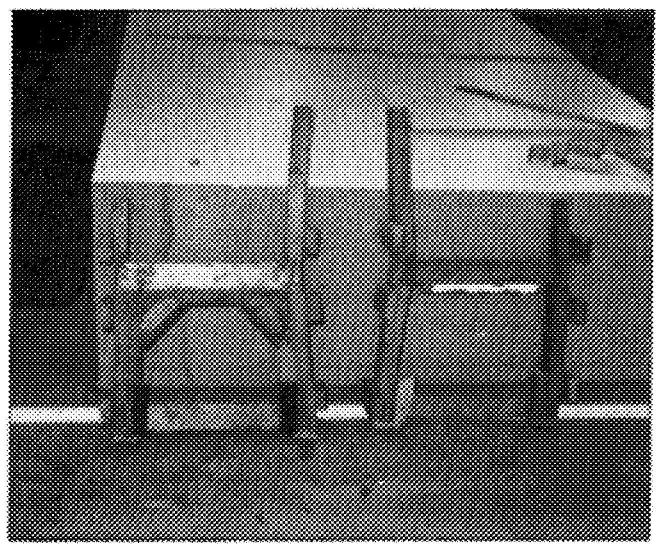


Figure 100. Final assembly jigs

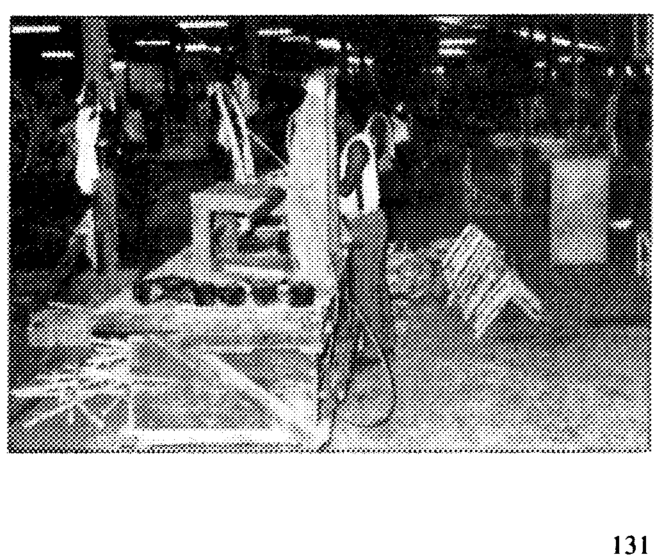


Figure 101. Final assembly jigs for checking of production

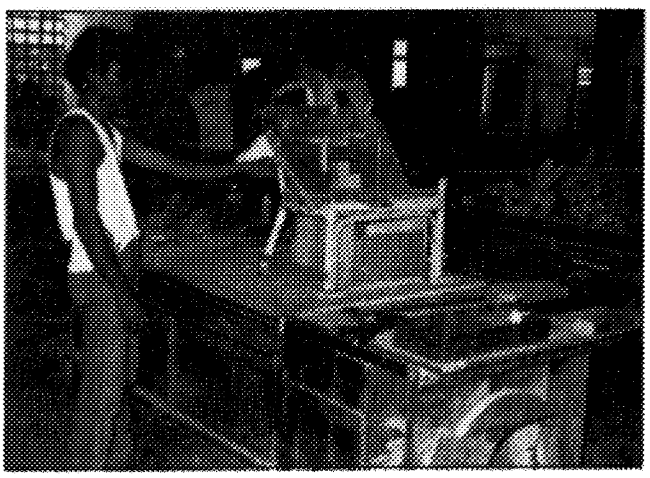
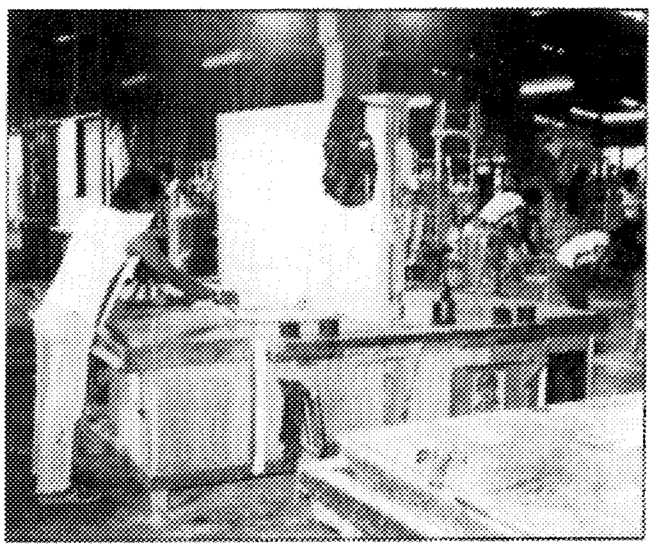


Figure 102. Checking for symmetry



Generally the target should be to have all subassemblies pneumatically nailed or pinned together in a suitable jig. Final assemblies, however, especially main structural components, should be screwed together to avoid lateral and angular hammering in the jig. Figures 98-102 show different views of subassembly jigs.

Storage of jigs

Jigs designed and built for the serial production of furniture are an important part of the production facilities and should therefore be carefully stored. The following storage requirements should be met:

(a) Storage should be close to the tool maintenance workshop. In large factories, it is advisable to keep assembly jigs in a special storage area in the assembly shop;

(b) The storage area must be a special room, separated from the production workshop, to avoid chips and dust on the stored material;

(c) The relative humidity in the storage area should be the same as in the factory area in general. A jig should never be exposed to water (rain, pipe leakages);

(d) The most practical means of storing smaller jigs is by hanging them on special racks fixed to the walls. Shelves can be used for large and heavy jigs;

(e) The jigs must be provided with an identification number or code and stored accordingly;

(f) The jigs must be identified by a simple coding system.

The importance of jigs in the manufacture of rattan furniture cannot be overemphasized. If the jigs are not right, the production flow will not be smooth. A common and well-established practice is to use proven jig-makers, and in rattan furniture factories these are among the best-paid employees.

When designing a jig, it is also important to keep the objective in mind. Can a jig be improved to do something better or faster? Experience with jigs soon leads to the ability to change an established practice in order to increase productivity. In newly set up factories, the jigs to be used will depend upon the experts who assist and train the workforce. However, the method of the experts need not be regarded as the only solution. See what they propose and try to modify it if the solution is not entirely satisfactory; often a fresh mind can produce better results.

Processing activities and equipment used

A typical rattant furniture factory would have the equipment listed in table 11. Figures 103-110 illustrate some of the operations listed therein.

Figure 103. Cross-cutting poles to length

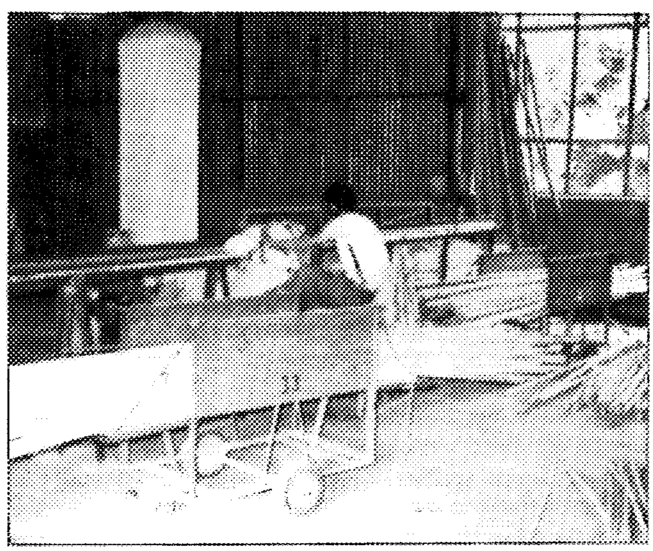


Table 11. Equipment in a typical rattan manufacturing plant

Activity	*Figure(s)*	*Process and equipment used*
Pole preparation		
Removal of leaf sheaths		Manual
Drying		Manual
Initial straightening		Manual
Straightening		Hydraulic straightening machine
Milling/sanding	104	Round-pole grinding machine
Pole sizing	105	Fixed cutting-die sizing machine, revolving-head sizing machine
Classification (variety, size, quality)		Manual
Component processing		
Cross-cutting	103	Pneumatic cross-cut saw
	108	Circular saw with table and fence
Straightening		Manual, hydraulic or radio-frequency heating
Steaming, bending, boiling	106	Manual (on jigs), coiling machine, pneumatic or hydraulic rams on jigs, radio-frequency heating
Adjusting		Manual, with torch
Jointing		
Boring	111, 113	Double- or single-head boring machine
Coping	109, 110, 112	Double- or single-head boring machine, coping machine
Halving		Cross-cut saw with wobble blade
Finger jointing		Spindle moulder with special finger-jointing cutter-block
Mitring		Rip- or cross-cut saw
Shaping		
Flattening		Surfacer, thicknesser, wide-belt sander
Tapering		Thicknesser with jig, wide-belt sander with jig
Grooving		Router (shaped), spindle moulder (straight), rip-saw
Rebating		Router, spindle moudler
Splitting		Rip-saw
Moulding		Spindle moulder, router
Sanding		Round-pole sander (straight), brush-type bent-pole sander, buffer/drum sander, disc sander, moulded-head sander
Subassembly	99	Manual (jigged, pneumatic) nailing, drilling, screwing and glue application
Final assembly	100, 101	Manual (jigged, pneumatic) nailing, drilling, screwing and glue application
Binding		Manual (pneumatic stapler)
Final sanding		Manual
Finishing		Manual (air or electrostatic) spraying

Figure 104. Sanding

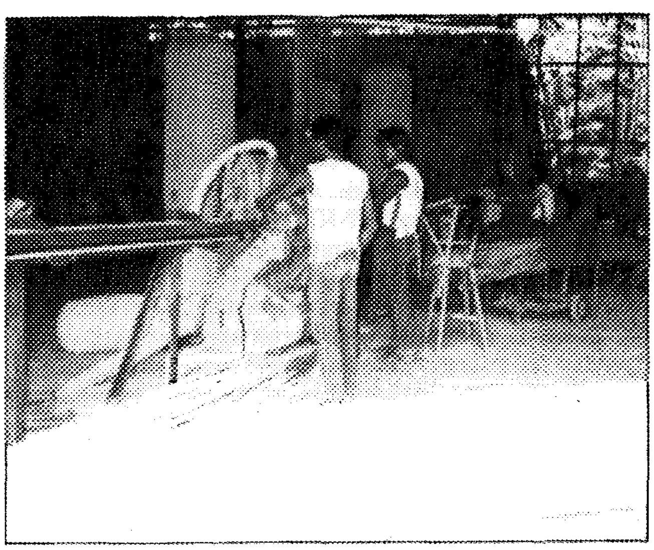


Figure 105. Sizing poles to required diameters

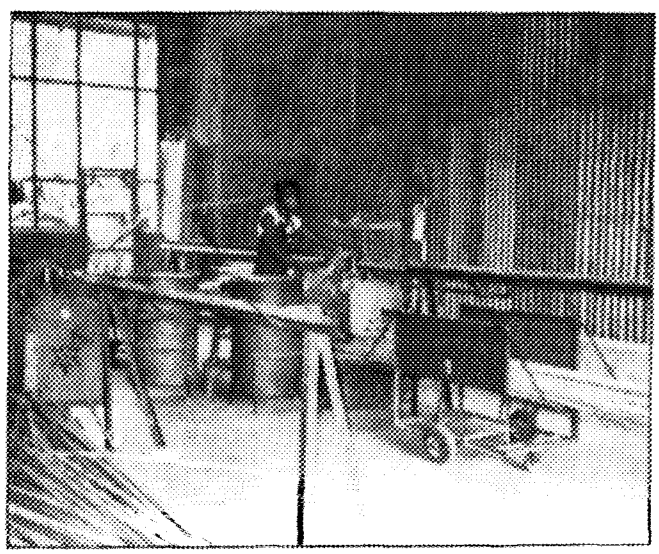


Figure 106. Rattan pole boiling baths

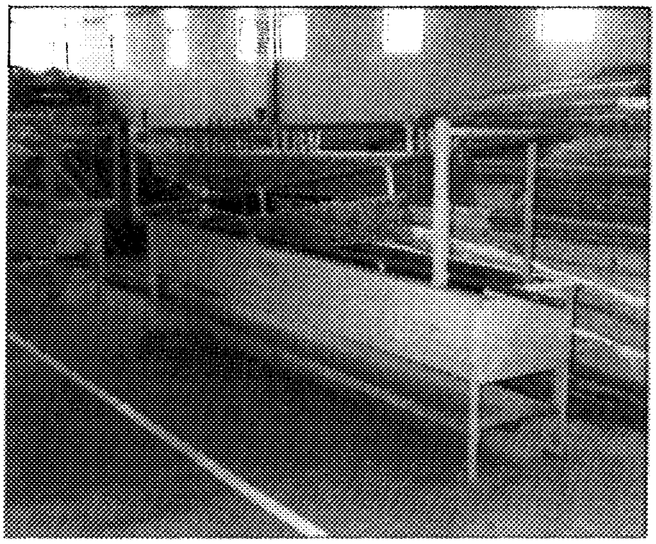
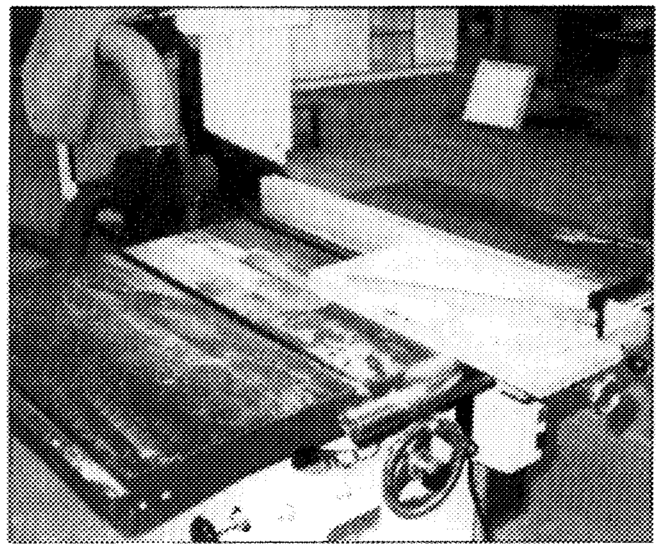


Figure 108. Brace preparation: cutting to length



Figures 114-120 relate to the processing of solid wood or wood-based panels.

If case-goods manufacture is considered, the panel saw that is being purchased should be fitted with a proper scoring saw, as shown in figure 121. The purpose of scoring is to prevent chips from being cut out of the bottom face. When cutting a laminated board with both sides laminated, a separate scoring saw must also be used. After cutting, the edges of the board must be filed or machined to avoid splitting. This is carried out as shown in figure 122, either with a cutter or a file after the edging.

Figure 107. Dowel-end forming

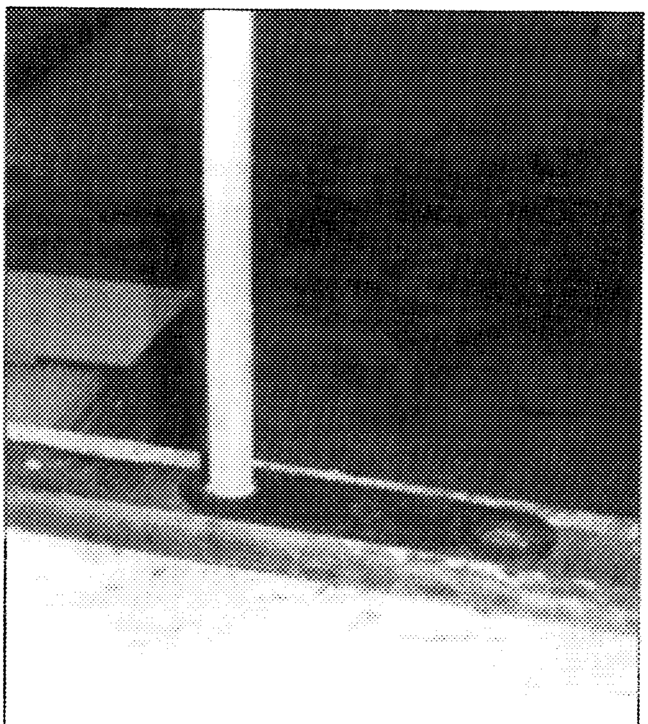
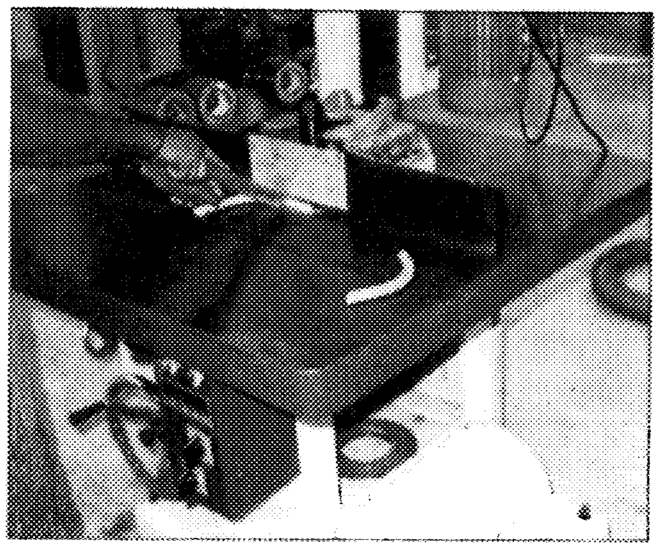


Figure 109. Brace preparation: spindle coping



Annex V on woodworking machine tools has been reproduced from *Furniture and Joinery Industries for Developing Countries* (UNIDO publication, Sales No. E.88.III.E.7). The rattan furniture industry has now completed the changeover to tungsten-carbide-tipped saws and drills, and only tools of the best quality steel should be purchased. If a machine has been set up properly, it can be operated for a longer time before the saw or drill needs to be changed. Good quality tools are therefore essential.

Annex VI, VII and VIII, which are also reprinted from the above-mentioned publication, deal with low-cost automation, the maintenance of machines and equipment and the maintenance of machine parts. All of these are important aspects of rattan furniture production.

Figure 110. Leg-top coping by drilling

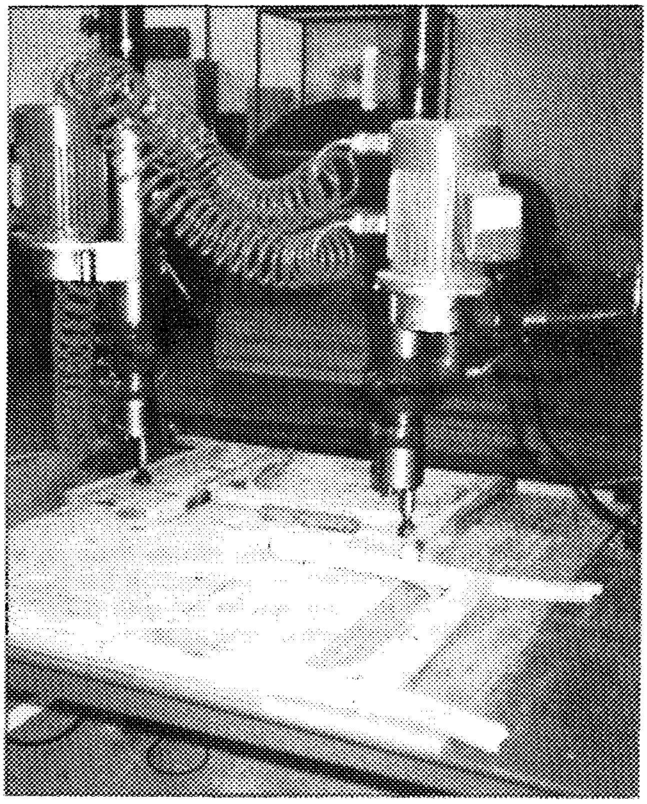


Figure 111. Drilling for side rails

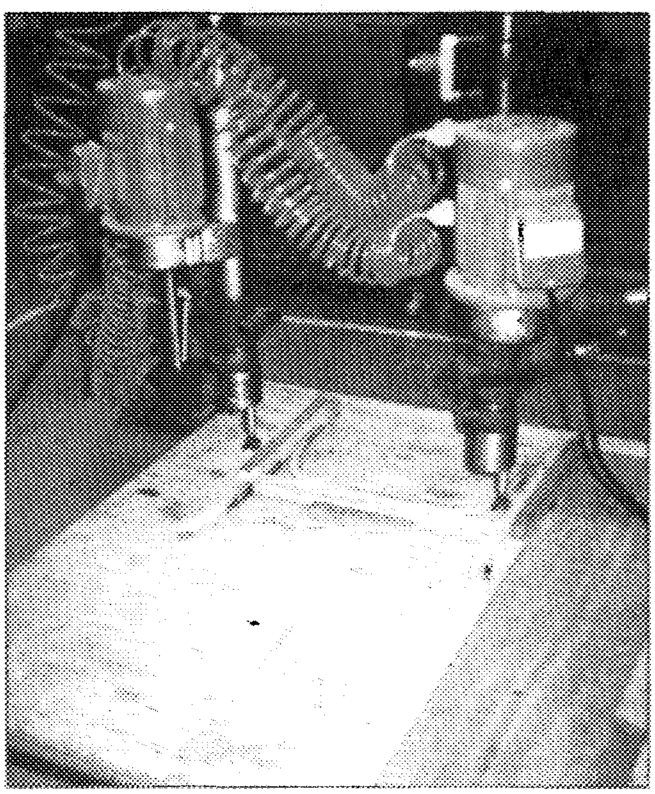


Figure 112. Angle coping by drilling

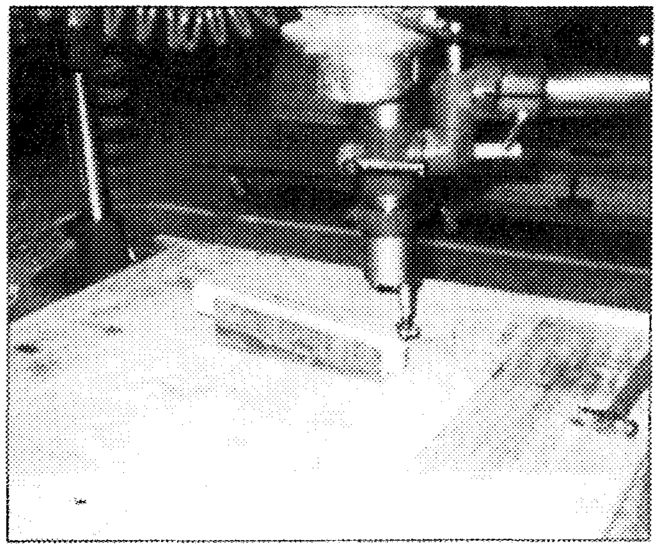


Figure 113. Front-leg drilling for double front rail

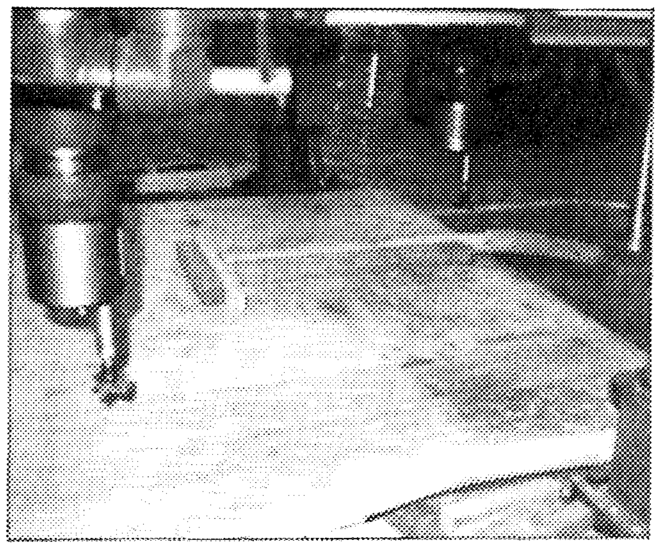


Figure 114. Panel sizing saw

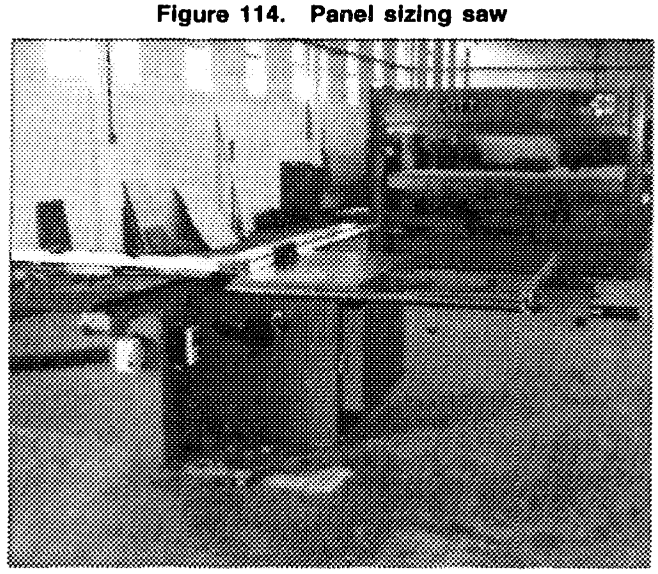


Figure 115. Single daylight hydraulic press

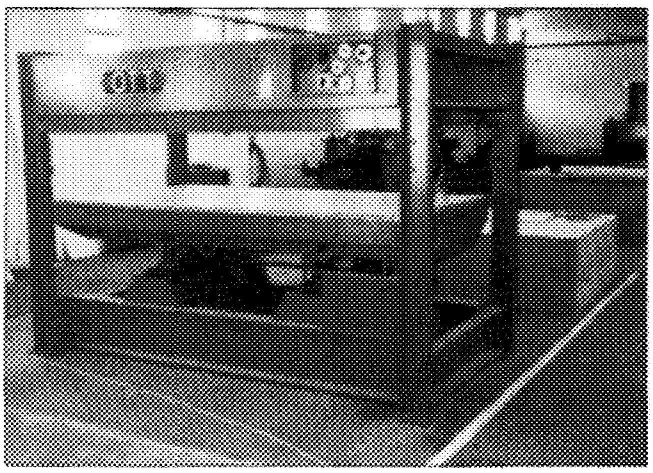


Figure 116. With this attachment, tenoning can be done on a spindle moulder/shaper on a repetition production basis. A complete tenon up to 2.5 in. long can be cut with either scribed or plain shoulders at one pass

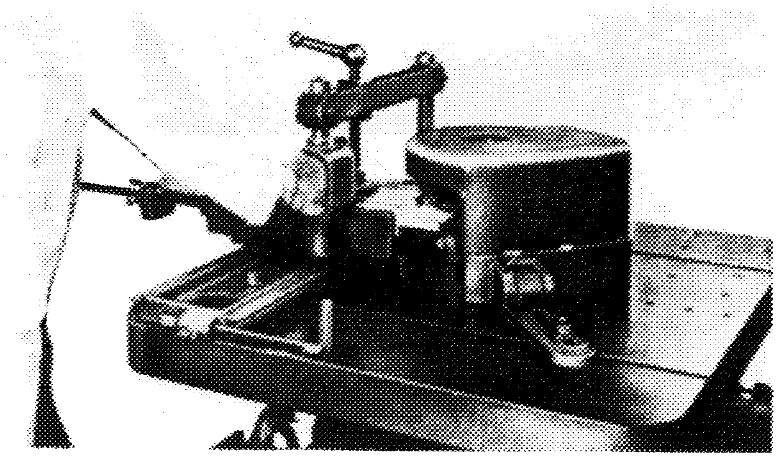


Figure 117. With this corner locking attachment, corners can be locked on boards up to 3 in. deep on a spindle moulder/shaper

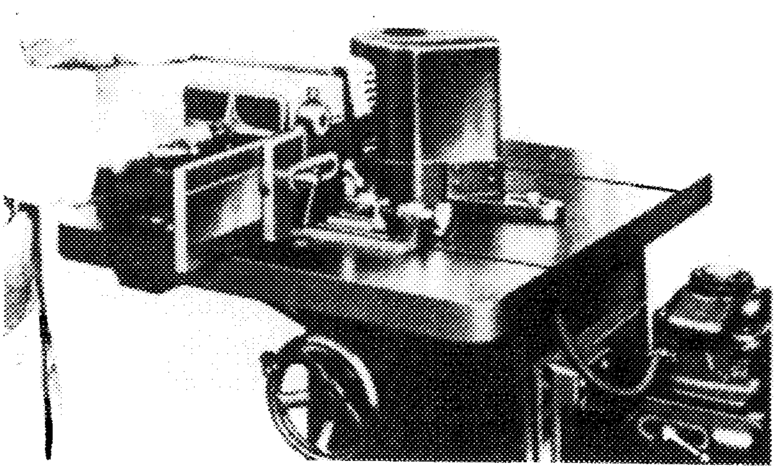
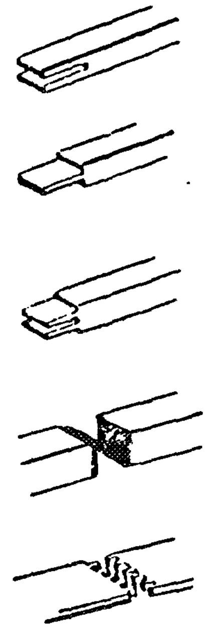


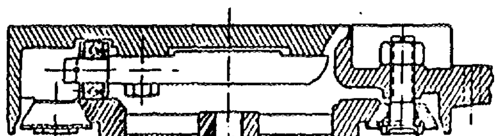
Figure 118. Tenoning attachments for spindle moulders/shapers

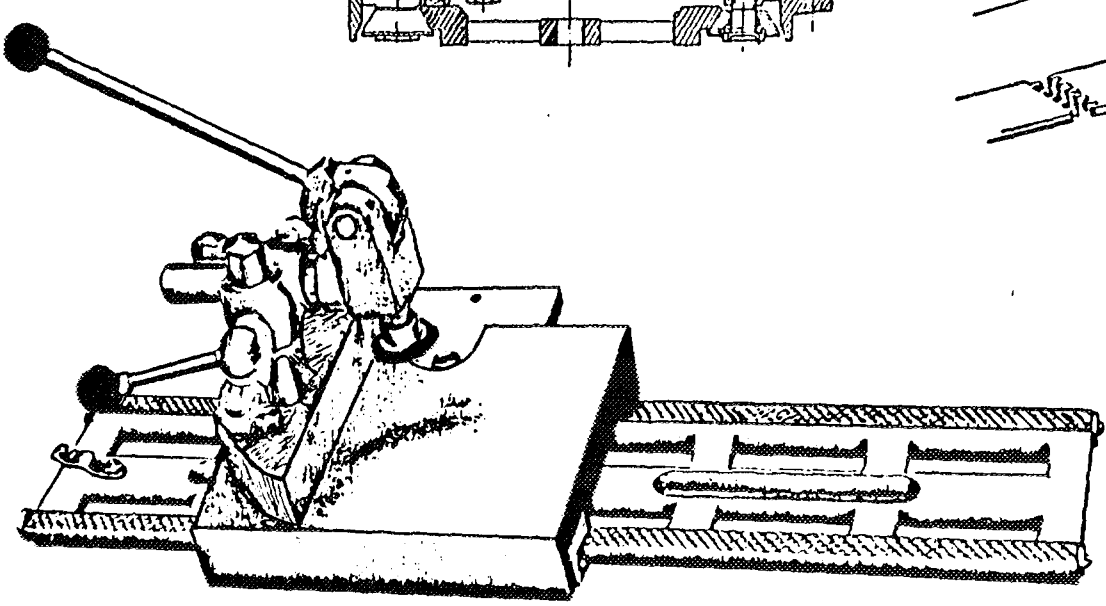
technical features
Heavy duty carriage : provides maximum vibration-resistant stability ; smooth, ball bearing action free of play ; take-up adjusted by a single screw. Rapid cam clamping gives strong, constant pressure irrespective of lever position.
Square adjustable to form tenons of up to 45.

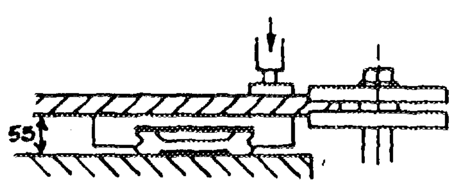
operation
With machine fixed to shaper table, a splinter prevention shield is screwed to the adjustable square by means of two threaded 10 x 150 holes
A wood support is then fixed to the special T surface at rear of table to extend surface area when working on long pieces.
Clamp height is then adjusted so that the work is clamped at approximately 3/4 of cam travel.

Dimensions
Carriage, dimensions 32 x 35 cm
Bearing surface 22 x 27 cm
Slide :
Width 180 mm
Length 900 mm
Total weight :
Net : 50 kg
Gross : 54 kg









Mounted on ball-bearings, with cam-actuated clamp. For tenoning, corner-locking etc., on the moulder. Table 300×300 mm, length of fence either 1000 or 1400 mm, with extension piece No.265.1 as required.

Art.Nr.	*Length*
265.010	1000
265.015	1400

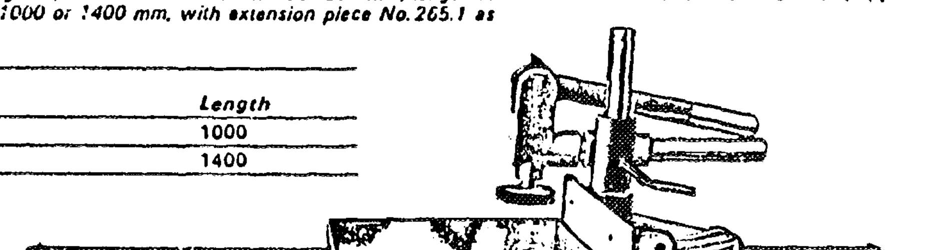
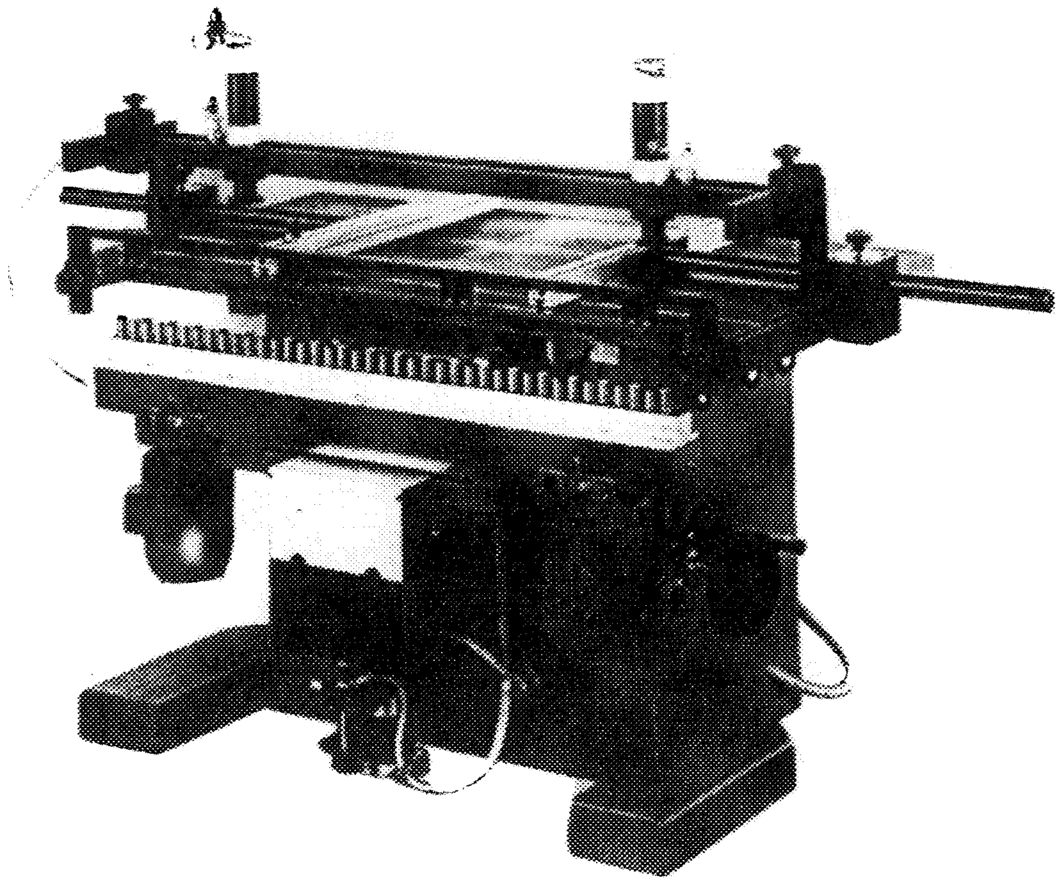


Figure 119. Multiple boring machine; the detail drawing shows the construction of a spindle head with a standard pitch



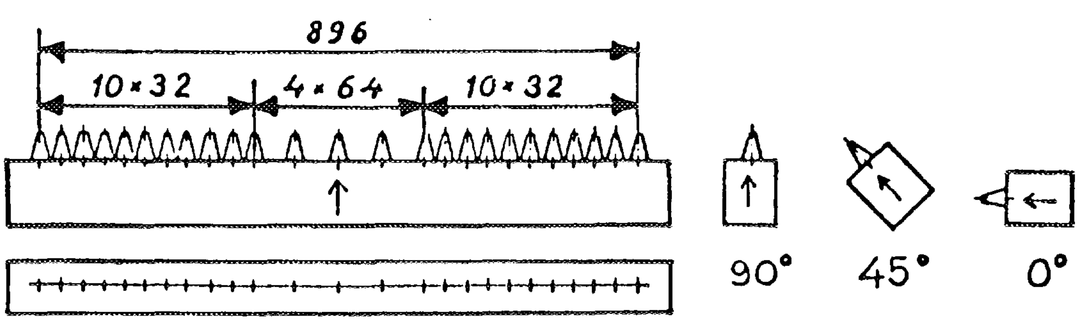


Figure 120. Spindle heads with fixed spindle centres for boring of narrow furniture parts

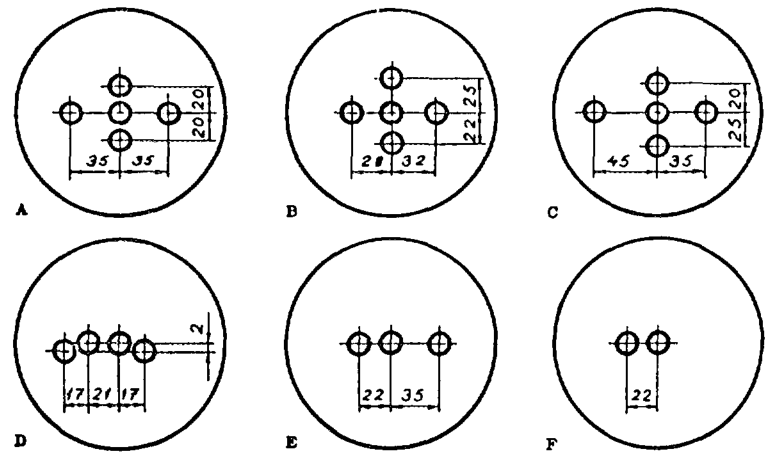


Figure 121. Scoring saw used to saw a board laminated on both sides

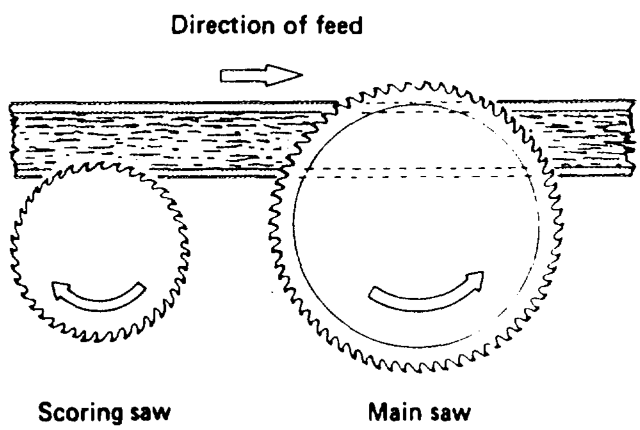
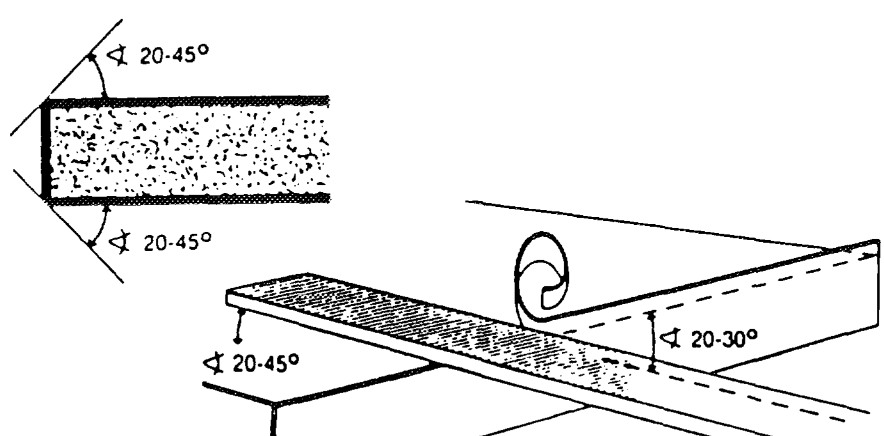


Figure 122. Filing the edges



Annex I

RULES FOR A BONUS INCENTIVE PLAN AND COMMENTS ON ITS OPERATION

1. A bonus incentive plan is a management prerogative and as such may be withdrawn or adjusted at any time.

2. All regular daily wage employees involved in production will be eligible for a bonus under the plan.

3. The bonus will be based on the performance of the framing, scraping/sanding and binding groups.

4. The rest of the factory must produce up to the level of these three groups. If it is found that these three groups are productive but the rest of the factory is not matching their output, the plan should be scrapped.

5. Bonus amounts for the balance of the factory will be an average of the bonus received by the framing, scraping/sanding and binding groups.

6. There is no limit to the amount of bonus a group may earn.

7. The bonus will be based on production during the normal pay period of one week. If some of it is earned during overtime, this should be taken into account.

8. One point in the bonus system is equal to one production hour. The initial value of a bonus point is calculated according to production targets, e.g. a 10 per cent increase in wages when a 25 per cent increase in productivity is achieved.

9. Points allocated may be adjusted periodically at the management's discretion to allow for improved mechanization, design alteration etc.

10. A group will be given a specified time (point value) in which to finish a production run. For a group of eight, the initial point value to be produced before a bonus comes into effect is as follows:

8 men × 7.5 hours × 6 days = 360

A group finishing the production run in less than the allocated time will be eligible for a bonus. The following example was calculated in Mauritian rupees (Mau Rs):

Production run	50 pieces
Point values	
Framing	5.0 points
Scraping/sanding	4.0 points
Binding/caning	2.0 points
Bonus value	3.0 Mau Rp

Framing:

50 pieces × 5.0 = 250 allocated points (production hours)
150 actual points (actual production hours)
Bonus points = 100 × 3.0 = Mau Rp 300
Divided among 8 workers = Mau Rp 37.50 each

Scraping/sanding:

50 pieces × 4.0 = 200 allocated points
125 actual points
Bonus points = 75 × 3.0 = Mau Rp 225
Divided among 8 workers = Mau Rp 28.13 each

Binding:

50 pieces × 2.0 = 100 allocated points
45 actual points
Bonus points = 55 × 3.0 = Mau Rp 165
Divided among 8 workers = Mau Rp 20.63 each

The bonus amount is divided between all members of the group, including group leaders and supervisors, proportional to daily attendance. The balance of the factory will receive an average of the three groups' bonus, or Mau Rp 28.75 each.

11. Pieces will be tagged to facilitate record-keeping. Any tampering with the tags or with the system is grounds for immediate dismissal and termination of the bonus incentive scheme.

12. Most important: quality must be maintained at all times. If there is a drop in quality, the programme should be discontinued immediately.

Comments

It is important to keep in mind that any incentive plan must allow the workers to calculate their own entitlement. If the calculations to determine the remuneration are too difficult for the workers to complete themselves, then the scheme will fail. The plan will permit each group to work out its own particular bonus.

The introduction of new machinery or processes requires the bonus scheme to be recalculated, and the bonus value is the best figure to change.

The plan is also designed to put the best people into the framing, scraping/sanding and binding groups since it is there that they will earn the highest bonus (the rest of the factory receive only an average of the bonus earned by these groups). These three groups have always been the bottleneck for rattan furniture production, so it make sense to direct the best workers to them.

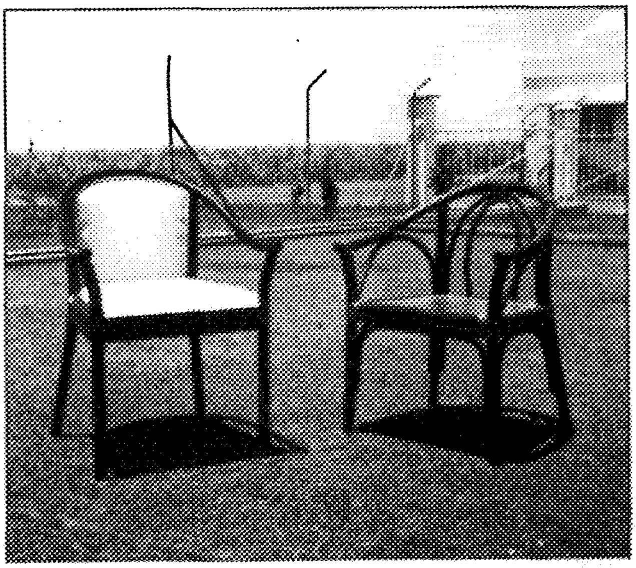
When the bonus plan is started, management should select the group leaders and let them select their own group members. Later, if a group wants to nominate its own leader, management may reserve the right to disagree. Allowing the leaders to select their own members also serves to identify, by default, those whom the workers themselves regard as poor contributors. These are normally reassigned to other duties.

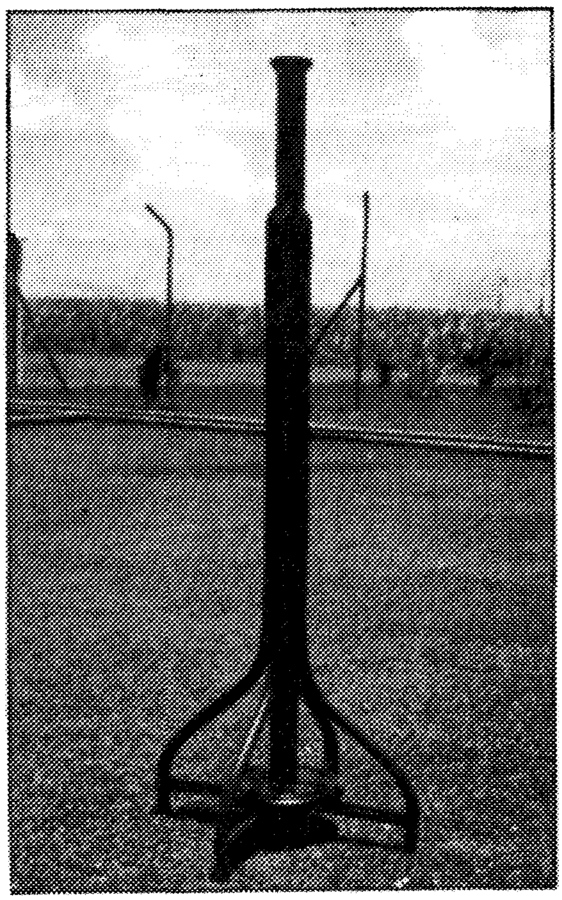
New employees do not usually begin work in the groups that operate on the highest bonus. If people leave these groups for any reason, management should first use people from other groups who have some company seniority and knowledge of the operations.

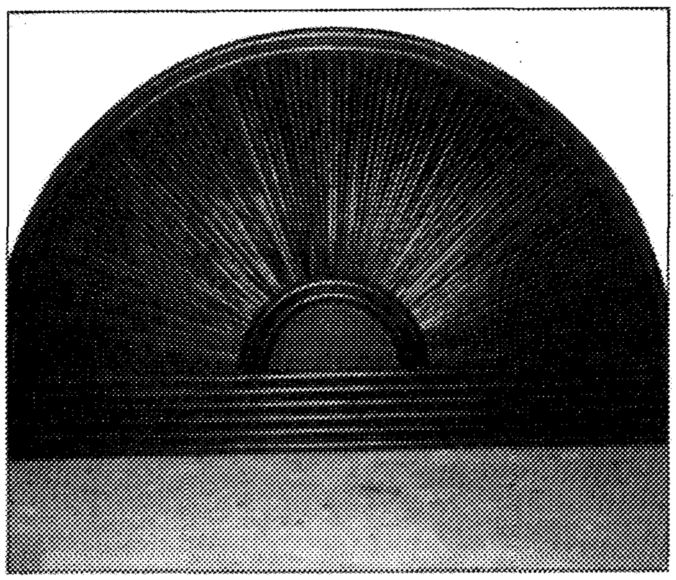
To minimize the loss of employees to other companies, taking their knowledge with them, it should be made clear that any worker who resigns will not be rehired under any circumstances. All current employees should be aware of this no rehiring policy.

Annex II

EXAMPLES OF RATTAN AND WOOD USED TOGETHER TO ADVANTAGE*







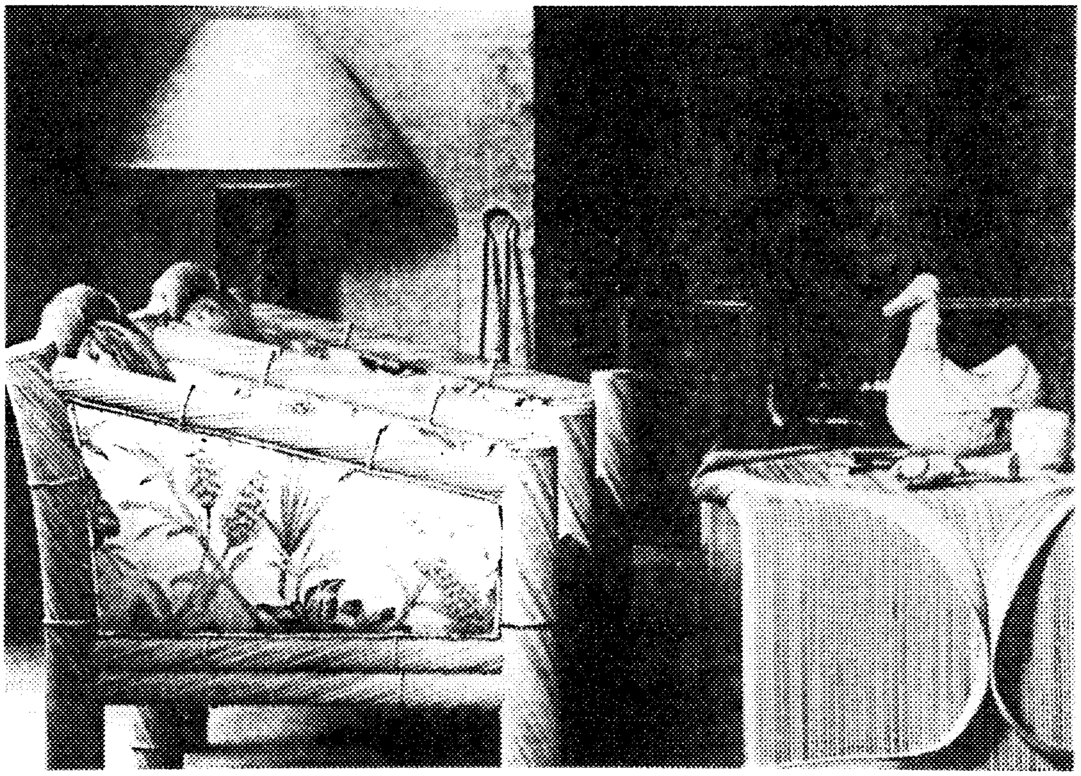
**Source*: Berger, catalogue for rattan furniture.

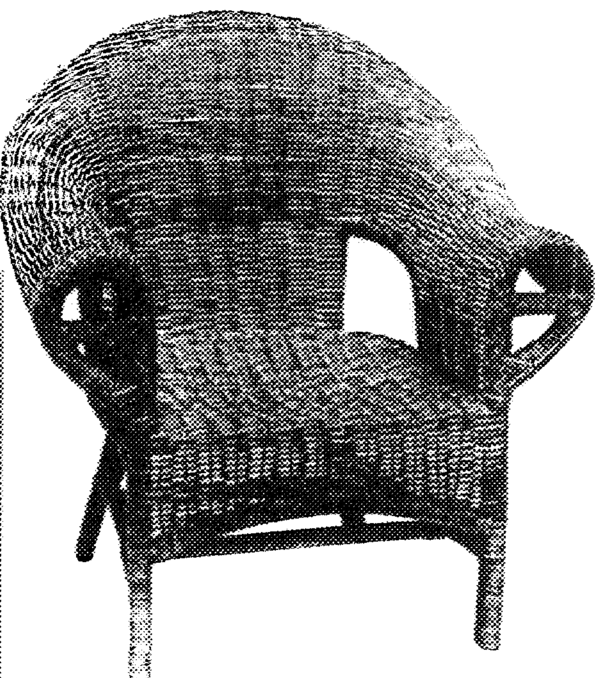
Annex III

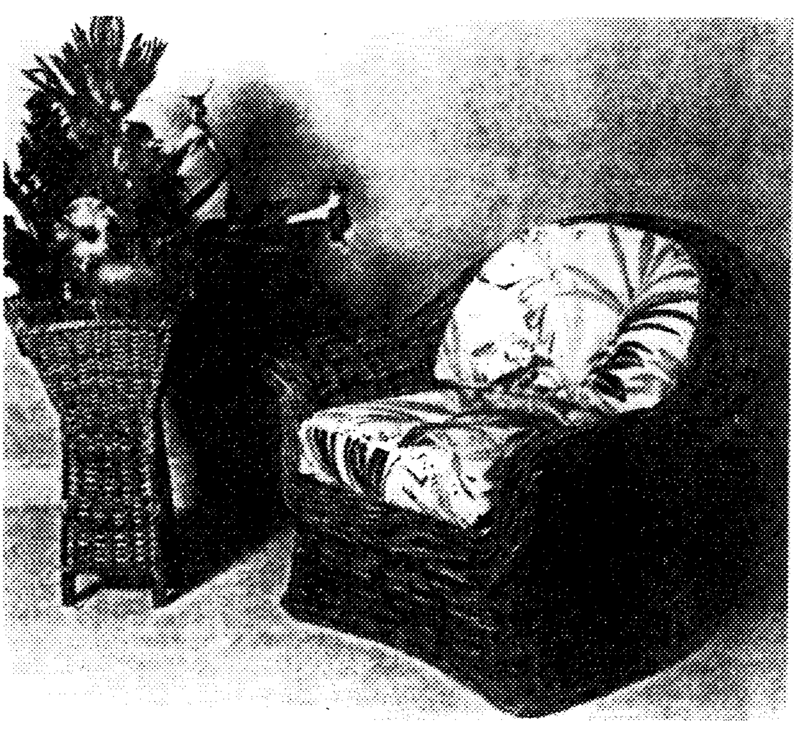
EXAMPLES OF SMALL-POLE AND LARGE-POLE RATTAN FURNITURE*

Designs using small-diameter poles

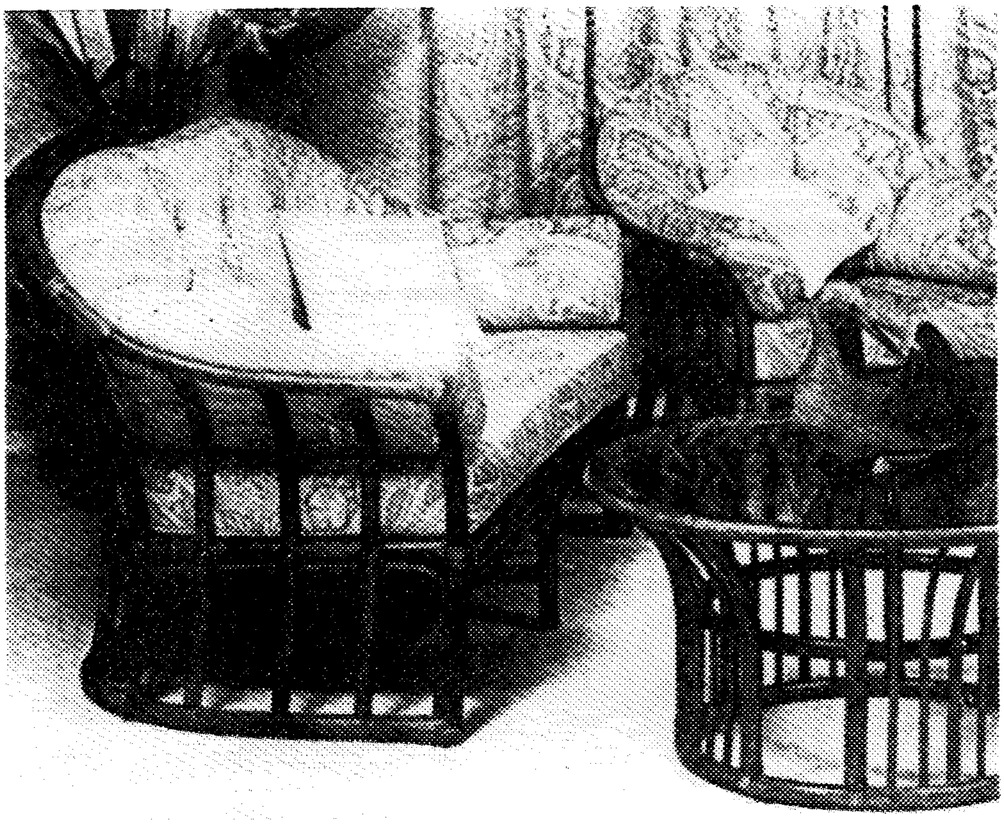
**Source:* Berger, catalogue for rattan furniture.







Designs using larger diameter poles



Annex IV

GUIDELINES FOR OFF-CUT RECOVERY

Typical off-cut recovery guidelines should provide for the following:

(a) After pole cutting, all off-cuts are set aside for classification and storing.

(b) They are classified according to grade, diameter and length as follows:

(i) Grade: A or BC

(ii) Diameter: smallest diameter to be taken when measuring.

(iii) Length to be sorted as follows:

Length (in.)	
12-18	48-60
18-24	60-72
23-30	72-84
30-36	84-96
36-48	96+

(c) The off-cuts are to be tied in bundles of 50. Only straightened poles are to be stored.

(d) Each bundle is to be either tagged with a plywood card showing grade, diameter and length or placed in an appropriate rack.

(e) Each entry and debit from the off-cuts stock is to be noted on a daily basis on a weekly stock sheet.

(f) A new stock sheet is to be prepared every Monday.

(g) All new cutting lists are to be checked against off-cut stock before full poles are issued for cutting.

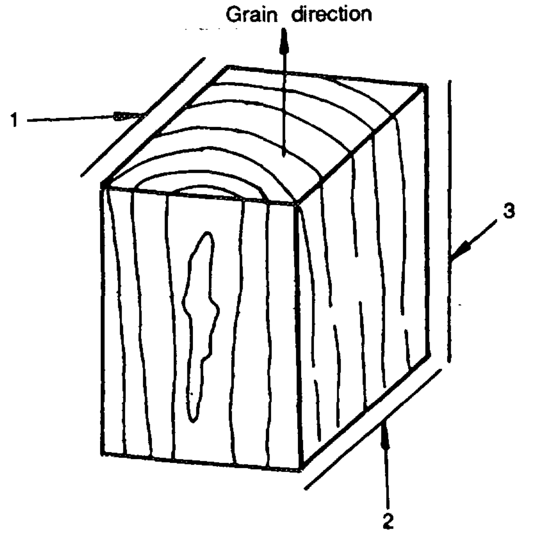
Annex V

TYPES OF MACHINE TOOLS FOR WOOD-WORKING

When contemplating the manufacture of furniture and joinery products on an industrial scale, the planners must have a good knowledge of machine tools for woodworking and of their proper maintenance. Such equipment is both complicated and costly, and its proper selection, operation and maintenance will be vital to the success of the operation. The nature, mode of operation and proper upkeep of some of the more important types of woodworking machinery are considered here in some detail.

Some machine tools used for cutting are illustrated in the figures that follow. As shown in figure 396, there are three ways in which logs and lumber can be sawn: (1) perpendicularly to the grain (cross-cutting); (2) parallel to the grain (ripping); and (3) parallel to the grain but moving across it. The tools used to perform these operations must be designed accordingly.

Figure 396. Cutting directions with respect to the grain of the wood

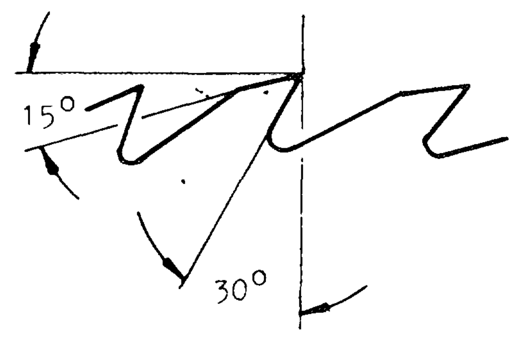


Key: 1 Cutting surface perpendicular to the grain
2 Cutting surface and movement parallel to the grain
3 Cutting surface parallel to the grain but moving perpendicularly to it

Circular-saw blades

Circular saws can be obtained with tooth shapes suitable for either ripping or cross-cutting. The standard tooth forms and angles are shown in figure 397. The saw must be well-balanced when running, and, in order to secure its satisfactory and steady rotation, the centre portion must be hammered in advance (pre-tensioned) so that it receives an extension corresponding to that produced in the saw rim when running at full speed.

Figure 397. Standard tooth forms and angles for circular saw blades



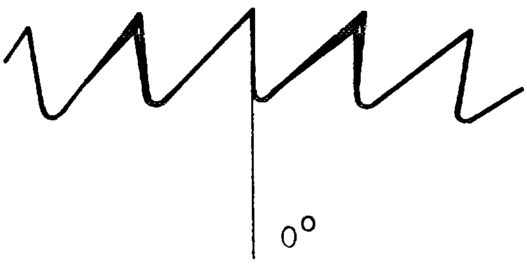
A. Front bevel angle = 0°
Back lèvel angle = 5°

B. Front bevel angle = 0°
Back level angle = 5°

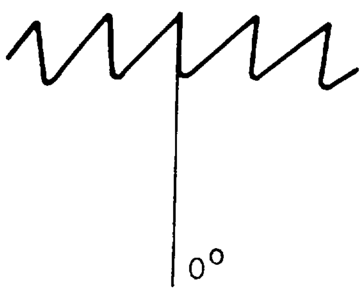
C. Front bevel angle = 0°
Back level angle = 5°

*By Erik Winnlert, Sandviken Jernverks, AB, Sandviken, Sweden, chapter XXXI of *Furniture and joinery industries for developing countries* (UNIDO publication, Sales No. E.88.III.E.7), pp. 279-288. Original figure and table numbers have been retained.

Figure 397 *(continued)*



D. Front bevel angle = 15°
Back level angle = 15°



E. Front bevel angle = 0°
Back level angle = 0°

F. Front bevel angle = 15°
Back level angle = 15°

Note: For definitions of front and back bevel angles, see figure 400.

The saws are balanced and tensioned correctly when received from the manufacturer, but cutting conditions will cause them to lose tension, which must be renewed by experienced personnel.

Normally the speed at the periphery is approximately 50 m/s. Rim speeds higher or lower than normal require adjustment of the tension; higher speeds require "looser" tensions and vice versa.

It is very important that the blades be absolutely even and flat when rotating and that they not deviate more than a couple of tenths of a millimetre from the straight plane. Hence the importance of tensioning.

Steel qualities for saws usually have an even hardness of approximately 46 HRC (Rockwell scale) with no sizable deviations. For the saw blades to do good work, it is necessary that they be filed and set correctly and that correct tooth shape, with suitable angles, be maintained by the saw filer.

The saw blade is mounted on a shaft which exactly fits its centre hole. The shaft is usually driven by a pulley drive, but direct drive by the motor shaft is used on some smaller machines.

In sawing, the log is fed towards the saw blade on a separate table or log carriage. Manual feed is still used in old-fashioned sawmills.

In joinery shops and similar industrial plants, manual feed is common, but rollers or conveyors are also used. The sawing of logs using circular saws is cheap as regards machine costs, but the exactness of the sawn wood is often not good, owing to the difficulty in supporting the saw blade mechanically. Correct tensioning and levelling of the saw blade are very important.

No sorting of the working material is necessary except to remove logs that are too large. In certain countries so-called twin saws are used for sawing big logs. A twin saw consists of two saw blades, one placed above the other in such a way that the saw curves meet in the kerf.

Circular-saw blades are not economical, since much wood is lost in the form of sawdust. These machines are therefore gradually disappearing, especially for log sawing. Instead, band saws and carbide-tipped circular saws will take over more and more of the market share held by the conventional smaller circular saw blades.

Carbide-tipped circular saws

Carbide-tipped circular-saw blades are gaining steadily in popularity. The introduction of more stable machines, designed especially with carbide-tipped saw blades in mind and better understanding of the use and care of these blades have resulted in increasingly improved economy.

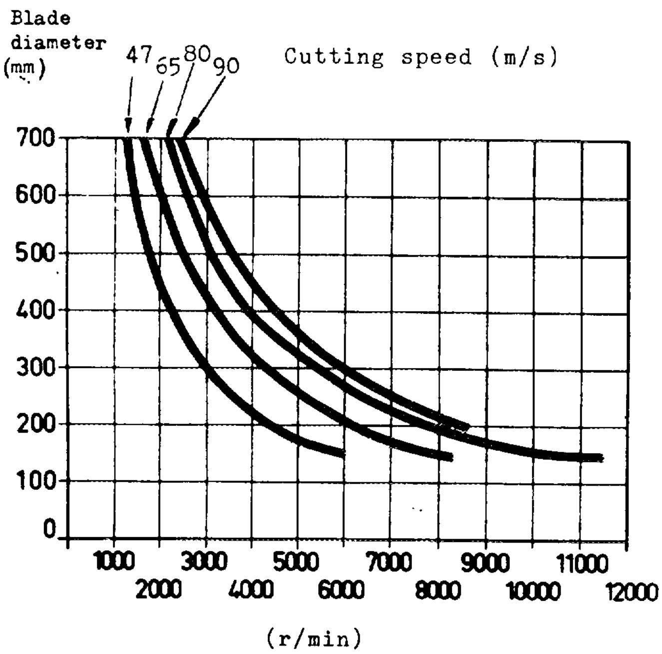
The wood-products industry in Sweden has undergone a thorough reorganization in recent years, and efficiency measures have been widely adopted. Increasingly stiff competition has forced most companies to try to concentrate their efforts on a limited range of products, resulting in long runs. In the course of this development the previously used universal machines have lost ground in favour of specialized machines of great precision and capacity.

When acquiring these frequently expensive specialized machines it is necessary, however, to see that the tools used with them permit the full exploitation of the machines' potential. Carbide-tipped circular-saw blades play an important role in this context. Because of their high durability, it has been possible to raise the ouptput and reduce the manufacturing costs per unit. However, the optimum performance of carbide-tipped blades can be achieved only under certain definite operating conditions.

Cutting speed

As a rule, machines of older types used in the wood-products industry are not adjustable for different speeds. They frequently have a speed that, with ordinary blades, gives a cutting speed of approximately 47 m/s (155 ft/s—see figure 398). When a switch is made to carbide-tipped blades, a smaller diameter can be employed because, with such blades, the diameter reduction will be much less than for an ordinary blade. Given these circumstances, a carbide-tipped blade in an older type of machine will give a much lower cutting speed than a conventional blade, which means in many cases that it cannot be used in the most economical way.

Figure 398. Cutting speed as a function of revolving speed of blade



Recommended cutting speeds for various types of material are given in table 23. The cutting speed for each group can be given only within relatively broad limits because of the differences in workability between wood species and wood-based panels. At the upper limits, it is necessary for the machine to be stable enough to ensure vibration-free blade running. If the feed per tooth is too low, no proper chip will be formed, the tooth edge merely acting abrasively on the material with excessive wear as a result. To reduce wear it is best to employ a large feed per tooth, since edge wear is principally dependent on the course of the tooth through the material. If an excessive feed speed is used, the cutting forces may become so large that the sintered carbide in the cutting edge will break down. The required finish of the section will always be an important factor in selecting feed rate.

Table 23. Cutting speeds of carbide-tipped circular saws in different materials

Material	*Cutting speed* *m/s*	*t/s*
Softwood	60-90	200-300
Hardwood	50-70	160-230
Plywood	60-80	200-260
Hardboard	70-90	230-300
Particle board	60-80	200-260
Veneered board	60-90	200-300

Feed speed

The feed per tooth should be between 0.05 and 0.30 mm (0.002 and 0.012 in.), according to the material being worked and the standard of finish required. It can be calculated using the formula:

$$F = \frac{s \times 1.000}{n \times z}$$

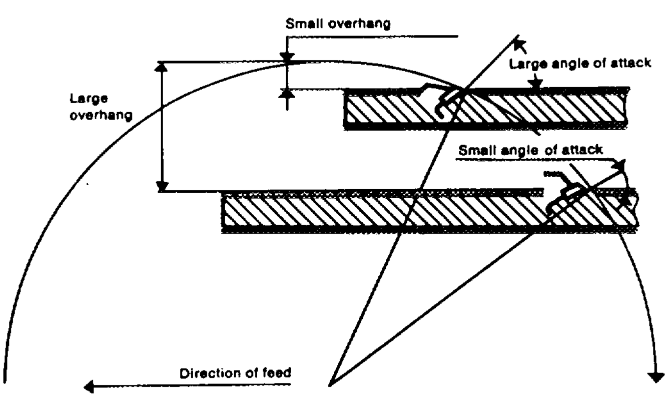
where:

F = feed/tooth in mm
s = feed in m/min of the piece being sawn
n = revolutions/min
z = number of teeth working on the saw in question

Height of blade over work

The hook angle of standard catalogued carbide-tipped blades is usually designed for a blade height over the work of 10 to 15 mm (3/8 to 5/8 in.). The angle of attack of the tooth against the material varies as the height of the blade is changed (see figure 399). In other words, it is possible to influence the finish of the section to some extent by varying the overhang. This is especially true of materials faced with plastic laminates or veneers. The optimum height of the blade must be established by trial and error in each case. Generally speaking, the greater the overhang the worse will be the breakthrough at the underside of the material, while the top face will be better. Reduced overhang, on the other hand, results in breakthrough on the top side but a fault-free underside. The former situation gives a shorter cutting path through the material, meaning less feed force and, in theory, reduced edge wear. The latter case, however, results in smoother blade running and therefore a better finish in the cut.

Figure 399. Variation of the angle of attack of the tooth against the material



Angles

The clearance angle is kept between 10° and 12° (figure 400). Thorough studies have shown that increasing the angle above this range will not lead to reduced cutting forces but may well weaken the edge. The tooth-point angle should not be less than 45°, for the sake of strength.

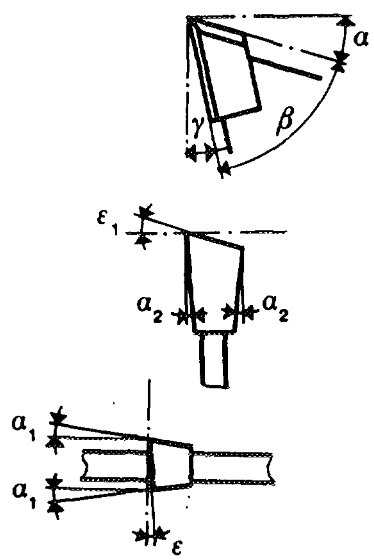
The hook is determined by the specific cutting properties, workability and hardness of the work. Normal values lie between 0° and 30°, the largest angles being employed for ripping softwoods and the smallest for cross-cutting and for trimming.

In ripping, the wood tends to separate ahead of the saw, which reduces the cutting forces. It is therefore possible to increase the hook without any risk of overloading the edge. Increased hook results in lower feed forces.

The tangential clearance angle is normally between 3° and 4°. The radial clearance angle is kept between 1.5° and 2°. If the blade tends to pick up deposits, however, this angle should be increased to 3°.

Front bevel is used on ordinary carbon steel blades with tooth shapes D and F, this being about 15° (see figure 397). On carbide-tipped blades front bevel is employed for mitre cutting and also for plywood and veneered boards where a clean cut is required. In these cases the angle is never greater than 5° in order not to weaken the edge. Back bevel is currently featured on most carbide-tipped blades. Compared with a blade having straight teeth, a blade with back bevel requires less power and less feed force. The angle is between 5° and 15°.

Figure 400. Accepted angle designations for carbide-tipped circular saw blades in Sweden



Key: α Clearance angle
β Tooth-point angle
γ Chip angle
α_1 Tangential clearance angle
α_2 Radial clearance angle
ε Front bevel angle
ε_1 Back bevel angle

As a rule, alternate teeth have left- and right-hand bevels; this applies to both front and back bevels. This practice results in smoother blade running than if all teeth were bevelled alike, although this would be desirable in some cases for the sake of a good finish in the cut.

Dimensions

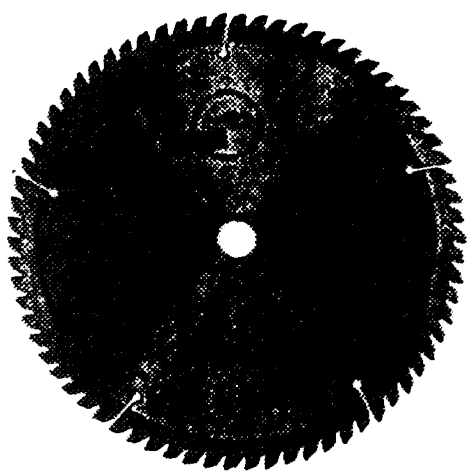
Swedish standards (SIS) governing the dimensions of circular saw blades with carbide tips have been established. Swedish standard 2370 contains a dimension schedule comprising diameter series, three tooth-width series and tooth-number series for pitches of 75, 49, 30, 19, 14 and 10 mm. Swedish standard 2371 sets forth data for cross-cutting circular saw blades and Swedish standard 2372 for ripping saw blades.

The thickness of the blade itself has not been standardized. Normally it is about 1 mm (1/32 to 3/64 in.) less than the width of the cutting edge. In other words, the blade has a clearance of about 0.5 mm (0.02 in.).

Blades with extra narrow cutting edges are sometimes made with a clearance of only 0.3 mm (0.012 in.). It is therefore necessary to pay special attention to the setting of such blades and to take particular care in sawing. Blades with carbide tips are usually somewhat thicker than ordinary carbon steel blades for steady running and to provide a good brazing attachment for the carbide tip.

In order to release the stresses arising in the periphery of the blade, which result mainly from the heat generated in sawing, carbide-tipped blades feature expansion slits and pin-holes, as shown in figure 401. These slits are found on all close-pitch blades and on those used for continuous sawing.

Figure 401. Expansion slits and pin-holes of carbide-tipped saw blades



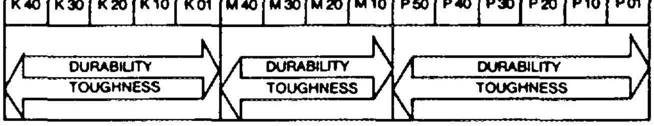
Grades of sintered carbide

Since 1959 sintered carbides have been described by ISO designations with regard to chip-forming machining operations. There are three main groups, as shown in figure 402. The arrows indicate the directions in which durability and toughness, respectively, increase. In woodworking, sintered carbides reveal the abrasive wear known as flank wear.

The grades of sintered carbide falling within group K (see figure 402) are particularly resistant to flank wear and are therefore employed in circular-saw blades. The grade used depends on the design of the blade itself and the material to be worked. It is important that the sintered carbide be sufficiently tough to resist breaking down the edge during sawing. Toughness and strength are mainly related to the kind of carbide, the cobalt content and the grain structure. Thus an increase in the cobalt content and a coarser grain structure result in greater toughness but less durability.

Figure 402. ISO grades of sintered carbide

K 40	K 30	K 20	K 10	K 01	M 40	M 30	M 20	M 10	P 50	P 40	P 30	P 20	P 10	P 01



Summary

The use of carbide-tipped blades is increasing steadily. The introduction of more stable machines, specially designed with the use of carbide-tipped blades in mind, and a better understanding of the use and care of carbide-tipped blades have resulted in inceasingly improved economy. New patterns and new grades of sintered carbide, suitably composed for various sawing conditions, will increase still further the potentialities of the carbide-tipped blades. It is desirable that the standards governing dimensions be observed and applied as far as possible.

Band-saw blades

Band-saw blades are normally toothed on one side only. The distance between tooth points (pitch) varies depending upon blade dimension and use. The size and type of material to be cut also affects the tooth pitch. Band-saw blades are exclusively used for ripping. Wider dimensions are used at sawmills and narrower dimensions at furniture and joinery plants.

Generally speaking, saw blades up to 70-mm wide are considered narrow, and those wider than 70 mm are considered wide. Band-saw blades for cutting logs are usually more than 150 mm in width.

The band-saw machine normally operates in a vertical position, but horizontal machines are gaining ground, especially in smaller sawmills. The machine consists of two wheels, held together by a rigid body, around which a toothed metal band, the saw blade, passes. The bottom wheel is driven by a motor and the top wheel by the saw blade, which acts as a transmission belt. In a vertical machine the band-saw blade always cuts in a downward direction, and all teeth work.

The purpose of tensioning, that is, the elongation of the middle of the blade by roller, is to make the blade fit the band wheels properly over its entire width during sawing, with normal friction and heating and with suitable strain in the machine. It is very important that the toothed edge be sufficiently stretched during sawing; otherwise the blade will not cut straight. The stretching of the blade is done by pushing the upper wheel upwards. This stretching should not be confused with the tensioning of the saw-blade centre.

Band-saw blades are normally purchased in coils, or cut to size, or with the ends joined, preferably by welding although it is done by brazing in some sawmills. A log carriage is used for log-breakdown saws but other forms of log feeding are usual, for example a table-feed machine with saw guides above and below the workpiece. The upper one can be moved vertically and adjusted as close to the workpiece as possible, which ensures a straighter cut.

The rims of the band wheels are convex to prevent the blade from wandering back and forth, provided the blade is correctly tensioned. Large machines with wide blades, for instance in the United States of America, have flat wheels, since the large surface contact is considered to give sufficient contact support without any extra measures.

Band sawing gives the smallest possible sawdust losses, and the sorting of logs according to diameters is not necessary. Band saws of various types are considered as the most economical machines for log breakdown and resawing. This is because of the thinness of the blade and because logs can be sawn according to dimensions and quality without waste of time in handling. Band sawing is becoming more and more popular all over the world.

The servicing of band-saw blades is more complicated than that of other machine-driven blades. The necessity of using good maintenance machines is more noticeable in band-saw mills than in other wood industries.

Machine knives

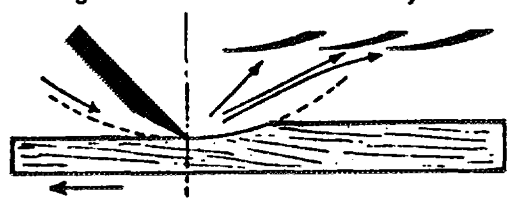
Most machine knives perform either reciprocating or rotary motions on discs, drums, shafts and the like; other knives remain stationary in the machine and the stock (workpiece) performs the necessary reciprocating or rotary motion. There are also single knives and knives that shear in conjunction with one another.

Machine knives can be classified by their cutting action as follows: rotating units, such as revolving cutters and chipper knives, and stationary units, such as veneer knives and surface scrapers.

Rotary cutters

In its simplest form, the individual rotary-cutter knife cuts principally along its face (cutting edge). Its function is to remove the surface, flat or curved, rather than to reduce the larger board into smaller units, which is the function of the saw. The action of such a device is shown in figure 403.

Figure 403. Action of a rotary cutter

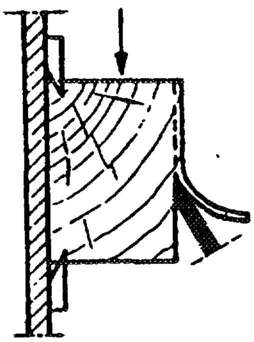


Stationary knives

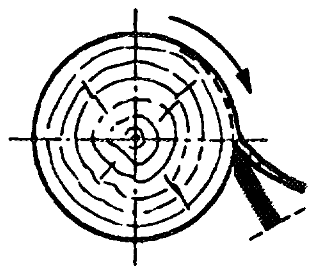
In many instances the knives for cutting wood are relatively stationary. The wood either revolves against the knife, as in a veneer lathe, or reciprocates across it, as in a veneer slicer. Another example is the suface scraper, where the wood is fed across a rigid knife, with a slightly turned edge to remove a thin (about 0.15 mm - 0.006 in.) shaving. Some examples are shown in figure 404.

Figure 404. Cutting veneers with stationary knives

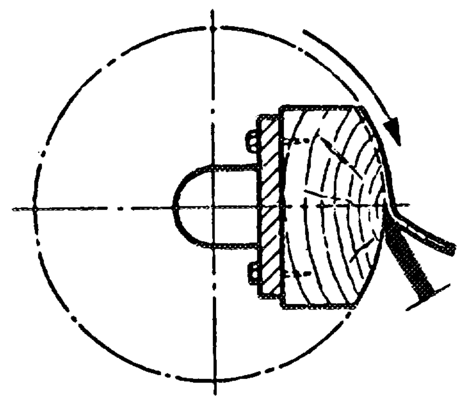
A. Slicing veneer from a flitch



B. Rotary cutting of veneer from a log or bolt



C Half-round cutting of veneer from a flitch with a lathe



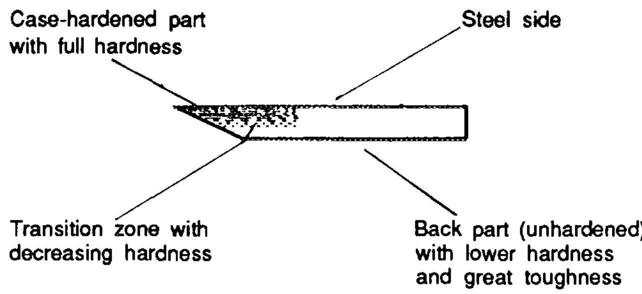
Chipper knives

Chipper knives are of two kinds: compound and case-hardened (figure 405). Some companies use the case-hardening technique for chipper knives. The raw material (steel) has a low carbon content (around 0.10 per cent) and consequently cannot be hardened. The carbon content in that part of the knife that is to be hardened is increased to a suitable percentage by a carburization process that penetrates to the required depth. During subsequent hardening, only the carburized section becomes fully hardened. The toughness of the low-carbon steel is retained in the body of the knife. The transition from hard to soft material is progressive, with no sharply defined limits that could raise stress under certain conditions.

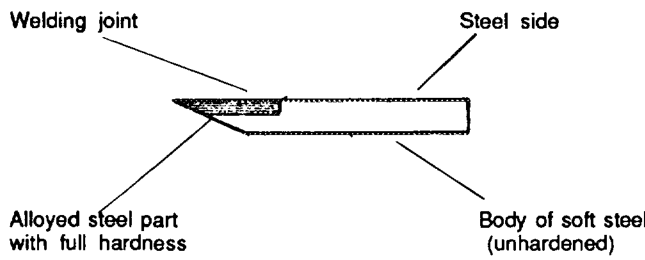
High-chromium steel is recommended for chipper knives because modern chippers operate at very high speeds and capacities, and the knife-edge temperature can rise to 450°C. For these machines it is therefore necessary to have knife material with a high annealing temperature. Thin knives are all hardened, but the thicker ones are high-frequency hardened. The hardness configuration is practically identical to that obtained with case-hardening.

Figure 405. Chipper knives

A. Case-hardened



B. Compound



Hog knives

Hog machines are used primarily for reducing waste-wood and bark into pieces of small size suitable for boiler fuel and are employed for this purpose by nearly all veneer mills and many other woodworking plants. Also, hog machines for converting bark to fuel are used by many sawmills that have a debarker and a steam plant and by a number of pulp mills. Other applications include the processing of pitch-pine stumps for the production of turpentine, chipping oak for tanning in extract plants and the preparation of fertilizing material for potting plants. Machines now in use include a large variety of models from 20 or more manufacturers. Between 10 and 36 knives are normally required for a set. Other machines of this general type, known as "hammer hogs" and "pulverizers", do not use knives.

Since there is hardly any quality requirement for the product from most hog-machine applications and plant procedures on handling waste frequently permit metallic and other foreign materials to go through the hog, the knives regularly receive much more abuse and careless maintenance than knives of other kinds. Thus, it is a common belief that the cheapest knives obtainable are probably adequate for the purpose and most economical in the long run.

This theory is valid only within certain limits. It is self evident that knives that stay in use longer before regrinding become essential and that have equal or superior resistance to damage from loose metal must offer worth-while extra value in reducing knife consumption and maintenance costs.

Some hog knives are made of very low-alloy steel with carbon content to permit hardness in the range of about 47 to 54 HRC. Cheap grades of ordinary commercial steel are used to permit the lowest possible prices in order to satisfy the prevailing wishes of buyers. Since the knives are fully hardened by conventional methods and properties of the low-grade steel can provide only moderate toughness, the hardness must be kept relatively low to avoid excessive breakage during use.

Veneer knives

Over the years, the Swedish company Sandviken has manufactured a case-hardened veneer knife. The knife is zone-hardened, which means that only a part of the knife (the cutting edge) has full hardness (59 to 60 HRC). The performance of this knife has proved to be very satisfactory with both softwood and hardwood.

Some years ago the company introduced a veneer knife of a new quality. It is a low-alloy steel knife, high-frequency hardened. Its construction is identical to that of the old case-hardened, zone-hardened type. Its edge hardness is 59 to 61 HRC. The edge-holding ability of this knife is very good; it stays sharp very long. In case of minor edge damages caused by stones, nails, hard knots and the like the edge can easily be restored in the lathe. In case of a bend, the edge can be straightened by using a hammer and then touched up by honing; if there is a nick, it can be corrected by filing and honing.

Pressure bars

Pressure bars are used on both veneer lathes and veneer slicers. On the former, there is either a roller bar or a solid pressure bar. The most usual type of pressure bar is manufactured with a Stellite edge, which gives it good edge-holding and wear properties. However, maintenance of this bar is expensive if it is damaged by a foreign item such as a steel nail. Often, the bar must be sent to a special shop for repair.

When certain species of wood, particularly oak, are peeled or sliced, staining is a problem, as all stained veneer is waste. To avoid such staining, the bar, together with the bar holder, must be removed quite frequently and cleaned. Attempts have been made to solve the problem by painting the bar, but with no great success. However, if the pressure bar is made from high-chromium steel, the staining problem seems to be solved. Furthermore, the customers are able to maintain the bar themselves, and in certain cases the edge-holding and wear properties are just about the same as in a Stellite bar.

Sharpening machine knives[1]

Careful sharpening of dulled knives results in improved cutting properties, longer life and a corresponding reduction of costs. Not infrequently, however, the sharpness of a reground knife is inferior to that of a new one and of shorter duration. In many cases, the reason for this is to be found in faulty regrinding, which has often given rise to unjustified complaints and may be prejudicial to the goodwill between a manufacturer and customer.

Knives should therefore be changed and reground before the cutting edge has become too blunt. If this precaution is taken, it is necessary to remove very little material when regrinding, which saves both time and costs for this operation and lengthens the life of the knife. A correctly ground cutting edge should be clean and straight along its whole length and free from burrs, burnt spots and grinding cracks.

The quality attained when sharpening machine knives is dependent on the following main factors: the grinding machine, the grinding wheel, the grinding method and the grinding performance. These factors are considered separately below.

The grinding machine

In most cases the machines used for grinding straight machine knives are surface grinders with horizontal spindles and reciprocating tables, fitted with cup- or cylinder-type grinding wheels. Small machine knives are frequently ground on surface grinders with vertical spindles and cup wheels.

In general, the machine knife is fixed by a magnetic chuck or by clamping it to the reciprocating table of the grinder, which moves reciprocally in front of the stationary spindle that carries the rotating grinding wheel. The quality of the grinding machine is of the greatest importance for the results obtained in grinding. It must not vibrate and be in good condition to ensure a uniform bevel and a clean, sharp cutting edge. In machines that are less rigid, particularly where no coolant is employed, grinding must be done with the greatest care.

The grinding wheel

It is extremely important to select a wheel of the proper grade and grain size for the job in hand.

Grade (hardness). The degree of hardness calls for special attention. A wheel that is too soft does not retain its size, particularly at the roughing stage; owing to its quick loss of shape its life is also shortened. On the other hand, a wheel that is very hard gives unsatisfactory working results. Such a wheel rapidly becomes glazed and dull and requires repeated dressing. A glazed and dull wheel tends to burn and ruin the knife. The grade of the wheel should be selected in accordance with the composition and hardness of the knife. The type and condition of the grinder, the shape and speed of the wheel as well as the cooling are also very important. It is preferable to try out a wheel that is soft, and then proceed gradually to a harder and more economical wheel.

Grain. Wheels with finer grains have come more and more into use for machine knives. In certain instances a No. 60 up to a No. 80 grit is employed, being correspondingly softer than coarser grits. The finer grains, being

[1]For more detailed information on the sharpening and maintenance of woodworking tools, see chapters XXXII and XXXIII.

smaller and sharper, penetrate the hard surface of the knife more readily than the coarser grains. A finer grit wheel therefore cuts with less pressure and less risk of burning and in addition produces a better surface.

The general rules applying to the selection of hardness and grain size are:

(a) Hard wheels: wheels of harder composition are used for soft material, small contact surfaces, greater depths of cut and with grinders that are not completely rigid;

(b) Soft wheels: wheels of looser composition are selected for hard material, larger contact surfaces, smaller cuts and very stable machines;

(c) Roughing and finishing: for roughing, large-grain wheels are used; wheels with a small grain should be employed for finishing;

(d) Standardized symbols: the system of symbols used for grinding wheels is internationally standardized; a grinding wheel designation contains all the data relating to the quality of the wheel;

(e) Wheels for machine knives: for grinding machine knives of tool steel, high-chrome alloyed steel or high-speed steel, Alundum vitrified wheels are generally used. As a rule only a vitrified bonding agent is used in wheels for knife grinding.

The grain sizes, grades and structure of wheels for grinding machine knives are presented in table 24.

Table 24. Optimal characteristics of grinding wheels for machine knives

Type of knife	*Grain size*	*Hard-ness*	*Struc-ture*	*Wheel shape*	*Peripheral speed* (m/s)	(ft/s)
Veneer knives	46	H	8	Cup	18-23	59-75
Chipper knives	46	H	8	Cup	18-23	59-75
Planer knives (high-speed steel)	60	J	8	Cup	20-25	66-82

The combinations presented in table 24 apply only to stable and vibrationless grinders; for machines that are less rigid, wheels with one or two more degrees of hardness should be selected. Similarly, lower peripheral speed necessitates harder wheels, and higher speeds need softer wheels than those recommended.

Segmental wheels. When a segmental wheel can be used in place of a solid one (particularly of larger sizes), this should be done, since the air circulating around the segments during rotation contributes to more rapid and cooler grinding. In addition, the removal of chips is more effective and the working capacity greater than with a solid wheel.

Truing and dressing the wheel. If the grinding wheel exhibits a tendency to burn, it must be dressed immediately. A newly mounted wheel must always be trued in order to get the grinding surface running evenly. The wheel must also be dressed from time to time to keep the cutting face clean, sharp and free-cutting, thereby minimizing the danger of burning the edge of the knife.

A special dresser for sharpening by hand, which is supported against the table and clamping plate, is recommended both for truing and dressing. A diamond tool may also be used but not an abrasive stone (such as a piece of grinding wheel) since it is difficult to hold it sufficiently steady. Furthermore, an abrasive stone is likely to produce a glazed surface on the wheel face instead of cleaning it and rendering it sharp and free-cutting.

The grinding procedure

Partially hardened knives. The grinding of selectively hardened machine knives (such as high-frequency hardened ones or compound steel) must be regarded as a very delicate job, since the grinding wheel must work on soft and hard material simultaneously. The soft material easily tends to stick to the wheel, which is then likely to become glazed and to burn the material.

Firm holding of the knife. The machine knife must be held firmly by a magnetic chuck or clamped to the table; it must never be held by hand. It is very important that the contact surfaces be free from projecting burrs, dirt or the like. The chuck should be rotatable to enable different angles of the cutting edge to be obtained according to the type of knife. When no suitable clamping device is available, the knife should be placed on an adjustable table with a stop against the rear edge of the knife.

Direction of rotation of the wheel. Machine knives should always be ground towards the cutting edge. By grinding towards the edge, the wheel retains its sharpness and the danger of over-heating the edge is reduced. If grinding is done in the opposite direction, the wheel draws the softer material of the bevel towards the cutting edge, causing the wheel to become glazed and lose its sharpness. Grinding is, however, sometimes carried out against the periphery of a cylindrical wheel. A hollow-ground bevel can be obtained by this method, which may be an advantage in certain cases. It is advisable not to employ a wheel with too small a diameter, since this will produce too deep a hollow and thus weaken the edge. Before grinding is begun, the coolant should be turned on; the wheel may then be set in rotation and a small feed is maintained.

Grinding finish. Grinding is finished with a die-out cut, that is, the wheel should be allowed to cut without any further feed until sparking ceases. In this way a bevel with a smoother surface is obtained and honing is simplified.

Grinding speed. The speed prescribed for each wheel should be carefully observed, since the maximum cut is obtained at this speed. If the speed is too low, the wear on the wheel is excessive, but, on the other hand, a speed that is too high produces such a heavy grinding effect that the cutting edge is burned and ruined. As mentioned earlier, however, an incorrect peripheral speed can be counteracted by selecting a suitable wheel hardness.

Maximum speed. It should be noted that, for safety's sake, the maximum speed given for every grinding wheel should not be exceeded. In general, the speed of the feeding table should be 18 to 24 m/min (about 60 to 80 ft/min).

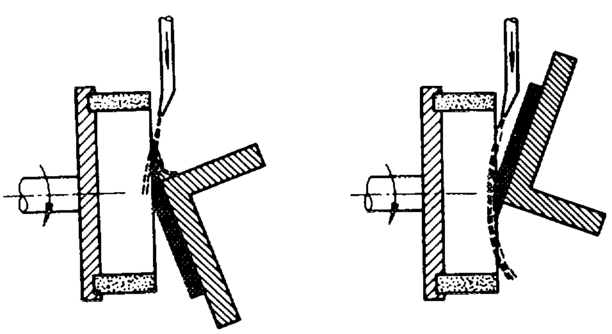
Feed. The feed must be small and should not exceed 0.05 mm/stroke (0.002 in./stroke); this also applies to roughing. If the feed and speed of the table are too great, the knives may easily be ruined. The best results are obtained by taking a light cut with a moderately rapid table feed.

Detrimental heating of the knife. Heating at the point of contact between the grinding wheel and knife may have a detrimental effect on the properties of the steel. If the original tempering temperature for the knife is exceeded, the steel will be annealed, with a consequent loss of hardness. If the temperature rises high enough, the cutting edge will become brittle and be ruined. An infallible indication of detrimental heating of the knife is the appearance of the tempering colours. As long as no colours are visible, the steel has not been converted. Tempering begins with a straw (yellow) colour at 250° to 300°C (480° to 570°F) and increases over blue at 300° to 350°C (570° to 600°F) to blue-grey and grey at 350° to 400°C (660° to 750°F). At the last of these temperatures the cutting edge is ruined, so that the damaged part must be entirely ground off.

Cooling (wet) grinding. Machine knives of any kind should preferably be ground wet. The flow of coolant should be directed at the point of contact between the wheel and the knife or close above in order to prevent burning the knife. A certain cleaning of the wheel is obtained at the same time (figure 406). The tank for the circulation coolant in a cooling system should be large enough to allow a minimum circulation time of 10 minutes, which calls for a capacity of 200 litres (44 gallons). The use of a filter in the cooling system is a great advantage because it prevents steel chips and fragments broken off the wheel from reaching the grinding point, where impurities of this kind may cause damage in the form of scratches on the bevel or edge of the knife.

Figure 406. Clamping and coolant feeding when sharpening machine knives

A. Correct **B. Incorrect**



Too little or intermittent cooling is worse than none at all. To direct the coolant against the knife when it becomes hot is a sure means of damaging or even entirely ruining the knife.

Coolant. Clear water may be employed as coolant, in which case plenty of it must be used, i.e. about 20 litres per minute (4 1/2 gallons) at least.

Rust-preventing coolant. The coolant must not cause rusting of the knife or the machine. When using water a rust-preventing agent should be added. This may be sodium carbonate, in a proportion of 4 kg sodium carbonate to 100 litres of water (or 4 lb per 10 gallons). A large number of oil emulsions also available on the market are very suitable as coolants, since they generally possess the excellent property of facilitating the production of a perfect surface.

Honing. After grinding has been completed, the cutting edge must be honed before the knife is ready for use. Not even the best grinding wheels are capable of producing a ground surface smooth enough for an entirely satisfactory knife edge. Scratches are always formed, resulting in a rough and uneven cutting edge that will soon become dull owing to the fact that the tops between the scratches on the edge are rapidly worn down. In order to obtain a satisfactory cutting edge that will retain its sharpness over a long period and permit the knife to work accurately, the wire or feather edge invariably left on the steel side by the grinding wheel must be honed away completely. Thorough honing has a direct influence on the life of the knife, the quality of its cut and on its operating economy.

The following rules may serve as a guide for honing the edges of machine knives:

(a) The knife should be supported in a vice or on a bench at a convenient height and with sufficient light on the edge;

(b) The oilstone must be perfectly even and should be applied against the bevel with a light pressure over the whole bevel and steel side to prevent the formation of a rounded edge (see figure 407);

(c) Honing of the steel side of the knife should be stopped as soon as the wire edge has disappeared or been straightened;

(d) Honing should not be forced and should be carried out with a sort of rotary motion along the bevel. It can best be carried out by first rough honing the edge with a coarse oilstone. A thin machine oil should be used on the stone and the pressure should be reduced gradually;

(e) Honing should be continued in the same way with a finer oilstone;

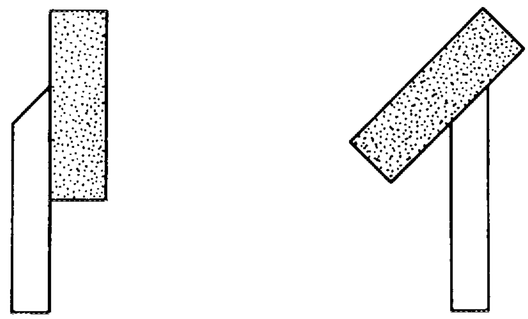
(f) Honing should be finished with a fine-grain hard oilstone on both sides of the cutting edge. For this purpose the stone should be tipped up slightly about 2 mm (or 1/16 in.) from the heel of the bevel;

(g) The edge should be examined with a magnifying glass (10-power, for instance) to ensure that it is free from all burrs and nicks.

One way of telling if a knife has been honed properly is to draw a piece of writing paper along the edge. It will cut the paper easily, but any uneven spots will cause slight but clearly perceptible vibrations of the paper. Such spots must be marked for further honing. After honing, the knife should be carefully wiped clean and dry.

Figure 407. Correct application of the oilstone on the hardened side and on the bevel of a machine knife

A. Hardened side **B. Bevel**



Inserted-tooth cutter

The inserted-tooth cutter is a relatively new tool intended for planing and milling. Its design is based on earlier designs used in the wood industry, but it incorporates the metal industry's advanced technique for mechanically clamped indexable inserts.

This tool is constructed on the changeable-insert principle so that the insert may be discarded instead of being reground after becoming worn. (See figure 408.) The miller body (cutter-head) is 25-mm thick (1) and is available in the five following standard forms:

Outside diameter (mm)	*Centre hole (mm)*	*Number of inserts*
100	40	3
120	60	4
140	60	4
160	60	4
180	60	6

The cutter can be used in all types of multi-cutting, table-milling (spindle moulder) and tenon-cutting machines. In the first of these, several millers can be joined to form a wide cutter (2), while in the latter two, the cutter can be used either as a single-tool or a multi-tool unit (1 and 2).

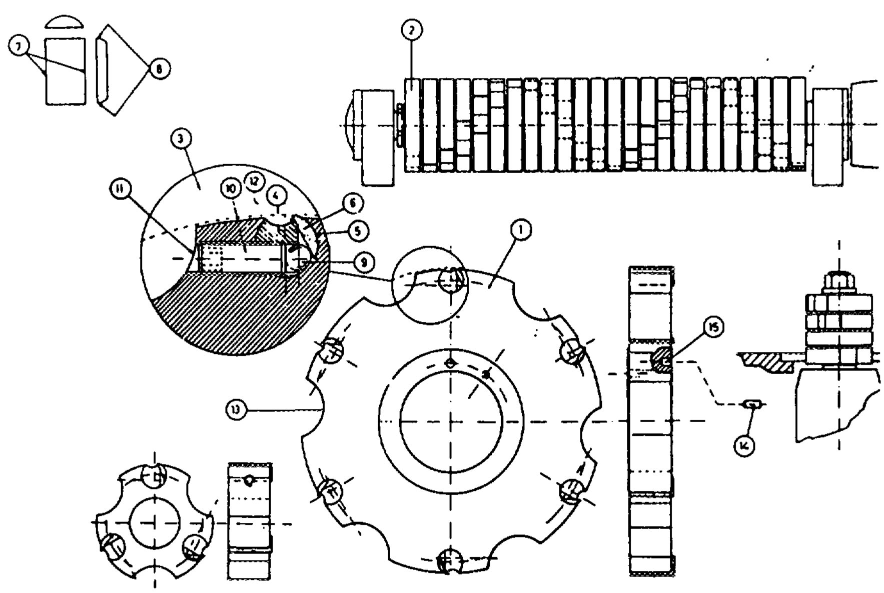
The purpose of the clamping system (3) is to locate and firmly hold the inserts; it consists of a flat bearing surface (4) and a cylindrical seat (5). The shape of the insert is a semicircle (6) with cutting edges 26 mm long (7). Each insert thus has two cutting edges. The ends of the inserts (8) can also be used for cutting purposes in rabbeting and grooving applications.

The inserts are clamped by a steel ball (9) and a screw (10) at right angles to the insert. The ball thrusts the insert against the seating and clamps it there firmly. The chip-breaker (12) in front of the insert breaks up and guides the chips away from the cutting zone.

The recesses (13) in the circumference of the miller body facilitate the adjustment or change of inserts when the tool is used as a multi-unit cutter (2). In order that the inserts of a multi-tool unit may be changed, an aperture is provided on the body lying alongside to permit access to the clamping system. Precise location is ensured by a pin and hole in each miller body. One advantage of this mounting system is that the inserts take a spiral form, which can be very useful from many points of view. In order to prevent the occurrence of lengthwise ridges in the material when utilizing a multi-tool layout (2), the inserts have been made 1 mm longer than the milling cutter's breadth. This creates the overlapping necessary to overcome this problem.

The steel used for the miller body is SIS 1672, apart from the component that forms the chip-breaker; to reduce the wear which chip removal creates, steel quality SIS 2140 is utilized for this latter component. By this means it is possible to supply the miller body without the necessity of special hardening processes.

Figure 408. Construction of the inserted-tooth cutter



Annex VI

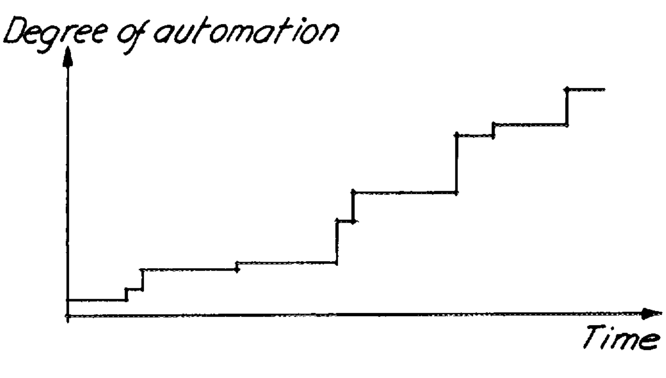
LOW-COST AUTOMATION SYSTEMS*

What is automation?

Automation is frequently associated with robots and computer programs, giving the impression that automation is a complicated and expensive process in which the machine performs human tasks. This results in prejudices on the part of entrepreneurs: it is too expensive; the production capacity is too small; the labour force is sufficient without it; automation causes unemployment; the workforce is not specialized enough; workers do not know how to operate automated machines; the market is small; there is no justification for automated production etc.

These are all assumptions. Therefore, it should be emphasized that automation does not mean a revolution in production; it means evolution. The degree of automation depends on the number of automated production functions. It can range from 0 to 100 per cent. Thus automation means production development that can proceed step by step according to the company's resources and current needs (figure 244).

Figure 244. Step-by-step implementation of automation



Why automate?

Automation is interesting in itself, but in industrial production, technology and automation are not goals as such; the company has to be able to benefit from automation.

The human factor

The main reason for automation is the human factor. This means developing production in such a way that the work is as pleasant as possible. This goal can be reached by removing monotony, danger, high speeds etc. All of these factors cause stress and make the work unpleasant. The work has to motivate the worker, be pleasant and be inspiring.

Safety

All work involves some degree of danger, but the machining phases in the furniture and joinery industries are particularly dangerous because the blades and knives rotate very fast. When the worker does not have to be near the blades and knives, safety at work increases considerably. Radiant heat, dust, humidity and noise also can be hazardous to the worker, and prolonged exposure can cause injury. Automation aims at distancing the worker from these hazards.

Accuracy

A human being can never work as accurately as a machine. Particularly when a difficult task has to be performed at a high speed, workers become tired, their senses dull and their muscles tend to slacken. This results in errors in measurement, shapes and surface quality. A machine can operate without tiring, and the accuracy of the work performed by machine is usually better and remains constant throughout the production process; therefore, the measurements, shape and quality are consistently accurate.

Capacity

The work to be done may require extremes of force, speed and efficiency, and the movements may be repetitive and monotonous. Human force is limited; it is approximately 1 kN, i.e. a human being's capacity is about 100 W. For a machine, this amount of force is quite small and there is practically no limit to repetitive actions (other than the wearing of the tool). Therefore, whenever a lot of power, speed, capacity and repetitive actions are required, only a machine can do the work.

Economic considerations

When the working speed, quality and accuracy increase, costs decrease. Also, since the performance of a machine is more uniform, machines last longer and knives and blades have longer lives, which also make the process more economical. In addition, the need for supervision decreases, less material is wasted and energy consumption diminishes; the result is lower production costs.

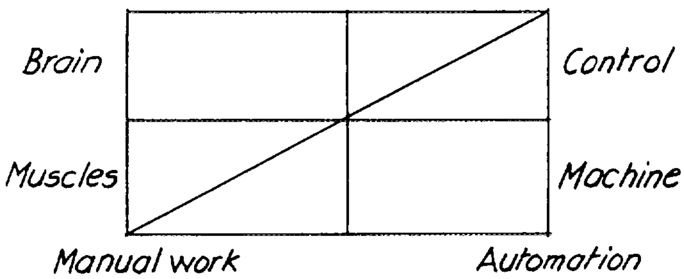
Concepts associated with productive work

Two elements in productive work can be distinguished: force and control. Force is derived from muscles or machines and control from the brain or control equipment.

*By Osmo Moilkanen, Lahti Institute of Technology, Lahti, Finland, chapter XXVII of *Furniture and joinery industries for developing countries* (UNIDO publication, Sales No. E.88.III.E.7), pp. 225-236. Original figure and table numbers have been retained.

With human labour, the muscles provide the force and the brain and the nervous system provide the control (figure 245).

Figure 245. Components of work performance



Manual work

Manual work can be defined as a task in which a person performs all of the work using muscles, and the brain controls the muscles. At the most, a worker can use small hand tools to help do the job.

Machinization

Machinization can be defined as work in which the machine does the muscle work but the actual control is done by a person. Machines can generate forces and speeds that are considerably higher than those generated by a worker. As a result, the working speed increases.

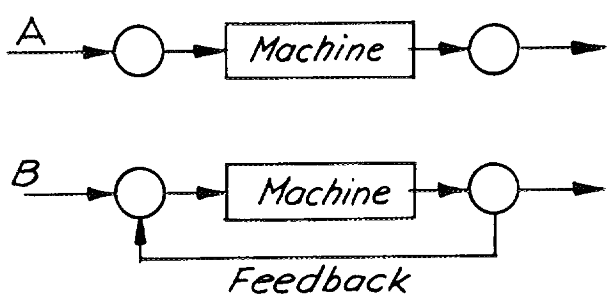
Mechanization

Mechanization means that a workpiece moves from one machine to another, or from one phase to another, mechanically; a worker does not have to perform these tasks. However, it is essential that the transfer takes place mechanically without the machine making any decisions.

Automation

In automation, the machine does both the muscle work and the brain work. The share of the brain work can vary from 0 to 100 per cent, depending on the degree of automation. Automation always includes feedback, which means that the product is measured and the result is fed back to the control system for eventual adjustment (figure 246).

Figure 246. Machining performed without (A) and with (B) feedback

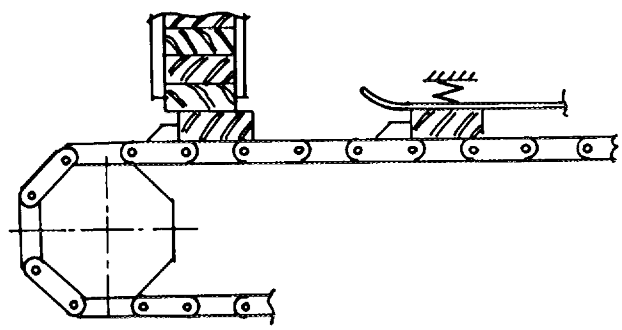


Tools of automation

Mechanical devices

Mechanical devices are the oldest tools of automation, because they are large and cumbersome and durable. However, their use has decreased to such an extent that only certain simple devices, e.g. mechanical feed systems (figure 247) are used today.

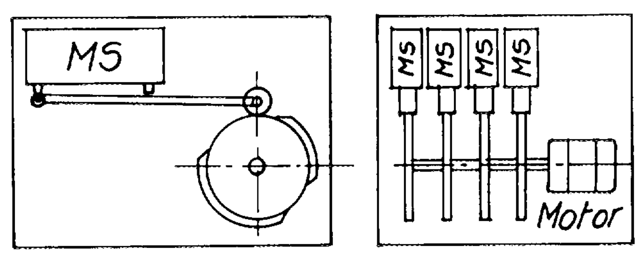
Figure 247. Mechanical component feed system



Electric and electronic devices

Electric devices have long been used in automation, and their use has continued to increase. Programming equipment can operate a device with micro-switches (see figure 248). Owing to the rapid development during the last decade, the role of electronics in automation has increased. Electronics has made it possible to design sophisticated automated control systems. A control unit using a microprocessor (MPU) with read only memory (ROM), random access memory (RAM) and connection to peripheral equipment (PIA) is illustrated in figure 249. Electronics is a complicated tool in automation, however, and it is not possible to discuss it in the context of this chapter.

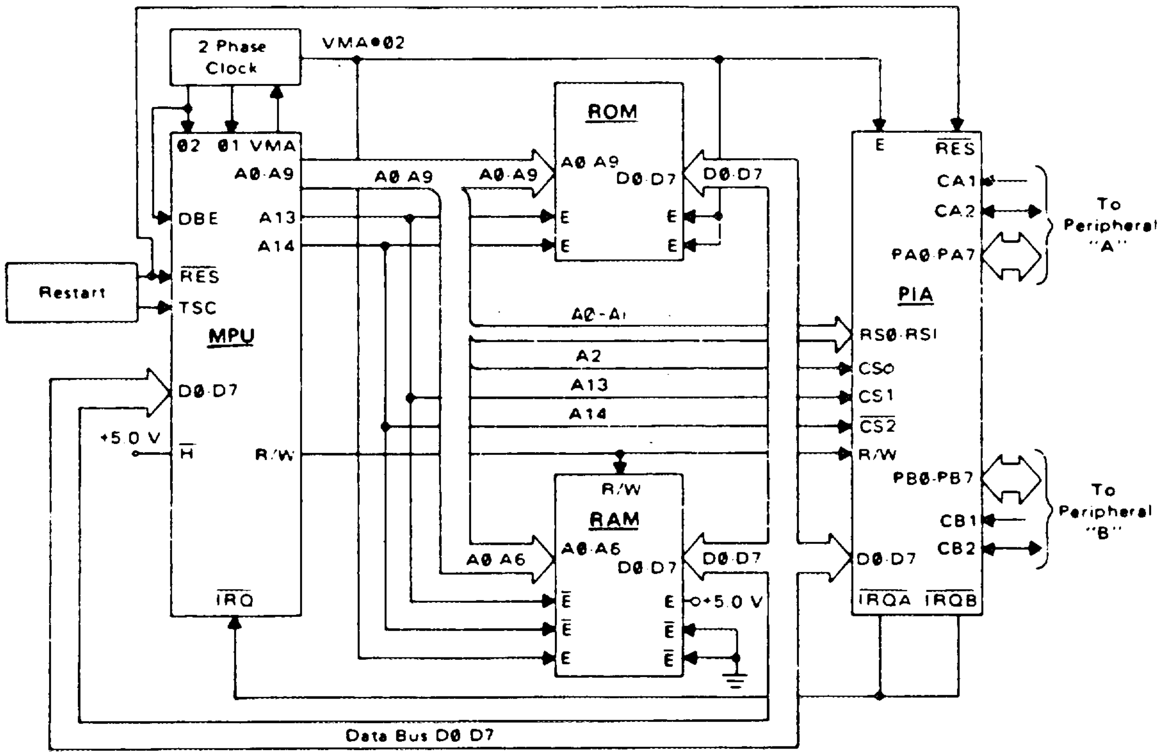
Figure 248. Micro-switch control for a programming device



Pneumatic devices

Owing to their simple construction, pneumatic devices have become popular in automation processes in which no complicated controls are required. This chapter will concentrate on pneumatic devices, which are discussed in more detail below.

Figure 249. Microprocessor control unit (MPU)



Key: ROM Read only memory
RAM Random access memory
PIA Peripheral equipment

Hydraulic devices

Hydraulic devices operate on basically the same principles as pneumatic ones; however, pneumatic devices use compressed air whereas the substance used for hydraulic devices is a fluid. Hydraulic devices operate at high pressures, and a large amount of force can be obtained with small-sized equipment. Since the fluid cannot be compressed, movements are accurate. Owing to the limited applications for hydraulic devices in furniture and joinery, they will not be discussed in detail here.

Pneumatics

Pneumatics is a technique in which compressed air is used to control and operate machines and devices, particularly in automatic operations.

Why is compressed air used?

Compressed air is used in automatic operations for a number of reasons, namely:

(a) Compressed air presents no hazard;

(b) Machines are fairly small and light in weight;

(c) Pneumatic machines are simple;

(d) Leaks do not cause problems;

(e) No return lines are necessary;

(f) Movements are soft and resilient;

(g) Rotation speed is easy to adjust;

(h) Machines can be loaded until they stop due to the resistance of the workpiece without risk of them being damaged.

Cylinders

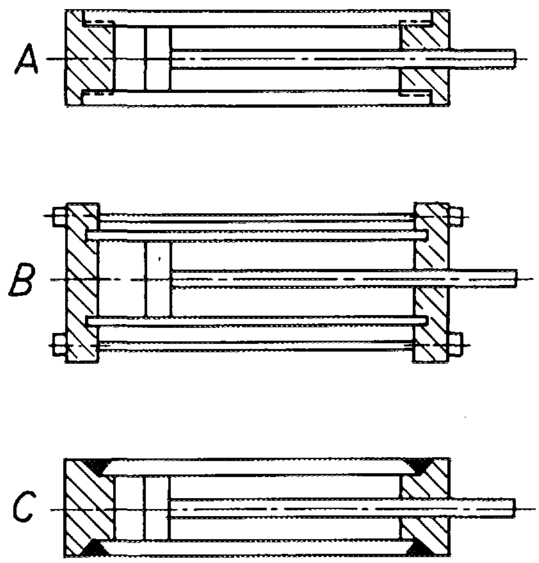
Cylinder functions

The cylinder forms the "muscles" of the pneumatic system, i.e. it performs the work requiring power.

Construction

A pneumatic cylinder can be constructed as a threaded cylinder, a bolted cylinder or a welded cylinder (figure 250). A threaded cylinder is used in small cylinders with a diameter of less than 25 mm; a bolted cylinder is used in larger cylinders. A welded cylinder is seldom used. The bolted cylinder is the most common type, its main components are the end covers, including the cushions; a barrel; a piston; and a piston rod. The end covers are usually made of light-metal alloys, the cylindrical barrel is of copper or light-metal alloys, the piston is of steel or light-metal alloys and the piston rod is always of steel. The piston rod and piston are sealed with rings of different cross-sections to prevent the leakage of compressed air.

Figure 250. Three main types of cylinders

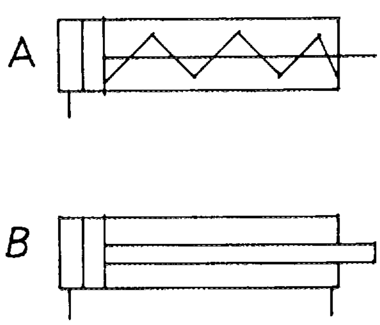


Key: A Threaded cylinder
B Bolted cylinder
C Welded cylinder

Cylinder functions

There are two kinds of cylinders: a single-acting cylinder and a double-acting cylinder (figure 251). A single-acting cylinder has pneumatic control in one direction only, and therefore it has only one opening through which the air enters and leaves. The return stroke is effected by a spring or, in lifting cylinders, by the load. Double-acting cylinders have pneumatic control alternately in opposite directions. The return stroke is also effected by compressed air. Since the double-acting cylinder is easier to control, it has become the most common cylinder; therefore the examples given in this chapter are usually for double-acting cylinders.

Figure 251. Single- and double-acting cylinders

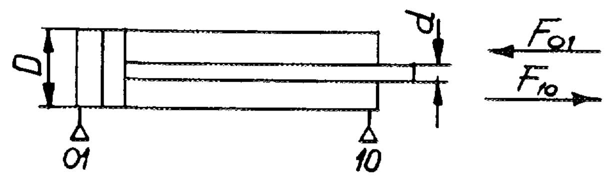


Key: A Single-acting
B Double-acting

Cylinder dimensioning

When dimensioning the cylinder, the things to consider are the cylinder friction and the fact that the piston rod reduces the piston area on one side and therefore the force obtained is not equal in both directions. The equation shown in figure 252 is used in dimensioning the cylinder.

Figure 252. Pneumatic cylinder dimensioning



$$F_{01} = 0.8 * p * 3.14 D^2/4$$

$$F_{10} = 0.8 * p * 3.14 (D^2 - d^2)/4$$

Key: p Pressure of compressed air
D Diameter of the piston
d Diameter of the piston rod
F_{01}, F_{10} } Force

The air volume used by the cylinder (V_0) can be calculated for a double-acting cylinder from the following equation:

$$V_0 = 2nAs \frac{P_1}{P_0}$$

Where: n = number of strokes
A = cylinder area
s = stroke length
P_1 = pressure of air in pipeline
P_0 = pressure of outside air (100 kPa)

Efforts have been made to establish international standards for cylinder sizes. The sizes of cylinders that are available locally should be taken into account when designing a circuit.

Cylinder installation

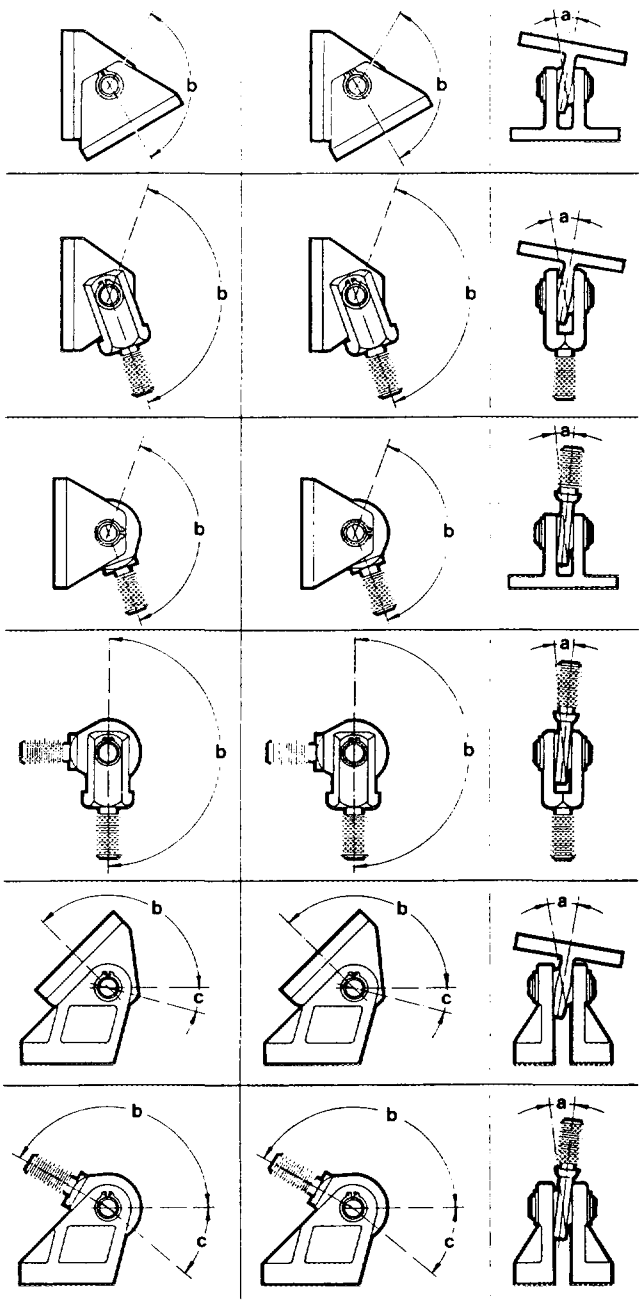
An important fact to keep in mind when installing a cylinder is that it should only receive loads in the direction of the piston rod. All other forces should be eliminated. The reason is that the piston and the piston rod move on seals, and if the piston receives forces perpendicular to the rod, they wear the seals very quickly which results in air leaks and decreased performance in cylinder operation. There are two main installation methods for cylinders:

(a) Non-articulated installation, where the forces are always in line;

(b) Articulated installation, which is used when the direction of the force varies (figure 253).

The cylinder is fixed on the frame with joints that move in the direction of two co-ordinates or are so-called ball-joints, which allow movement in three dimensions.

Figure 253. Articulated installation of pneumatic cylinder



Motion of the cylinder

The operation of the cylinder can be shown in a diagram, in which the horizontal axis is time and the vertical axis is the cylinder motion (see figures 254 and 255). This depicts both the movement and the speed of cylinder movement. The end positions of the cylinder are designated with the numbers 0 and 1. The 0 indicates the basic position of the cylinder, i.e. the position in which the piston rod is inserted in the cylinder, and number 1 indicates the position in which the piston rod is withdrawn from the cylinder. Because of the time axis, the diagram can also indicate the speed, which can be seen from the slope of the line in figure 255.

Figure 254. Pneumatic cylinder positions

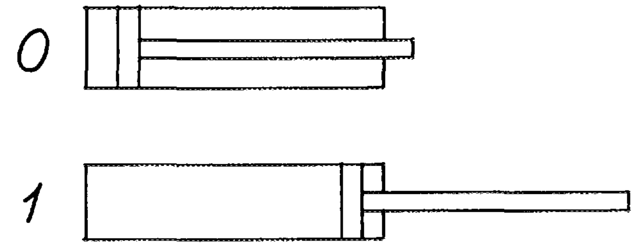
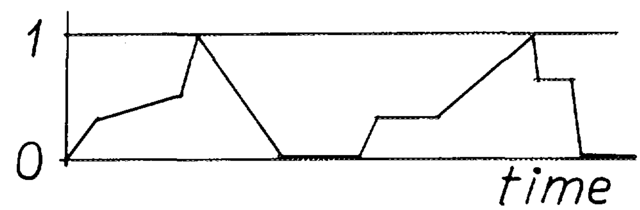


Figure 255. Motion diagram of cylinder



Special cylinders

In addition to standard cylinders, a large number of special cylinders are also manufactured. These are e.g. diaphragm cylinders, cylinders with double-ended piston rods, three-position cylinders, four-position cylinders, telescopic cylinders and cylinders with adjustable stroke length.

Applications

Some cylinder applications are shown in figure 256. Cylinders can be used in several different places wherever linear motions occur.

Valves

Valve functions

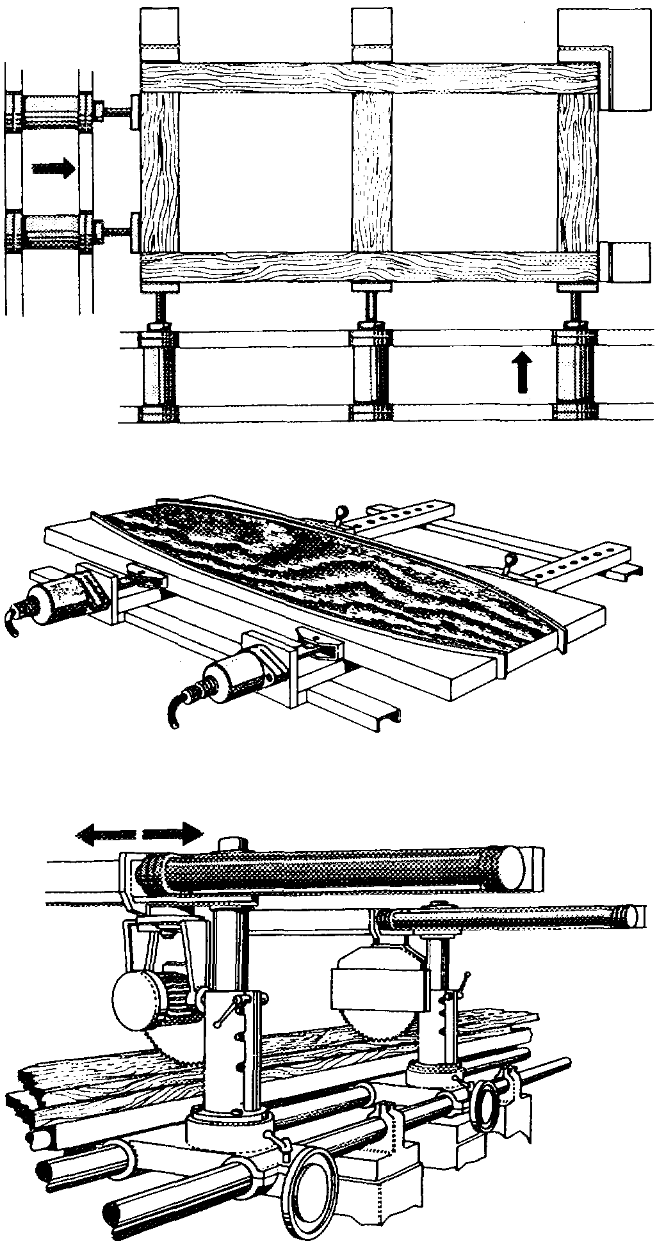
The function of valves is to guide the air so that the desired operation is performed. The valves are the brains or operators of the system. They ensure that the cylinders and motors move in the desired way.

Control valves

The symbol for a control valve is a square. The square represents one valve position. If the valve has several operating positions, the diagram has the same number of squares as there are positions in the valve. Lines inside the squares indicate open or closed flow lines. The control method is marked at the ends of the valve. A number of valve diagrams are shown in figure 257.

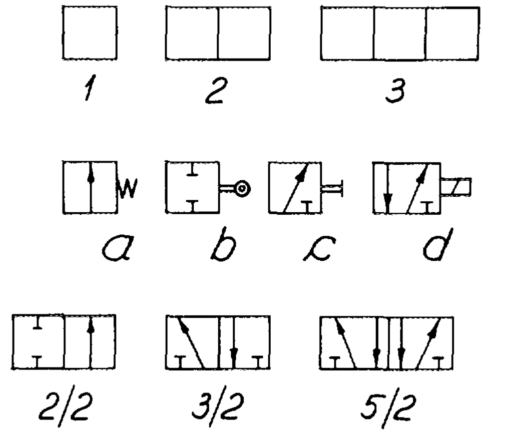
Directional control valves. The function of the directional control valves is to guide the air along different lines to other valves or operational equipment in the system (cylinders and motors). Directional control valves are designated by numbers; the first number indicates the number of connections and the second number, following a slash, indicates the number of positions, as was shown in figure 257. For example, a 2/3 directional control valve is a valve with two connections and three positions; 5/2 has five connections and two positions. The most common directional control valves used in pneumatics are shown in the diagrams in figure 258.

Figure 256. Examples of pneumatic cylinder applications



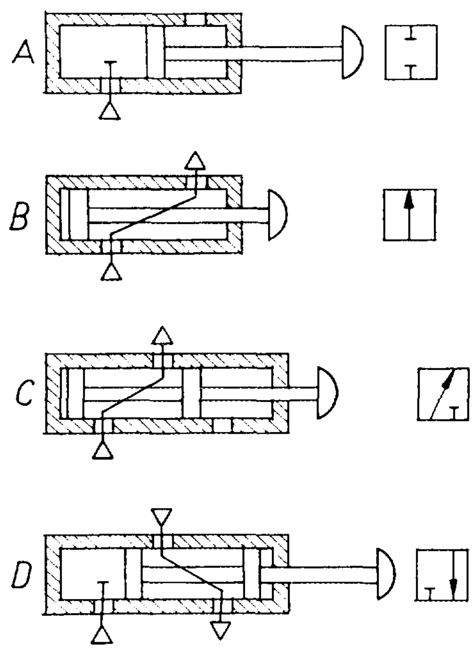
Non-return valves. Non-return valves allow a flow in one direction only (figure 259). A shuttle valve has two inlet ports, which join at the starting connection.

Figure 257. Control-valve diagrams



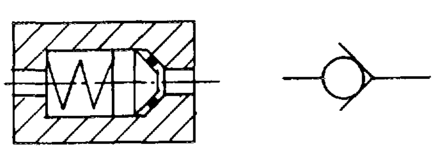
Key:
1 One position
2 Two positions
3 Three positions
a, b, c and d Different flow-paths
2/2 Control valve with 2 ports and 2 positions
3/2 Control valve with 3 ports and 2 positions
5/2 Control valve with 5 ports and 2 positions

Figure 258. Control-valve construction principles



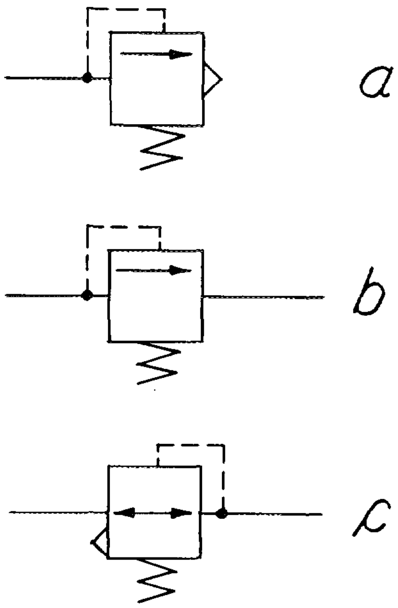
Key:
A 2/2 valve closed
B 2/2 valve open
C 3/2 valve allows compressed air flow through
D 3/2 valve allows exhaust air flow through

Figure 259. Construction of and symbol for a non-return valve



Pressure-control valves. Pressure-control valves regulate the pressure (figure 260). The pressure-relief valve is a so-called safety valve, which opens when the inlet pressure exceeds a pre-set valve. The pressure-control valve opens when the inlet pressure overcomes the opposing force of the spring force, and its purpose is to regulate the pressure for some subsequent operation. The pressure-reducing valve with variable inlet pressure gives substantially constant outlet pressure.

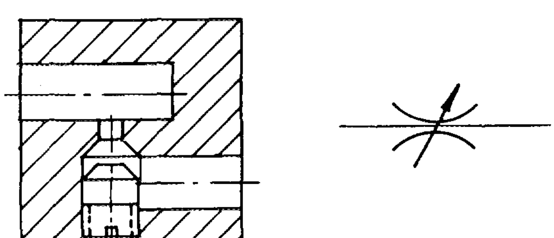
Figure 260. Different pneumatic valves



Key: a Pressure-relief valve
b Sequence valve
c Pressure-reducing valve

Flow-control valves. Flow-control valves are designed to control the volume of air flow. The simplest flow-control valve is a restrictor valve in which the air volume is regulated with a screw (figure 261). If a non-return valve is connected in parallel with the restrictor valve, the flow in the opposite direction becomes unrestricted, the speed of the operation increases and the flow is controlled in one direction only. Other types of flow-control valves are rarely used in pneumatics, while several different types are used in hydraulics, where the control of fluid is much more accurate than that of air.

Figure 261. Construction of and symbol for a flow-control valve



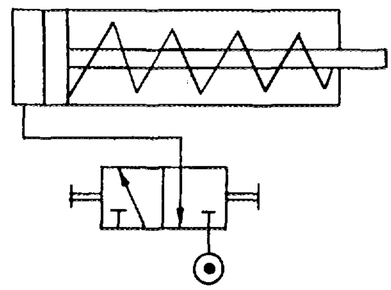
Installation diagrams

The operation of valves and cylinders is usually depicted in installation diagrams using the symbols mentioned above. The figures below present installation diagrams and the operations in detail.

Control of a single-acting cylinder

The control of a single-acting cylinder is shown in figure 262. There is only one incoming flow path, and the cylinder is controlled by a 3/2 valve.

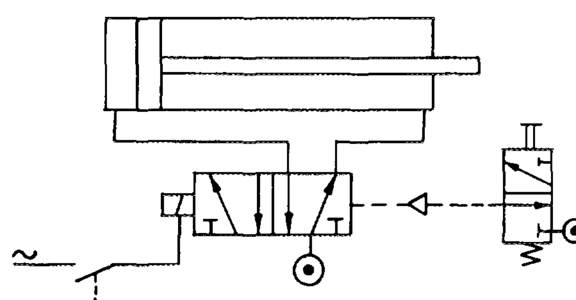
Figure 262. Manual control of a single-acting cylinder



Control of a double-acting cylinder

The cylinder is controlled either with direct control, which means that the main valve is operated directly, or through remote control, which means that the main valve receives its control from a remote-control point by means of air or electricity. Air is usually recommended, although electricity provides greater control speed, and the control line is smaller and lighter. Therefore, if the distance is long, electricity is more convenient. Electricity is suitable when pneumatics forms part of another system using electricity. The control of a double-acting cylinder is shown in figure 263. The diagram in the figure is only an example; each system requires its own design. Making these schematics is an essential function of pneumatics, and the schematics usually form the most difficult part of the design of pneumatic systems. If the schematic design is successful, the basic task of pneumatics has been carried out. The choice of the equipment, its installation and location is easy. It can be done only after precise information has been obtained about the type of machines and equipment to which they will be connected.

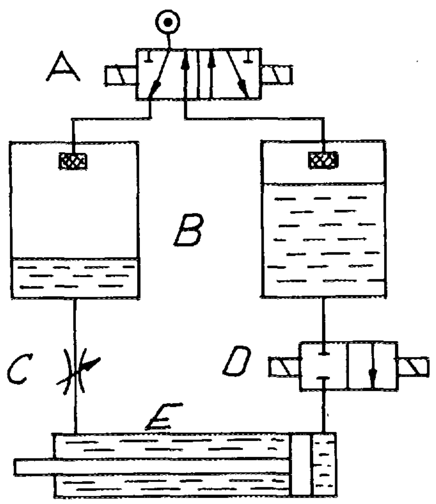
Figure 263. Electric and pneumatic control of a double-acting cylinder



Pneumo-hydraulic systems

A disadvantage of compressed air, when precise and even motions are desired, is its elasticity. An alternative to pneumatics is hydraulics, but if that cannot be considered alone, a combination of the two can be used. In pneumo-hydraulic systems the source of energy is air, but the actual motion is generated by fluid. Thus the precision of a hydraulic system, as regards distance and speed, can be obtained. The best kind of pneumo-hydraulic systems is one where the reservoirs are located on both sides of the acting cylinder. Such a system is completely hydraulic in its operation and has the accuracy required of hydraulic systems. The reservoir is filled partly with air and partly with fluid. To prevent the air from mixing with the fluid, a separate nozzle has to be installed in the feed unit, which distributes the air so that it will not mix with the fluid. Hydraulic systems are used in lifting and working operations when stable motion is required. A diagram and functional principle of a pneumo-hydraulic system is shown in figure 264.

Figure 264. Pneumo-hydraulic system



Key: A 5/2 flow-control valve
B Containers for air and fluid
C Flow-control valve for controlling the speed of the fluid cylinder
D 2/2 valve for starting and stopping the motion of the fluid cylinder
E Fluid cylinder

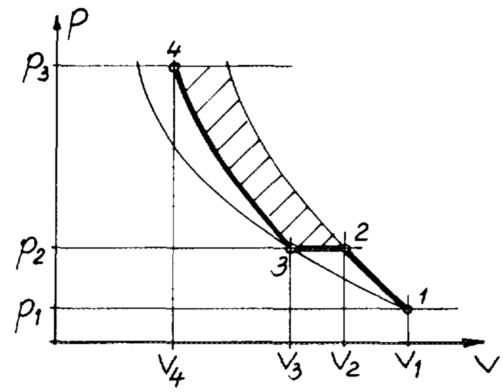
Production of compressed air

Compressing of air

When air is compressed, its temperature rises; the temperature of compressed air when it comes out of the compressor ranges from 100° to 200° C. At the same time, the relative amount of water in the compressed air increases; in other words its humidity increases. While the air is hot, the increased amount of water remains in the air as vapour, but as the air cools, it starts to condense and a considerable amount of water is released. The amount of water depends on the humidity of the outside air; therefore, in a warm climate where the humidity of the air is high, a lot of water is condensed from compressed air. The amount varies from 50 to 200 g per cubic metre of compressed air.

Air can be compressed either in one stage, which means that the final pressure is obtained in one operation, or in two stages (figure 265), in which case the air is removed from the compressor after the first stage, cooled and fed back to the second stage, in which the final required pressure is attained. From the point of view of energy consumption, two-stage compression is more economical, and therefore almost all industrial compressors are two-stage compressors. Only very small compressors are still manufactured for one-stage compression. Intermediate cooling in two-stage compression is done with water or air. Air-cooling has become common, owing to its simplicity. Only large compressors use water-cooling. The most common operational pressure of compressed air ranges from 600 to 1,000 kPa, and the volume of compressed air ranges from 10 to 1,000 litres per second.

Figure 265. Air compression in two stages



Key: 1 to 2 First compression stage
2 to 3 Intermediate cooling
3 to 4 Second compression stage

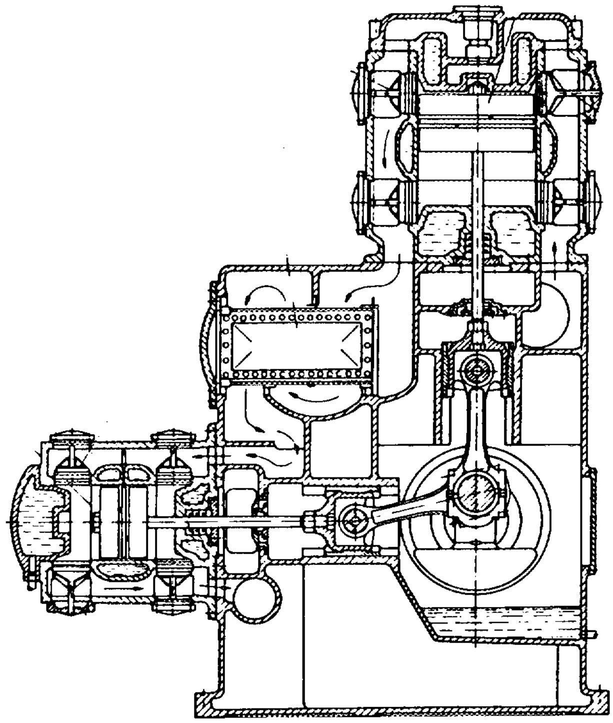
Compressors

Today three main compressor types are used for compressed air production.

Piston compressors

In the piston compressor (figure 266), the piston draws the air into the cylinder and compresses it there to the required pressure. After that, the piston forces the air into the pneumatic pipeline. Air intake and outlet are regulated through valves, which can operate freely or be controlled. The compressor can also operate so that the air is taken in and let out from both sides of the piston. This operation is more efficient since there is simultaneous suction on one side and compression on the other side. The piston compressor is the most common industrial compressor in use today because it is efficient and the required pressures are easily obtainable. Its construction has also been tested and proven, and, after decades of experience in its manufacture, defects have been eliminated. A disadvantage of the piston compressor is the vibration caused by the reciprocal motion of the piston. Owing to this fact, the compressor has lost some popularity within the past few years.

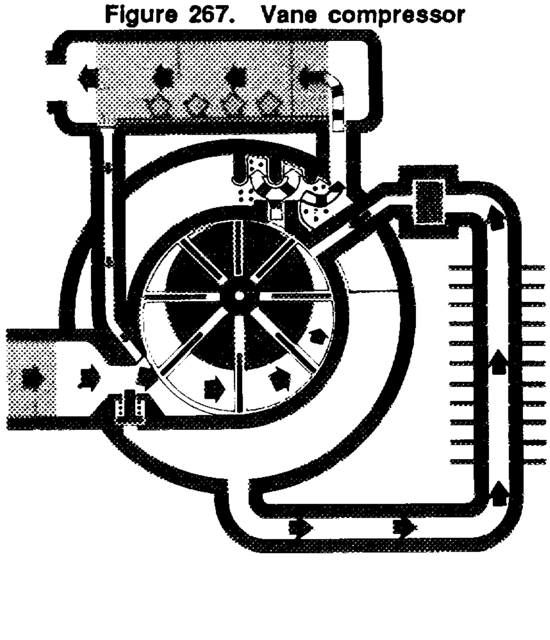
Figure 266. Two-stage water-cooled pneumatic compressor



Vane compressors

The vane compressor (figure 267) has an eccentric rotor with vanes in its grooves. The vanes move freely in the radial direction. Since the rotor is eccentric, the volume of air between the vanes changes and the air becomes compressed while the rotor rotates. Efficiency is not quite as good as in the piston compressor, but the vane compressor rotates evenly and without vibration, which makes it popular as a small compressor. However, the vanes rubbing against the frame cause heat owing to friction, and therefore the compressor has to be cooled with large amounts of oil. The compressor must be provided with an oil trap, which returns the oil through coolers for recycling.

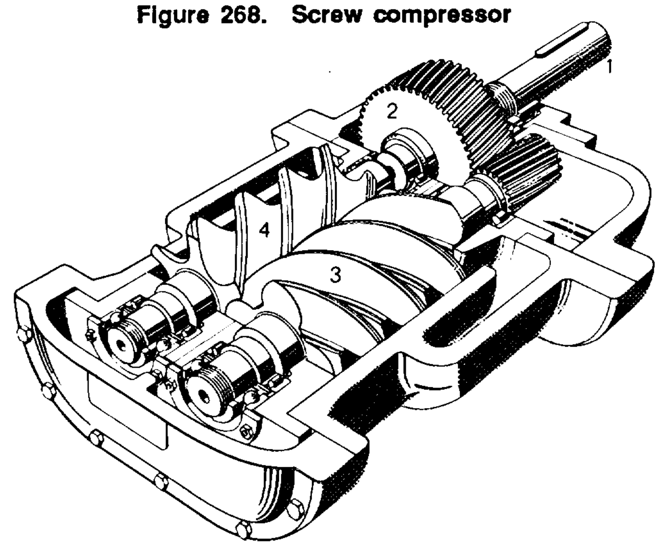
Figure 267. Vane compressor



Screw compressor

The screw compressor (figure 268) is the newest type of compressor and has therefore not been used much. It has become increasingly popular during the past few years, however. Its manufacture and use have increased to the extent that it is already threatening to replace the piston compressor. The screw compressor has some restrictions, and therefore it is not as suitable for general purposes as the piston compressor. It seems probable, therefore, that both the piston and screw compressors will keep their positions as commonly used types of compressors. The screw compressor is most applicable for heavy tasks. It usually has two screws, between which the air is taken in. While the screws rotate, the air is compressed and removed from the other end. The compressor is well-balanced and rotates without much noise, although high speeds of air can cause high-pitched sounds. These compressors are usually larger than 200 l/s.

Figure 268. Screw compressor



Key:
1 Drive shaft
2 Helical reduction gear
3 Compressor screw
4 Compressor screw

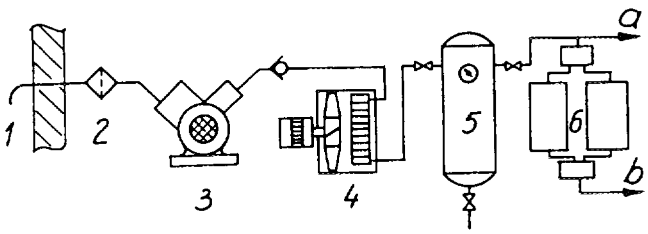
Pneumatic centre

In addition to the compressor, a number of other devices are required for the production of compressed air. They are located in the pneumatic centre (figure 269). Recently, compressor packages, manufactured for small compressors, have become popular. They contain all the equipment needed in a pneumatic centre.

Location of the pneumatic centre

The pneumatic centre should be located in the centre of the operation where it is to be used. It is not always possible to use this ideal location. Therefore, it should be positioned in a place near the centre of activities where the compressor does not disturb other activities and where the supply of clean cold air is sufficient. Also, access for easy maintenance should be considered as well as the availability of cooling air or water. The pneumatic centre for a piston compressor should be positioned on the ground so that vibrations will not be transferred to the building and as noise to the environment. Other compressors do not require any special foundation.

Figure 269. Pneumatic centre diagram



Key:
1 Air intake from outside
2 Air filtering
3 Compressor
4 Cooling of compressed air
5 Reservoir for compressed air
6 Drying of compressed air
a Compressed air for immediate use
b Compressed air to be dried

Air intake

Air should be taken into the compressor from a place where it is as cold and as clean as possible, ideally from outside the building and, if possible, from the shade. The immediate surroundings of the location for air intake must be clean, preferably a grassy area; air intake from a dusty area or near gravel piles or unpaved roads should be particularly avoided. The air intake should also be protected from rain and debris. The incoming air is filtered before it comes into the compressor, either through dry or oil filters. Dry filters are the most common because of their simple structure.

Cooling compressed air

The air coming from the compressor is hot and contains a lot of water. If the air is not cooled before use, it cools on its way and the excessive vapour in it is condensed into water and the pipeline will have water in it. Therefore the compressed air is cooled after it has come from the compressor, and in this way a considerable amount of the water can be removed. Compressed air cools a little after this stage, and some water is condensed, which has to be taken into consideration later on. This amount of water, however, is insignificant compared with the amount of water that would otherwise be in the pipeline. Compressed air is cooled either with air or water: small amounts are cooled with air and large amounts with water. In the cooling process large amounts of water are removed from the air and disposed of.

Reservoir for compressed air

Compressed air is stored in a reservoir. Its volume must be at least 10 times the production of the compressor per second. The reservoir is a pressure-resistant steel container, which is protected with rust-preventing paint. The reservoir must be inspected from time to time to ensure that no corrosion occurs. If possible, the reservoir should be located in the shade and painted silver on the outside. The reservoir is equipped with a pressure-regulating device and a safety valve and the necessary valves for air intake and outlet and water removal.

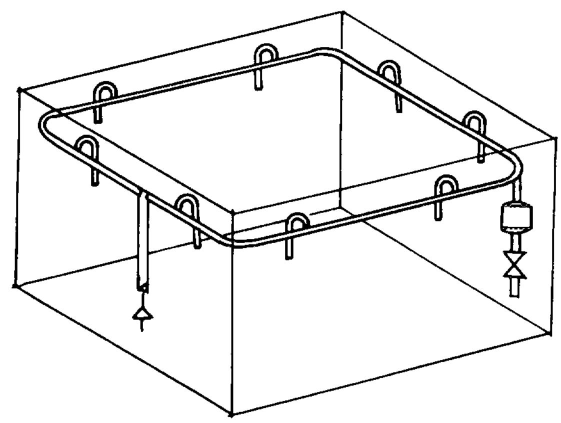
Drying compressed air

After all the water that could be condensed from the compressed air has been removed, it must be dried. This is especially important if the equipment that uses compressed air is very sensitive or contains narrow passages. Compressed air is usually dried with aluminum oxide, which absorbs the water into its porous surface. Water contained in the aluminium oxide can be removed with warm dry air, and thus the same substance can be used several times. Compressed air can also be dried with a refrigeration unit. This is a very clean and neat method of drying, but it is somewhat expensive.

Pneumatic pipeline

The function of the pneumatic pipeline (figure 270) is to transfer the air to the point of operation with as little loss as possible, at the right pressure and in sufficient quantity.

Figure 270. Pneumatic pipeline



Shape and dimensioning of the pipeline

The design for a pipeline is in the shape of a ring; if the pipeline is large, the ring is further divided into sections so that the distance in one ring between the reservoir and its furthest use point does not exceed 40 m. Straight mains should be avoided, since there is usually little compressed air at the end. The simplest way to dimension a pipeline is to have an air-flow speed of 5-10 metres per second in the main pipeline and 15-20 metres per second in the side lines. The pressure losses usually remain reasonable. Diagrams are available to assist in selecting the dimensions.

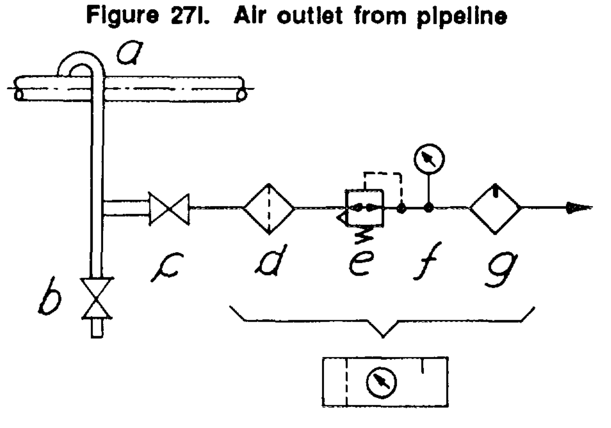
Pipeline construction

The pipeline is of welded steel pipes, either of ordinary or stainless steel. The distribution pipes can be also made of stainless steel, copper or plastic. The pipeline is installed so that it is inclined in the direction of the flow with a slope of about 1:100. In this way the water flows with the air flow to the water-removal pipes. For water removal vertical pipes are used as water traps at 30-50 metre intervals.

Air outlet from the pipeline

The air used in the operation must be dry, clean, at the correct pressure and usually lightly oiled. To prevent the water from the pipeline from entering the instrument line, the air has to be taken out from the top through a small curved pipe (figure 271 a). In case water should enter the instrument pipe, a horizontal pipe is equipped with a water trap at the bottom (figure 271 b). The water should be removed from that container from time to time. The pipe leading to the point of operation should branch off at least half a metre above the water container. To ensure that the air is pure, it is first led to a filter (figure 271 d), which usually consists of a centrifugal separator and a ceramic filter. There any eventual water and all impurities, such as rust, organic material and other debris, will be separated. To obtain the correct air pressure, a pressure regulator (figure 271 e) and a pressure gauge (figure 271 f) are installed after the filters. The pressure regulator is actually a pressure-reducing valve, since the pressure of the incoming air can be regulated only to a lower level than the pipeline pressure. The pressure regulator guarantees uniform operating pressure to the point of operation, since the pipeline pressure can vary depending on the use. In this way pipeline pressure variations do not cause changes at the point of operation. To provide light lubrication of the air coming to the point of operation, a lubricating device (figure 271 g), which feeds oil spray into the compressed air, is installed immediately after the pressure regulator. This oil spray lubricates the valves, cylinders and the motors, which do not usually require additional lubrication except in some special cases.

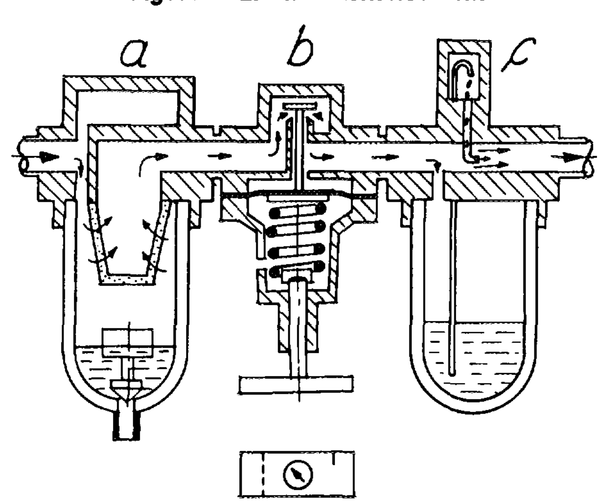
Figure 271. Air outlet from pipeline



Key: a Air intake
b Water trap
c Valve
d Filter
e Pressure-reducing valve
f Gauge
g Lubricator

Three components, filter, pressure regulator and lubricator, form one entity and it is called the *maintenance unit* (figure 272). They are usually constructed together and also purchased as a package. Such a maintenance unit must be placed before every operating point to ensure that the air that will be used meets pre-determined requirements. There is a main valve in connection with the maintenance unit, which opens and closes the air flow to the point of operation.

Figure 272. Maintenance unit



Key: a Water trap and filter
b Pressure-reducing valve
c Lubricator

Maintenance of pneumatic systems

The maintenance of a pneumatic system is similar to that for machinery and equipment in general, and therefore only some details that are important in pneumatic system maintenance will be discussed here.

The *compressor* is a machine that requires quite a lot of adjustment. Therefore most components of a compressor are equipped with automatic control and regulation, so that continuous maintenance is not necessary. However, the operator must take care to ensure that the amount of oil is sufficient, the cooling equipment operates properly, the motor is not overloaded and the compressor bearings, valves and pistons operate properly. Often these are controlled by automatic equipment that alerts the operator in case of over-heating, low oil pressure and other critical parameters. Other pneumatic devices generally require only little maintenance if water removal has been arranged automatically. If this is not the case, care should be taken to remove water regularly. Because of rust, the reservoir, water trap and other parts must be inspected regularly. They have to be painted and cleaned at regular intervals. The pipeline generally requires only little maintenance, and only when there is often water in the pipeline must the pipeline be inspected for corrosion and the corroded places replaced. Particular care should be taken in removing water. If automatic water traps are not used, maintenance should include regular emptying of water containers.

The *maintenance unit* requires constant care as it is one of the components in the system that requires the most maintenance. The filter has to be kept clean, the water has to be removed from it at regular intervals, the operation of the pressure regulator must be observed, and oil must always be added to the lubricator as it is consumed.

In the operating equipment the valves are the most sensitive part of the system. They can be easily clogged by dust, water, rust, corrosion waste and dry oil. A functional disturbance in the valves can lead to a functional defect of the whole system, and it is therefore necessary to clean them regularly. The seals and rings should be inspected, and they must be replaced early enough to prevent leaks. It is of particular importance to have spare valves in stock, so that they can be exchanged easily and quickly in case of malfunction. To facilitate the change, all valves should be selected to provide a so-called installation base so that the valve can be exchanged quickly without having to touch the actual connection.

Cylinders and motors require very little maintenance and therefore can often remain unattended until they break down or the operation stops. It is therefore reasonable to periodically open the cylinders and motors, check the seals, inspect for corrosion and lubricate the rotating parts of the motors.

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Annex VII

MAINTENANCE OF MACHINES AND EQUIPMENT*

This chapter is limited to the machines and equipment that perform primary functions in large and middle-sized industrial plants, although much of the information given is also applicable to well-managed smaller plants. These functions comprise:

Maintenance of machines and tools
Advance service and lubrication
Erection of new machines and equipment
Modifications of various kinds
Generation and distribution of electricity, steam, compressed air etc.

The so-called secondary functions in maintenance work comprise:

Cleaning
Handling of trash, waste etc.
Experimental work, building of new machines and equipment
Certain stocking functions
Plant security and fire protection

These secondary functions must be accomplished as a centralized part of maintenance in a large-scale plant if it includes several shops or if it deals with several fields of the woodworking industry and not only with furniture and joinery products.

The amount of maintenance work in industry has continually increased, and the same tendency may be expected to continue. At present, the number of maintenance workers in the mechanical wood-processing industry is 10 to 15 per cent of the total number, and in the particle board industry this number is even greater.

The continual increase of maintenance work results from the following circumstances:

(a) The rapid and continual increase in mechanization, automation and the general development of the industry which have greatly reduced the number of production workers in actual industry;

(b) The considerable increase in facilities and tools for maintenance;

(c) The decreasing importance of worker absenteeism and the increasing importance of machine down time;

(d) The increasingly capital-intensive nature of industry with the concomitant need for continuous operation, in other words, for two- or three-shift work;

(e) The increasing speeds, pressures, temperatures and capacities of machines, resulting in more rapid wear;

(f) Consumer demand for higher precision of machines and improved quality of products;

(g) Need to rearrange machines and equipment;

(h) Safety at work, air-conditioning and industrial hygiene;

(i) The increased awareness of the social and economic problems related to the treatment and disposal of industrial wastes.

The demand for craftsmanship required for maintenance has also continually increased, especially for instrumentation and automation. The use and handling of new materials, such as plastics, contribute to this trend. Previously, maintenance meant simply repairing something that had broken down. At present, however, there is a strong tendency towards preventive maintenance, which must be considered as a fairly advanced form of maintenance.

Equipment is becoming complicated, and its maintenance and repair call for workers with such great professional skill that only large companies can afford to employ them. Other enterprises must resort to spare-part replacement arrangements. Damaged parts are sent to a special factory or shop for repair. Importers or licensed manufacturers give information on such special repair shops. Annual or other long-term agreements will ensure that the special repair shop always has spare parts or machines in readiness for the customer.

In general, such external help in repair work will become more usual, particularly since it will make possible specialized service for tasks that cannot be done within small organizations. The diesel motor for trucks or for other machines is a good example of such a changeable part. This motor is usually changed and taken to a special shop for repair, where a new motor is in readiness if some damage occurs. This arrangement is suitable for lumber and log yards. However, it should be remembered that when machines are purchased their motors should be of the same type and at least made by the same manufacturer.

Organization of maintenance

The organization of maintenance has changed decisively over the years. Formerly, all repair work was done by one person, but a modern form of organization has gradually developed. The position of maintenance in an enterprise has also changed: once subordinate to production, it is now becoming equal to it and directly accountable to the highest management.

In connection with the reorganization of maintenance and with organization in general, the following circumstances should be noted:

(a) If the field of tasks becomes wider, technical and economic know-how should be added to the supervision of

*By Ahti Akkanen, Lahden Rautateollisuus Oy, Lahti, Finland, chapter XXIX of *Furniture and joinery industries for developing countries* (UNIDO publication, Sales No. E.88.III.E.7), pp. 271-276. Original figure and table numbers have been retained.

maintenance. In general, when the amount of work increases, the number of fitters and other workers is also increased but not the number of engineers and technicians. If the office staff is inadequate, the maintenance supervisory personnel must often do much mechanical and routine work, to the detriment of planning control etc. It is often forgotten that increasing the number of persons and the amount of labour always calls for additonal staff for supervision, control and routine work. If technical staff is lacking, foremen can be designated in certain areas, leaving supervisory personnel to control larger groups;

(b) The use of too many unskilled workers should be avoided; the number of such auxiliary workers should not exceed 20 per cent of that of craftsmen. The maintenance department, however, should not become a place for superannuated persons, and the repair shop should not become a museum of outdated woodworking machines. Securing new and skilled labour calls for training, but the training should not be done in such a way that a young worker goes on year after year helping an older craftsman. It should be done under the leadership of competent trainers;

(c) Furthermore, it should be noted in budgeting and in future planning that entirely new tasks and departments are coming into the maintenance organization such as, for instance, separate departments for preventive maintenance, scrapping and repair, plastics and instrumentation and automation (possibly even electronics).

In general, within the overall maintenance organization, there are so-called decentralized and centralized systems. In the former, maintenance personnel are divided into small groups around the factory and are often in some way subordinated to the local production supervision, whereas in the latter, work is directed from one point and is subordinated to centralized supervision. Both systems have their benefits and disadvantages. The appropriate system should be selected separately in each particular case, taking into consideration such circumstances as the nature of the working process, the cost of down time per minute, the number of interruptions in work, the degree of mechanization and automation and the general development of maintenance work.

As a rule, small enterprises should strive for centralization. However, when the factory area becomes so large that unnecessary (and time-consuming) walking is a considerable cost factor, it is advisable to consider at least a partly decentralized organization. It is, however, advisable to try to retain centralized supervision. The same applies to automation and to a situation in which expensive basic machines with high capacities (for instance, in the furniture and joinery industries, a painting line) are in operation. In such cases it is worth having maintenance workers to control the operation and the condition of the equipment.

Nevertheless, the following functions should be centralized:

Planning work
The generation and distribution to production areas of electricity, steam, compressed air etc.
Maintenance of elevators, cars, trucks etc.
Care of the sprinkler fire-extinguishing system, pneumatic conveyors and air-conditioning
Machining works
The major part of wood-based panel plants
Building and repair shops
The internal telephone network
Assignment of auxiliary labour power

In principle, each group should be led by a foreman of the same occupation. It is inadvisable, for instance, to make maintenance workers subordinate to production leadership. It would be advisable, however, to subordinate decentralized maintenance groups directly to the maintenance leadership, but their work should be assigned by the production leadership.

Maintenance card files

The proper organization of maintenance is not possible without card files. It is almost impossible even to begin preventive maintenance without repair statistics made over several months and, preferable, over several years for each individual machine. It is easy to record data on a machine card when it is at hand—such data as the number of the bearings when the machine is disassembled, the number of the belts before they are worn out and the weight of a machine when it is to be seen on the bill of lading.

The objects that should have file cards are similar in various industrial plants. However, it is worth noting which objects should or should not have such records. For instance, in the furniture and joinery industries, the objects for filing are woodworking machines, presses, conveyors and certain hand tools such as sanders.

The basic card also serves as an inventory list for fire and other insurance. If it includes sufficient data on belts, bearings, lubricants and the like, it makes an excellent starting point for the standardization of maintenance procedures. Cards have sometimes been prepared separately for each machine type, but in the furniture and joinery industries, such differentiation is of little value. In practice, the data common to different machines are most generally needed. Thus, a single form with plenty of room for notes is generally sufficient.

The card for electric motors might be mentioned as an exception. This form may be small and should usually be kept in the electrical repairs department. Only basic electro-technical data such as motor type, serial number and revolutions per minute need to be entered on the card. For practical reasons, data on repairs and maintenance are entered on a separate blank form, which can be kept together with the machine card. Data on repairs accumulate quickly, and it is difficult to provide space enough on the basic card for detailed work descriptions, data on spare parts used etc. The basic card and repair card as such can also be used for time-schedule control (inspections of preventive service, lubrication service etc.).

The numbering of machines for the machine card file can be done in various ways; the most usual way is to give a running number to the buying or arriving order or a certain number series for each machine type. A third alternative is to have a separate series of numbers for the machines of each individual department.

Preventive maintenance

Correct preventive maintenance should cover the entire plant, including the factory building and its transportation lines and utility mains and not merely the machines and equipment.

In general, the nature of maintenance is still passive; its function normally begins only when the machine breaks down. It should be active, however, through inspection and service lubricating and continuous observation of the condition of the machine. Basic repairs, carefully planned, should be made at the appropriate time in conjunction with production.

Preventive maintenance is not a new idea. In some fields, as for instance in lifts, aircraft, railroads and pressure chambers, regular inspection has been standard practice for decades. It is an extensive function, entailing:

(a) Inspection of machines and devices;

(b) Minor repairs, adjustments, cleaning and the like performed during inspections;

(c) Complete overhauls planned in advance and work done during shut-downs;

(d) Lubrication service;

(e) Investigation into, and selection of, new parts and raw materials;

(f) Investigation, comparison and recommendation of various protective devices and coatings.

Preventive maintenance naturally involves some costs, so that the objects and scope of maintenance should be carefully planned. In the furniture and joinery industries, maintenance should be extended to painting and laminating equipment, rapidly rotating bearings, drive belts, chains and sprockets.

Before an extensive maintenance programme is begun, the persons concerned should be entrusted only with this work and with nothing else. The following documents and data will then be essential:

Card files on all machines and devices
All documents and instructions for each machine
Drawings of machines and devices, particularly of large ones
Statistics on breakdowns
Data on repairs
Diagrams of all utility lines
Organization of a reliable spare-parts service

Furthermore, it is important that the preventive service group consist of eager and active workers.

Inspection includes two different functions: routine inspection and maintenance; and inspection according to the programme for each particular machine. In the furniture and joinery industries, the former functions should be applied to:

Electric motors
Power transmission devices
Piping, valves and pumps
Conveying equipment, elevators and lift tables
Air-conditioning and dust-extraction devices
Lighting devices
Office machines
Instruments and automation devices

As examples of inspection periods, the functions could comprise:

(a) Weekly inspection of scales, cooling equipment, photoelectric cells, tools with electric or compressed-air motors and spraying and air-conditioning devices for paint shops;

(b) Inspection every second week of belts, couplings, starters and electric motors; of instruments and electrical control devices; and of air compressors, pumps and air-conditioning equipment;

(c) Monthly inspection of blowers and belt, pneumatic and hydraulic conveyors; of water-treating plants; and of lifting devices and elevators;

(d) Inspection every three months of chargers for accumulators, boilers and lighting, welding machines and transformers;

(e) Inspection every six months of fire-extinguishing equipment, water tanks and their fittings, piping, power lines and heating apparatus;

(f) Yearly inspection of small electric blowers and normally operating ball-bearings.

A good example of preventive maintenance is the observation of a shaft bearing the cutter heads which, for a high-speed machine such as a single-spindle shaper, operates at more than 9,000 rev/min. A broken bearing may cause the breakdown of the entire machine. By observing this bearing regularly, it will be possible to determine the right moment for replacing it, and thus damage can be avoided.

The above lists serve only as examples; some equipment may require several different inspection periods, such as daily cleaning, weekly adjustment, monthly inspection of operation and annual overhaul. The correct determination of the inspection period is the basic requirement for a successful programme of preventive maintenance. Too frequent inspection wastes labour and money; too infrequent inspection jeopardizes the machinery. The periods between inspections must be changed to conform to changed conditions, and by observing the changes that have occurred, it is possible to adjust these periods.

Inspections may take place either when the machines are operating or when they are not. In the first case, this is done when abnormal vibration, wear, lubrication faults (oil leakages), excessive heating, poorly fixed parts, play of shafts etc. can be observed. However, it should be noted that in the furniture and joinery industries a knife in poor condition may cause some of these abnormalities, so that the intervals between the replacement of knives in wood-working machines should be carefully observed.

When machines are not operating, the possibilities for inspection are considerably greater; experience has shown that at least every third inspection should be made at this time since inspection and measuring of shafts, bearings, gear wheels, slide surfaces, belts and flanges, as well as of tensions, will then be possible. Machines that produce a great deal of sawdust and chips should be inspected especially when idle because parts not normally visible can then be checked. For inspection, the dust and chips should be removed from the machines. In tropical conditions, the thickness and degree of protection of grease coatings should be ascertained at the same time.

Preventive engineering

Preventive engineering entails the investigation and selection of raw materials and various protection, so that the need for repair can be avoided or reduced. When the preventive maintenance programme has developed, some causes of breakdowns and repairs are discovered, and in many cases this can be attributed to poor construction, raw materials and protection. Much work remains to be done in this area.

The first task is to investigate repair statistics and analyse the most essential and frequent repair jobs. The second task is to determine whether changes in construction, raw material or protection would improve the situation.

Lubrication maintenance

The primary purpose of lubrication is to reduce the effects of friction. Successful lubrication has the following advantages:

(a) The machines are kept in condition;

(b) The lifetime of machines is extended when wear is reduced;

(c) The efficiency of the machines is increased;

(d) Accident hazard is reduced.

To attain these advantages, it is essential to use the proper lubricant at the right place and time.

All the following considerations are important in lubricaton:

(a) The assortment of greases to be stocked should be as small as possible;

(b) The lubricants chosen should be included in the factory standards and marked with the same sign as that on the lubrication points and tools;

(c) All lubrication points should be lubricated correctly; that is, the lubrication must be done according to a plan drawn up by an expert. Oil companies distribute such plans free of charge;

(d) Lubrication should be carried out at the right time, but unnecessary lubrication must be avoided. It has been ascertained that over-lubrication is more frequent than under-lubrication, especially where ball-bearings are concerned. In general, a small or medium-sized bearing in normal use and with usual rates of rotation will need lubrication only once a year.

The amount of grease in one filling can be calculated approximately from the formula:

$$G = \frac{D \times B}{200}$$

where:

G = amount of grease required (in grams)
D = major diameter of the bearing (in millimetres)
B = width of the bearing (in millimetres)

To economize on lubrication costs and to ensure reliable lubrication, some large enterprises, and especially sawmills and plywood factories, have installed automatic lubrication whereby hydraulic pumps press grease through piping to lubrication points, as required. The amount of grease for each point is adjustable. This way of lubricating is becoming general, as for instance on the slide surfaces of conveyors and in the process industry. In the furniture and joinery industries, however, there are not many points that can be lubricated in this manner.

Oils that have been used once or even several times should not be discarded; efforts should be made to clean them. In general, waste oil is taken to special cleaning plants. If this is not possible, a filter arrangement can be easily built, using waste wool.

Prevention of corrosion

Most damage to machines and other equipment used in industry is caused by corrosion. While this is always a problem, it is particularly severe in warm and moist environments. For instance, the speed with which steel rusts is directly proportional to the temperature. Usually, corrosion is caused by water or oxygen. Oxygen is an especially difficult factor because the strength of the metal in some cases calls for its presence, since it causes the formation of a protective film of oxide on the surface of the metal; sometimes, however, it contributes greatly to corrosion.

In principle, the prevention of corrosion is rather simple. By protecting steel surfaces, for example, the speed of corrosion is reduced, either by mechanically preventing the surface of the steel from coming into contact with oxygen or moisture or by inhibiting the rusting process. In practice, the following methods of preventing corrosion are used:

(a) Making constructions in ways that protect corrodable materials from air, warmth and moisture;

(b) Changing the environmental conditions;

(c) Covering vulnerable materials with corrosion-resistant materials (paints, plastics, rubber, ceramic materials), glazing or using protective boiler masonry, metal coatings or platings;

(d) Cathodic protection;

(e) Use of inhibitors of some reactions involved in corrosion;

(f) Using materials that do not tend to corrode in the given circumstances.

Stocks for maintenance

The materials to be held in maintenance stock are mainly:

Parts of standard nature: pipes, nuts, bolts, fuses, bearings etc.

Parts for separate machines: special bearings, spare parts etc.
Spare assemblies: motors, pumps, condensers, couplings etc.
General supplies: packing materials, lubricants, paints etc.
Machine tools: knives, drills, grinding wheels etc.
Hand tools: wrenches, measuring gauges, compressed-air tools, electrical tools etc.

Ever-increasing mechanization and automation have also contributed to the capital value of maintenance stock. The increasing costliness of down-time has had the same tendency. Repairs must be accomplished as quickly as possible, and there should be sufficient spare parts in stock to permit this.

There are two opposing factors to be considered in relation to maintenance materials. On the one hand, in order to expedite repairs and reduce down-time, increasing amounts of spare parts and devices for the most essential machines should be held in stock. On the other hand, however, in order to hold down costs, the stock should be kept as small as possible. In general, the final solution must be some kind of compromise.

If the factory is located far from the country where its machinery is produced, as is the case in most developing countries, the spare-part stock should be rather large to ensure continuous operation of the factory. However, the spare parts that will probably be needed should be noted when the machine is being ordered, and a list of spare parts to ensure the operation for two years, and even for a longer period, should be ordered.

Standardization should also be striven for; for instance, all the machines and machine parts, threads, holes and bearings should be either in the metric system, or the so-called imperial (inch) system. The concurrent use of both systems should be avoided.

It is easy to keep the stock up-to-date if it is kept in order and the cards duly filed. The so-called "alarm limit" or required time of ordering should be marked on as many cards as possible, so that an order may be placed immediately as soon as the amount of parts in stock falls beneath the limit. The use of a goods card or spare-part card is helpful. With regard to small machines, only the most essential spare parts are written on the machine card. With standard spare parts that are used in many machines, a summary must be prepared for departments and for the whole plant to indicate their total number. Such parts are, for example, belts, chains, motors and bearings. The summary list forms a base for acquisition, stocking and internal standardization. In all such listings, spare parts are usually identified by a number or letter code. The spare parts list and its record should be kept up-to-date in an orderly fashion so that needed items can be found without loss of valuable time.

As the maintenance function evolves to meet changing needs, repairs can be made with increasing rapidity. On the other hand, they entail costs, and there is inevitably a limit which it would be uneconomic to exceed. It is thus advisable to calculate in advance how much capital should be tied up in spare parts for the more essential machines; alternative methods should be costed carefully. The example given in table 22 is for a large, essential electric motor in three-shift operation. Although not directly applicable to the furniture and joinery industry, it has been included to draw the principle to the attention of the reader. Its down-time cost has been calculated at $52/hour. When it is time for the regular servicing of this machine, this work can be done in any of four ways: *(a)* complete overhaul with no replacement of parts; *(b)* complete rewinding etc.; *(c)* replacement of the entire rotor; and *(d)* replacement of the entire motor. The costs of these four methods would compare as shown in the following table. Inspection of this table reveals that the third of these ways, namely the replacement of the rotor, is the most appropriate, and it is therefore economic to keep a complete rotor in reserve.

Table 22. Comparative costliness of four ways of performing the periodic overhaul of a large electric motor

Type of overhaul	*Repair time (hours)*	*Costs ($)* [a]			
		Downtime	*Parts*	*Labour*	*Total*
Complete overhaul	240	12 400	—	1 500	18 400
Rewinding etc. of rotor	144	7 400	300	700	8 400
Replacement of rotor	7	400	2 100	75	2 500
Replacement of motor	3	200	4 100	25	4 300

[a]Based on original figures in FmK, rounded to the nearest hundred.

Mounting the machines

Each machine must be mounted with great care, since incorrect or faulty mounting can cause irreparable damage in operation. Before mounting is begun, the instructions that are normally delivered with the machine should be carefully studied. Indeed, when possible, these instructions should be ordered and received before the machine is delivered. Even though the ways of mounting the most usual woodworking machines do not differ greatly, it is worth while to note the necessary tools and arrangements in the instructions for each particular machine. This is important even if the machine is familiar, because designs of machines and devices change frequently.

Some heavier machines such as wide-belt sanders and wide planing and thicknessing machines can be mounted in place without fastening. In such a case, a vibration-damping rubber mat should be placed below the machine. However, this method of mounting requires an absolutely even and straight floor level.

In any case, no matter what the machine is, the mounting can be done with fastening bolts. When the site of the machine has been fixed, cavities for the foundation bolts should be made in the floor or, if the plant is under construction, the required holes can be located at an early stage. These holes or cavities must conform absolutely to the drawings of the manufacturer; in no case must the hole or cavity for the bolt be smaller than the drawing indicates or the fastening bolt will work loose as soon as the machine is started.

In the installation, the machine is placed exactly, and the foundation bolts are inserted into the holes of the frame and project downward into the holes or cavities in the floor. The machine is then hoisted from the floor (about 20 to 25 mm) by means of metal wedges, lead plates or the like between the frame and the floor level. The wedges should be placed as near as possible to the fastening holes. (At this time, a spirit level should be employed to check the horizontal position of the machine.) The bolt cavities are then filled with cement grout. When it has hardened, the foundation bolts are tightened. At this stage, care should be taken that no tension is created in the machine; in other words the bolts must not exert a bending or twisting effect on the frame, which can occur if the machine is not steady or level. Torsion and bending hinder the functioning of moving parts, and even the frame may be damaged.

When the placement of the machine is planned, the needed electric cables, compressed-air and hydraulic pipes, and dust-extraction ducts must be provided.

The removal of sawdust and wood shavings is a matter of prime importance. If this is not properly done, the efficiency as well as the health and safety of the workers will be impaired. Furthermore, the maintenance of a dusty machine is easily neglected. There is also an increased fire hazard, since drive motors embedded in wood shavings and chips often become over-heated, and their windings burn, with the consequent risk of major damage. Finally, it should be stressed that a clean factory produces more and better goods in fewer working hours per product unit and that it runs with minimal maintenance costs.

The best way to cope with shavings and sawdust is to remove them pneumatically from the cutter-head knife, where they originate. The pneumatic shaving-suction system must be extended to the whole factory hall and to each machine. The advantages of such a centralized system are not limited to safety and cleanliness; the waste thus gathered can be further used to generate steam or even sold to particle board or pulp mills.

The fitting of such wood-waste duct work in old buildings may present difficulties and extra costs, but they are not usually disproportionate. In such cases, ducts hanging from the ceiling are often the only solution. The suction network should also have ducts at the floor level so that the shavings on the floor can be swept into holes to be transported away.

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Annex VIII

MAINTENANCE OF MACHINE PARTS*

General points

A company's machinery represents a considerable investment. Therefore, it is necessary to realize the importance of machine maintenance. Proper maintenance lengthens the life of the machinery considerably and accordingly lowers capital costs.

Continuous wear and increasing age cause the value of the machine to decrease. The life of the woodworking machine is 4 to 20 years, depending on the use and the quality of the machine.

The first consideration before deciding to purchase a new machine is whether there is enough work for it. This depends on the size of the company and number of its orders.

The capacity of the machine depends on its size and quality, which must be in correct relation to each other. The more expensive the machine, the more work it should perform. Therefore, it is not wise for a company to buy a very efficient and expensive machine and only use it part of the time.

Arrival of a new woodworking machine

When the machine has arrived in the factory, it is important to check that it has not been damaged during transporation. The cutter spindles and the rotors of electric motors must revolve freely and silently when rotated manually from the end of the shaft.

The next thing to check is that the stampings on the plate of the machine are correct and in accordance with the order. It is important to check the voltage of the electric motors and whether it is a Y or D coupling.

When mounting and test running, it is very important that the electric motor runs in the desired direction, since rotation in the wrong direction can break the machine immediately.

During complete service the motor must always be disconnected. Before starting the machine it is necessary to check the rotation direction using a short start, i.e. giving a start impulse and, immediately thereafter, a stop impulse.

The company that manufactures the machine must always be asked to supply the purchaser with detailed installation, maintenance and safety instructions with diagrams in the language agreed upon. These must be carefully observed.

In general, manufacturing companies lubricate the bearings of a machine before delivery. Owing to the exceptionally high temperature and relative humidity in many developing countries, considerably shorter intervals between service are required. Accordingly, the bearings must be protected by lubricating them more frequently than would be necessary in a dry and cool atmosphere.

Only high-quality lubrication materials must be used in the lubrication of machine parts, preferably those recommended by the manufacturer. If another brand of lubrication material is going to be used, the old material must be thoroughly cleaned away. Mixing lubrication materials often results in thickening and an almost complete loss of lubricating qualities and consequently damaged bearings.

The most suitable materials for cleaning ball- and roller-bearings are white spirit, good water white, petrol or benzine. The last two are inflammable and must therefore be handled with extreme care.

After they are cleaned, the bearings must not stay dry; immediate oiling or greasing is necessary. The bearings are rotated so that the oil or grease enters all important points and prevents them from rusting. This is particularly important when lubricating the bearings of machines that will stay unused for a long time.

Intervals between lubrications of ball- and roller-bearings should be:

Rev/min	*Lubrication*
1 000	After 2 400 hours in operation
1 500	After 1 200 hours in operation
3 000	After 200 hours in operation
Over 24 000	Daily

Maintenance of electric machine parts

An electric motor must never be covered or encased. It is recommended that dust be brushed off daily or blown off with an electric blower. Encased electric motors are equipped with a fan on the outside which cools the motors. The fan opening must not be placed against the wall or in a way that would prevent air from flowing into the opening. If the electric motor is situated in a place where glue, paint, lacquer or grease might drop on it, daily cleaning is necessary. A thin layer of grease on the surface prevents the glue or paint from sticking to the surface.

Inspection of starting equipment

Starting equipment is inspected in connection with the annual service. If the model is simple and has a pressure switch with an on-off control or a 3-stage switch with a lever, the contacting surfaces are sanded with abrasive paper No. 400 or 600 wrapped around a wood or plastic strip. This must always be done by an electrician.

An improved, and also more expensive, model has been equipped with a heat-protection release. In case of overload, e.g. if the blade of a circular saw is struck in the workpiece, the "on" switch is automatically released and

*By Eino Marttinen, Lahti Technical Institute, Lahti, Finland, chapter XXX of *Furniture and joinery industries for developing countries* (UNIDO publication, Sales No. E.88.III.E.7), pp. 277-278. Original figure and table numbers have been retained.

the machine will not start again until the bi-metal strip of the protective equipment has cooled off. The machine is serviced in the same way as the one described above, except that in addition the bi-metal strips of the heat-protection equipment are inspected. Their fasteners are standard parts and can be replaced.

There are also switches that can be locked with a key. In general, special machines are locked so that they will not be operated by unauthorized persons. The mains current can also be locked, thus preventing the start of all machines. It is very important to have a spare key.

The most common starting switches of electric motors are heat-protection switches and contactor switches which are provided with automatic release mechanisms; if the machine is overloaded or if the blade is stuck in the work-piece, the heat-protection release stops the motor. The motor will not start unless the heat protection is set again in the starting position. There are also constructions in which the start button automatically sets the heat protection.

A contactor is safe to use since disturbances in the distribution net of electric energy release the switch, and the machine will not start again by itself even when the current is on again. This is called a memory switch.

Maintenance and service of a contactor switch

Contactors, heat protection and coil are standard parts and can be easily replaced. The contactor coil can be 220 V or 380 V, the latter being normal for industrial use.

Contactors filled with transformer oil are used for switching on strong currents. The contacting surfaces of the switch must be serviced annually and replaced if necessary. They are standard parts. The oil must be changed if it is not transparent or seems to have particles in it that will result in its losing its insulation qualities.

The moving connection cables must be carefully inspected. The insulation of the cables may have worn or be otherwise broken or damaged; they can be dangerous in operation and may even cause a fire. Any faulty electric equipment must immediately be replaced.

Inspection and maintenance of ball- and roller-bearings of electric motors

Listening to ball- and roller-bearings while they are in operation is a way of checking that they are faultless. This can be done e.g. by putting one end of a stick against the ear and the other end against the bearing chamber. If the bearing is in good condition, a silent humming sound is heard. If the sound becomes louder or one of the bearings is louder than the others, there is something wrong with that bearing. If the bearing ring is faulty, a clinking sound is heard. Frequently, a faulty bearing ring causes over-heating of the bearing chamber soon after start-up. As soon as a faulty bearing has been found it must be replaced. It is very important to have spare bearings in stock.

Changing the bearing

In changing the bearing, the fuses of the feed conductor of the electric motor should be removed and a sign should be put up in the distribution centre to warn people that work is in progress. Only the person who put up this sign should take it down again.

A skilled mechanic must change the bearings in an electric motor. Most makes of motor are equipped with their own tool sets. There are operation instructions in the service manual which must be carefully observed.

If a bearing is broken during operation, particles of it and grease are thrown into the coil of the motor. Only detergents that do not damage the lacquer and the coils can be used.

The intervals between lubrications of the bearings of an electric motor should be the ones given above.

If the motor is situated in a place where excessive moisture, dust, corrosive agents etc. can enter the bearing chamber, it has to be protected by more frequent lubricating than would be necessary in a clean place. Only high-quality ball-bearing grease should be used, preferably one recommended by the manufacturer.

When changing from one grease to another, it is important to wash away carefully the remnants of the grease used before; mixtures of lubrication materials thicken and lose their lubrication qualities almost completely.

If an electric motor is disconnected from its conduits, the wiring must be marked with tape to ensure the correct revolution direction.

In case of flood or if the motor has become wet, no attempts should be made to start it. It must be disconnected from its wiring and taken apart. The coil must be dried carefully. Trying to start a moist or wet motor will damage the coil.

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VIII. SURFACE FINISHING

H. Wad*

Introduction

The objective of this chapter is to provide information on finishing, with special reference to rattan and bamboo products.

The art of finishing has gradually become the science of coatings, some of which enhance the natural character of the wood and others of which change it. Finishing materials and techniques are becoming more and more complex. Chemicals and finishes must be introduced that satisfy specific demands, that comply with environmental restrictions and that are compatible with the sophisticated application and drying equipment that is being developed to allow more productive finishing operations.

The chapter takes a broad look at these new products and procedures in order to single out what can be useful for the finishing of rattan and bamboo. There are, in this respect, some special considerations that limit choices and possibilities:

(a) Rattan and bamboo products/furniture are, by their nature, complicated objects with many sides. This places constraints on the application and drying equipment and, to a certain degree, on the finishing materials used;

(b) The countries in which rattan grows have tropical climates. This limits the choice of finishes and may give rise to special needs, such as drying facilities;

(c) The fact that the largest markets are the United States and Western Europe places special demands not only on the finishing systems but also on the quality and type of finishing material.

The chapter points out these considerations and illustrates how they often influence the final choices.

Finishes and finishing systems

General considerations

Rattan and the various species of wood used in combination with it (bamboo is initially excluded to simplify things) are, generally speaking, soft, porous and sticky materials that attract dirt and moisture. Moreover, they are difficult to clean and look quite dull before they are stained and/or lacquered.

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Surface finishing, therefore, has two basic functions: first, it gives protection from wear, abrasion, liquids, microorganisms and insects; secondly, it brings out the natural and often hidden beauty of the wood and substrate.

Also, the application of finish to all parts of the object minimizes potential blotching and swelling. When necessary, surface finishing can be used to change the shade of the substrate; it can also be used to hide or intensify the natural variation in the colour.

Surface finishing can make light wood darker and dark wood lighter. Surface finishes can be clear lacquers, stains or pigmented lacquers. Different finishing materials give different degrees of sheen: glossy, semi-glossy, silk-matt or matt.

The proper choice of finishing material makes the object more attractive and more appealing to the buyer. All in all, it has the vital function of selling the furniture.

Surface finishing is both an aesthetic and a commercial consideration, and it is a well known but often neglected fact that a very good finish can make a modest design acceptable, whereas a poor finish can spoil even the best design. Although most salespeople and many producers would agree with this, it is remarkable how often the importance of the finishing procedures and the finishing department is not acknowledged.

The finish contributes at least one third of the value of the furniture, and yet the investment in finishes and surfacing facilities is marginal compared to the investment in production facilities.

The main reasons for applying a finish therefore bear repeating:

(a) To stabilize the surface;

(b) To protect the surface from mechanical and chemical exposure;

(c) To emphasize the beauty of the substrate;

(d) To give the surface a new appearance, using either dye or pigmented finishes;

(e) To enhance the design and facilitate the sale of the object.

Requirements of the export markets

To understand the often very specific demands of the two main export markets, Europe and the United States, it will be useful to draw up a simplified picture of the markets.

The United States is a vast country with an enormous potential for low-priced, mass-produced furniture on the one hand and an important demand for high-priced show-pieces, on the other. There is not much interest in anything in between these two extremes. The common denominator is a design that offers an exotic look and a well-defined overall impression and that follows often-changing design fashions, with specific regard to staining and colouring. The durability of the construction and of the finish is, generally speaking, less important.

Most furniture in the United States is sold as finished and assembled, so there is more emphasis on the overall appearance of the furniture than on the details. Because the market is extremely consumer oriented, the product finishing lines must be very flexible to be able to adjust to changing fashions in colour.

These points are made not to tell producers that they should ease up on quality when dealing with buyers in the United States, but to tell them that this market places a high demand on their flexibility and ability to adjust to new standards and trends, especially with regard to staining and colouring procedures. It requires a great deal of support from the finish supplier, who must offer a wide choice of products, and from the finishing department, which must employ people with some artistic skills.

As for the European market, it is important to note that it is not one homogeneous market but rather many different markets, each having its own history and traditions. The European market is much more conservative than the United States market, and it was only in the late 1960s that rattan and bamboo furniture began to be accepted there as a supplement to traditional furnishings.

Orginally, rattan and bamboo furniture had been thought to be too exotic, rough and cheap with respect to design and finish, so its basic qualities, i.e. its light weight and durability, were overlooked and it was forced to live out its days as garden furniture. Only when the design had been modified with regard to durability and appearance and when the quality of the finish had been improved was rattan furniture allowed a place in the house.

Conservatism derives from traditions, and to understand the general demand for quality in all details that seems to characterize the European market, it may be useful to note that there is not, as such, a single European look. Rather there is a broad diversity in style and design. However, there is definitely a European style of furniture manufacturing, namely the knock-down method using panel-derived products.

There is also a European style of finishing, known as flat-line finishing. Flat-line finishing, with its sophisticated application, drying and sanding equipment, generally gives high and uniform quality at a reasonable price, which explains the high standards of the European market. The end-user has simply become accustomed to a certain level of quality by virtue of the manufacturing and finishing techniques traditionally used by the endemic industry.

Since Europe is very production oriented and fashions and trends are not easily accommodated in a specialized finishing layout, there is often a focus on detail, for instance, on the resistance and wearability of the finish.

These facts about the European market are very important, and the rattan or bamboo producer should always ask for technical specifications and be aware of his options. Again, the producer has to rely on a finish supplier with a broad spectrum of products, but the level of artistic skills in the finishing department is less important than the quality of the application and drying equipment.

As mentioned earlier, a finish has two basic functions: coloration and protection. The difference between the two main markets with regard to finishing lies in the relative importance given to each of these two purposes. In Europe (and, for that matter, in Japan), protection and durability are more important than coloration. In the United States, where the furniture industry is a fashion industry, the cosmetic and artistic aspects are more important.

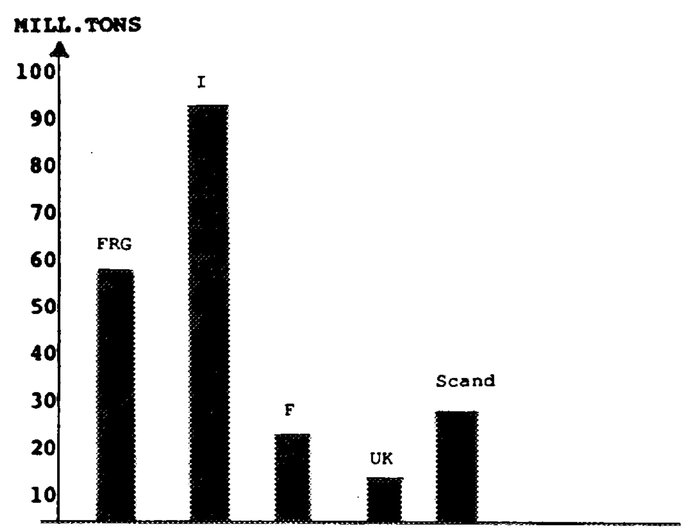
For practical reasons it will be useful to see how these two approaches are reflected in the consumption and type of finishing products used. For purposes of comparison, clear lacquer and pigmented finishes are not dealt with separately within the different types. Thus, when nitrocellulose finishes are discussed, both clear and pigmented nitrocellulose finishes are comprehended.

Figure 123 shows the consumption of furniture coatings in western Europe. The traditional preference for filled, high-gloss treatments in Italy explains their large consumption there relative to Germany.

Table 12 shows market share for different coating systems. It is evident that there is no single European style.

In Scandinavia, acid-curing coatings dominate. Nitrocellulose coatings, often of the modified type, are more important in France, Germany, the United Kingdom and the United States.

Figure 123. Consumption of furniture coatings in a given year



FRG = Former Federal Republic of Germany
I = Italy
F = France
UK = United Kingdom
Scand = Scandinavia

Table 12. Market share of coating systems, 1983 (Percentage)

Country	Nitro-cellulose	Acid-curing	Unsaturated polyester	Poly-urethane	UV-cured	Water borne	Others
France	50	18	10	18	4	–	–
Germany, Federal Rep. of	60	10	6	17	4	2	1
Italy	4	6	25	50	15	–	–
Japan	5	20	8	63	4	–	–
Scandinavia	3	85	3	4	2	3	–
United Kingdom	50	34	4	4	2	3	3
United States	89	1	3	4	1	2	–
Lower cost ←					→	Higher cost	

In Italy, the most popular finish is a high-gloss, closed-pore system based on either polyurethane or polyester, the latter being cured by ultraviolet (UV) to an increasing extent.

These figures are from 1983. Since then, environmental factors have become increasingly important, especially with regard to solvent emissions. By 1989, there were signs of the growing use of solvent-free UV-cured products and water-based lacquers and enamels to satisfy environmental regulations and government restrictions.

As an example, in 1989 a new finishing line in Denmark could not release more than 35 kg of solvent in 8 h. This is roughly equivalent to 50 litres of ready-mixed clear lacquer, enough for 100 rattan chairs. The producer can choose to change the finishing material, accepting possible drawbacks, or to invest in expensive installations that burn off the solvents and so conform to the regulations.

It is important to note that these changes in coating material are being provoked by local environmental regulations and not by higher quality; indeed they often sacrifice some of the advantages of the systems in use. The prognosis for various coating systems is shown in table 13.

Table 13. Prognosis for the utilization of coating systems[a]

Country or area	Nitro-cellulose	Acid-curing	Unsaturated polyester	Poly-urethane	UV-cured	Water borne
France	–	0	+	+	+	0
Germany	–	–	+	+	+	+
Italy	0	0	–	0	+	0
Japan	0	–	0	0	+	+
Scandinavia	0	–	0	?	+	+
United Kingdom	–	0	+	+	+	0
United States	–	0	0	0	+	+

[a] – = decreasing; + = increasing; 0 = no change; and ? = unknown.

Characteristics and limitations of the finishes

At this point it will be useful to look at each type of finish in relation to the export of rattan furniture to Europe and the United States: what are the finishing options and what restrictions are likely to be enforced in the near future?

Nitrocellulose and related finishes

The products in this category are one-component coatings that dry by solvent evaporation exclusively. No chemical reaction (curing) takes place, and it is possible to redissolve the dry film with the lacquer solvent or thinner. When recoating, the solvent of the second (wet) lacquer dissolves part of the first dry coat and this fuses to it. This causes swelling and shrink-back, but it also ensures good adhesion between the coats without sanding being required.

The most common binder is nitrocellulose (NC), but vinyl and butyrate binders are also used, especially for washcoats, owing to their good adhesion and colour stability.

Generally, nitrocellulose finishes have a low solids content due to the use of high-polymer solvents as binders. A solids content of 20 per cent by weight is common. The chemical resistance of the dry film is not very good: it is sensitive to water and alcohol and is flammable. Several coats, typically four or five, are necessary to obtain a decent build or appearance of the final finish. Hence, although this type of finish may appear to be less costly in the can, solvent loss and the need for multiple coatings often mean the cost of the dried finish is not as attractive as it first appears.

The advantages of nitrocellulose finishes are that they are fast drying, easy to handle and apply and easy to repair. Also, they are free from formaldehyde, the effects of which are controversial.

As is clear from table 12, it is fair to say that most buyers in France, Germany, the United Kingdom and the United States will accept rattan furniture finished with a nitrocellulose coating. However, in Europe, nitrocellulose products are often heavily modified to improve their flexibility and resistance, which are the weak points. Thus, one must always specify the best if this type of finishing material is chosen and generally be more careful with the packing and wrapping of the furniture.

In Italy nitrocellulose finishes are generally not acceptable for the traditional high-build treatment because they tend to exhibit shrink-back. In Scandinavia, they are not popular because they lack resistance.

Special restrictions are of local importance only (solvent emissions during application and drying).

The following must be checked:

Buyer: That there are no specific demands as to the resistance of the coating;

Production: That approximately four coatings/applications per piece do not cause bottlenecks in the finishing department.

Conversion coatings

Conversion coatings rely on a chemical polymerization reaction between the various components. This reaction is initiated and accelerated by the addition of a catalyst and heat. In some conversion coatings, the polymerization reaction is started by exposure to ultraviolet light. Unlike with coatings that dry by evaporation, where the only real choice is NC systems, with conversion coatings there are many choices.

Acid-curing (catalyst) finishes

When an acid-curing (AC) product is used, a chemical reaction starts between the acid and the binders in the lacquer. The reaction continues while the solvent evaporates, for up to one month from the application time. It can be accelerated by providing ample ventilation and heat to the surface treated.

The use of acid-curing lacquers calls for an ambient temperature of not less than 18° C and relative air humidity of less than 65 per cent; otherwise the film may not cure fully.

Acid-curing products can be of the one-pack precatalyzed type or the two-pack catalyzed type, which means a separate catalyst has to be added before use. A chemical reaction takes place between binders in the product when an acid solution (the catalyst) is added. The final cured film resists water, alcohol and common household chemicals. Furthermore, it is hard, tough and scratch- and impact-resistant.

With a two-pack coating there is a limited period of use (pot-life) after the addition of catalyst. This can range from one day to more than a week, depending on levels of catalyst and ambient temperature and humidity. Precatalyzed products normally have a shelf life of at least six months.

The solids content can vary from 25 to 75 per cent by weight, but generally it is from 35 to 50 per cent, i.e. typically twice the solids content of nitrocellulose products. Two coats replace four to five nitrocellulose coats. Drying (curing) is fast when the high solids is taken into consideration. Forced drying at elevated temperatures reduces the drying time. Temperatures below 20° C and humidities above 70 per cent can lengthen the drying time and lower the chemical resistance. Therefore, it is advisable to have some kind of heating facility to lower the humidity and secure the optimum drying rate.

Since repair work is difficult owing to the high resistance of chemically cured film, it is highly advisable to sand between coats to obtain a good adhesion between the different layers.

Acid-curing film is normally classified as being resistant to the spread of flame and is therefore often recommended for use in hospitals, hotels etc.

Acid-curing products can be subdivided into the following groups:

(a) Ample acid-curing (amino alkyd type);

(b) Fast-drying acid-curing (modified type);

(c) One-component acid-curing (precatalyzed type);

(d) PVC-modified acid-curing.

From table 12, it is evident that for the Scandinavian countries, the acid-curing products are essential. Generally, the ample type will be more suitable for rattan furniture, taking into consideration economics and the fairly slow finishing procedure if drying is not used. The more complicated the design of the furniture, the more important it is to reduce the number of coatings. The key words here are chemical resistance and flexibility, and as such this type of finish is acceptable in all European countries except Italy, where high-gloss, polished treatments are in demand.

However, there is one warning: during drying, all acid-curing products emit formaldehyde, the quantity of which is more or less dependent on the formulation. The formaldehyde is emitted at three points:

(a) In the pail, in the free space between the lacquer surface and the lid;

(b) In the wet, catalyzed lacquer stages. Emissions at this point affect mainly the working environment;

(c) From the dry film of the lacquered surface. Emissions here affect the use environment.

European Governments, especially those of Germany and, to a lesser extent, the United Kingdom and Scandinavia, are in the process of imposing restrictions on the maximum emission of formaldehyde from furniture in use. In Japan and the United States, maximum values of 1-2 ppm are being discussed.

A typical ample acid-curing lacquer emits approximately 0.25-0.35 mg formaldehyde/m^3 air after about three weeks. This can be compared to two cigarettes, which emit 0.18 mg/m^3. It is possible to formulate acid-curing lacquers that comply with the new restrictions, and a few types are already available, but they are often more expensive than already existing acid-curing products. This problem of formaldehyde emission partly explains the increased interest in UV- and water-based products.

Check the following:

Buyer: Whether there are any restrictions on formaldehyde emissions.

Production: That proper drying facilities are available, since the more drying that is done, the less formaldehyde should subsequently be generated.

Polyurethane products

For those countries that demand chemical resistance and low formaldehyde emissions, polyurethane (PU) products are an alternative. These products mostly have two components, but one-component products (moisture-curing) are also used.

Polyurethane products are chemically different from acid-curing products. The unmodified type is characterized by its excellent film properties, high chemical resistance, flexibility and good abrasion resistance.

The chemical reaction takes place between binders in the product and binders in the hardener and does so without any emission of formaldehyde. The pot-life of the liquid on the market is generally short, varying from two to six hours, depending on ambient humidity and temperatures.

The curing is slower than for acid-curing products and is not accelerated much by forced drying. However, a polyurethane film is not likely to be affected by high humidity, as are acid-curing products. The ready-for-use mixture of the two-component type has a solids content ranging from 30 to 50 per cent by weight. The film can be formulated to give a high-gloss wet look.

Rubbing and polishing properties are very good. The finish is generally more expensive than acid-curing or nitrocellulose finishes.

Polyurethane products can be used for both indoors and outdoors, depending on the hardener. Good colour retention can also be had by using a more expensive hardener.

Because they dry slowly and have a short pot-life, polyurethane products are not very common in Europe, except for Italy, where the polishing properties are important in connection with high-build, high-gloss treatments. In the United States, their use is also limited since urethanes do not adhere well to the stains and glazes commonly used to achieve the desired design and aesthetic effects.

Several countries, including the Scandinavian countries and the United Kingdom, strictly regulate the application of polyurethane products since they contain free isocyanate, which is suspected to be carcinogenic. To be safe, it is recommended that operators or people working with polyurethane finishes should use face masks.

The conclusion is that the dry film of the polyurethane products can satisfy customers in both Europe and the United States. Its drawbacks will have to be weighed by the rattan and bamboo furniture producers themselves.

Check the following:

Buyer: That the extra cost of polyurethane products is acceptable.

Production: That there is room/capacity to dry the finish and that proper application facilities are available.

Polyester products

Polyester products are composed of unsaturated polyester binder and a chemical monomer such as styrene. The curing can be effected in two ways:

(a) By adding catalyst (peroxide) and then activator (cobalt);

(b) By ultraviolet radiation, in which case a special UV-sensitive photo-initiator is incorporated.

The product can be either two-pack or three-pack. In the three-pack system, a cobalt activator and a peroxide catalyst are added. In the two-pack system, the cobalt activator is included by the finish supplier so only the peroxide catalyst needs to be added.

These products normally have a 100 per cent solids content and offer excellent build. However, to achieve proper adhesion, special stains and sealers have to be used.

Curing is rapid, considering the high solids content, but dust pick-up is a problem. The pot-life is short, from 5 to 25 minutes, which means that two-pack spray equipment has to be used for most industrial applications.

Certain wood substrates contain inhibitors for polyesters; in this case, a sealer coat has to be applied first. The film properties of a polyester coating are excellent: good chemical resistance and a hard surface good for rubbing and polishing.

Polyester products can be either wax containing or wax free. The wax-containing products are normally cheaper but need a lot of sanding to remove the wax surface before polishing or application of a top coat. This is not the case with the wax-free type, which in many cases (for example, vertical surfaces) does not need polishing.

Special precautions, such as the wearing of rubber gloves, must be taken when handling the peroxide catalyst, which attacks the skin. Furthermore, the peroxide component and the cobalt component must never be directly mixed, as such a mixture is explosive. Proper mixing instructions must therefore be followed, and operators must be aware of these methods.

For rattan furniture having complicated shapes and design, polyester products are not suitable. The main use of polyester is found in Italy, on flat panels. If a high gloss is needed, filled treatments or other alternatives, such as polyurethane products, are available.

Ultraviolet coatings

Ultraviolet (UV) products, as already indicated, were an outgrowth of polyester products. Instead of using peroxide and cobalt as separately applied catalyst and activator, a photo-initiator can be added to the polyester product, allowing it to be cured by ultraviolet radiation. This curing is fast (30 seconds) and is especially suited for flat-line application. Basically, the same chemical reaction occurs as when using peroxide and cobalt, but with a far higher reactivity.

The product is one-pack and has a shelf-life of six months. The solids content is 100 per cent. Acrylic binders now often replace polyester binders to give an even shorter cure time with better adhesion to the substrates and a more flexible finish.

The advantages of ultraviolet coatings are obvious in Europe, with its flat-line technology and demands for low solvent emissions, but to the rattan and bamboo furniture industry the fast cure time and high solids content are still of no practical use. Moreover, the products are very expensive, and attempts to modify them for spray application have so far not been very successful. Finally, the curing facilities for pieces such as chairs are still relatively costly. However, the rapid developments for this type of coating could soon change the picture.

As previously mentioned, the increased use of this type of coating is largely in response to the technical demands and environmental restrictions that prevail in Europe. The same is to some extent also true for the last category of conversion coating material, water-based products.

Water-based products

Water-based products can be of the physical drying type or the chemical curing type. Their properties vary a lot, but they generally have longer drying times and poorer film properties than solvent-based products. Development work is presently being done to formulate water-based wood finishes, of the same quality as solvent-based finishes, but so far this work has not been truly successful.

The flat-line industry has adopted water-based products mainly because of restrictions on solvent emissions. Here, forced drying can be used to get fast evaporation of the water and curing of the product.

The water-based lacquers used in the furniture industry are the acrylic emulsions, so called because the wet lacquer consists of small acrylic particles finely dispersed in water.

When the water evaporates, the particles link together, and after application and evaporation a lacquer film is formed.

The water content in the lacquer makes the wood swell somewhat, especially during the first application, and this swelling is not helped by the longer drying time.

It is unlikely that many European countries will accept the import of furniture finished with water-based lacquers because such lacquers give inferior surface characteristics; they are, however, used for domestic production because they comply with solvent regulations. Moreover, savings in respect of insurance costs and the costs of fire-proofing installations are considerable. As the formulations stand today, water-based products cannot be recommended for tropical areas. Owing to the high humidity, it is difficult to control film formation, and problems with regard to swelling and moisture absorption of the substrate are excessive. Finally, the product is thermoplastic, which means that the surface becomes soft at temperatures above 35-40° C. Anyone can imagine what would happen to a 40-foot container stuffed with rattan chairs standing under the sun in a port.

Comparison of finishing materials

The conclusion of this overview is that the rattan and bamboo producer will not get much help from the latest developments with regard to environmentally more attractive ultraviolet and water-borne formulations. Nitrocellulose, acid-curing and polyurethane products are still, therefore, the main choices for surface finishing.

This means that it is of utmost importance to secure an optimum working environment by improving ventilation at the curing or drying stage. This is true in all three cases: solvents from nitrocellulose products, solvents and formaldehyde from acid-curing products and solvents and free isocyanate from polyurethane products.

Table 14 offers guidelines for the use of the three suitable finishes, but the customer's exact needs must of course be ascertained.

Table 14. General guideline for specific finishes, by country or area

Finish	*United States*	*Germany/ Benelux countries*	*Spain/ Italy*	*France*	*Scandinavia*	*United Kingdom*
Nitrocellulose	OK	OK if of good quality	OK	OK	Not accepted	OK
Acid-curing[a]	OK	OK	OK	OK	OK	OK
Polyurethane	OK	OK	OK	OK	OK	OK
Ultraviolet	Not yet formulated for spray application.					
Water-based	Not recommended, because they are thermoplastic.					

[a]Formaldehyde regulations are likely to change.

Table 15 lists the relative advantages and disadvantages of each type of finish. Table 16 rates the technical characteristics of each finish on a comparative basis. Table 17 compares the individual drying times at different temperatures. The chemical and heat resistance of each finish are presented in table 18.

Table 15. Comparison of product properties

Product	*Advantage*	*Disadvantage*
Nitrocellulose lacquers	Simple application, one-pack	Low solids content
	Fast drying	High solvent emissions
	Temperature-independent	Not heat-resistant
	Good wetting of wood	Film is flammable
	Spot repair possible	Poor chemical resistance
	Sanding between coats not necessary	
Acid-curing products	Not flame spreading	Limited application time (pot-life)
	Good chemical resistance	Two-pack in most cases
	Fair light stability	Emits formaldehyde
	Good mechanical properties	Sanding between coats necessary
	Good flexibility	Good drying facilities needed to eliminate the effects of humidity
	Fast drying and good stacking	
	Inexpensive, moderately priced	
	Suitable for flat line application	
Polyurethane products	Good mechanical properties	Short pot-life
	Good surface hardness	Expensive
	Good flexibility	Inferior stacking
	Excellent chemical resistance	Long drying time
	Not flame spreading	
	Good for polishing (wet look)	

Table 16. Comparison of surface finishing product technical properties[a]

	Type of finish					
Property	*NC*	*WB*	*AC*	*PU*	*PE*	*UV*
Solids content w/w (%)	30	35	30–70	30–50	100	100
Catalyst	No	No	Yes	Yes	Yes	Yes
Solids content (%)	20	20	30–60	30–50	50–100	100
Two-day pot-life	Yes	Yes	Yes	No	No	Yes
Curtain coating	+	+	+	+	+	–
Roller coating	+	+	+	+	+	+
Spraying	+	+	+	+	+	–
Curing at 20° C	+	+	+	+	+	N.A.
Curing at 60° C	++	++	++	+	+	N.A.
Stacking	+	–	+	–	+	+
Heat resistance	–	–	+	+	+	+
Durability	–	–	+	+	+	+
Thermoplasticity	No/Yes	Yes	No	No	No	No
Build	–	–	+	+	+	+
Mechanical resistance	–	–	+	+	+	+
Chemical resistance	–	–	+	+	+	+
Yellowing	Fair	No	Fair	Fair	Fair	Fair
Flame spreading	Yes	No	No	No	No	No
Flexibility	–	+	+	+	+	+
Spot repair	+	–	–	–	–	–
Polishing	+	–	+/–	+	+	+
Open/closed grain	o+c	o	o+c	o+c	c	o+c
Shrink-back	Yes	Yes	Yes	No	No	No
Price	Low	High	Low	High	Low	High
Pigmented products	Yes	Yes	Yes	Yes	Yes	(Yes)
Intercoat adhesion	+	Sand	Sand	Sand	Sand	Sand
Suitability for rattan	+/–	–	+	+	–	–
Suitability for bamboo	–	–	+	+	–	–

[a] + = Positive; – = negative; N.A. = not applicable.

Table 17. Times needed for proper drying at three different temperatures for various surface finishes (Minutes)

	NC	*WB*	*AC*	*PU*	*PE*
At 20° C	30	120	60	120	240
At 60° C	10	15	20	40	60
At 100° C	3	10	3	15	30

Table 18. Chemical and heat resistance of different surface finishes[a]

Agent	*Exposure time*	*NC*	*WB*	*AC*	*PU*	*PE*	*UV*
Water	24 hr	3	4	5	5	5	5
Alcohol/water (1/1)	1 hr	3	5	5	5	5	5
	6 hr	2	4	5	5	5	5
	16 hr	2	3	4	5	5	5
Acetone	2 min	1	3	5	5	5	5
Coffee	16 hr	3	4	5	5	5	5
Tea	16 hr	3	4	5	5	5	5
Dry heat	15 min	3	3	5	5	5	5
Wet heat	15 min	1	2	3	5	5	5

[a]The comparison represents an average evaluation based on two coats. Testing was done three weeks after the coatings had been applied. PU products are still therefore the most popular choice for surface finishing. The ratings are as follows: 5 = no damage; 4 = slight change of gloss visible from certain angles; 3 = area affected visible from all angles; 2 = partly dissolved; 1 = dissolved.

Economic considerations

Which category of finish provides the best value for money? The answer to this question depends on two factors: *(a)* the facilities available, i.e. application facilities, drying facilities and production capacity, and *(b)* the buyer's requirements for performance of the final finish.

It is suggested that a list should be made of the producer's demands and the customers' demands, from it to be determined the product that covers all of the customers' demands and as many of the producer's as possible. This is, however, easier said than done, especially because many aspects of surface finishing selection come down to price.

In this connection, care must be taken when comparing prices. Before a fair judgement can be made, the price per percentage of solids applied on the rattan must be known; it would be a mistake to compare prices per litre.

The best comparison figure is the solids content, which tells what percentage of the liquid lacquer applied will be left on the surface once all the solvents have evaporated. Thus, the higher the solids content, the better the filling and the fewer coatings needed. Extra thinner required for spray applications must also be taken into account as the supplied solids content of the materials could be reduced further by the need to make it suitable for the equipment. Efficiency of the equipment is also important in this regard. It should be kept in mind that all solvents evaporate and are, as such, a waste of money as they contribute nothing to the solid film applied on the furniture item.

Table 19 shows how the three types of finishes compare with regard to number of applications and build. It is necessary to separate the clear finishes from the pigmented finishes to facilitate this comparison.

Finishing systems

The finishing products suitable for rattan and bamboo furniture having been discussed and the options with regard to the main export markets evaluated, the more practical side of finishing, i.e. the actual systems and their application, can now be dealt with. In general, three main types of finishing system are distinguished: natural finish, stained finish and pigmented finish.

Natural finishes

A natural finish is relatively easy to handle, and the producer basically has to determine the following in consultation with his customer:

Table 19. Type of product and number of applications to achieve two different builds

	Medium build		*High build*	
Finish	*No. of applications*	*Product*	*No. of applications*	*Product*
Clear				
Nitrocellulose	1-2	Sealer	1-2	Sealer
	2	Top coat	3-4	Top coat
Acid-curing	2	Top coat (ample type)	3	Top coat (ample type)
Polyurethane	1	Sealer (ample type)	1	Sealer (ample type)
	1	Top coat (ample type)	2	Top coat (ample type)
Pigmented				
Nitrocellulose	1-2	Primer	1-2	Primer
	2	Enamel	3-4	Enamel
Acid-curing	1	Primer (ample type)	2	Primer (ample type)
	1	Enamel (ample type)	1	Enamel (ample type)
Polyurethane	1	Primer (ample type)	2	Primer (ample type)
	1	Enamel (ample type)	1	Enamel (ample rype)

(a) The filling of the finish, for example, semi-filled, also known as medium build;

(b) The gloss (reflectivity) of the finish, for example, full gloss (90-100 per cent), semi-gloss (40-50 per cent) or matt gloss (15-20 per cent).

(c) Special requirements with regard to the performance of the finish, for example, colour-fastness, wearability and resistance and formaldehyde emission.

Once the specifications have been laid down, the producer should confer with the finishing department to determine which system would be best from the standpoint of the number of coats needed and the drying facilities available.

Since bamboo, rattan with skin, French web etc. all have a very dense and smooth surface, the finish does not have much chance to adhere to the material. Whenever possible, therefore, the surface should be opened up by sanding lightly with paper No. 320.

Rattan with skin often retains a sticky surface that is due to resinous secretions from the surrounding forest. This surface is rubbed off, prior to sanding, with a mixture of solvents, for instance xylene and Solvesso 100. Good ventilation is essential for this operation.

Overall, it is important to note that a finish that is suitable for rattan is not necessarily the best choice for bamboo and vice versa. The theory is that to achieve the best possible adhesion one must use a product with the least possible inner tension, in other words, a comparatively soft and flexible product. The tension of the film is lowered further by applying as thin a coating as possible. Since for bamboo the finish serves more of a cosmetic purpose than a protective one, that is, it gives gloss and feel, this simple rule should cause no problems.

Generally, it is a good idea to ask the finish supplier whether his products are formulated to suit the specific use, but the following information can also serve as a guideline:

Bamboo, rattan with skin, French web etc.

With nitrocellulose finishes, avoid sealers that are hard and not very flexible. Use lacquers of good quality that are normally formulated with an overweight of alkyd binders and softeners. With acid-curing finishes, avoid special sealers formulated for easy sanding. Use unmodified nitrocellulose or amino-urea/alkyd types. With polyurethane finishes, avoid sealers. Use unmodified nitro types in combination with a flexible hardener, i.e. the expensive, slow-drying type.

Rattan and wicker

If a natural finish is being used, there is often the requirement that the appearance should be close to that of the untreated material and, further, that the finish should have good colour retention.

Special sealers, often known as light sealers, are formulated especially to give the least possible wetting of the wood (colours). They use binders that do not yellow with time and may also incorporate additives (pigment and UV absorber) that delay the natural ageing (colouring) of the substrate.

Such sealers are available for all three systems. If they are used in combination with ordinary top coats, the customer will be assured of a good non-yellowing standard.

In extreme cases the light sealer coat(s) may have to be combined with a non-yellowing top coat. In this case, it is worthwhile noting that most standard finishes themselves yellow slightly after some time. Again, for such special requirements, the finish supplier must be consulted.

Rattan and, especially, wicker may now and then be bleached. Depending on the method used, the finished furniture may appear slightly greenish, or "dead". One way to overcome this problem is to add to the finish approximately 2 per cent of non-grain-raising (NGR) or lacquer stain mixed from black, yellow and orange in, for instance, the following proportion: 31 parts orange, 63 parts yellow and 6 parts black.

The recommended finishing systems for natural finishes are given in table 20.

Table 20. Suggested finishing systems for use with natural finishes[a]

	Substrate	
Natural finish	*Bamboo, rattan with skin*	*Rattan, wicker etc.*
Nitrocellulose	Furniture system No. 1	Furniture system No. 4
Acid-curing	Furniture system No. 2	Furniture system No. 5
Polyurethane	Furniture system No. 3	Furniture system No. 6

[a]Annex I contains details of furniture systems Nos. 1-6.

Stain finishes

Whereas with natural finishes it is a simple matter to determine the customer's requirements in regard to filling and gloss levels, with stained finishes it is likely to be much more difficult to identify the requirements.

Too often there will not even be a sample to work from, and the finish is typically described in very broad terms, with the customer or buyer unable to describe exactly the appearance. The customer will specify mahogany, walnut, white wash or pickled finish, knowing that these are very broad terms and leaving it up to the finishing producer to make a huge collection of samples for him to choose from.

A stained finish is defined as a coloured, transparent finish where the balance between the texture of the wood and the colour contributes to the overall look of the furniture.

With rattan, wicker and bamboo furniture, the treated surface area is quite small compared to that of, for example, a table top. Therefore, when stains on small samples are being discussed, the overall impression of the furniture must not be neglected; if it is, the full piece may turn out to be too dark and muddy.

There are many opinions on which products and procedures should be used to achieve a particular stained finish. Most of them, however, are based on conventional wood furniture and are not necessarily the best suited for rattan and bamboo. Many of the conventional systems can be modified and simplified.

Once the characteristics and application methods of the most common types of stain have been examined, the possibilities can be narrowed down. Two basic types of stains are used, water-based and solvent-based, each of which can be either penetrating or non-penetrating. The most frequently encountered types of stains are compared in table 21.

Type of stain

Water stain: The advantage of a water stain is that it is very easy to apply. Even if the stain overlaps during application, the colour evens out due to the very good penetration. For the same reason, it can be used for flow-coating (pouring), and it does not sweat or bleed from the end-grain. The overall look is very bright and transparent, which underlines the natural texture of the wood.

The disadvantages are the slowness with which it dries, which is even more pronounced in a humid environment, and its excessive grain raising, which occurs when water is absorbed and swells the fibres.

Even though their advantages are numerous, water stains cannot be recommended in eastern Asia, for exemple, for porous materials such as rattan and wicker unless forced-drying facilities are available.

Water stains are also not suitable for bamboo and similar materials as they cannot penetrate or stick to the surface. Finally, water stains cannot be mixed with solvent-based coatings, which are necessary for the staining of skin-covered materials.

Combi stain: A combi stain has all the advantages of a water stain, but the latter's disadvantages with regard to drying time and swelling are considerably reduced by replacing most of the water by ethanol.

The combi stain is highly recommended for complicated designs such as chairs, where ease of application is important. When used with care and applied in not-too-thick, wet coats by brush, spray or pouring, the combi stain is well suited for rattan and wicker. However, it cannot be used for skin-covered substrates since it is not compatible with solvent-based coatings.

Non-grain-raising stain: A non-grain-raising (NGR) stain is in many ways similar to a combi stain, and the solvent combination that excludes all water almost elimi-

Table 21. General comparison of various stains

Category	Base	Type	Method of application: Flow coating dipping	Method of application: Brush wiping	Method of application: Cloth	Method of application: Spray	Drying time: 30° C	Drying time: 50° C	Price level	Mixability with lacquer	Colour-fastness	Resistance to acid
Water-based												
Water stain	Water	Penetrating anilinie dye; no binder	+	+	–	+	5 h	1 h	Low	–	+	+
Combi stain	Water/ ethanol no binder	Penetrating analine dye;	+	+	–	+	1 h	25 min	Low to medium	–	+	+
Non-water-based												
NGR stain	Methanol/ ethanol no binder	Penetrating aniline dye;	–/+	–/+	–	+	15 min	5 min	Medium	+	+	+
Lacquer stain (non-wipe)	Acetate/ aromatic hydro-carbon solvents	Partly penetrating aniline dye/ pigment; small addition of binder	–	–	–	+	10 min	2 min	Medium to high	+	+	+
Wiping stain	Aliphatic hydro-carbon solvents, mineral spirit etc.	Non-penetrating pigment; drying oil/alkyd binder	+ (limited coverage)	–/+	+	+	1 h	30 min	Low	–	++	+/–
Glaze stain	Aliphatic hydro-carbon, mineral spirit etc.	Non-penetrating pigment; non-drying oil/ alkyd binder	–	–	+	(+)	(1 h)	(1 hr)	Medium	–	++	+/–

Note: + = Positive
– = Negative
+/– = Indifferent

nates grain raising as a problem. The same solvent combination does, however, cause the stain to dry almost instantly, which leaves part of the colour on the surface of the substrate and could cause overlapping problems.

NGR stain is more difficult to apply on complicated designs, and it takes some learning and skill to avoid overlapping and colour variations when applying it by spray and brush methods. Owing to the fast drying, NGR stain also tends to blotch when applied by pouring or dipping methods.

NRG stain is recommended for wicker and rattan only if there are skilled operators. It can be mixed with solvent-based coatings for application on bamboo etc.

Penetrating vs. non-penetrating stains

Lacquer stain (non-wiping): The advantages of a lacquer stain are its fast drying time and its ability to almost seal the wood while at the same time giving colour. Because of this it is best suited for covering up variations in the colour of the substrate, and it can uniformly stain even large surface areas.

For the same reasons, it is not suitable for complicated designs: it can give uneven colouring and some loss of transparency, mainly because its small proportion of binder and some pigments tend to stay on the surface of the wood. Lacquer stain is not suited for pouring as it tends to blotch and bleed from end-grains. It is, however, very suitable for tinting solvent-based coatings and can thus be used for finishing skin-covered substrates. A lacquer stain should not be applied directly to bamboo and related products as it may cause inferior adhesion.

Wiping stain: The composition of a wiping stain differs considerably from that of the stains previously discussed: it contains finely ground pigment, slow-drying solvents and a fairly large proportion of resinous binder. It is equally suited for dipping, brush and spray application but requires wiping to remove excess pigment and to ensure uniformity.

Again, the main use is on larger surfaces, where a patinated, antique look is required. The wiping stain can be manipulated to various degrees of clarity depending on how thoroughly the stain is wiped. For more complicated designs, the wiping stain is of less interest. Generally speaking, it can only give a limited colour intensity and if not wiped it will appear muddy and painted.

The stains mentioned so far can normally produce the same look on small surfaces and with good overall clarity. Wiping stain should not be used if solvent-based coatings are chosen; its adhesion to bamboo and similar materials is poor, and this can cause the subsequent coating to chip in use.

Glaze stain: A glaze stain is mainly used over other base stains and between lacquer coats to add depth and richness to the finish. Glaze enhances the dimensional effects as they are worked and highlighted after brush or spray application.

The highlighting is commonly done with sandpaper, steel wool or a synthetic scouring pad. Different grades of abrasive are used to achieve different effects. The technique requires a great degree of skill and artistic ability.

A glaze is normally used on show-pieces, where it is possible to obtain a contrast between, for example, the bindings and the main surface of the furniture. It is always used on a coated surface, never directly on the substrate, because doing so will cause a muddy appearance and adhesion failures.

Any application of wiping glaze or stain will interfere with adhesion between the film-forming coatings. Leaving excess glaze material between the finishing material may result in easy delamination. Whenever possible, the surface to be glazed should be sanded lightly. Much care is therefore required when a glaze is used, and it is best to try to avoid its use.

Water, combi and NGR stains have one advantage in common over the lacquer (non-wiping), wiping and glaze stains. The former are all based on generally the same type of dye and do not contain any binder, which means that they are of the penetrating type. By virtue of the penetration, the colour is evenly distributed in the substrate; the colour tone impression is very uniform and does not change much when viewed from different angles and in different lighting. This is not the case with non-penetrating stains, which creates a problem when colours and shades are discussed with the customer.

Adhesion of stain to finish

The different finishes have different adhesibility in respect of the above-mentioned stains. This is shown in table 22, where three different finishes are related to five different stains. As can be seen from the table, a glaze stain performs very poorly with polyurethane finishes, and the wiping stains have to be treated with care.

In very general terms, the stains just described can be used on different substrates, as shown in table 23.

Application of stains

Brush: Water and combi stains are suitable for application on rattan. Use soft, short-haired brushes appropriate to the size of the surface to be stained. The stain must be stored in plastic containers.

Spray: Water, combi, NGR and lacquer stains are suitable for direct spray application on rattan and wicker. Conventional, pressure-feed or airmix (air-assisted) airless equipment can be used. Generally, air pressure of 1.7-2.1 bar is used at the gun and fluid pressure of 0.5-1.0 bar in the material tank.

Table 22. Adhesion of finish to stain

Finish	*Water stain*	*Combi stain*	*GR stain*	*Wiping stain*	*Glaze stain*
Nitrocellulose	Good	Good	Good	Fairly good	Fairly good
Acid-curing	Good	Good	Good	Fairly good	Fairly good
Polyurethane	Good	Good	Good	Poor	Poor

Table 23. **Suggested stains for various substrates**

	Substrate	
Stain	*Rattan and wicker*	*Bamboo and similar products*
Water stain	Generally OK, provided curing facilities are available	Cannot be used
Combi stain	Generally OK	Cannot be used
NGR stain	Generally OK, but needs skilled operators	Can be used for shading/ tinting but not directly on the material
Lacquer stain	Some limitations; needs very skilled operators	Can be used for shading/ tinting but not directly on the material
Wiping stain	Limitations in colour intensity, application	Cannot be used
Glaze stain	Can be used with much care between lacquer coats	Can be used with much care between lacquer coats

For assisted airless equipment, a material pressure of 2 bar and an air pressure of 1.5 bar are suitable.

NGR and lacquer stains can be applied to bamboo and other skin-covered products but must be mixed with lacquer prior to application in a ratio of 1:1 to obtain maximum adhesion.

When used in combination with acid-curing products, the stain (dye or pigment) must be acid-proof. If used in combination with polyurethane products, the stain should not contain alcohols since these tend to absorb water and water reduces the pot-life of polyurethane products considerably.

Pouring: Water, combi and NGR stains can be used for colouring wicker and rattan. Lacquer stains are not suitable due to their tendency to bleed from the end-grain.

To avoid excessive absorption and swelling, the stain is applied by pouring, not immersing, and the objects are placed on a grating fitted over a plastic or galvanized vat with a sloping bottom. The lower end of the vat is fitted with a drain to collect stain for recirculating.

In use, solvent will evaporate and the strength of the colour has to be adjusted from time to time. If NGR stains are used, this must be done more often. The objects are wiped with clean cloths immediately after pouring to avoid discoloration.

Wiping and glaze stains are not applied by pouring as their use is more specialized, as previously outlined.

The rattan/wicker producer should base production of stained furniture on the combi type of stain because of its ease of application and versatility. For the bamboo producer, the choice is between NGR and lacquer.

Colour

Colour matching often has to be done in close cooperation with the matching paint producer, but most of the preliminary work probably has to be done by the producer himself. Furniture producers must cooperate with a reliable finish supplier who is able to supply not only the type of stain needed but also a specific and consistent quality, which makes it possible to reproduce any colour at any given time.

The following qualities are basic requirements for stains:

(a) The colour (shade) must be uniform;

(b) The strength of colour must be uniform;

(c) Dyes and pigments must be colour-fast;

(d) Dyes and pigments must be acid-proof;

(e) If acid-curing products are used, pigments must be non-bleeding.

Just as when cooking food, to obtain the best results one has to use good raw materials, be well organized and follow certain well-established rules.

The technical aspects of the raw materials, i.e. the stains, has already been outlined. To be well organized means that a certain stock of basic stain colours, such as brown, red, yellow, black, orange, blue, green and a colour reducer, plus a scale or measuring cup for accurate mixing, must be on hand. At the same time a record should be kept of how the stains were mixed, in simple recipe form.

The well-established rules are few but very important. Use as few basic colours as possible to match a given colour. In the case of a wood colour (walnut, mahogany etc.), it is a good idea to start with a neutral brown and then add basic colours as required. Finally, the strength of colour is adjusted with a reducer to fit the actual method of application.

The same procedure is used for pastel colours, but here the base is white. If fine adjustments such as the antique look are required, these are achieved with glaze after application and sanding of the first top coat.

The finishing coat is selected by the producer and the customer along the guidelines discussed earlier. Formulas for selected shades of combi (jet stain) and nitrocellulose stains are provided in annex II. This is based on table 24, which recommends the finishing systems that should be used on top of such stains.

Table 24. **Suggested finishing systems for use with stains**[a]

	Substrate	
Stain finish	*Bamboo, rattan with skin*	*Rattan, wicker etc.*
Nitrocellulose	Furniture system No. 7	Semi-filled surface furniture system No. 10
Acid-curing	Furniture system No. 8	Semi-filled surface furniture system No. 11
Polyurethane	Furniture system No. 9	Semi-filled surface furniture system No. 12

[a]Annex III contains details of furniture systems Nos. 7-12.

Pigmented finishs (opaque)

Compared to stain finishes, a pigmented finish (often called an enamel finish) is relatively simple to handle. Like a natural finish, it is basically a matter of determining the following, in consultation with the customer:

(*a*) Required filling of the finish: semi-filled surface (medium build, often silk matt) or filled surface (high build, often glossy, wet look);

(*b*) Required gloss of the finish: full gloss, semi-gloss or matt gloss;

(*c*) Any special requirements with regard to the performance of the finish, such as wearability or formaldehyde emissions;

(*d*) Colour/shade to be applied: see annex V, which gives formulations for typical pigmented finishes.

For points (*a*) to (*c*), it is a question of choosing the type of product (nitrocellulose, acid-curing or polyurethane) that is more suited for the finishing department and the substrate, using guidelines for bamboo and similar products. In the pigmented system, primers have the same disadvantages as sealers in the clear system.

The colour can often be selected from any available colour card since the pigmented finish is a full covering treatment and there is no need for a balance between the texture of the wood and the transparency of the colour.

The preferred pigmented finishing systems are given in table 25, from which it will be noted that a nitrocellulose finish is not included for the wet look (gloss) system simply because shrink-back makes it almost impossible to obtain a stable build.

Table 25. Suggested finishing systems for use with pigmented stains[a]

	Substrate	
Stain	*Bamboo, rattan with skin*	*Rattan, wicker etc.*
Acid-curing	Furniture system No. 13	Semi-filled surface furniture system No. 15
Polyurethane	Furniture system No. 14	Semi-filled surface furniture system No. 16 or 17
Acid-curing-based wet look		Wet look surface furniture system No. 12

[a]Annex IV contains details of furniture systems Nos. 13-17.

As was suggested for stains, a range of basic pigmented finishes can be stocked to allow for different colour and shade applications.

Preparation of the lacquer or enamel before use

Before a lacquer or enamel is used it must be carefully stirred as pigments and matting agents may have settled during storage. If stirring is incomplete, there is a risk of colour and gloss variations. Shaking or rolling the pail is not a satisfactory form of mixing. It is better to have a proper electric stirrer of the correct size for the amounts used.

It is often more convenient to mix the products directly in a pail. If, however, the ready-mixed lacquer is kept in the pail, there is a risk of discoloration with acid-curing types after a day or two because the hardener will attack the metal of the pail. The mixture can become somewhat red-brown and will discolour light woods. To avoid discoloration, the acid-curing mixture should be kept in a suitable plastic container after mixing or use.

The lacquer/hardener/thinner can be mixed using a litre measuring vessel or by marking the mixing ratio on a measuring stick calibrated to the size of pail used. The latter method offers the best security against faults. However, the mixing container must have the same measurements at top and bottom, i.e. it must be perfectly cylindrical.

If, for instance, the mixing ratio of lacquer/hardener/thinner is 10:1:2, a mark is made on the measuring stick at 10 cm for the lacquer, another mark at 11 cm for the hardener (+1 cm) and, finally, a mark at 13 cm for the thinner (+2 cm). These markings can be adjusted according to the height of the container used.

The addition of excess hardener does not reduce the drying time. To the contrary, it can make the lacquer film brittle, causing crazing or exudation on the surface. If more rapid drying of the finish is desired, this should be discussed with the finishing supplier.

The finishing procedure

To obtain a satisfactory result, the following rules should be observed during finishing:

(*a*) The best temperature for the application of lacquer and enamel is 20-28° C;

(*b*) Viscosity should be adjusted in an appropriate measuring cup;

(*c*) Only the recommended thinner should be used. If cheaper thinners are used they may alter the drying rate of the finish;

(*d*) Matt lacquers should be applied in an even coat to obtain a uniform surface;

(*e*) When spraying, it is essential to adhere to the suggested equipment spraying pressure to avoid surface defects. The oil/water separating unit on the compressed air line should be emptied at least once a day to prevent water ingress into the finish;

The air humidity should be kept below 70 per cent and the moisture content of the substrate should be 7-11 per cent.

Careful intermediate sanding between coats is required for acid-curing and polyurethane finishes. Chemically curing products are very resistant to solvents. To secure good adhesion between coats, sanding ought to be done the same day as the overcoating takes place, especially if the curing is at elevated temperatures.

Important technical terminology

Viscosity

Viscosity refers to the liquid thickness of the material, i.e. its consistency at a particular temperature. Thick liquids have high viscosity and thin liquids have low viscosity at the same temperature.

Viscosity is determined by the liquid's percolation time in a special measuring cup. To ensure the constant viscosity of the liquid, it is best to try and measure it at a constant temperature. The cup is filled and overflow removed before starting the percolation.

A thermometer is needed to measure the temperature of the paint. Ideally, the temperature should be 20° C but in any case as constant as possible. There are three types of measuring cups with which to measure viscosity: the Ford cup No. 4, the DIN cup No. 4 and the Frikman cup No. 4. All three measure the percolation time, in seconds, for 100 cc of the liquid (a stopwatch is also needed). This percolation time should be within a predetermined range. If it is too long, solvent must be added; if it is too short, more material must be added.

Solids content

The solids content is the percentage amount by weight of dry film left after full curing of the lacquer. It is usually measured after overnight evaporation of the solvent in an oven. However, if testing equipment is not available, the manufacturers' figures are usually reliable guidelines.

Specific gravity

Specific gravity is the weight of a certain volume of a product, in g/m^3, kg/m^3 or kg/litre.

Pot-life

Pot-life is the usable time for two-component products after hardener has been added. Only that amount of material should be mixed that will be used up before the pot-life expires.

Determination of gloss

Gloss is quantified by measuring light reflection with a Gardner 60° gloss-meter. To test gloss, the product is applied on glass and is exposed to light at an angle of 60°. A photocell measures the amount of light reflected. On absorbent and uneven surfaces, gloss is reduced. Different levels of reflectivity are often described in the following (or similar) terms:

Reflectivity (%)	*Descriptive term*
1-15	Dead matt
16-29	Matt
30-50	Silk matt
51-90	Silk gloss
91-100	Glossy, wet look

Covering capacity

Manufacturers' indications of covering capacity, stated in net g/m^2, should be considered average values. They serve as a guideline on how much area the finish will cover, but this is a nominal figure: gross consumption is very much dependent on the method of application as the waste will be different in each case, with average values as follows:

Method	*Waste %*
Spraying	30-60
Roller coating	2-10
Curtain coating	2-5
Immersing	2-5

Thinner

Thinner serves primarily to adjust the viscosity of the finishing material, allowing it to be used with the application equipment available. It is often assumed to be unimportant because it normally evaporates completely, but this is an unwise assumption.

The solvents used to formulate the thinner must be selected not only to achieve a good dissolution of the binder in the solvent, thus giving the finish optimum flow and application characteristics, but also to achieve a well-defined evaporation rate that gives the best possible film formation.

Excessively rapid evaporation leads to quick surface settling and a high risk of blistering. Slow evaporation leads to improved flow but may also increase the tendency of the film to sag or run. A thinner is therefore normally a mix of fast-, medium- and slow-evaporating solvents, giving the correct balance between these characteristics.

No single solvent can dissolve all types of binders; indeed, the dissolving ability of a solvent is often limited to one or two types. A solvent that does not dissolve a particular binder is regarded as a diluent, and it may serve to improve the characteristics of the finish by, for instance, improving drying through balanced evaporation. However, if too much the non-solvent or diluent is added, the binder will separate, causing a cloudy, whitish appearance. Such non-homogeneous coatings do not work correctly.

Therefore, a thinner must be formulated with several distinctly different solvents, ensuring that each finish has the intended characteristics. Most film problems can be traced to the use of inferior or unsuitable thinners; often the customer tries to save money by using a locally available, cheaper thinner instead of the thinner prescribed by the manufacturer.

The best practice, in the view of the writer, is to always use the recommended thinner in the specified amounts and to consult the supplier before using a locally available thinner.

Hardeners

Acid hardeners

An acid hardener acts as a catalyst, that is, it initiates a chemical reaction without participating in it. The dry film is a network of large and small molecules. The reaction starts when the concentration of hardener in relation to binder reaches a certain level as a result of solvents having evaporated after application of the finish. Good ventilation is therefore needed for fast and correct curing.

Once the chemical reaction has started, the mixed finish must be used within a given time. This is called its pot-life. After this time the mixture starts to gel and eventually becomes too thick to use.

Pot-life can generally be extended considerably by storing the mixture at cooler temperatures or inside a refrigerator. In such an instance, the cooling equipment must be of the flame-proof type and suitable for use with solvents.

It is good practice never to use a mixture that has been stored overnight without first adding new material in the ratio 1/3 old material to 2/3 new.

The hardener ratio must always be strictly observed. Too much hardener will reduce film resistance and discolour light woods and may cause acid sweating on the surface of the dry film. In electrostatic spray application, even a small surplus of hardener will reduce the wraparound effect considerably.

The best practice is to use correct levels of hardener at all times.

Polyurethane hardeners

A polyurethane hardener has other characteristics. It becomes part of the finish. Since it reacts with water and alcohols, no thinner containing these agents may be used (they would interfere with the reaction of the hardener partly or totally, and the film might harden). It should be noted that the pot-life of polyurethane hardener mixture is limited and cannot be prolonged much by storage at low temperature.

It is also necessary to repeat earlier comments about polyester finishes and the associated catalyst and activator, which are peroxide and cobalt. These two must never be mixed together as they can be explosive. Each should be mixed with the polyester and not with the other.

This information demonstrates the importance of using the correct mixing operations and specified quantities. All workers handling chemicals should have this information explained to them in great detail.

Finishing equipment

Introduction

A great variety of methods are used to apply finishes but only a few are suited for the application of wet coats to the complicated shapes that are characteristic of rattan and bamboo furniture.

Brushing and dipping are two possibilities, but they are generally not of interest because they are too slow and they form inferior film. This, of course, does not apply to stains, where such methods are frequently encountered. Roller and curtain coaters cannot be used as they are suited only for flat surfaces. A single option is left, namely, spraying.

A spray gun is a simple and versatile tool in practised hands and allows the operator to apply the finish to all sides/surfaces in one pass, no matter what the design of the furniture.

The key pieces in any spray equipment are the spray gun and the compressor, which produces the air needed to atomize or convert the finish into tiny droplets. The design and function of the spray gun vary according to how the material is supplied to the gun. Two main systems may be distinguished: compressed air atomization with conventional spray and high-pressure feed with airless spray.

Within the two systems there are different designs. The choice of spraying equipment is often based on criteria such as quality of the application and material consumption, but other factors, such as material control, life of the equipment, price, maintenance and energy consumption, should also be considered.

The principles, operation, advantages and disadvantages of the different systems are described next.

Air atomization, conventional spray

Principle

There are three feeding systems that can be used with a conventional spray gun, as shown in figure 124 and table 26:

(a) Gravity feed. A cup is mounted on top so that the finish pours by gravity into the spray gun. This system can handle high-viscosity materials, but it is difficult to spray complicated designs as the gun cannot be turned sideways or upside down. The material supply is limited by the small size of the cup, and the system is mostly used for spraying the sealer coast and for stain touch-up operations;

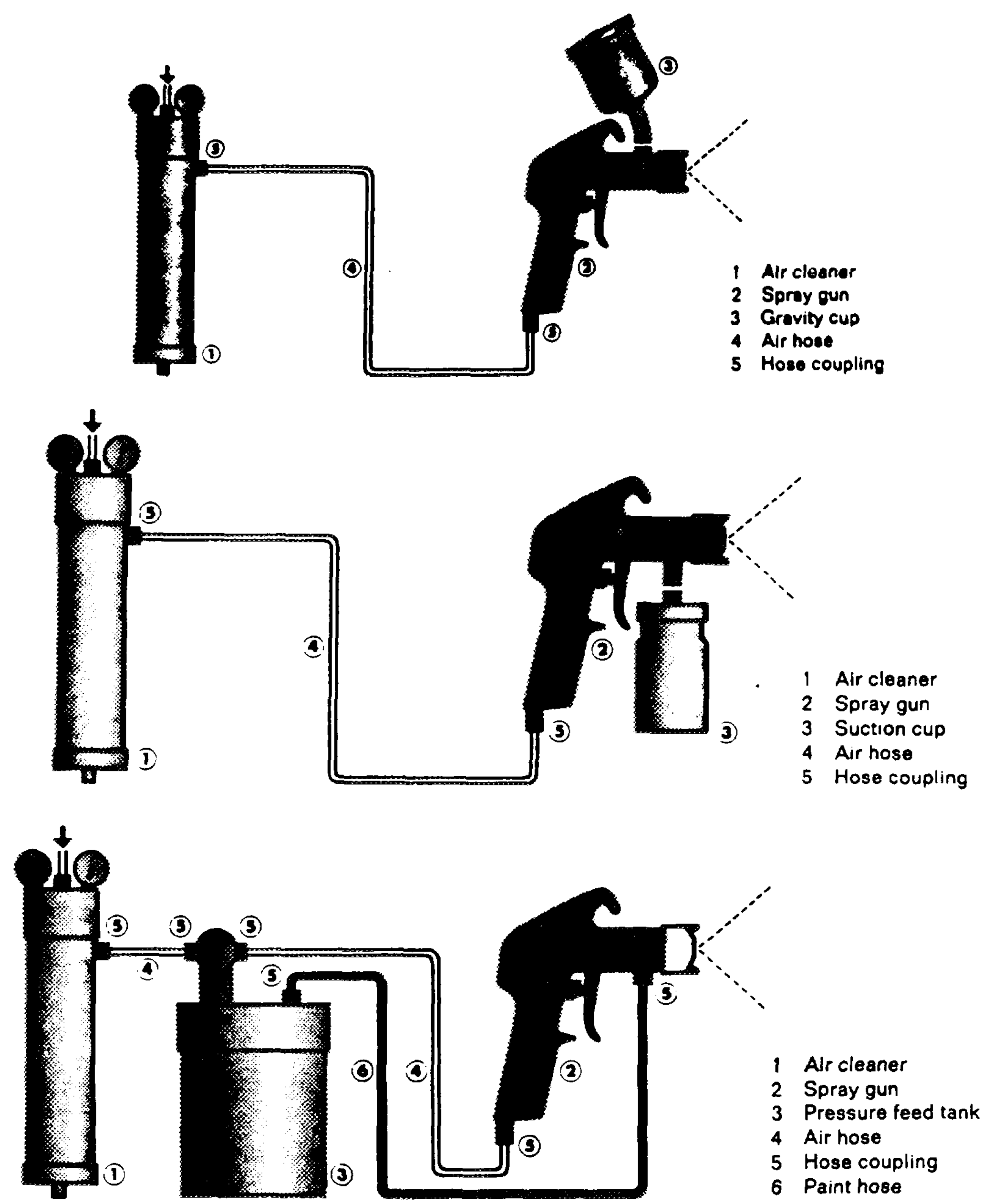
(b) Suction feed. The cup, which holds approximately one litre, is mounted beneath the gun, from which a suction pipe is directed into the cup. When triggered, a slightly negative pressure will suck up the finish material and pass it on to the nozzle. Here, too, the material supply is limited and there is not much room for tilting the gun. The system is mainly suited for smaller staining jobs;

(c) Pressure feed. An extra hose (fluid line) is connected to the gun and the finishing material is led through the hose under pressure either from a pressure pot or a pump driven by compressed air. A greater volume of material flow, freedom to move the gun through any angle and the lighter weight of the gun make this system more suited for industrial application.

Table 26. Suggested use of three feed systems for conventional, low-pressure spraying

Type of feed	*Use*
Gravity feed (paint cup mounted on top of the spray gun)	Paints of low and medium viscosity Frequent colour changes
Suction feed (paint cup mounted below the spray gun)	Low-viscosity paints Frequent colour changes
Pressure feed	High-viscosity materials Large amounts of paint of the same colour High capacity

Figure 124. Spray guns with, from top to bottom, gravity feed, suction feed and pressure feed

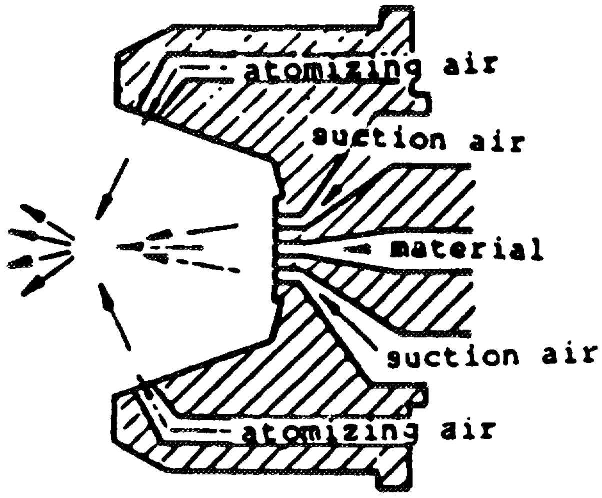


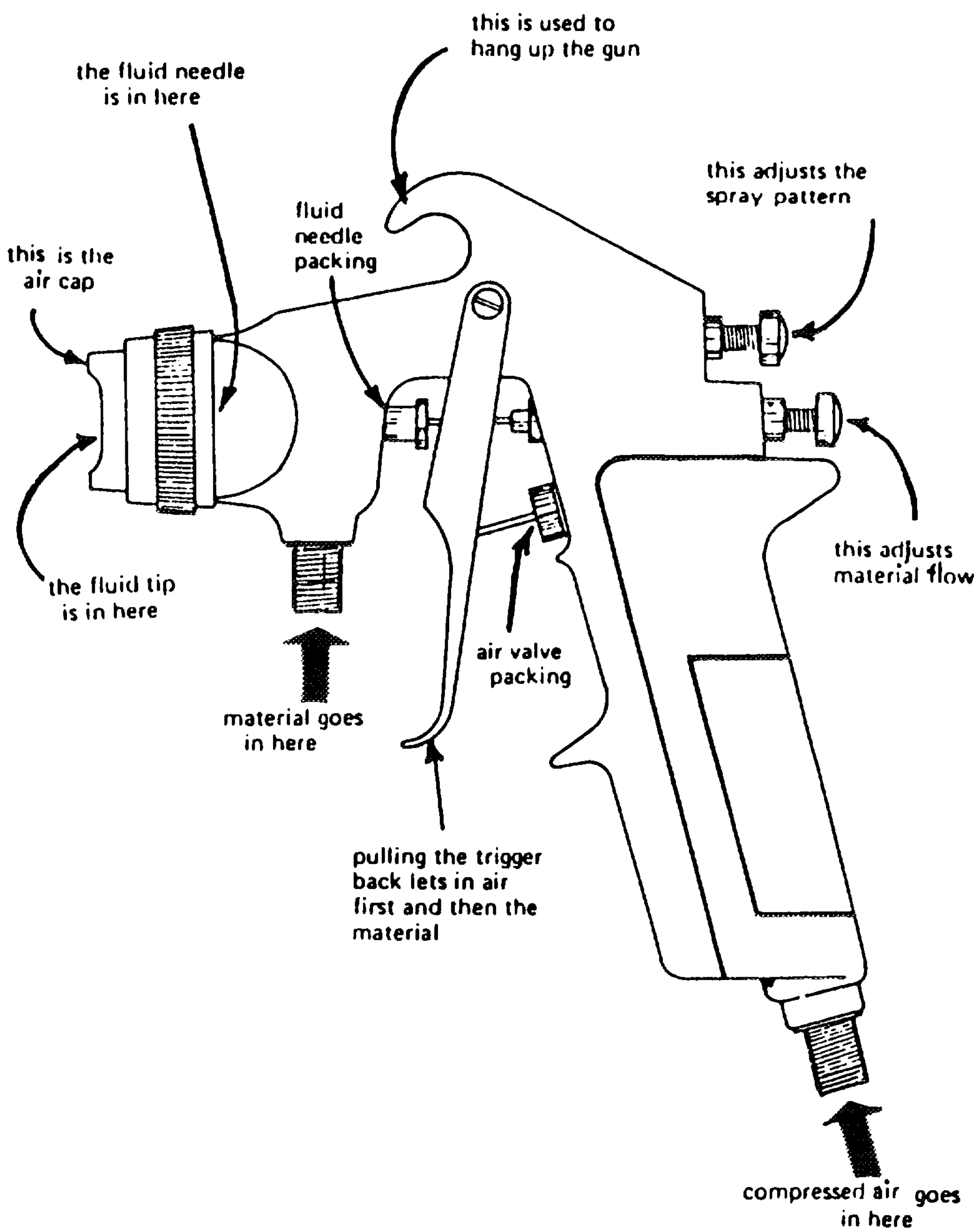
All three feeding systems make use of the same type of air-atomized spray gun that is shown in figure 125. When the gun is triggered, compressed air can flow through an air nozzle. The fluid needle is withdrawn from the fluid nozzle and finishing material is discharged in a liquid stream. The stream is immediately surrounded by a hollow column of compressed air, which is emitted from the center orifice of the air nozzle. The air converts the liquid stream to small droplets and forces the particles forward. Additional air is fed through holes in the air cap, which breaks the finish into a fine mist—the more holes, the finer the mist—and eventually two currents of air blown through horns on each side of the air cap mix with the mist and propel it outwards, away from the gun to the surface. This is necessary to obtain uniform application.

Operation

The spray gun is adjusted with two controls, one for material flow and one for air, which decides the size of the spray fan (normally about 15 cm). The basic rule with conventional equipment is to use the lowest pressure that will give a satisfactory spray pattern. A typical working air

Figure 125. Conventional spray gun





pressure is 2-2.5 bar for atomizing and 1-1.5 bar in the pressure pot.

As a precaution, the air supply should always include a pressure regulator plus a moisture and oil trap (the compressor produces heat while the air deposits water by cooling, and the traps remove both). An air drier fitted to the compressor is the optimum solution. The spray gun is operated at a distance of approximately 25 cm from the workpiece. Some guidelines for the correct operation of conventional air atomization spraying are depicted in figure 126.

Advantages and disadvantages

The main use of an air atomization system is for small to medium-size spray jobs or for repair work or touch-up where frequent changes of colour and material occur. The system has several advantages. It gives a very fine finish and fine particles. Versatile, it is usable with any coating material, from stain to spray putty. In addition, it is simple to operate, with the size and shape of the spray pattern adjustable, and it is fast, permitting the coverage of any shape.

It has disadvantages as well, however. Air consumption is high (150-600 l/min). The atomized particles hit at higher speeds and bounce back. There is a high risk of dry spraying, especially on complicated designs. It has a low transfer efficiency and produces a great deal of turbulance around the spraying area.

Moreover, it presents a health hazard from inhaling overspray (solvent content). The booth generally needs a better exhaust system than a booth for airless spraying.

High-pressure feed, airless spray

Principle

The finish material is moved by a pump through a high-pressure hose to the spray gun (figure 127). When the finish under pressure leaves the fluid tip, the sudden decrease in pressure makes the finish atomize, or "explode". It is much the same phenomenon seen with a simple garden hose: the more the handle is squeezed, the more the pressure builds up and the finer the water is atomized.

The feeding system is usually pressurized by a hydraulic pump or an air-driven pump. A common ratio is 30:1, which means that the pump can increase the fluid pressure up to 30 times the air pressure used to drive the pump. Fluid pressures for furniture finishes are typically 70-80 bar.

Unlike the conventional system, the airless gun has no air passage, only a fluid passage through a nozzle closed by a needle. The gun is either full on or full off, and atomization is controlled by the pump pressure and the size and shape of the nozzle. Therefore, selection of the proper nozzle and fluid pressure is essential. High-pressure nozzles are often made of tungsten carbide and are secured in a protective steel body. A retaining ring for nozzles is supplied together with every high-pressure spray gun. Each nozzle has a certain designation. For example, the designations for spray guns and self-cleaning nozzles used by Altas Copco are built up in accordance with the following example: 6803 26 65, where the first four digits indicate the equipment for which the nozzle is suitable (in this case, a high-pressure spray gun), the next two digits indicate the equivalent orifice diameter (0.026 in.) and the last two digits indicate the spray angle (65°).

When choosing nozzle size, start from the paint material to be sprayed; find a suitable orifice diameter in the following table and choose a nozzle, bearing in mind the desired capacity and spray width:

Material	*Nozzle diameter (0.001 in.)*
Cellulose lacquers, oil varnishes, synthetic varnishes	11, 13, 15, 18
Hardening lacquers	11, 13
Surfacer, primer	11, 13, 15
Anti-corrosive paint	11, 13, 15, 18
Anti-corrosive paint, thixotrope	18, 21
Asphalt aluminium	18, 26
PVAC, PVC, SB-latex	15, 18

Airless spray can pass very high volumes of finish, always at high pressure, to produce good atomization. Thus, the orifice of the nozzle is very fine when adjusted for smaller surfaces, and it can block up easily. The lack of forward velocity and air for the finish usually gives coarser particles and the distance of the gun from the work must be carefully controlled. However, these same features give almost no bounce-back off the substrate, and the airless system is generally excellent for spraying into corners and onto large surfaces, where it is possible to apply a comparatively thick coating for good flow.

Advantages and disadvantages

The main use of high-pressure spraying is where there is a premium on working speed and good surface coverage over larger areas. The system has some advantages. It saves on material: overspray and bounce-back are minimal. Also, it is labour saving, as a single application is sufficient.

However, it has a number of disadvantages:

(a) Lack of flexibility: on-line gun adjustments are limited owing to the fixed nozzle;

(b) High nozzles clog easily;

(c) High compression can cause the finish to "boil". If the solvents evaporate too quickly, air is caught in the film, resulting in an irregular surface;

(d) Difficult to control application on complicated designs;

(e) Not suited for stain application.

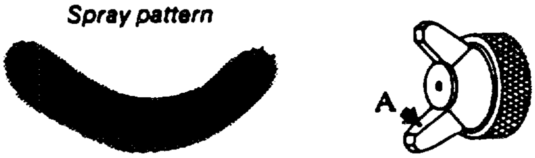
Airmix (or air-assisted) airless system

A more recent type of spraying equipment gives the airless system some of the advantages of the conventional system without sacrificing the former's good qualities of

Figure 126. Guidelines for the operation of a conventional spray gun

CORRECTION OF FAULTY SPRAY PATTERNS

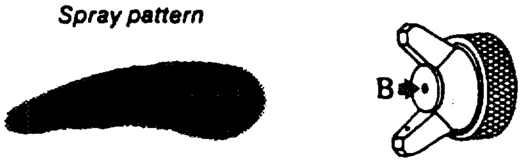
Spray pattern



Reason
Dried material in the side nozzle hole (A) prevents the air flow. This results in the air flow from the clean hole driving the pattern towards A.

Remedy
Dissolve the dried material with thinner. NOTE! Do not stick a pointed metal object into the hole!

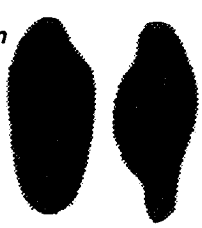
Spray pattern



Reason
Dried material around the outside of the liquid nozzle (B) prevents the flow of atomizing air through the central hole in the nozzle. This spray pattern can also depend on a loose fitting air nozzle.

Remedy
If the dried material is the cause, remove the air nozzle and remove the material with a cloth dipped in thinner. Make sure that the air jet is fitted firmly.

Spray pattern



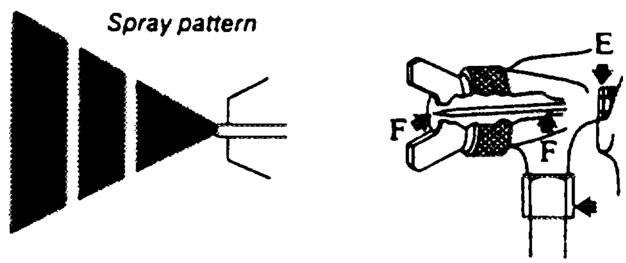
Reason
A spray pattern that is concentrated to the middle or has a grainy surface (non-atomized material) shows that the atomizing air pressure is insufficient.

Remedy
Increase the pressure of the air system. Correct the air pressure in accordance with the instructions.

Spray pattern

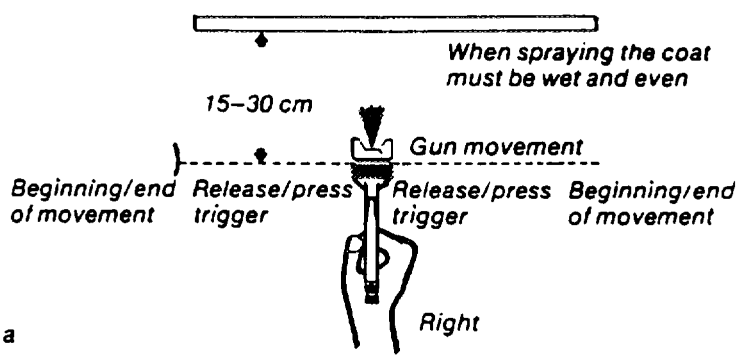
Reason
A spray pattern that is divided or in the shape of an "8" is usually caused by (1) excessive atomizing air pressure or (2) a spray width that is excessive in relation to the amount of varnish

Remedy
Reduce the air pressure if it is too high. If (2) is the reason, increase the varnish supply and reduce the spray width.



Reason
(1) The seal around the needle valve for the material has dried out and the air can thus flow into the liquid duct.
(2) The material nozzle is loose and dirt has collected between the nozzle and the seat.
(3) The material hose is loose or defective.

Remedy
If (1) is the reason, tighten the nut (E). If the seal is poor, replace it.
If (2) is the reason, remove the material nozzle (F) and clean its base and the seat with a cloth dipped in thinner.



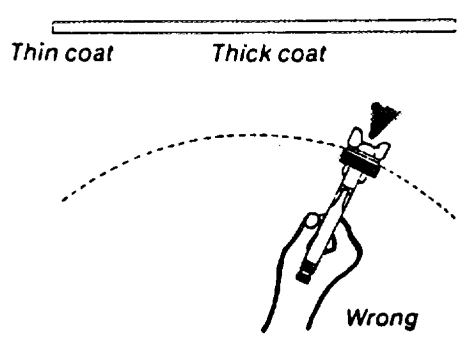


Figure 126. *(continued)*

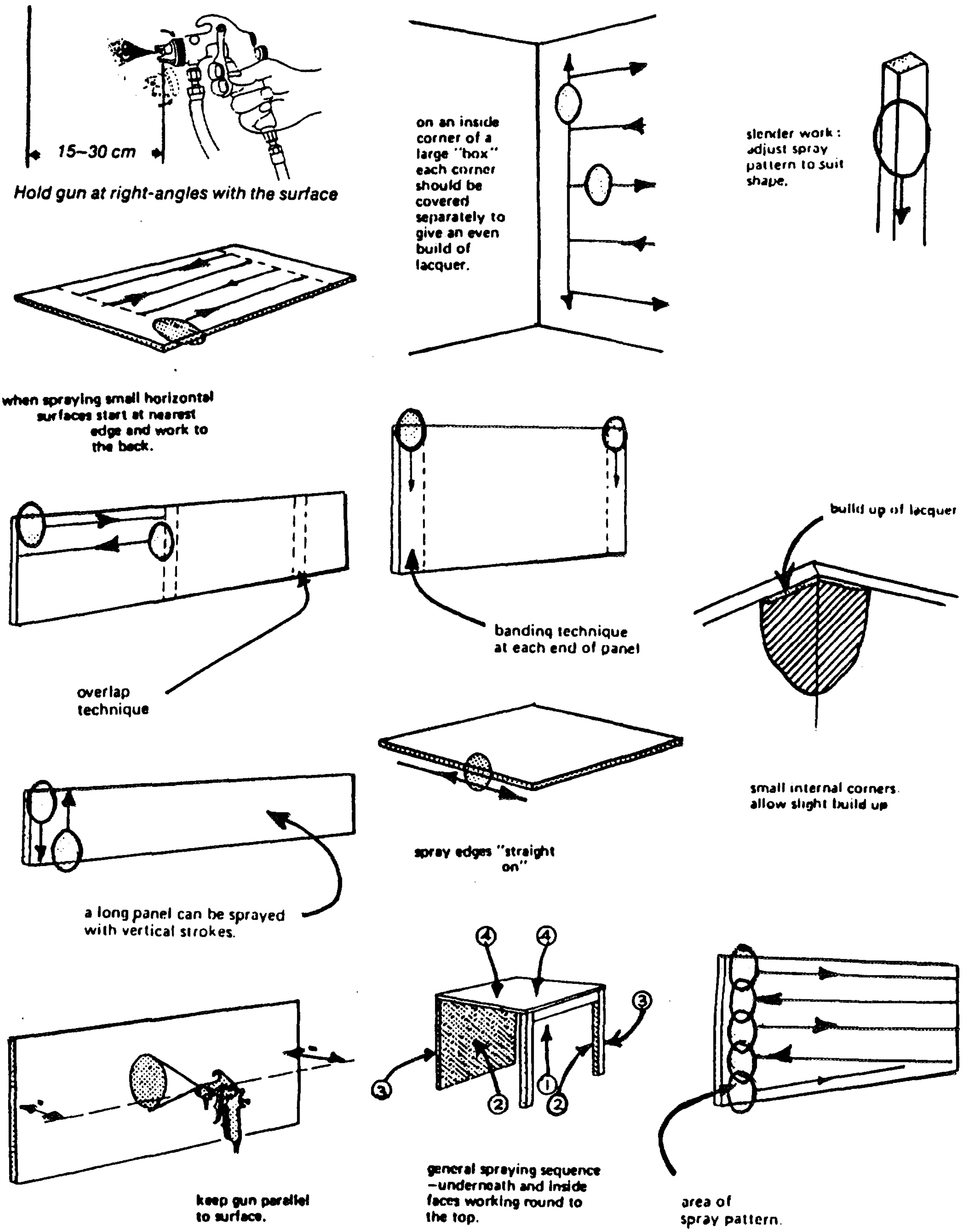
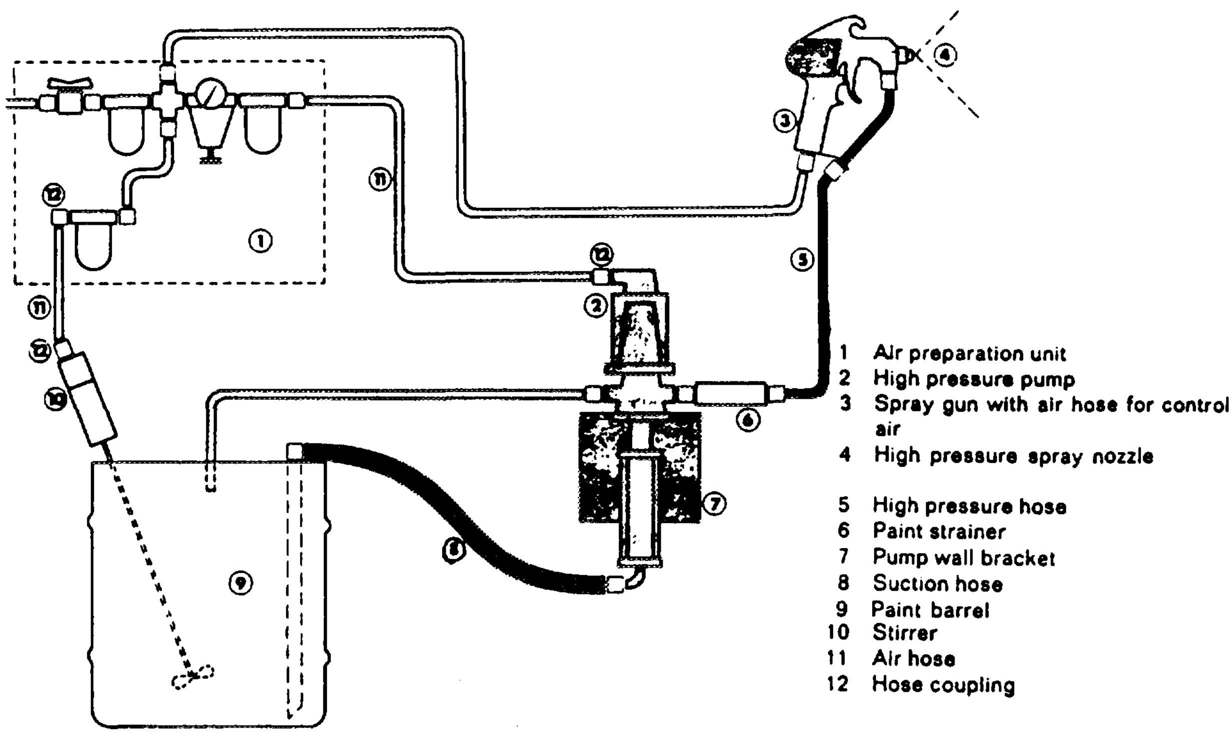


Figure 127. High-pressure feed, airless spray gun



minimal overspray and bounce-back. The newer system, which is of the low high-pressure type, is generally known as the airmix, or air-assisted, airless system (figure 128). It is as easy to use as a conventional spray gun. It sprays normal coatings (single-component paints and lacquers) and has a very high transfer efficiency.

Principle

This system uses a lower fluid pressure, 60 bar, than the high-pressure airless system to produce atomization and has a forward stream of air to assist in maintaining the velocity of the finish (hence the terminology "air-assisted" or "airmix").

With airless spray at low pressure the spray fan normally splits up, resulting in a spray pattern marred by "rat tails". By combining the airless nozzle with an air cap, as in the conventional system, this rat tail phenomenon can be controlled, allowing the best features of both systems to be combined.

Carrying out high-pressure spraying at a somewhat lower pressure and assisted by air makes it easier to control the material flow, reduces air consumption (25-100 l/min) and uses lower air pressure (0.5-2 bar) than conventional spraying.

Advantages and disadvantages

The main use of the airmix system is for the industrial application of finishes to large, plane surfaces and smaller, complicated designs. It has a number of advantages: easy working procedure, good material flow; suitability for plane surfaces as well as complicated designs; and little bounce-back and waste. A disadvantage is that the spray fan and material flow are adjustable only within narrow limits. Larger adjustments required a change of nozzle.

Electrostatic spraying system

Principle

An electrostatic spraying system can utilize the principles of the conventional as well as the airmix/airless system. During atomization, the finish material is charged to high potential (75-90 kV) and will be attracted by any object of opposite polarity. In practice, the finish is negatively charged and the object to be sprayed is connected to a positive earth.

The finish is attracted by the earthed object so effectively that the finish wraps around even the back of curves, such as those of chair legs; the transfer efficiency is very high, and overspray is limited (figure 129).

Generally speaking, the electrostatic spraying system has not proven to be very successful for furniture, mainly because wood is a poor conductor of electricity (a moisture content of at least 8 per cent is needed to achieve adequate conductivity).

Factors such as air humidity, temperature and air speed through the spray booth can also have a negative effect and can cause problems with the method of applying the charge onto the gun and the substrate.

Considering the investment cost, which is comparatively high, the writer suggests that the producer should weigh the

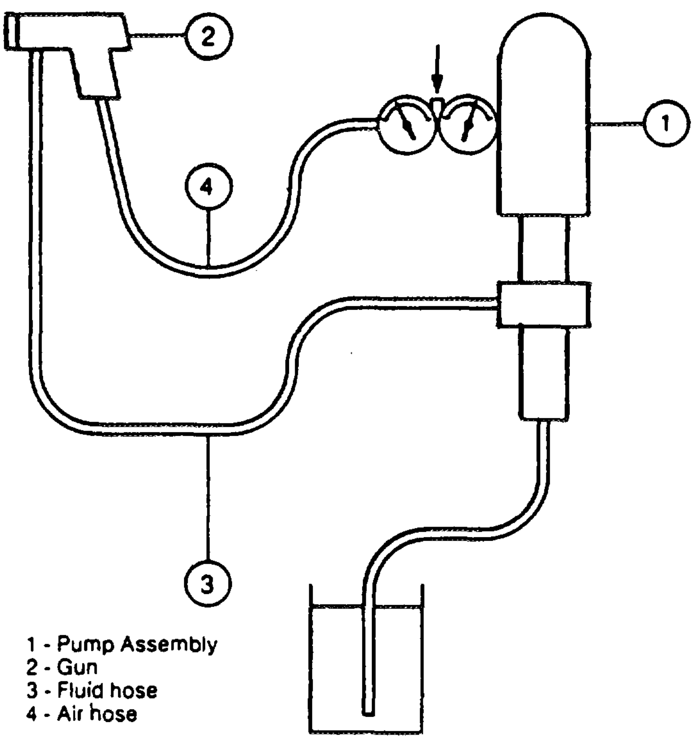
Figure 128. Airmix system

Standard Airmix

As easy to use as a conventional spray gun.

Sprays normal coatings - single component paints and lacquers.

Very high transfer efficiency.



pros and cons very carefully, in consultation with the equipment supplier, before investing in electrostatic spraying equipment. The writer was very surprised to note the large number of electrostatic spray systems in Indonesian rattan factories.

Advantages and disadvantages

An electrostatic system has three advantages: it is time-saving when used for complicated designs, the spraying technique is simple and there is a saving on materials.

The system has disadvantages as well. Specially developed coatings are needed, and it is not suited for all kinds of materials. The equipment demands a high level of maintenance, and an earth connection is needed. There are, as well, special requirements with regard to air humidity, temperature and air speed.

Comparison and recommendations

Looking at the general characteristics of the four main spraying methods, it is fair to say that they each have their own unique potential. As mentioned earlier, the choice of spraying equipment will mostly be based on the quality of the finish produced and the transfer efficiency, but other factors such as material control, durability of the equipment, spray booth maintenance and energy consumption also have to be considered.

Figure 130 and table 27 compare the four systems in relation to the criteria for choosing spraying equipment.

Conventional spraying equipment is basically outmoded in Europe, mainly because of the waste factor. The consideration is not so much the cost of the solvent wasted but rather the solvent's adverse environmental impact. Airmix airless equipment is becoming increasingly popular owing to its versatility: it is suited for both flat surfaces and complicated designs.

For wood, electrostatic equipment gives results that vary greatly. Generally speaking its high transfer efficiency is very dependent on such factors as air humidity, ambient temperature and air flow in the application area. However, its extensive use in Indonesian rattan factories is noted.

The writer suggests that airmix airless equipment is a very good choice for rattan and bamboo furniture, when its investment costs are weighed against its flexibility and the fine finishing results that are obtained with it.

Adjustment of air pressure

Conventional spray (suction feed)

With a conventional spraying system, the material and atomization air pressure is 2-3 bar. The exact pressure needed depends on, among other things, the number of holes in the air cap, from two to six. The more holes, the higher the pressure and the finer the atomization. The nozzle size is 1.4-1.8 mm and the average material consumption is 100-175 ml/min.

Pressure feed spray

With pressure feed spray, the pressure in the material container is 0.8-1.0 bar and the atomization air pressure is 2.8-3.5 bar. The exact atomization air pressure depends on, among other things, the number of holes in the air cap, which can vary from six to nine. The nozzle size is 1.0-1.2 mm and the average material consumption is 150-600 ml/min.

Airless spray

With airless spray, the air pressure is 2.5-3.5 bar. The pressure is normally raised 25-30 times by an airless pump. The nozzle size depends on the requirement. The material consumption depends on nozzle size.

Airmix spray

With airmix spray, the air pressure is 2.5-3.5 bar. The pressure is normally raised 10-12 times by the pump. The atomization air pressure is 1.0-1.5 bar. The nozzle size is

Figure 129. Electrostatic system

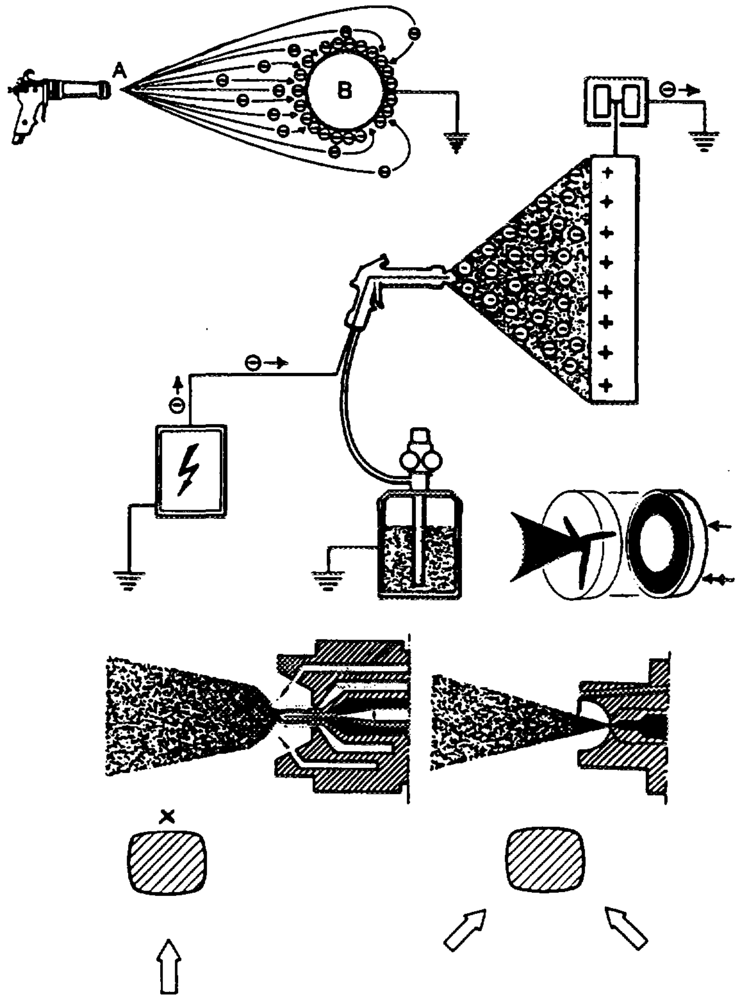
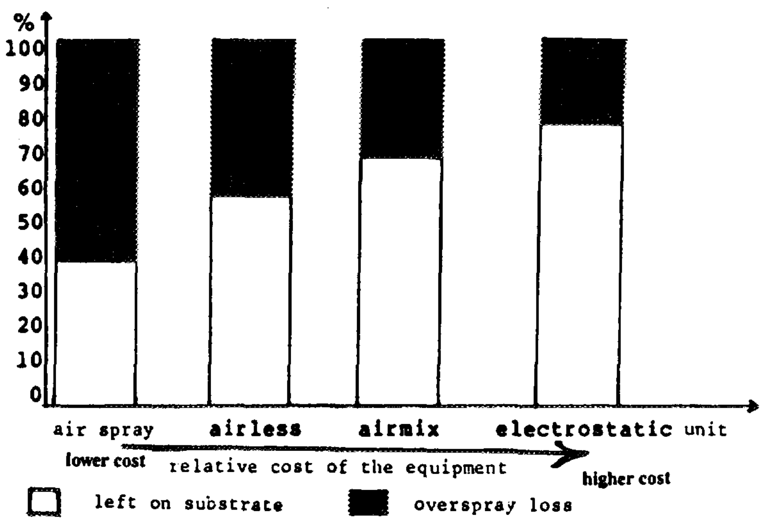


Table 27. Comparison of four different spraying systems

Critical factor	*Conventional spray*	*Airless spray*	*Airmix spray*	*Electrostatic spray*
Quality of the finish	Fine	Coarse	Good	Fine/good
Material control	Limits within low to medium supply, but no more than 0.9 l/min	Limits within high to very high supply, but no less than 0.7 l/min	Great choice in supply = 0.2-1.5 l/min	Dependent on system
Spray booth maintenance	Excessive overspray, high level of maintenance	Limited overspray; little need for maintenance	As for airless	Generally very little overspray; minimal need for maintenance
Spray fan adjustment possible?	Yes	No	Yes	Dependent on system used
Nozzle replacement needed?	No	Yes	Less often than airless	Dependent on system used
Durability	Very good, low material pressure	High wear on nozzles and pumps	Less wear on nozzles and pumps than airless	Dependent on system used, but generally the gun is delicate
Energy consumption	Low efficiency at high air pressure	Good efficiency for atomization	Highest efficiency, low consumption	Dependent on system used
Loudness level/noise	Very high	Low	Low	Low
Solvent release	High level	Low level	Low level	Dependent on system used

Figure 130. Comparative paint transfer efficiencies of the four spraying systems



dependent on the requirement. The material consumption depends on nozzle size.

The most efficient atomization pressure is the lowest possible air pressure that will give the desired results. Annex VI contains some guidelines on the selection of nozzles for different end-uses.

Manufacturers and suppliers of spraying equipment often employ different units when specifying material and atomization air pressures. To reduce the confusion, table 28 shows the relationship between the various units of pressure.

Table 28. Air pressure conversion table

	Kilograms per square centimetre (kg/cm^2)	*Pounds per square inch (psi or lb/in^2)*	*Bar*	*Atmosphere (atm)*
Conversion factor	1.000	14.223	0.987	1.000
Approximate air pressure equivalents	1.0	14.2	1.0	1.0
	1.5	21.3	1.5	1.5
	2.0	28.4	2.0	2.0
	2.5	35.5	2.5	2.5
	3.0	42.6	3.0	3.0
	3.5	49.7	3.5	3.5
	4.0	56.8	4.0	4.0
	4.5	63.9	4.5	4.5
	5.0	71.0	5.0	5.0

Spray booths

The information presented here is not intended to enable the putting together of one's own spray booth. Rather, it is meant to present the options and to warn that this important facility should be entrusted only to specialists. Too often the construction and use of the spray booth are regarded as of minor importance.

The main purpose of a spray booth is to remove toxic materials and flammable solvents from the spraying area so as to prevent injury or damage to operators and property. It must also prevent overspray from settling on the piece being worked on, and the overspray must be trapped to prevent the contamination of surrounding objects. Two types of booths are normally distinguished: the dry filter booth and the water wash booth.

While a simple wall-mounted extraction fan can draw some overspray away (ventilate), often the air flow will merely be dispersed instead of concentrated. Finish can stick to the fan blades and the motor, causing an unbalanced situation that may lead to overheating, damage and fire. Therefore, this solution is not of interest.

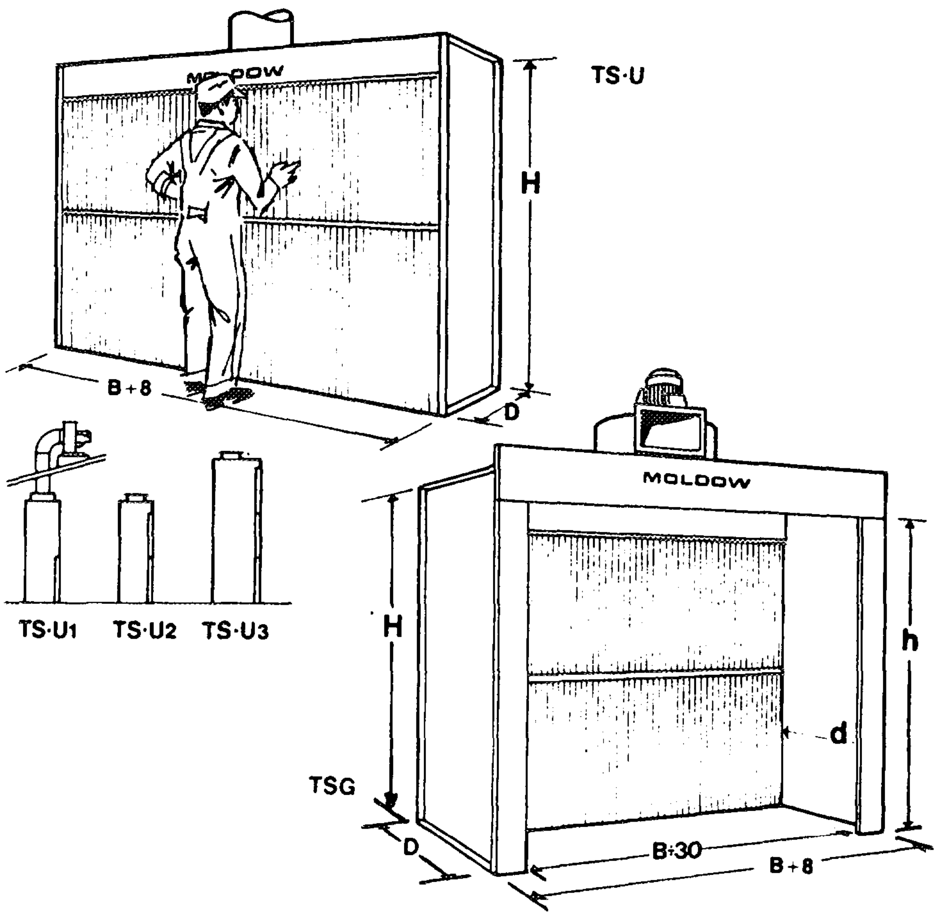
Dry filter booth

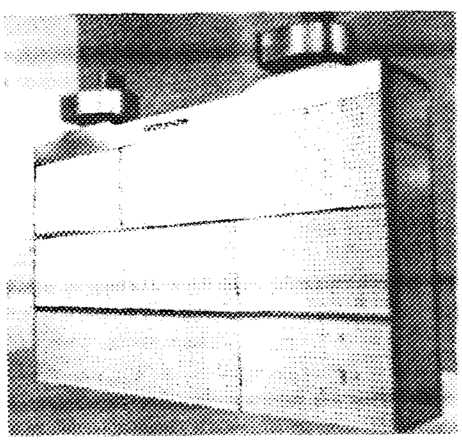
A dry filter booth is normally installed where the volume of finish material sprayed does not exceed 50 l per day. It consists of a chamber with a fan on top plus a dry filter at the front to trap the paint particles (overspray).

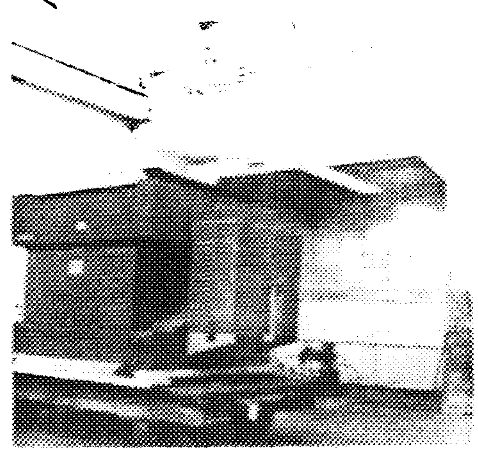
The simplest filter is made from two rows of metal panels (baffle type), which divert the air flow and disperse the finish. It is an inexpensive construction but takes time to maintain. Typical pieces of equipment from two manufacturers in Denmark are shown in figures 131 and 132.

The most common filter, the paper filter (figure 133) is constructed from several layers of perforated heavy paper, which can trap 85-95 per cent of the overspray. The filter should be installed to cover as nearly as possible the full area of the booth, and the mean velocity should not exceed 61 m/min. To install, the filter should be fitted with eight corrugations per foot (30.4 cm) of booth width, and to facilitate cutting, the filter is marked at every eighth corrugation. Clip in one end, stretch across the frame and clip in the other end, an operation taking a minute or less. If any short pieces are left over, they can be attached to a new

Figure 131. Dry spray booth

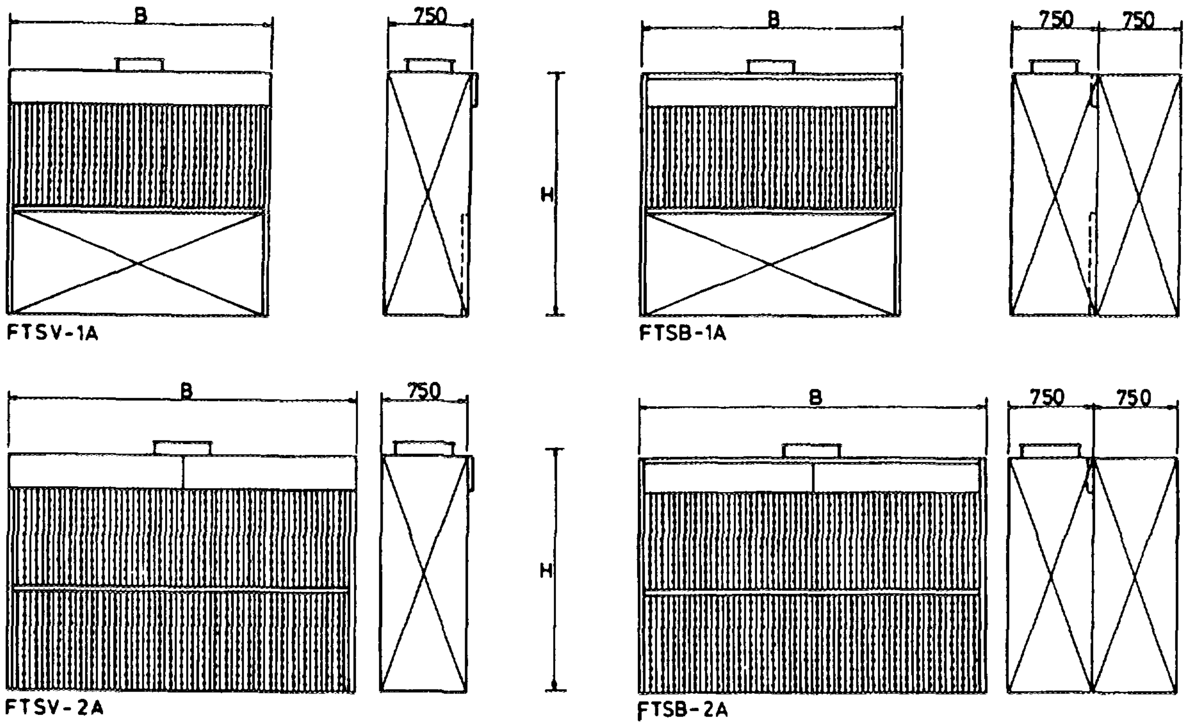


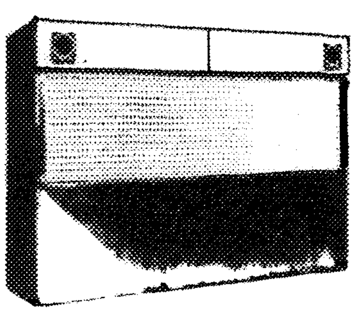




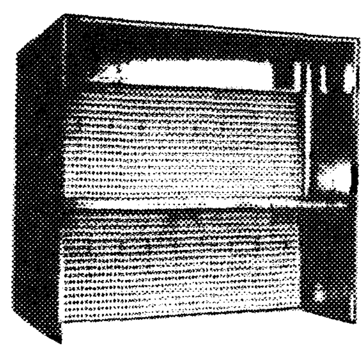
TYPE	cm				B cm									
	d	D	h	H	120	180	240	300	360	420	480	540	600	
TS-U1		67		214	2000	3000	4000	5000	6000	7000	8000	9000	10000	Air Consumption m^3/h
TS-U2		67		214	4000	6000	8000	10000	12000	14000	16000	18000	20000	
TS-U3		97		304	6000	9000	12000	15000	18000	21000	24000	27000	30000	
TSG-PG	105	173	195	214	3200	5200	7400	9500	11500	13500	16000	18000	20000	
TSG-PM	180	248	195	214	3200	5200	7400	9500	11500	13500	16000	18000	20000	
TSG-RM	180	248	240	244	3900	6500	9000	11500	14000	17000	19500	22000	24500	
TSG-VL	165	248	300	304	4900	8000	11500	14500	18000	21000	24500	27500	31000	
TSG-ZL	165	248	360	364	5800	9500	13500	17500	21500	25500	29000	33000	39000	
Lighting Fittings Watt					100	100	100	200	200	200	300	300	300	

Figure 132. Dry spray booth





FTSV-1A



FTSB-2A

Type	Type	B	H	m³/h	HK/HP/PS
FTSV- 25-1A	FTSB- 25-1A	1580	2150	2500	2,0
FTSV- 34-1A	FTSB- 34-1A	2330	2150	3400	2,0
FTSV- 50-1A	FTSB- 50-1A	3080	2150	5000	2,0
FTSV- 63-1A	FTSB- 63-1A	3830	2150	6300	2,0
FTSV- 75-1A	FTSB- 75-1A	4580	2150	7500	3,0
FTSV- 90-1A	FTSB- 90-1A	5330	2150	9000	7,5
FTSV-100-1A	FTSB-100-1A	6080	2150	10000	7,5
FTSV- 50-2A	FTSB- 50-2A	1580	2150	5000	2,0
FTSV- 68-2A	FTSB- 68-2A	2330	2150	6800	2,0
FTSV-100-2A	FTSB-100-2A	3080	2150	10000	7,5
FTSV-125-2A	FTSB-125-2A	3830	2150	12000	7,5
FTSV-150-2A	FTSB-150-2A	4580	2150	15000	2 x 3,0
FTSV-180-2A	FTSB-180-2A	5330	2150	18000	2 x 7,5
FTSV-200-2A	FTSB-200-2A	6080	2150	21000	2 x 7,5

length, either by a strip of masking tape or by stapling. The filter is often of the roll-out type, which is easy to maintain whenever it becomes clogged. Overall maintenance procedures must be established for cleaning and replacing the filters regularly so as to prevent the combustion of accumulated finish and to secure optimum ventilation.

Water wash booths

Water wash booths are recommended when the volume of finish sprayed is high. A water wash booth will remove overspray and solvent at a uniform rate and minimize the hazard of accumulated combustible overspray. Water wash booths come in many different forms, but they all consist of an air washer and a material tank.

The classic type has a wash chamber at the back, which removes the air-borne finish. It can be fitted with water jets that are fed from the tank by means of a pump (pump type) or with heavy-duty centrifugal fans that produce turbulence on the surface of the water in the tank (no-pump type). In both cases, baffles are fitted higher up in the chamber to throw any water droplets out of the air again. Their construction and the position of the baffles is shown in figure 134, and figure 135 shows wet spray booths with and without pumps for water circulation.

The front of the water wash booth normally consists of sheet metal down which a water curtain flows evenly from a container at the top.

The collected overspray is either floated or made to sink to the bottom of the tank through the addition of various chemical compounds. Generally, water wash booths need good attention to ensure proper functioning.

Basic design and operation

Whether of the dry or wet type, a spray booth must be large enough to allow at least 1 m clear space all around the largest workpiece, and it must be deep enough to allow the operator to work within the walls.

An exhaust fan of proper size and horsepower will remove the toxic and flammable materials. The amount of air ventilated from the spray booth depends on the speed of the air as it moves through the booth enclosure, which must be fast enough to carry overspray from the object being finished.

Fairly high air speeds, i.e. 0.8-1.0 m/min, are required when spraying with conventional systems in a dry filter booth. Airless and electrostatic systems, where the bounce-back is minimal, require an air speed only of 0.3-0.5 m/min. Generally, the air movement must be even and not turbulent and distributed evenly over the entire face of the booth. Air consumption in relation to a given size of standard dry filter booth was indicated in the tables in figures 131 and 132.

The fan and the motor are the most vulnerable parts of the spray booth. The exhaust fan must be spark-proof, and it is a good idea to fit an anti-spark lining in the fan or the duct. Since the fan motor must be located outside the duct itself, the fans are normally belt driven.

The motor should be spark proof and of the induction type. It is often used as a drive for both the exhaust fan and the water pump.

Even with these safeguards it is important to note that the best-designed system may be inadequate if regular maintenance practices are not established and implemented.

The writer observed that many factories using spray booths did not maintain them properly and that factory management did not understand the importance of maintenance.

Light fixtures are another important detail. If mounted at the top front edge of the booth, they must be vapour-proof and the reflector mounted in a sealed enclosure protected from breakage. Power requirements were given in figure 10 for different sizes of booths relative to wattage needed.

General maintenance

Maintenance entails regular examination of the dry filters and replacing them when necessary. Fans and ducting should be checked for paint build-up at least once a month. Factory management should ensure that this is done regularly and should try to avoid continuous use with no maintenance since the efficiency of the spray booth will decrease noticeably if correct maintenance is not carried out.

In a water wash booth the water has to be skimmed from three to four times a day and the tank has to be cleaned thoroughly every two to four weeks, depending on the workload. If nozzles are fitted, these have to be checked often. Pumps have to be checked now and then, and if they run hot they have to be dismounted and cleaned. The walls of the spray booth must be cleaned from overspray when necessary. To make this easier, a thin coat of grease may be applied to the freshly cleaned walls.

Air make-up

A typical spray booth consumes approximately 10,000 cm^3 of air every hour. If the booth does not have a sufficient supply of fresh air, the fan cannot ventilate it properly. A standard factory room normally supports three air changes per hour through the windows and doors; but if the suction power of the fan at the back of the booth is greater than three times the volume of the room, even a well-designed booth and fan may be unable to ventilate properly.

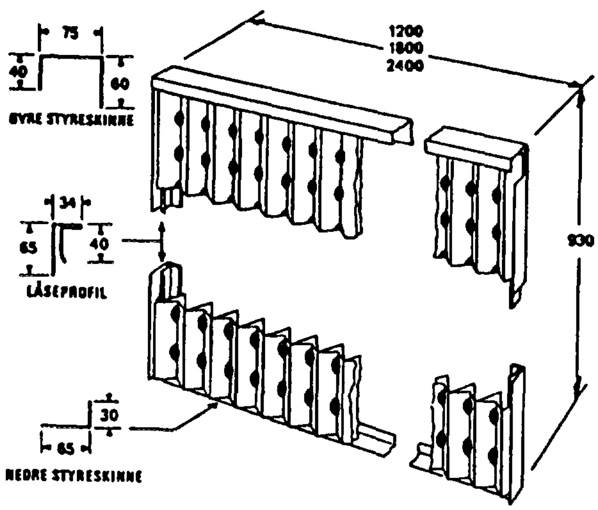
The fresh air unit or supply device shown in figure 136 serves two important purposes:

(a) It introduces sufficient air to ensure maximum performance of the spray booth;

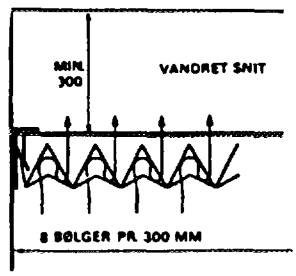
(b) It introduces clean air through filters in a volume slightly greater than that of the air exhausted by the spray booth fan. This keeps the finishing room pressurized and prevents dust from the surrounding production area from entering the finishing room.

In South-East Asia, the fresh air does not need to be heated.

Figure 133. Disposable spray booth filter



- Simplest and most economical dry filter ever produced
- Easily fixed — Quickly replaced
- Folds to compact size for easy storage and transport
- Expendable paper filters for dry back spray booths
- 85% to 95% filtration
- Low resistance to air flow
- Outlasts any other filter three to five times



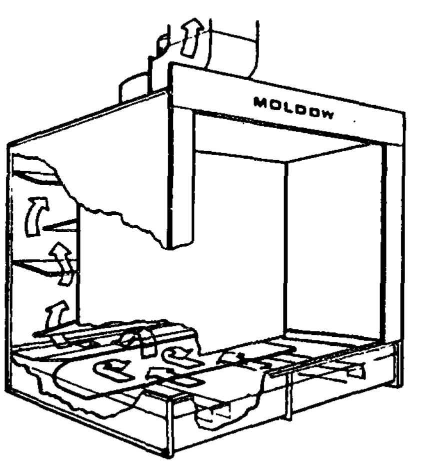
The Binks Bullows disposable paper filter consists of two sheets of heavy paper with corrugations of unequal size which are attached at the corrugations. Each sheet has rows of perforations staggered relative to the other both vertically and horizontally, resulting in a tortuous passage so that the air stream stikes at least four surfaces before it leaves the filter. In doing so the sticky deposits strike the surfaces and adhere, only the air being finally discharged.

Supplied in 30 ft. (9·1 *metres*) lengths, 3 ft. (·91 *metres*) wide, (·836 *sq. metres*). Carton containing 60 sq. yds. (50·17 sq. metres) at 10% discount. The only support necessary is an angle iron at the top and bottom, and at the horizontal joint if more than one filter high. The material is of sufficient strength to support itself over the 3 ft. (·91 metres) width for an indefinite length.

The filter should be installed to cover as nearly as possible the full area of the booth and mean velocity should not exceed 200 ft. (61 metres) per minute.

To install, the filter should be fitted with eight corrugations to every foot (30·4 cm.) of booth width and to facilitate cutting, the filter is marked at every eighth corrugation. Clip in one end, stretch across the frame and clip in the other end, an operation taking a minute or less. If any short pieces are left over, they can be attached to a new length, either by a strip of masking tape or by stapling.

Figure 134. Difference between spray booth with and without a pump for circulation of water

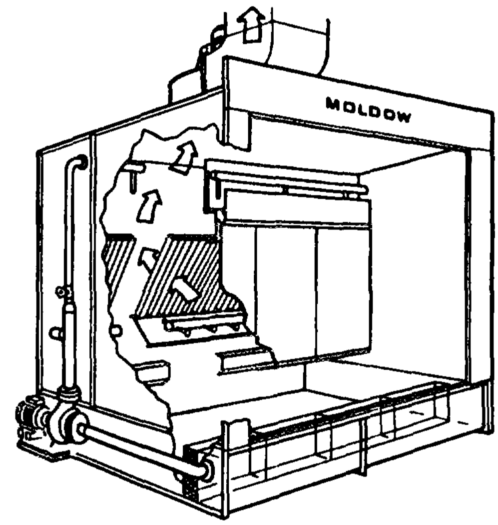


Nopump Spray Booth

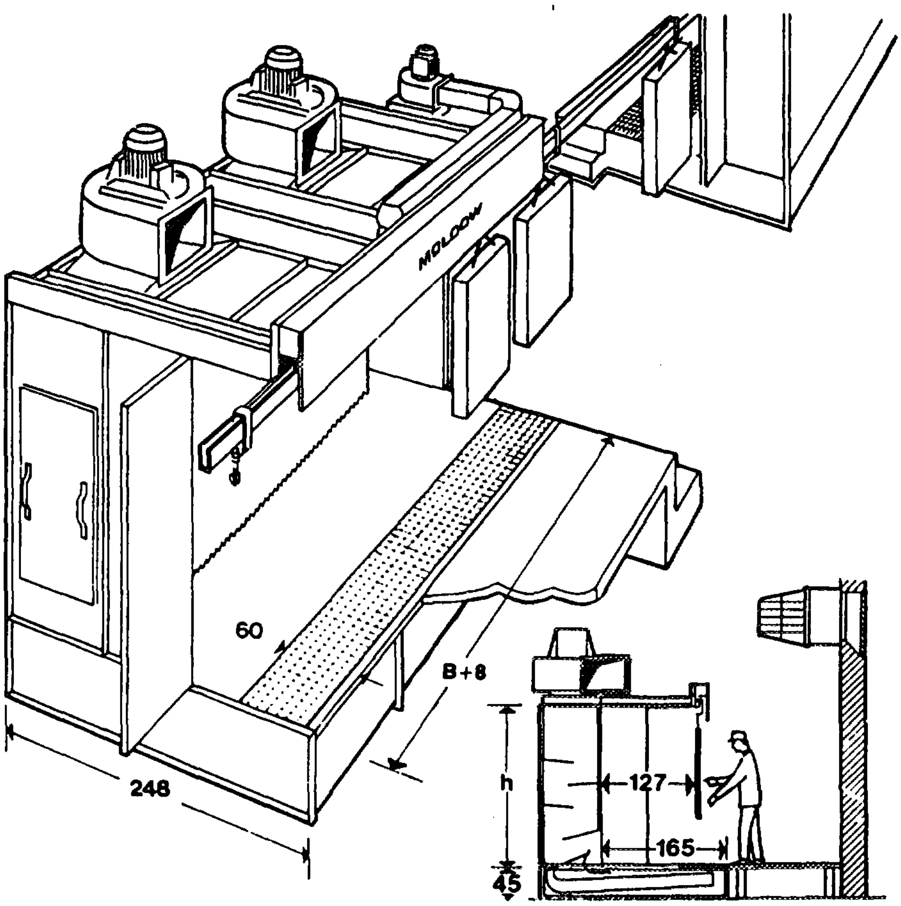
The Nopump Booth has been developed and patented by Binks-Bullows Ltd. The system differs in design from the conventional Waterwash Booth in that it has no water curtain, circulating pump, pipework or any other mechanical part requiring maintenance.
The washing action is achieved by a high velocity air stream passing over the water surface and forming a vigorous water cyclone in the specially designed washing chamber, in which the collected particles of paint are efficiently washed and passed on to the bottom tank.
The paint is decomposed by means of a special chemical additive to form a non-adhesive mass which is precipitated, and should normally be removed only when the bottom tank is filled to about 10 cm below normal water level.

Figure 134. *(continued)*

Spray Booth with Pump Circulation

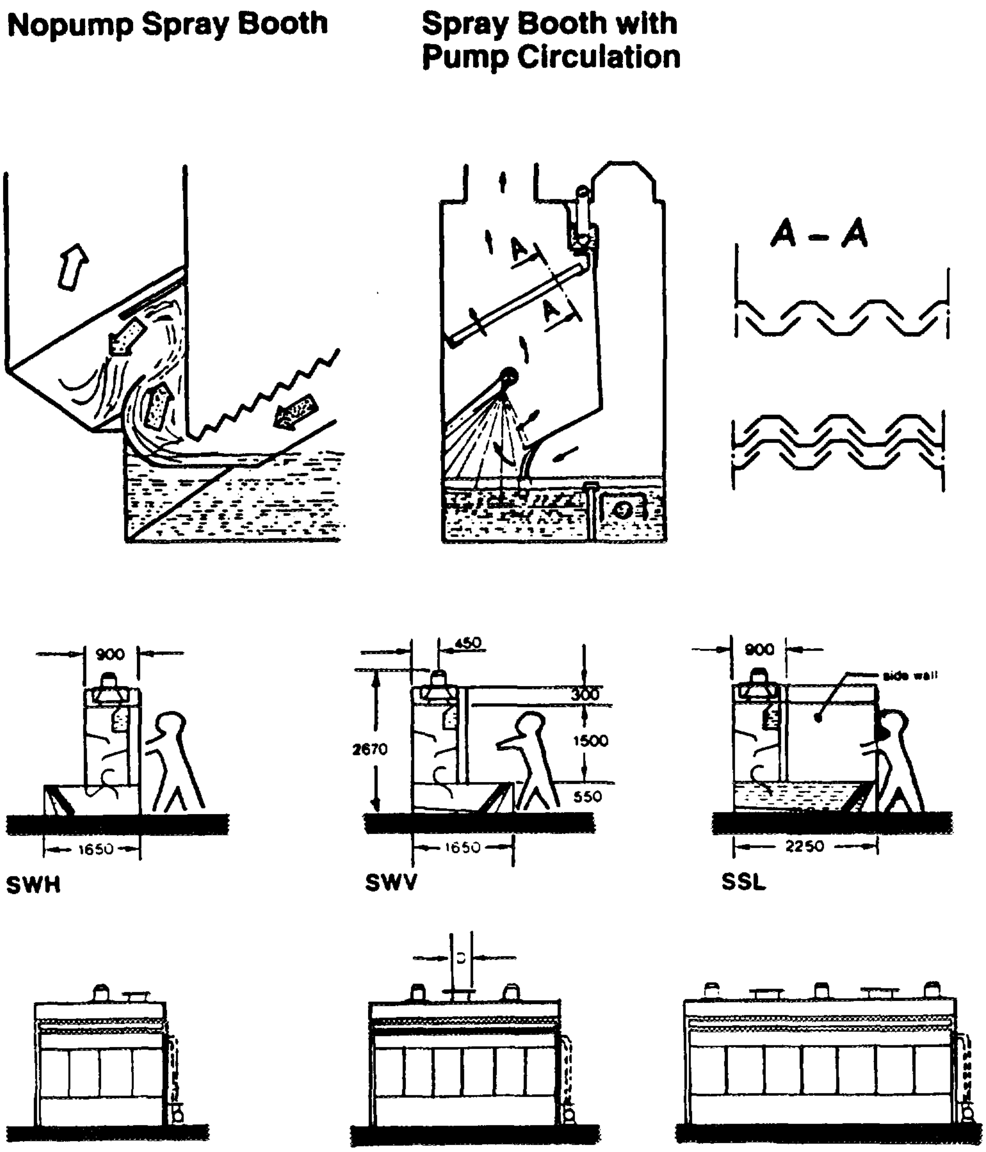


The conventional wet spray booth having pump circulation, is fitted with a water curtain in the work room so that any particle of paint striking the water curtain will be conveyed to the bottom tank.
The particles carried by the exhaust air are efficiently washed in the nozzle battery of the washing chamber. The water is recirculated by means of one or two specially designed centrifugal pumps and efficiently filtered with a sieve filter.



TYPE	cm	B cm									
	h	180	240	300	360	420	480	540	600	720	
VSY-KH C	150	4800	6500	8000	9500	11500	13000	14500	16000	19500	Air Consumption m^3/h
- -MH C	180	5800	7800	9700	11500	13500	15500	19500	19500	23000	
- -PH C	210	6800	9000	11500	13500	16000	18000	20500	23000	27000	
- -RH C	240	7800	10500	13000	15500	18000	21000	23500	26000	31000	
- -TH C	270	8800	11500	14500	17500	20500	23500	26500	29000	35000	
VSY-VH C	300	9500	13000	16000	19500	22500	26000	29000	32500	39000	

Figure 135. Wet spray booths



Layout of the finishing room

Figure 137 shows how a simple finishing room can be arranged. Figure 138 shows some guidelines for the positioning of operators relative to the booth and the object being sprayed.

Drying

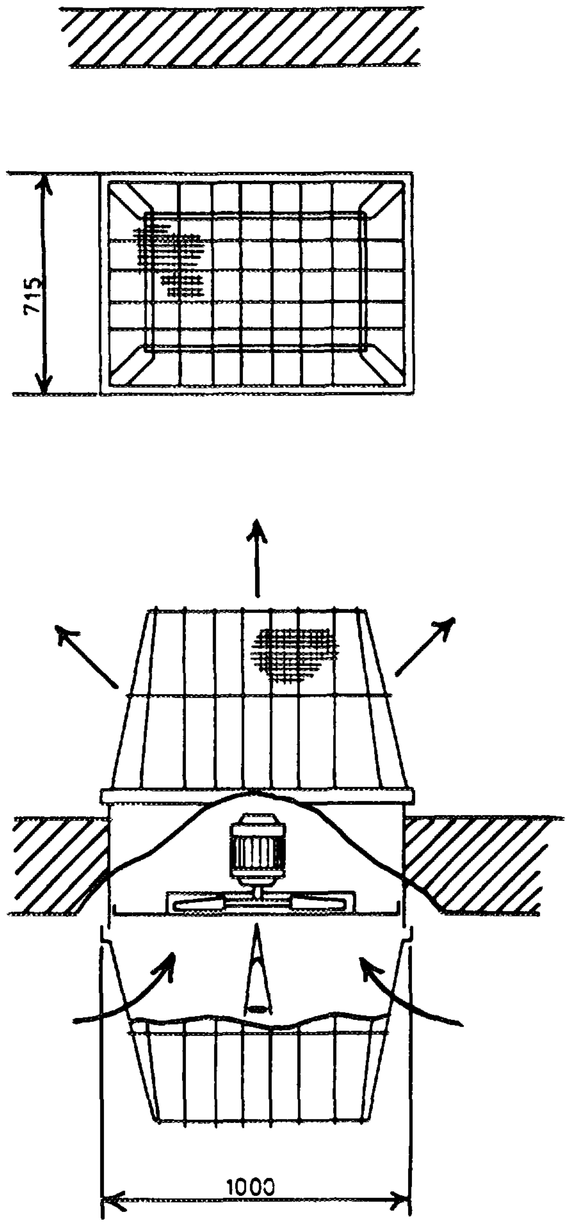
Once the finish has been applied, normal practice is to put the furniture aside and sand or recoat it whenever convenient and often without any proper drying. This practice is unfortunate since there must be a well-defined drying schedule if a uniform finish of high quality is to be obtained.

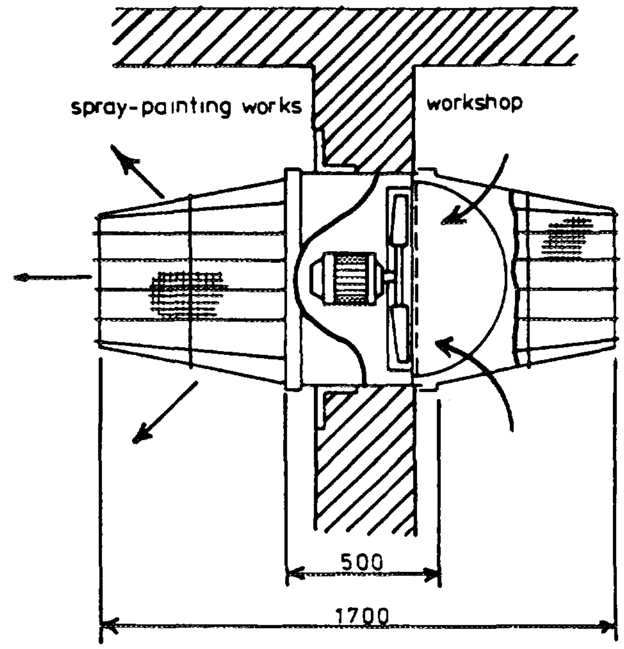
Many of the finishing problems seen today in the rattan and bamboo industry result from the fact that little attention is paid to the furniture once the finish has been applied. Instead, the excuse is often made that it is hard to get a good and consistent finishing result with equipment ill suited to furniture of complicated design.

The truth is, however, that even with the best finishing material and the most sophisticated application equipment, it is not possible to achieve uniformity and quality unless the finishing is combined with good ventilation and drying facilities. This becomes even more evident when the finishing is carried out in difficult climatic conditions, such as especially high and always changing air humidity and heavy rain, as well as in dusty finishing facilities with a production flow that creates bottlenecks.

Figure 136. Air supply device

Air-supply device type: FTA





Quantity of air:	6,000 m³/h
Motor:	0,75 HK/HP/PS - 900 °/min.
Filter area:	4 m²
Weight:	ca. 95 kg.
Wall hole:	750 × 1050 mm

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FINNROSE

Figure 137. A typical spraying set-up for factories in Indonesia

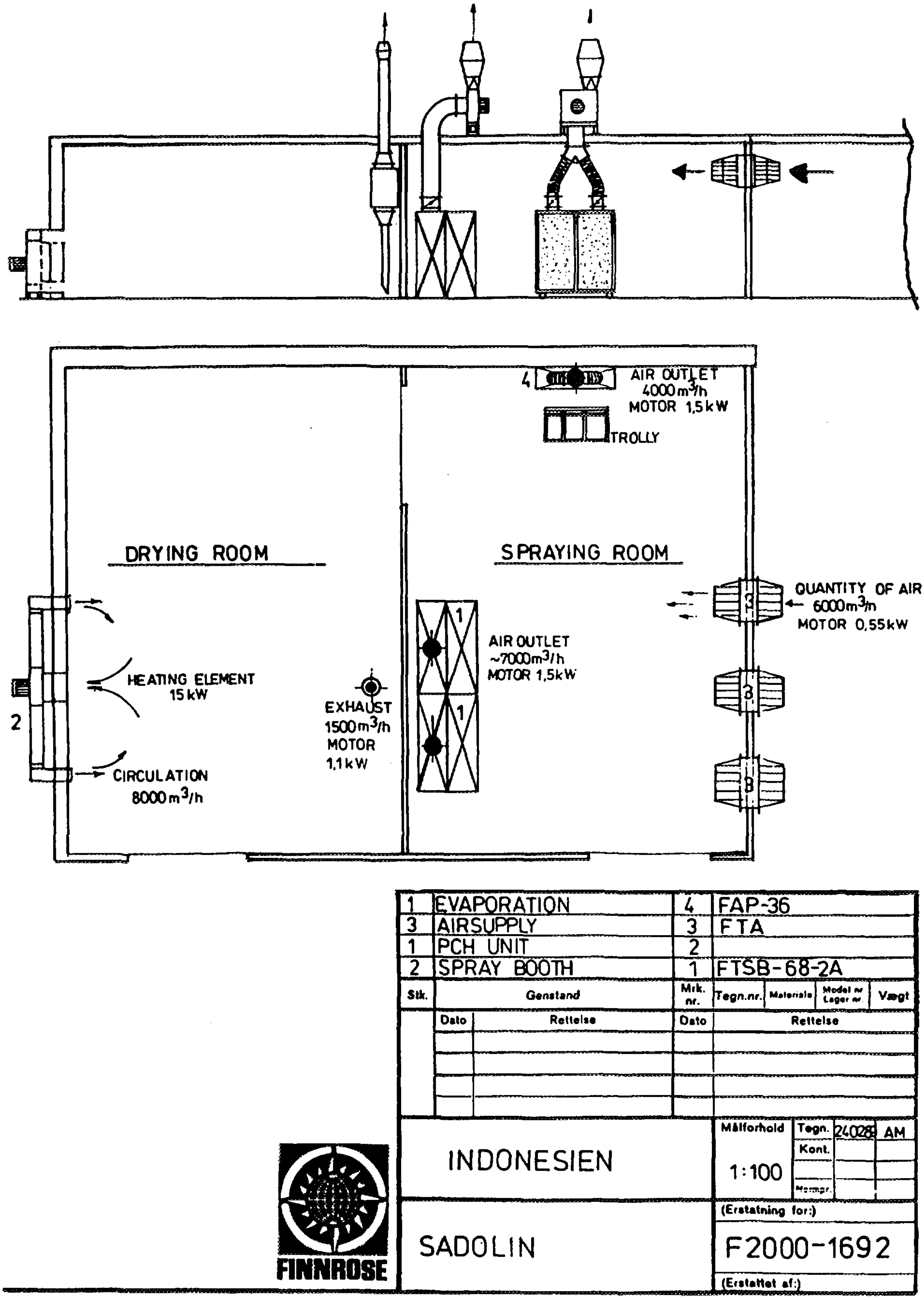
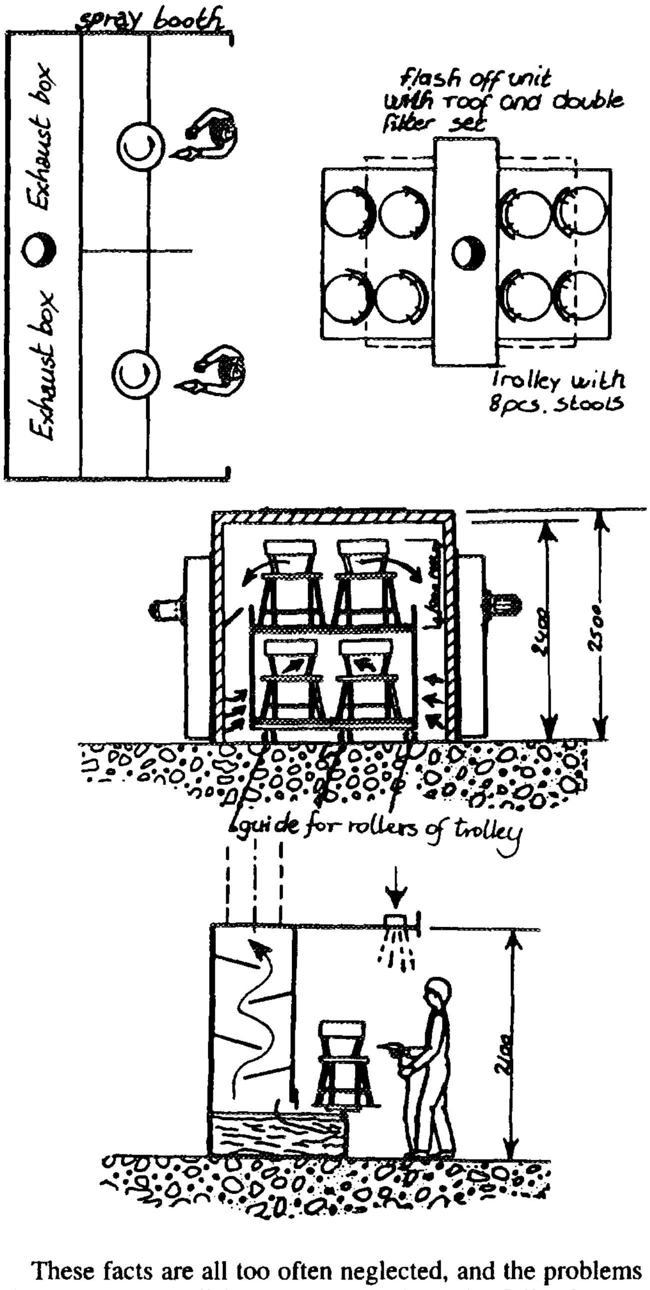


Figure 138. Guidelines for the positioning of spray operators and for drying oven stacking procedures



These facts are all too often neglected, and the problems that result are well known, among them the following:

(a) Uneven and rough surfaces, because sanding is carried out on a half-dry coat and dust accumulates during the long interval needed for the finish to dry;

(b) Shrink-back, because solvents are still evaporating after sanding;

(c) Packing marks, because solvents are trapped in the lacquer film, making it soft and prone to marking;

(d) Scratches, because the furniture is moved around before it is completely dry.

All these faults are a consequence of poor drying. When the furniture is dried in free air, i.e. without forced air circulation, the following conditions must prevail: good ventilation; relative humidity not greater than 85 per cent; dust-free working facilities; drying time before sanding, at least from one to two hours, and drying time before packing, at least rom four to eight hours.

How many of these requirements can be met at all times, and how often is the finishing department ahead of the production schedule by such comfortable margins? In most factories not too many of these conditions prevail, and it is probably only seldom that they all prevail.

However, by installing a heating unit (preferably with an air filter) in the drying area or a simple oven of good design (convection type), both adjusted to the product, it is possible to eliminate all the negative factors mentioned above, namely, poor ventilation, high air humidity and insufficient drying capacity.

The principles of good drying may be stated as follows:

(a) The drying time of a lacquer finish can be considerably reduced by supplying energy in the form of hot air or radiation. Doing so often gives a film with improved characteristics;

(b) Raising the temperature of the spray finish and the workpiece speeds the evaporation of solvents from the finish and, for some types of finishes, initiates a chemical reaction. A rule of thumb is that each time the temperature of an acid-curing finish is increased by 10 per cent, the curing time is cut in half. When the temperature is above 50° C, the curing times are very short;

(c) After a lacquer coat has been applied, most of the solvent has to evaporate before more energy is supplied to shorten the curing/drying time. This interval, which is called the flash-off period, must be respected to avoid blisters in the dried film.

Any form of improved drying is beneficial to a surface finish. Moreover, surface preparation, such as sanding, can start much sooner and the production schedule becomes more reliable since the exact drying times are known.

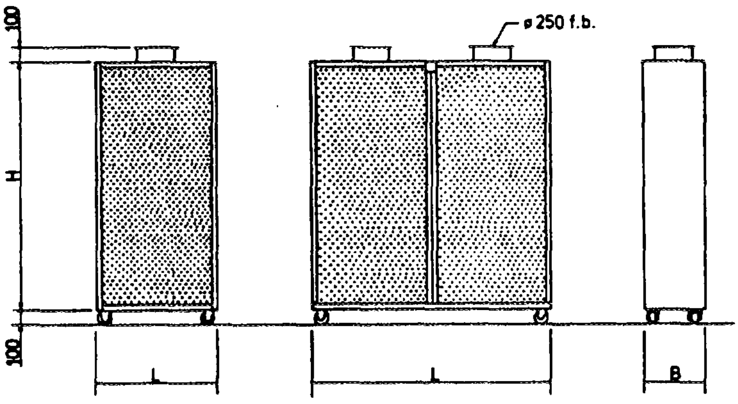
Figure 139 shows the simplest, least expensive form of drying: an evaporation panel, which can be left in the finishing room, with objects to be dried placed near it. The panel comes in two sizes. Both are 2,000 mm high. One has a length of 1,000 mm and exhausts 3,600 m^3/hr of air. The other has a length of 2,000 mm and exhausts 7,000 m^3/hr of air. More sophisticated and costly drying equipment would entail a forced air circulation drying tunnel with automatic feeding. Annex VII contains details of such systems.

Because he feels strongly that surface finishing systems require good and effective drying, the writer suggests that the installation of such equipment at a convenient time should be considered. A local finishing supplier can advise on the drying times needed at the recommended temperatures, which then become the critical specifications for the oven to be purchased.

Layout and planning of the finishing department

The finishing department should be large enough to accommodate the production fully. It should be clean, well

Figure 139. Evaporation panel



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	Q	L	B	H
Type/Typ	m^3/h	mm	mm	mm
FAP-36	3.600	1.000	495	2.000
FAP-70	7.000	2.000	495	2.000

ventilated and dust free (pressurized, if possible, to keep out dust). Its temperature and humidity should be controlled and its capacity adjustable to the production output. Good lighting of the correct type is also required. Only if all these demands are met will it be possible to maintain a uniform finish of high standard.

As previously mentioned, finishing is probably the most vital operation and the one that gives the furniture its reputation, so it should not be forgotten. The skill and training of the people involved in the process add the final touch.

Individual pieces of equipment and entire facilities for finishing, drying, curing and mixing are only one component of quality. The other vital part is people, no matter in which department they work—production, engineering, material control, design or any other department. Organizing these people to cooperate and coordinate is crucial to the whole quality process.

The most important tool of quality control is the arrangement of the finishing department. If it is well organized, the only thing that needs doing is checking the furniture, once finished, for colour, ampleness of coating and gloss. If not organized well, the finishing department will be a daily headache.

Preparation (sanding)

The preparation, or pre-sanding, of a workpiece is very important to the final finish. Each sanding must therefore be considered in relation to the preceding or succeeding operation. For example, using a grit that is too coarse for a particular operation may mean high productivity, but it will cause problems and create additonal costs for the following operations.

It makes no economic sense for the finishing shop to accept a poor sanding job. If a piece is returned to it, the sanding room has to correct its errors. When this happens with rattan, where the sanding is done manually, the flow of production is interrupted, operating costs go up and quality usually declines.

As a general rule, as coarse a grit as is needed to perform the job economically should be used. If the finish is to be upgraded, the grit number used should be the next higher one available.

A sanding sequence in a rattan factory is carried out at the following locations:

(a) Machine room, where poles are sanded by machine before assembly;

(b) Sanding room, where furniture is sanded before and after finishing;

(c) Finishing room, where surface defects are repaired by sanding before recoating.

In the machine room the sanding is typically performed by machines with automatic feed. A good grit sequence is 80, 100, 150, 180, 220, but this may depend on the actual job.

In the sanding room the sanding is performed by hand. The main job is to smooth the surface after bending and to remove putty marks covering nails or screws. Usually, the paper backings should be of C and B weights as they are stronger. Garnet, aluminium oxide and silicon carbide materials can be used, and 180 plus 240 grits normally give a finish suitable for the finishing room.

In the finishing room the hand sanding is connected with the sealer and the first top coat. For a natural or pigmented finish, the sealer/primer coat can be sanded with paper No. 240. For a stained finish, it may be necessary to use a finer paper, such as No. 320, to avoid cutting through the lacquer film. The first top coat can be sanded with No. 240. For high-gloss pigmented finishes, it may be necessary to use No. 320 or even finer for the final base coat.

In all cases, silicon carbide paper of the open coat type is recommended. It is the hardest and sharpest mineral used in coated abrasives and is superior to any other abrasive in its ability to penetrate and cut rapidly under light pressure.

For wicker, which is difficult to sand, it may be an advantage to use the Fladder system, described in annex VIII in detail. The Fladder system was developed to improve wood finishing before the first coat and for denibbing/sealer sanding. If wood sanding is concluded with a sufficiently fine grit (180-200) and the first coat of finish is applied after sanding with the Fladder, then almost all the fine wood fibres (along the edges) are removed without new fibres appearing, and the need for denibbing/sealer sanding is considerably or totally reduced. It is usually a quicker operation than conventional hand sanding operations.

In normal wood sanding, the individual grains of grit cut the fibres and leave a lot of loose fibres. This happens especially when sanding is done perpendicular to the fibres. Even with very fine grits, this cannot always be avoided.

If these loose fibres are subsequently exposed to moisture, such as that from a further lacquer coat, they will expand and raise up, necessitating denibbing/sealer sanding (figure 140).

The Fladder is not an aggressive sander, so it is relatively easy to carry out the denibbing (sealer sanding) as only the particles that protrude through the lacquer will be sanded away.

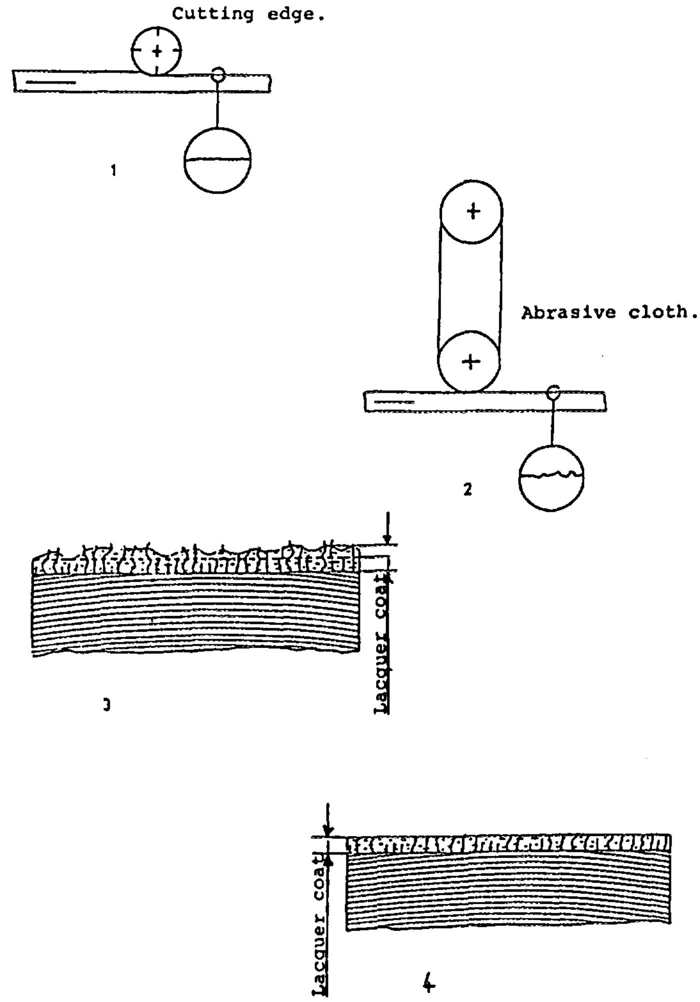
If there is sanding dust in the lacquer or if the coat of lacquer is so thick that it covers the fibres, the Fladder will not be able to sand the coat away.

To obtain the full effect of the Fladder system it is important that the preparatory work is done carefully, that the lacquer room is clean and free of dust and that relatively small amounts of lacquer are used.

The Fladder system thus differs from all other denibbing/sealer sanding systems, such as nylon brushes, sanding heads and sanding lamellas, by removing only the tiny unwanted particles and keeping the surface finish itself unchanged. At the same time, it is very flexible and will be able to get into profiles where no other non-manual sanding systems can reach.

A number of Fladder machines have been developed to exploit Fladder characteristics, from a small, hand-held machine with six Fladder blades, which weighs less than 1 kg, to a large, automatic through-feed machine with individual programming of the 12 Fladder drums mounted on two rotating heads and with a total of 192 Fladder blades.

Figure 140. Effect of denibbing sanding on surface using Fladder system



Health and safety precautions

As indicated earlier, most finishes contain solvents and other ingredients that are harmful and dangerous to operators and buildings. Therefore, precautions must be taken in four areas of concern: handling and mixing; fire precautions; personal protection and hygiene; and accidents.

Handling, mixing

To avoid risks from flammable and harmful liquids, vapours and aerosols, a number of precautions are necessary:

(a) At the outset, the factory inspector from the licensing authority should be consulted to ascertain that the individual buildings meet requirements, especially with regard to the storage of finishing materials before use;

(b) All possible sources of ignition should be eliminated, and smoking should be prohibited in all areas where paint materials are handled;

(*c*) All handling, mixing and application activities should be arranged so that no solvent vapours are inhaled and contact with the skin and the eyes is avoided;

(*d*) Care should be taken to avoid spillage. Spillage and empty drums and cans emit vapour and should be removed immediately.

Ventilation guidelines

Operators should never work in confined areas without adequate ventilation which ensures that harmful or flammable concentrations of vapour do not occur. If forced ventilation is used, extraction should take place as near as practicable to the source of vapours, and the fresh air supply should be arranged so that clean air enters the breathing zone of the operators.

Contaminated exhausted air should be expelled to a location from where there is no risk of re-entry into buildings. Should the vapour level approach the limit value at any time, operators must use gas masks or fresh air breathing apparatus.

Mixing guidelines

All decanting and mixing should be carried out in a well-ventilated area away from the storage and application areas.

Scraper/sponge guidelines

All applications of the product by scraper or sponge must be arranged so as to avoid contamination of the skin and inhalation of the vapour.

Drying guidelines

The air in a room containing newly treated pieces or in the drying area of a workshop is subject to solvent vapour build-up and should be ventilated to enhance the drying of the wood and to reduce the build-up of vapour.

Sanding guidelines

Sanding dust should not be inhaled and care should be taken not to contaminate the skin with sanding dust for long periods. Ideally, the sanding tools should be connected to an extraction system. A dust mask should be worn and the workplace regularly cleaned to avoid build-up of dust. These procedures will improve the quality of the finish as well as protect the operators.

Fire

The products used emit flammable vapours from organic solvents and must be handled accordingly, especially as the vapours can be ignited by a spark, a hot surface, a cigarette etc.

The vapours are heavier than air and may spread along floors or collect at the bottom of containers, where they may form explosive mixtures with air. Sufficient ventilation should be provided to disperse these local build-ups.

All possible sources of fire and ignition should be eliminated. For example, smoking must be prohibited in all areas where paint is stored, handled or used, and adequate precautions against the generation of static electricity should also be taken.

All personnel should be instructed in correct procedures, in the event of fire and in the use of extinguishers.

Discarded paint rests, dry spray dust, cleaning solvents, rags and all other combustible materials should be deposited in a metal container with a close-fitting lid or should be removed without delay after every production break.

Personal protection and hygiene

Persons with a history of asthma should not be engaged in any process that involves the use of isocyanates. Firms engaged in spraying products containing isocyanates are advised to have prospective spray operators medically examined before employing them in this work. Persons showing adverse symptoms should obtain medical advice immediately. All personnel who handle or use paint materials should be properly instructed. The working environment should be arranged so as to avoid the inhalation of vapour and skin contact with paint materials.

Inhalation

The inhalation of solvent vapour in high concentrations and of spray mists is harmful. Spray mists contains isocyanates, which may cause respiratory sensitization. A sensitized person will react to very low concentrations of isocyanates. Symptoms of chest tightness or wheezing may occur, but there is a rapid recovery when exposure ceases. Cartridge respirators or air-line breathing apparatus should be worn by operatives handling isocyanate products. Care should be taken to ensure that filters are changed when necessary and, in the case of air-line breathing apparatus, to ensure that the supply of air to the compressor is drawn from an uncontaminated source and that an efficient oil/water and fume filter is fitted to provide clean air for breathing. Where operators are required to work within a spray booth, an alarm system should be fitted to warn them whenever the air pressure falls to the lowest level at which it is safe to work.

Skin

Repeated or prolonged skin contact will irritate the skin. Cotton overalls and, if necessary, neoprene gloves and an apron should be worn. Contaminated skin should be cleaned with soap and water as soon as possible and solvents should never be used for hand washing. A suitable barrier cream applied on the skin before starting work will facilitate cleaning, and a nourishing hand cream should be applied after cleaning.

Eyes

Splashes or spray mist in the eyes will cause instant irritation. Whenever there is a risk, goggles should be worn.

Ingestion

Ingestion in harmful quantities is unlikely to occur in the course of normal working procedures. Accidental ingestion should be avoided by washing hands before meal breaks and at the end of the working day. Samples of paint materials should be kept in clearly marked containers and away from food.

Accidents

Apply specific first aid measures for the following types of accident:

(a) Inhalation. In the event of overexposure, move the victim to fresh air and keep him warm. Give nothing by mouth. If a person shows severe symptoms, medical assistance should be sought immediately;

(b) Skin. Remove contaminated clothing promptly and clean contaminated skin with soap and water or, if necessary, with a cleansing cream;

(c) Eyes. Splashes of paint in the eyes should be treated at once by copious irrigation with clean water, holding the eyelids apart for at least 10 min. Contact lenses must be removed. Medical attention should be sought immediately;

(d) Ingestion. Do not induce vomiting. If it should occur, keep the victim's head low to avoid solvents getting into the lungs by inhalation of vomit. If he is conscious, give him copious amounts of water. Medical attention must be sought;

(e) Burns. Cool by drenching with water until the pain has ceased. While drenching with water, remove all clothing from the burnt area that has not fastened in the wound. If hospital treatment is necessary, continue drenching with water during transport.

Fire should be fought with foam, dry powder, carbon dioxide or Halon, never with a jet of water, which will spread the fire. Precautions must be taken to avoid the inhalation of combustion products.

When there has been a spillage, all possible sources of ignition should be removed and the inhalation of vapours and contamination of the skin avoided. The spillage should be absorbed on non-flammable granulate or sand and dealt with as flammable, chemical waste using a method approved by the waste disposal authority. Granulate, which is wet by oil, should be kept in a metal container with a lid to avoid self-ignition.

Storage must be arranged with due consideration for the fact that the product is a flammable liquid. The quantity of paint products in the workroom should be kept as low as is practicable, e.g. one day's working requirements. All containers should be kept securely closed when not in use.

Empty or partly empty containers, which present a greater explosion hazard than full containers, should not be allowed to accumulate in the workroom and should be returned to the store or disposed of at the end of the working day.

Annex I

RECOMMENDED FINISHING SYSTEMS FOR NATURAL FINISHES

Furniture system No. 1: Nitrocellulose system, fast drying

Suited for: Bamboo, rattan with skin etc.

Appearance: Natural, transparent

Gloss: Any

Application: Spray, any type

Total drying time: 20-90 min, depending on the drying facilities

Remarks: Low to medium quality; formaldehyde-free

Filling
- Drying:
- Sanding:
- Mixing ratio:

Staining
- Drying:
- Sanding:
- Mixing ratio:

Sealing/priming: Sealers not recommended; they could give poor flexibility and adhesion
- Drying:
- Sanding:
- Mixing ratio:

Top coat(s): One or two thin applications of NC top lacquer of good quality
- Drying time range: Approximately 90 min at 25° C before packing/20 min at 50° C before packing
- Sanding: None
- Mixing ratio: Add NC thinner to obtain a viscosity of ~18 sec/D4/25° C*

Additional: Pre-sanding with, if possible, paper No. 320 to improve adhesion

Furniture system No. 2: Acid-curing system, medium drying

Suited for: Bamboo, rattan with skin etc.

Appearance: Natural, transparent

Gloss: Any

Application: Spray, any type

Total drying time: 1-6 h, depending on the drying facilities

Remarks: Medium to high quality; emits formaldehyde

Filling
- Drying:
- Sanding:
- Mixing ratio:

Staining
- Drying:
- Sanding:
- Mixing ratio:

Sealing/priming: Sealers not recommended; they could give poor flexibility and adhesion
- Drying:
- Sanding:
- Mixing ratio:

Top coat(s): One thin application of AC top lacquer, unmodified type
- Drying time range: Approximately 6 h at 25° C before packing/1 h at 50° C before packing
- Sanding: None
- Mixing ratio: (typical) 100 parts AC lacquer, 10 parts hardener, 20-30 parts thinner to obtain a viscosity of ~18 sec/D4/25° C*

Additional: Pre-sanding with, if possible, paper No. 320 to improve adhesion

Furniture system No. 3: Polyurethane system, medium drying

Suited for: Bamboo, rattan with skin etc.

Appearance: Natural, transparent

Gloss: Any

Application: Spray, any type

Total drying time: 2-8 h, depending on the drying facilities

Remarks: High quality; no formaldehyde emissions

Filling
- Drying:
- Sanding:
- Mixing ratio:

*Percolation time at 25° C using a DIN cup No. 4.

Staining	
Drying:	
Sanding:	
Mixing ratio:	
Sealing/priming	Sealers should not be used—poor flexibility and adhesion
Drying:	
Sanding:	
Mixing ratio:	
Top coat(s)	One thin application of PU lacquer, unmodified type
Drying time range:	Approximately 8 h at 25° C before packing/2 h at 50° C before packing
Sanding:	None
Mixing ratio: (typical)	2 parts PU lacquer, 1 part hardener, 0.5-1.0 part thinner to obtain a viscosity of ~16 sec/D4/25°C*
Additional	Pre-sanding with, if possible, paper No. 320 to improve adhesion

Furniture system No. 4: Nitrocellulose system, fast drying

Suited for:	Rattan, wicker etc.
Appearance:	Natural, transparent, semi-filled surface
Gloss:	Any
Application:	Spray, any type
Total drying time:	Between 2 h 45 min and 4 h, depending on drying facilities
Remarks:	Low to medium quality; no formaldehyde emissions
Filling	
Drying:	
Sanding:	
Mixing ratio:	
Staining	
Drying:	
Sanding:	
Mixing ratio:	
Sealing/priming	One application of NC sealer, heavy coating
Drying time range:	Approximately 40 min at 25° C/15 min at 50° C
Sanding:	Paper No. 240
Mixing ratio:	Add NC thinner to obtain a viscosity of ~18 sec/D4/25° C*
Top coat(s)	Three applications of NC top lacquer
Drying time range:	Approximately 40 min between coatings at 25° C/15 min between coatings at 50° C. Packing 2 h after application of top coat
Sanding:	Not required
Mixing ratio:	Add NC thinner to obtain a viscosity of ~18 sec/D4/25° C*
Additional	Apply as few sealer coats as possible to maintain the best possible flexibility (soft base material)

Furniture system No. 5: Acid-curing system, medium drying

Suited for:	Rattan, wicker etc.
Apppearance:	Natural, transparent, semi-filled surface
Gloss:	Any
Application:	Spray, any type
Total drying time:	Between 90 min and 8 h, depending on drying facilities
Remarks:	Medium to high quality; emits formaldehyde
Filling	
Drying:	
Sanding:	
Mixing ratio:	
Staining	
Drying:	
Sanding:	
Mixing ratio:	
Sealing/priming	One application of AC top lacquer, unmodified type
Drying time range:	Approximately 2 h at 25° C/30 min at 50° C
Sanding:	Paper No. 240
Mixing ratio:	100 parts AC lacquer, 10 parts hardener, 20-30 parts thinner to obtain a viscosity of ~18 sec/D4/25° C*
Top coat(s)	One application of AC top lacquer, unmodified type
Drying time range:	Approximately 6 h at 25° C before packing/ 1 h at 50° C before packing
Sanding:	None
Mixing ratio:	100 parts AC lacquer, 10 parts hardener, 20-30 parts thinner to obtain a viscosity of ~18 sec/D4/25° C*
Additional	AC lacquers are relatively easy to sand and do not normally need a special sealer

Furniture system No. 6: Polyurethane system, slow drying

Suited for:	Rattan, wicker etc.
Appearance:	Natural, transparent, semi-filled surface
Gloss:	Any
Application:	Spray, any type
Total drying time:	3.5-11 h, depending on drying facilities
Remarks:	High quality; no formaldehyde emissions
Filling	
Drying:	

Sanding:	
Mixing ratio:	
Staining	
Drying:	
Sanding:	
Mixing ratio:	
Sealing/priming	One application of PU sealer, unmodified type
Drying time range:	Approximately 3 h at 25° C/1.5 h at 50° C
Sanding:	Paper No. 240
Mixing ratio:	2 parts PU sealer, 1 part hardener, 0.5-1.0 part thinner to obtain a viscosity of 16 sec/D4/25° C*
Top coat(s)	One application of PU top lacquer, unmodified type
Drying time range:	Approximately 8 h at 25° C before packing/2 h at 50° C before packing
Sanding:	None
Mixing ratio:	2 parts PU top lacquer, 1 part hardener, 0.5-1.0 part thinner to obtain a viscosity of 16 sec/D4/25° C*
Additional	

SOME EXAMPLES OF STAIN AND LACQUER FORMULATIONS FOR SPECIFIC COLOURS

Table A.II.1. Combi stain (jet stain) formulas
(Parts by weight)

Basic colour No.[a]	Stain colour[b]																			
	Warm, dark mahogany	*Honey*	*Teak*	*Walnut*	*Medium green*	*Bright red*	*Dark walnut*	*Old burgundy*	*Turquoise*	*Tobacco*	*Itaian mahogany*[c]	*Fruitwood*[d]	*Pecan*[e]	*Rosewood*	*Medium brown*	*Maroon*	*White*	*Pink*[f]	*Pastel blue*	*Purple*
824-2242, brown		2	84	88		50	88			93		94		60	19	50				
824-4442, DB brown	70							20			70		83							
824-2243, black			9	3			4	20		7		6	6	10		20				
824-2238, red	10					50		20			10		11	10	1	30		2		5
824-2237, orange	20				7						20			20						
824-2241, yellow		3	10																	
824-2239, blue									80										12	10
824-2240, green					13				20											
812-2244, reducer		95	137	9	20							100	100		10		30	40	35	50
870-0351, white																	5	5	1	1
Total	100	100	240	100	40	100	92	60	100	100	100	200	200	100	30	100	35	47	48	66

[a]Numbers refer to products of Sadolin Industrial Paints.
[b]These colours are referred to by number, 1-20, in production documentation.
[c]Bright reddish.
[d]Light dark oak.
[e]Light reddish brown.
[f]Pastel red.

Table A.II.2 Lacquer stain (NC stain) formulas (Parts by weight)

Basic colour number[a]	*Stain colour*[b]							
	Light grey	*Light pastel blue*	*Beige*	*Rose*	*Light pastel green*	*Light pink*	*Mahogany*	*Walnut*
890-7012, tint brown								
880-7089, brown								
889-7089, black	1						4	10
890-7083, red				1		1	10	2
890-7007, orange			1				4	9
890-7010, yellow			1					
890-7076, blue		1						
890-7097, green					1			
890-7000, reducer							11	80
890-7072, white	100	100	100	100	100	200	—	—
Total	101	101	102	101	101	201	29	101

[a]Numbers refer to products of Sadolin Industrial Paints.

[b]These colours are referred to by number, 1-8, in production documentation.

Annex III

RECOMMENDED FINISHING SYSTEMS FOR STAIN FINISHES

Furniture system No. 7: Nitrocellulose system, fast drying

Suited for:	Bamboo, rattan with skin etc.
Appearance:	Stain (glazed) finish
Gloss:	Any
Application:	Spray, any type
Total drying time:	80-175 min, depending on the drying facilities
Remarks:	Low to medium quality; formaldehyde-free
Filling	Pre-sanding with, if possible, paper No. 320 to improve adhesion
Drying:	
Sanding:	
Mixing ratio:	
Staining	One thin application of NC top lacquer of good quality tinted with NGR or lacquer stain
Drying time range:	40 min at 25° C/15 min at 50° C
Sanding:	None
Mixing ratio:	100 parts NC top lacquer, no more than 50 parts stain, NC thinner to obtain a viscosity of ~18 sec/D4/25° C*
Sealing/priming	
Drying:	
Sanding:	
Mixing ratio:	
Top coat(s)	One thin application of NC top lacquer of good quality
Drying time range:	Appproximately 90 min at 25° C before packing/20 min at 50° C before packing
Sanding:	None
Mixing ratio:	Add NC thinner to obtain a viscosity of ~18 sec/D4/25° C*
Additional	A glazing can be made before application of the top coat. After wiping, the glaze must dry at least 45 min at 25° C.

Furniture system No. 8: Acid-curing system, medium drying

Suited for:	Bamboo, rattan with skin etc.
Appearance:	Stain (glazed) finish
Gloss:	Any
Application:	Spray, any type
Total drying time:	2-8 h, depending on the drying facilities
Remarks:	Medium to high quality; emits formaldehyde
Filling	Pre-sanding with, if possible, paper No. 320 to improve adhesion
Drying:	
Sanding:	
Mixing ratio:	
Staining	One thin application of AC top lacquer tinted with acid-proof NGR or lacquer stain
Drying time range:	Depending on the product used, minimum 1 h, maximum 6 h at 25° C/minimum 15 min, maximum 30 min at 50° C
Sanding:	None, therefore minimum/maximum drying specifications must be strictly observed
Mixing ratio:	100 parts AC top lacquer, 10 parts hardener and not more than 50 parts NGR or lacquer stain, thinner to achieve viscosity of ~18 sec/D4/25° C*
Sealing/priming	
Drying:	
Sanding:	
Mixing ratio:	
Top coat(s)	One thin application AC top lacquer, unmodified type
Drying time range:	Appproximately 6 h at 25° C before packing/1 h at 50° C before packing
Sanding:	In case of glazing, sanding with paper No. 320
Mixing ratio:	100 parts AC lacquer, 10 parts hardener, 20-30 parts thinner to obtain a viscosity of 18 sec/D4/25° C
Additional	A glazing can be made before application of the top coat. After wiping, the glaze must dry at least 45 min at 25° C.

*Percolation time at 25° C using a DIN cup No. 4.

Furniture system No. 9: Polyurethane system, slow drying

Suited for:	Bamboo, rattan with skin etc.
Appearance:	Stained finish
Gloss:	Any

Application:	Spray, any type
Total drying time:	2.5-10 h, depending on the drying facilities
Remarks:	High quality; no formaldehyde emissions
Filling	Pre-sanding with, if possible, paper No. 320 to improve adhesion
Drying:	
Sanding:	
Mixing ratio:	
Staining	One thin application of PU top lacquer, unmodified type tinted with alcohol-free lacquer stain
Drying time range:	Minimum 2 h, maximum 6 h at 25° C/ minimum 15 min, maximum 1 h at 50° C
Sanding:	None, therefore minimum/maximum drying specifications must be strictly observed
Mixing ratio:	2 parts PU lacquer, 1 part PU hardener, no more than 1 part lacquer stain, and thinner to obtain a viscosity of ~16 sec/D4/25° C*
Sealing/priming	
Drying:	
Sanding:	
Mixing ratio:	
Top coat(s)	One thin application of PU top lacquer, unmodified type.
Drying time range:	Approximately 8 h at 25° C before packing/2 h at 50° C before packing
Sanding:	None
Mixing ratio:	2 parts PU top lacquer, 1 part hardener, 0.5-1.0 part thinner to obtain a viscosity of ~16 sec/D4/25° C
Additional	Glazing cannot be recommended as glaze is normally incompatible with PU lacquers

Furniture system No. 10: Nitrocellulose system, fast drying

Suited for:	Rattan, wicker etc.
Appearance:	Stained, semi-filled surface
Gloss:	Any
Application:	Spray, any type
Total drying time:	3-6 h, depending on the drying facilities
Remarks:	Low to medium quality; formaldehyde-free
Filling	
Drying time range:	
Sanding:	
Mixing ratio:	
Staining	One application of combi or NGR or lacquer stain
Drying time range:	At 25° C, 1 h or 15 min or 10 min/at 50° C, 15 min or 5 min or 2 min, depending on type of stain
Sanding:	None
Mixing ratio:	
Sealing/priming	One application of NC sealer, heavy coating
Drying time range:	Approximately 40 min at 25° C/15 min at 50° C
Sanding:	Paper No. 320
Mixing ratio:	Add NC thinner to obtain a viscosity of ~18 sec/D4/25° C*
Top coat(s)	Three applications of NC top lacquer
Drying time range:	Approximately 40 min between coatings at 25° C/15 min between coatings at 50° C. Packing may take place 2 h after application of top coat
Sanding:	Not required
Mixing ratio:	Add NC thinner to obtain a viscosity of ~18 sec/D4/25° C*
Additional	A glazing can be applied between first and second top coats. After wiping, the glaze must dry at least 45 min at 25° C.

Furniture system No. 11: Acid-curing system, medium drying

Suited for:	Rattan, wicker etc.
Appearance:	Stained, semi-filled surface
Gloss:	Any
Application:	Spray, any type
Total drying time:	2 h and 15 min to 9 h and 45 min, depending on the drying facilities
Remarks:	Medium to high quality; emits formaldehyde
Filling	
Drying:	
Sanding:	
Mixing ratio:	
Staining	One application of combi or NGR or lacquer stain
Drying time range:	At 25° C, 1 h or 15 min or 10 min/at 50° C, 15 min or 5 min or 2 min, depending on type of stain
Sanding:	None
Mixing ratio:	
Sealing/priming	One application of AC top lacquer, unmodified type
Drying:	Approximately 2 h at 25° C/30 min at 50° C
Sanding:	Paper No. 320
Mixing ratio: (Typical)	100 parts AC lacquer, 10 parts hardener, 20-30 parts thinner to obtain a viscosity of ~18 sec/D4/25° C*
Top coat(s)	One application of AC top lacquer, unmodified type

Drying time range:	Approximately 6 h at 25° C before packing/or 1 h at 50° C before packing
Sanding:	None
Mixing ratio:	100 parts AC lacquer, 10 parts hardener, 20-30 parts thinner to obtain a viscosity of ~18 sec/D4/25° C*
Additional	A glazing can be made before application of the top coat. After wiping, the glaze must dry at least 45 min at 25° C.

Furniture system No. 12: Polyurethane system, slow drying

Suited for:	Rattan, wicker etc.
Appearance:	Stained, semi-filled surface
Gloss:	Any
Application:	Spray, any type
Total drying time:	3.5-11 h, depending on the drying facilities
Remarks:	High quality, no formaldehyde emissions
Filling	
Drying:	
Sanding:	
Mixing ratio:	
Staining	One application of combi or NGR or lacquer stain
Drying time range:	At 25° C, 1 h or 15 min or 10 min/at 50° C, 15 min or 5 min or 2 min, depending on type of stain
Sanding:	None
Mixing ratio:	
Sealing/priming	One application of PU sealer, unmodified type
Drying time range:	Approximately 3 h at 25° C/1.5 h at 50° C
Sanding:	Paper No. 320
Mixing ratio:	2 parts PU sealer, 1 part hardener, 0.5-1.0 part thinner to obtain a viscosity of ~16 sec/D4/25° C*
Top coat(s)	One application of PU lacquer, unmodified type
Drying time range:	Approximately 8 h at 25° C before packing/2 h at 50° C before packing
Sanding:	None
Mixing ratio:	2 parts PU lacquer, 1 part hardener, 0.5-1 part thinner to obtain a viscosity of ~16 sec/D4/25° C*
Additional	Glazing cannot be recommended as glaze is normally incompatible with PU lacquers

Annex IV

RECOMMENDED FINISHING SYSTEMS FOR PIGMENTED FINISHES

Furniture system No. 13: Acid-curing system, medium drying

Suited for:	Bamboo, rattan with skin etc.
Appearance:	Pigmented finish
Gloss:	Any except high gloss
Application:	Spray, any type
Total drying time:	1-6 h, depending on the drying facilities
Remarks:	Medium to high quality; emits formaldehyde
Filling	
Drying:	
Sanding:	
Mixing ratio:	
Staining	
Drying:	
Sanding:	
Mixing ratio:	
Sealing/priming	Primer is not recommended because it could give poor flexibility and adhesion
Drying:	
Sanding:	
Mixing ratio:	
Top coat(s)	One thin application of AC enamel, unmodified type
Drying time range:	Approximately 6 h at 25° C before packing/1 h at 50° C before packing
Sanding:	None
Mixing ratio:	100 parts AC enamel, 10 parts hardener, 20-30 parts thinner to obtain a viscosity of ~18 sec/D4/25° C*
Additional	Pre-sanding with, if possible, paper No. 320 to improve adhesion

Furniture system No. 14: Polyurethane system, slow drying

Suited for:	Bamboo, rattan with skin etc.
Appearance:	Pigmented finish
Gloss:	Any
Application:	Spray, any type
Total drying time:	2-8 h, depending on the drying facilities
Remarks:	High quality; no formaldehyde emissions
Filling	
Drying:	
Sanding:	
Mixing ratio:	
Staining	
Drying:	
Sanding:	
Mixing ratio:	
Sealing/priming	Primer is not recommended because it could give poor flexibility and adhesion
Drying:	
Sanding:	
Mixing ratio:	
Top coat(s)	One thin application of PU enamel, unmodified type
Drying time range:	Approximately 8 h at 25° C before packing/2 h at 50° C before packing
Sanding:	None
Mixing ratio:	2 parts PU enamel, 1 part hardener, 0.5-1.0 part thinner to obtain a viscosity of ~18 sec/D4/25° C*
Additional	Pre-sanding with, if possible, paper No. 320 to improve adhesion

*Percolation time at 25° C using a DIN cup No. 4.

Furniture system No. 15: Acid-curing system, medium drying

Suited for:	Rattan, wicker etc.
Appearance:	Pigmented finish, semi-filled finish
Gloss:	Any
Application:	Spray, any type
Total drying time:	1.5-8 h, depending on the drying facilities
Remarks:	Medium to high quality; emits formaldehyde
Filling	
Drying:	
Sanding:	
Mixing ratio:	

Staining

Drying:

Sanding:

Mixing ratio:

Sealing/priming: One application of AC Primer, unmodified type

Drying time range: Approximately 2 h at 25° C/30 min at 50° C

Sanding: Paper No. 240

Mixing ratio: 100 parts AC primer, 10 parts hardener, 20-30 parts thinner to obtain a viscosity of ~18 sec/D4/25° C*

Top coat(s): One application of AC enamel, unmodified type

Drying time range: Approximately 6 h at 25° C before packing/1 h at 50° C before packing

Sanding: None

Mixing ratio: 100 parts AC enamel, 10 parts hardener, 20-30 parts thinner to obtain a viscosity of ~18 sec/D4/25° C*

Additional

Furniture system No. 16: Polyurethane system, slow drying

Suited for:	Rattan, wicker etc.
Appearance:	Pigmented finish, semi-filled finish
Gloss:	Any
Application:	Spray, any type
Total drying time:	
Remarks:	High quality; no formaldehyde emissions
Filling	
Drying:	
Sanding:	
Mixing ratio:	
Staining	
Drying:	
Sanding:	
Mixing ratio:	
Sealing/priming	One application of PU primer, unmodified type
Drying time range:	Approximately 3 h at 25° C/1.5 h at 50° C
Sanding:	Paper No. 240
Mixing ratio:	2 parts PU primer, 1 part hardener, 0.5-1.0 part thinner to obtain viscosity of ~16 sec/D4/25° C*
Top coat(s)	One application of PU enamel, unmodified type
Drying:	Approximately 8 h at 25° C before packing/2 h at 50° C before packing
Sanding:	None
Mixing ratio:	2 parts PU enamel, 1 part hardener, 0.5-1.0 part thinner to obtain a viscosity of ~16 sec/D4/25° C*
Additional	

Furniture system No. 17: Polyurethane system, slow drying

Suited for:	Rattan, wicker etc.
Appearance:	Pigmented finish, semi-filled finish
Gloss:	Glossy
Application:	Spray, any type
Total drying time:	
Remarks:	High quality; no formaldehyde emissions
Filling	
Drying:	
Sanding:	
Mixing ratio:	
Staining	
Drying:	
Sanding:	
Mixing ratio:	
Sealing/priming	Two applications of PU primer, unmodified type
Drying time range:	Approximately 3 h at 25° C between coatings/30 min at 50° C between coatings
Sanding:	Paper No. 240, first application; paper No. 320, second application
Mixing ratio:	2 parts PU primer, 1 part hardener, 0.5-1.0 part thinner to obtain a viscosity of ~16 sec/D4/25° C*
Top coat(s)	Two applications of PU enamel, unmodified type, wet on wet
Drying time range:	20-40 min between coats then 12 h at 25° C before packing/3 h at 50° C before packing
Sanding:	None
Mixing ratio:	2 parts PU enamel, 1 part hardener, 0.5-1 part thinner to obtain a viscosity of ~16 sec/D4/25° C*
Additional	

Annex V

SOME EXAMPLES OF PIGMENTED FORMULATIONS FOR SPECIFIC COLOURS

Table A.V.1. Enamel formulas (Parts by weight)

Basic colour No.[a]	*Enamel colour*[b] *Almond (beige)*	*Rose*	*China red*	*Grey*	*Green*	*Turquoise*	*Lavender*	*Broom yellow*
117-0001, white	920.0	100		400	1 120	400	470	400
117-1077, jet black	0.22		5	35	16			
117-0101, permanent green	0.25				135	170		
117-0116, violet							18	
117-0165, red		15						
117-0018, post red			600					
117-1002, orange								
117-1009, oxide red								
117-1028, permanent blue							40	
117-1074, oxide yellow	14.0				10			75
117-1093, chrome yellow			150	25	90	3		31
Total	934.47	115	755	460	1 371	573	528	506

[a]Numbers refer to products of Sadolin Industrial Paints.

[b]These colours are referred to by number, 1-8, in production documentation.

Annex VI

THE SELECTION OF NOZZLES

Table A.VI.1. Guide to nozzle sizes for different spray guns[a]

Type of spray gun	*Office chairs and other thin components*	*Office table tops and other flat surfaces*
Conventional spray		
Paint	1.0-1.5 mm	1.0-1.2 mm
Stain	0.8-1.0 mm	0.8-1.0 mm
Airless and airmix airless	0.28-0.33 mm; 10-20° at 7-14 cm spraying distance	0.33-0.43 mm; 40-50° at 20-26 cm spraying distance
Airmix airless type for stain	0.23 mm, 20°	0.23 mm, 50°
Electrostatic	Nozzle for normal surfaces; 0.28 mm; 50-60°	Nozzle for flat surfaces; 0.33-0.43 mm; 40-50°

[a]Text of figure 128 shows how nozzles are coded for high-pressure airless system uses.

DATA ON FORCED AIR CIRCULATION TUNNEL DRIERS

A typical forced air circulation drier is shown in figure A.VII.1. It can be seen to consist of four different sections. In the first, called the flash-off zone, the solvent of the applied finish is removed. This section is shown in figure A.VII.2, along with the air volumes needed to remove the solvent that is flashed off from the finish. The air circulation inside the flash-off zone is important; figure A.VII.3 shows the special circulation arrangements there. A close-up of the air circulation fan is given in figures A.VII.4 and A.VII.5. The heat for the drying comes from electricity, heat battery or circulated hot water.

The second section of the drier is called heating zone 1. It is at this point, after solvent flash-off has occurred, that the curing of the finish starts. Again, air circulation inside the section is important (figure A.VII.6). Heating zone 2 is very similar to heating zone 1, with the difference often being the temperatures in the zones. Figure A.VII.7 shows suction arrangements for exhausting air from the first thee sections of the dryer. Figure A.VII.8 shows the cooling zone, which is the last section of the drier tunnel, and the intake and outlet for air needed to cool the dried furniture to room temperature to allow for denibbing sanding (on first coats) or final packing (after the last top coat). The circulation of air inside the cooling zone is shown in figure A.VII.9. A conveyor/trolley system with an automatic feed system to move the trolleys from one zone to the next though the drier is shown in figure A.VII.10, and a close-up view of the trolley feed arrangement is provided in figure A.VII.11. An overall view of the drier arrangement is given in figure A.VII.12

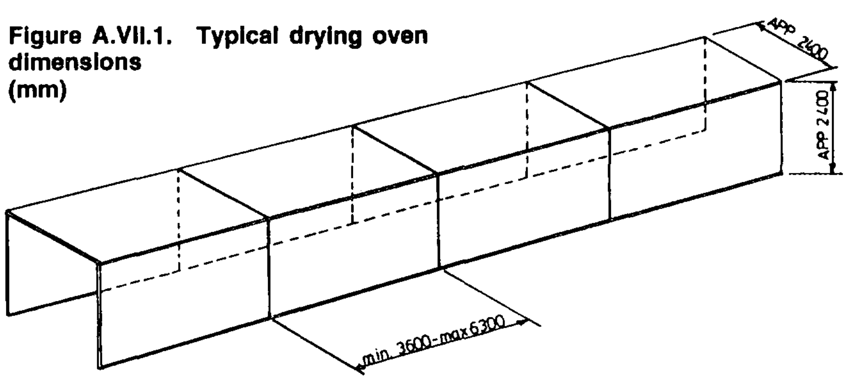
Some drier tunnels are set up with an overhead-feeding conveyor, using hooks to suspend the objects being dried. Such a system is shown in figure A.VII.13. Useful information on designing suspended conveyor feed systems is given in figures A.VII.14-A.VII.23, which come from the firm Lytzen, in Denmark. The system includes a drive unit, which transfers power to a worm gear. On the output shaft of the worm gear is mounted a 12-toothed chain wheel, which gears into and conveys the conveyor chain. The drive unit can be supplied for placement on a straight piece of rail or in a curve. It can be supplied with a fixed number of revolutions or variable maximum 1:9 within the range 0.01-40 m/min conveyor speed. For extra long conveyor plants, several drive units with hydraulic synchronization are used.

When a conveyor system is designed, there should be attention to making it easy to mount, dismount and alter. It should be easy to lubricate without oil drip (the chain can pass though an oil bath), and it should be easy to keep clean and dust-free.

To help in evaluating offers, the cost, in United States dollars, of each element in such a system is as follows (the prices are from Finnrose in Denmark and are 1989 prices):

		US$
	Flash-off zone (figure A.VII.3) with two fans, including ducting, inlet/exhaust box, filter and jet cap	3,000
or		
	Flash-off zone with pre-circulation heating (PCH) unit (figure A.VII.3), excluding heating element	4,300
	Heating zone with two PCH units (figure A.VII.4), each with a circulation of approximately 8,000 m³/h driven by a 4 kW motor and an electric heating element of approximately 15 kW in two steps	10,500
	Exhaust fan (standard extraction) (figure A.VII.7), including regulation damper, jet cap, roof flashing and ducting	1,500
	Cooling zone (figure A.VII.8) with two fans, including regulation dampers, inlet/outlet cap and ducting	2,000
	Conveyor, 25 m (figures A.VII.10 and A.VII.11)	11,300
	Two trolleys, standard execution (figure A.VII.10)	800
	Control panel for the system, 3 × 220 V, 60 Hz, direct earthing	3,000

Figure A.VII.1. Typical drying oven dimensions (mm)



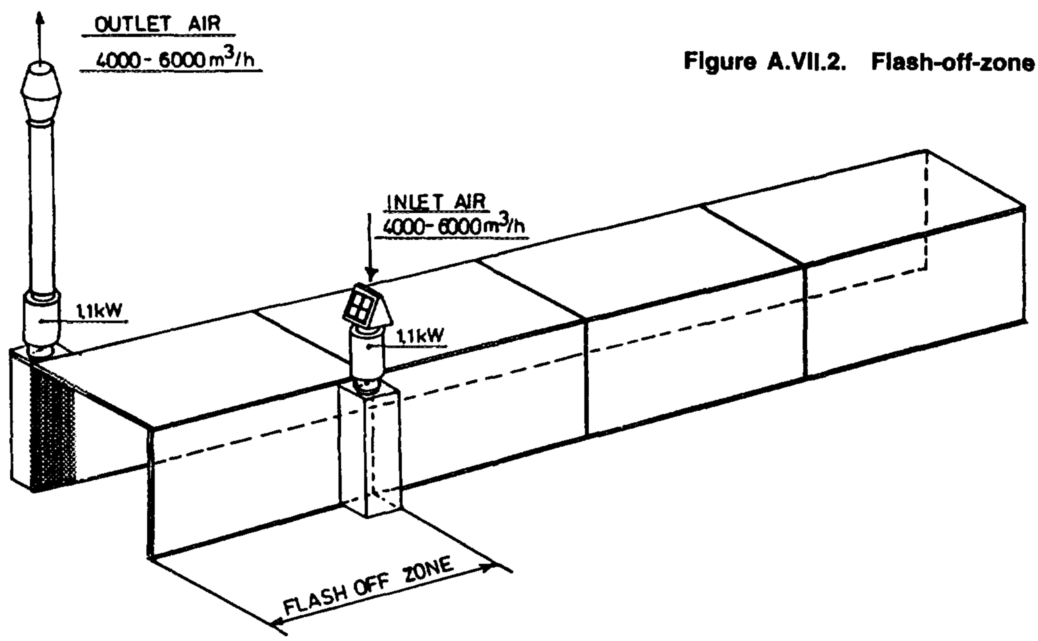


Figure A.VII.2. Flash-off-zone

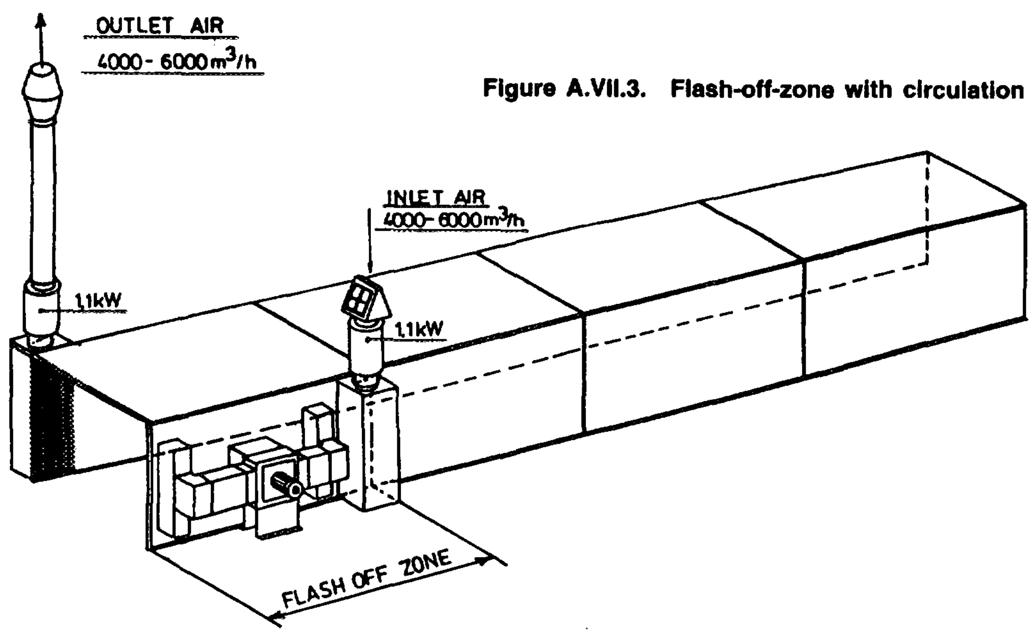
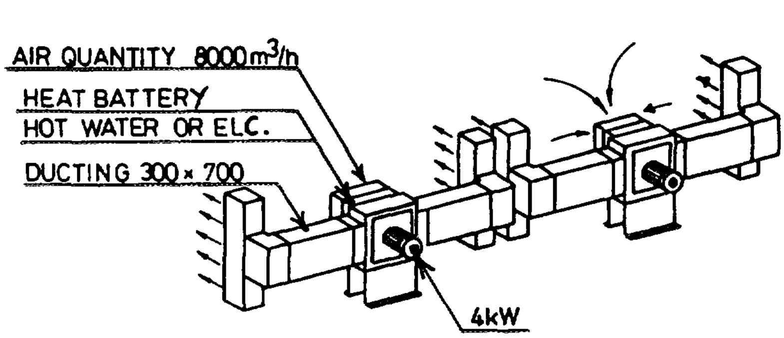


Figure A.VII.3. Flash-off-zone with circulation

Figure A.VII.4. A typical air circulation fan set-up



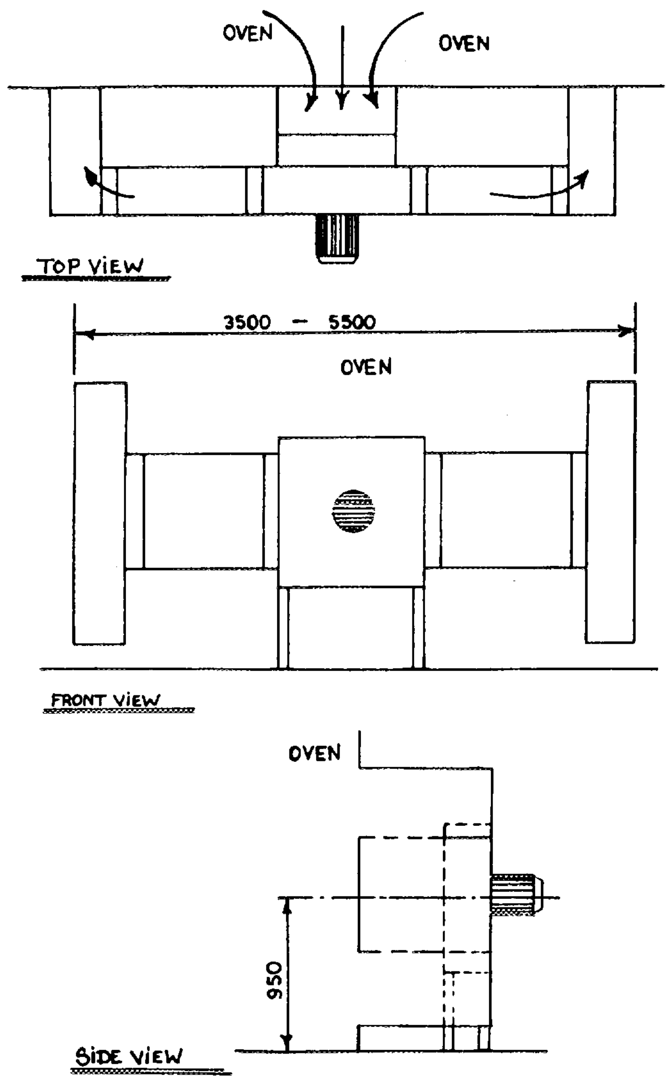
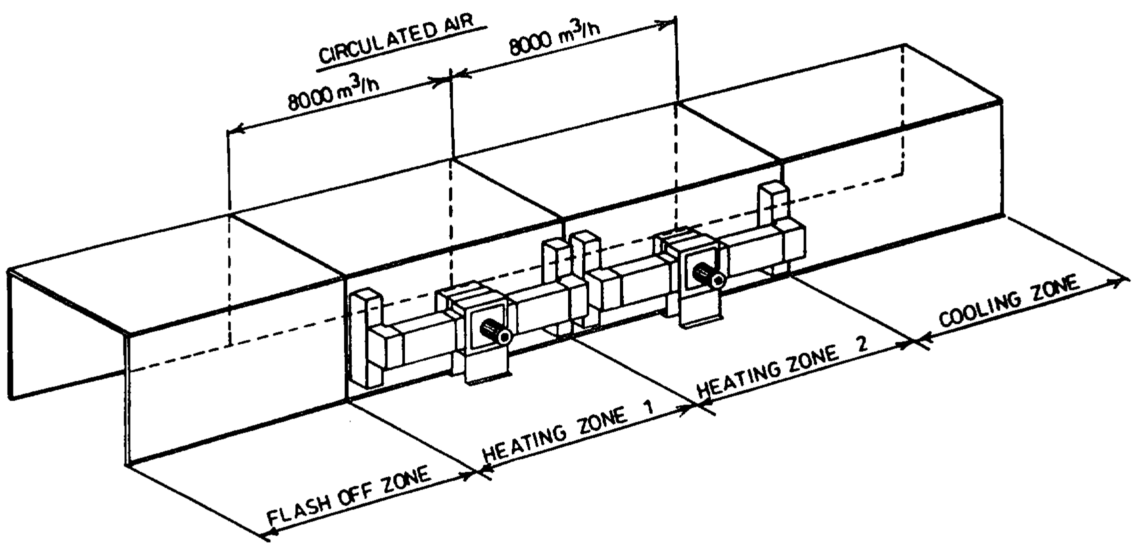


Figure A.VII.5. A close-up view of a pre-circulation heater (PCH) unit air circulation device

Figure A.VII.6. A typical heating zone arrangement



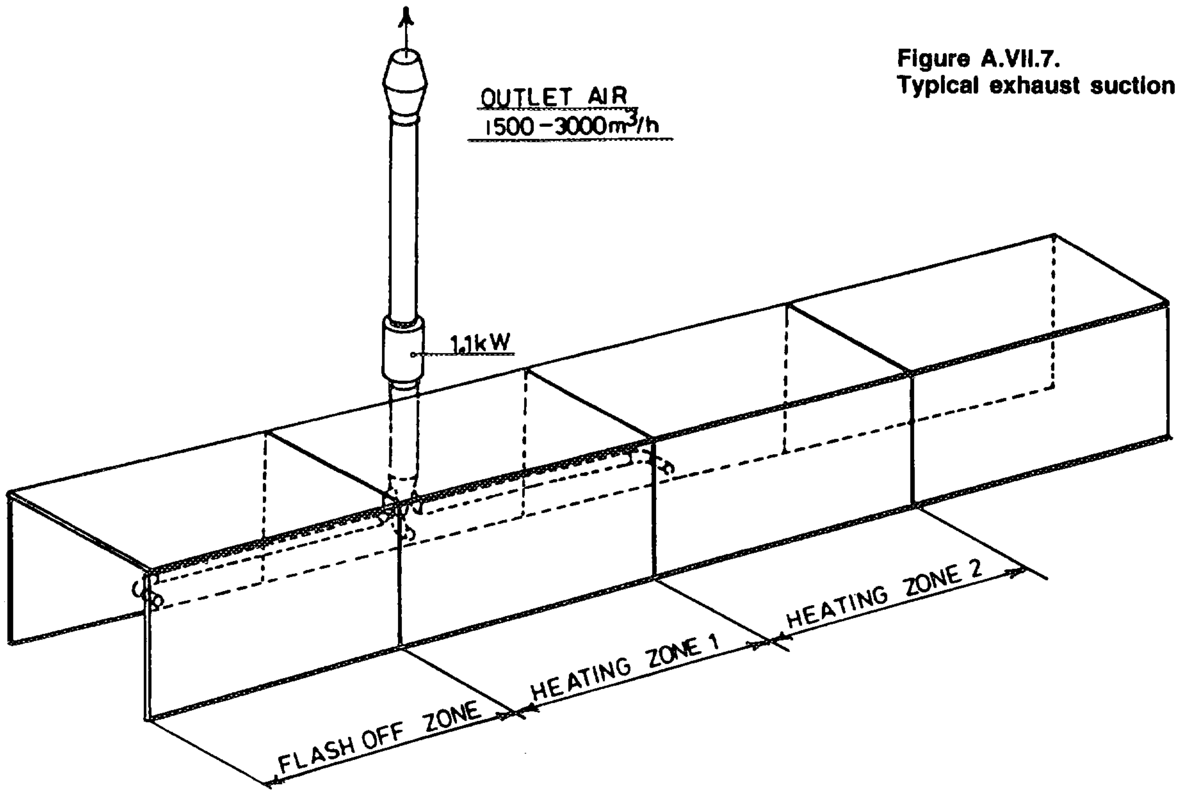


Figure A.VII.7.
Typical exhaust suction requirements

Figure A.VII.8. A typical cooling zone arrangement

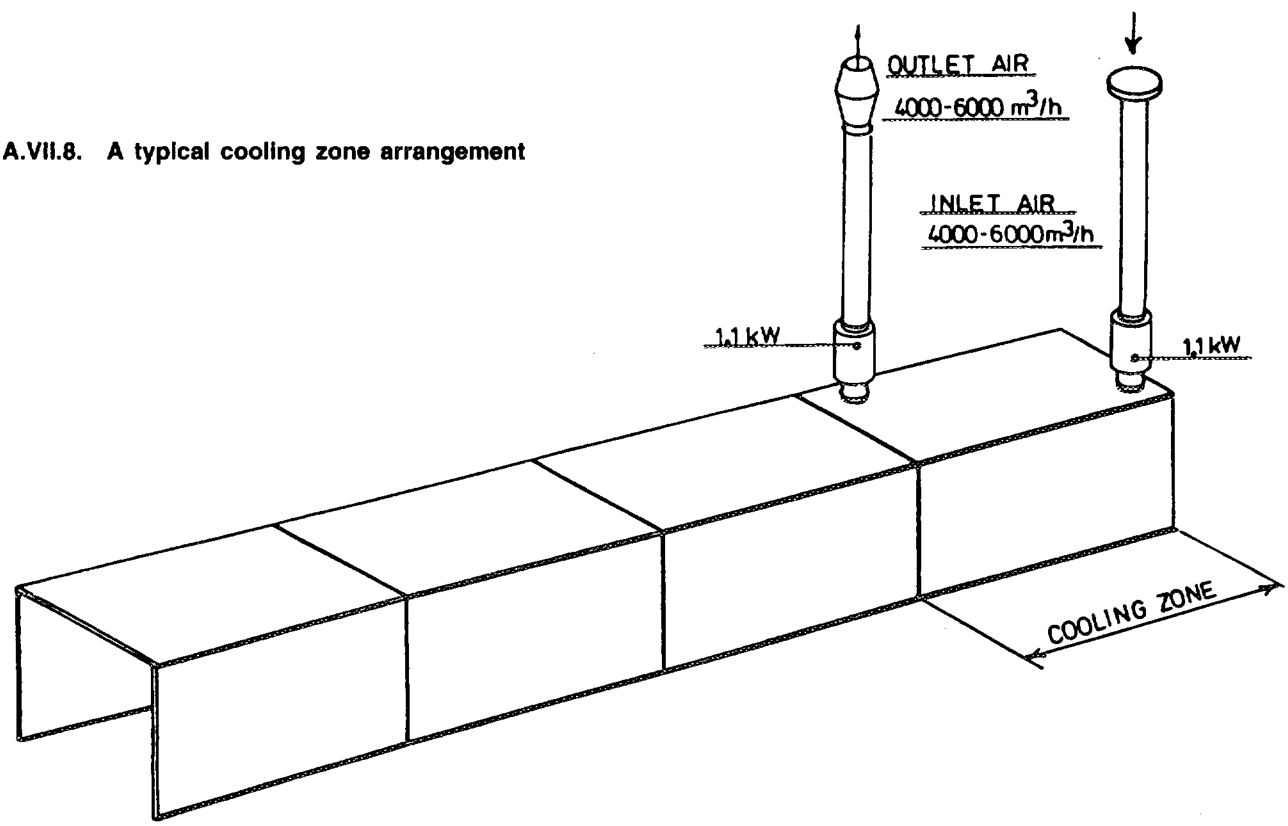


Figure A.VII.9. A typical cooling zone with PCH unit air-circulation

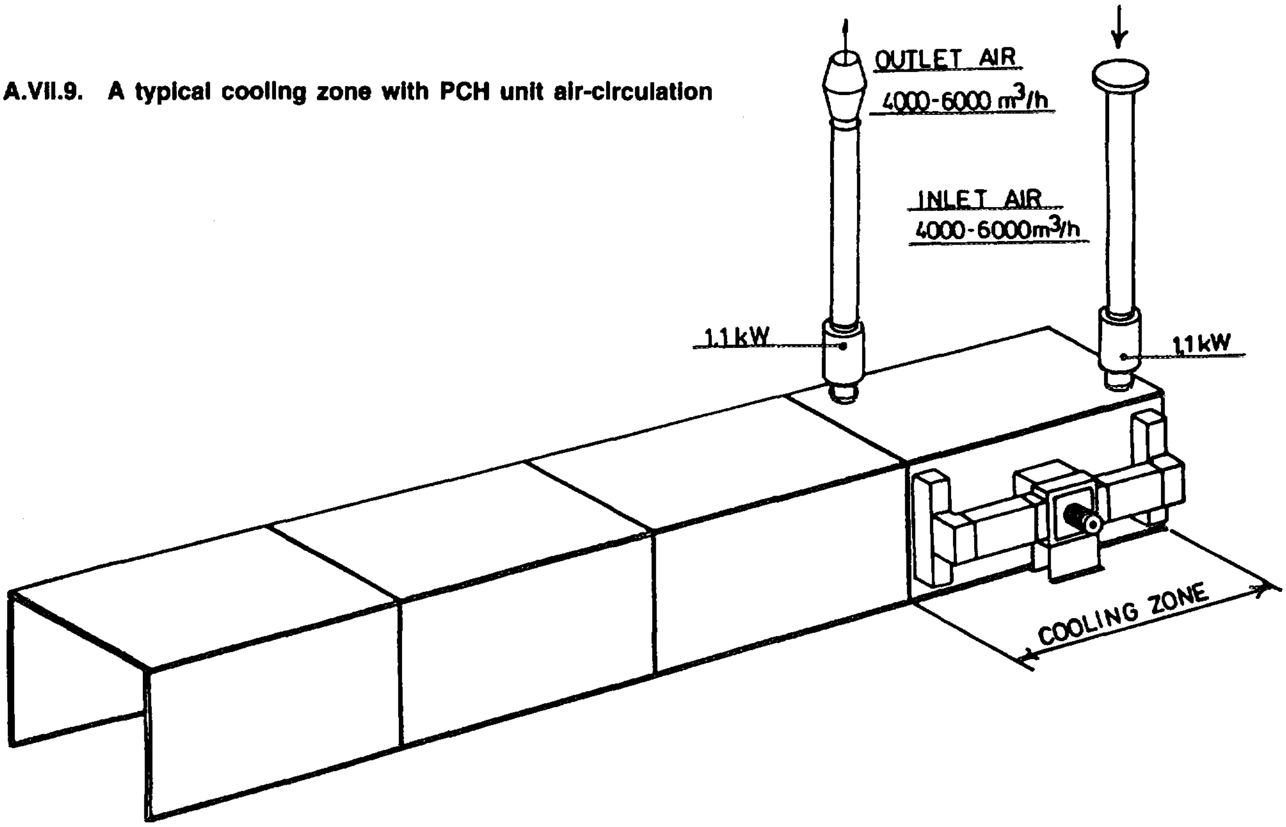


Figure A.VII.10. Typical conveyor/trolley arrangement

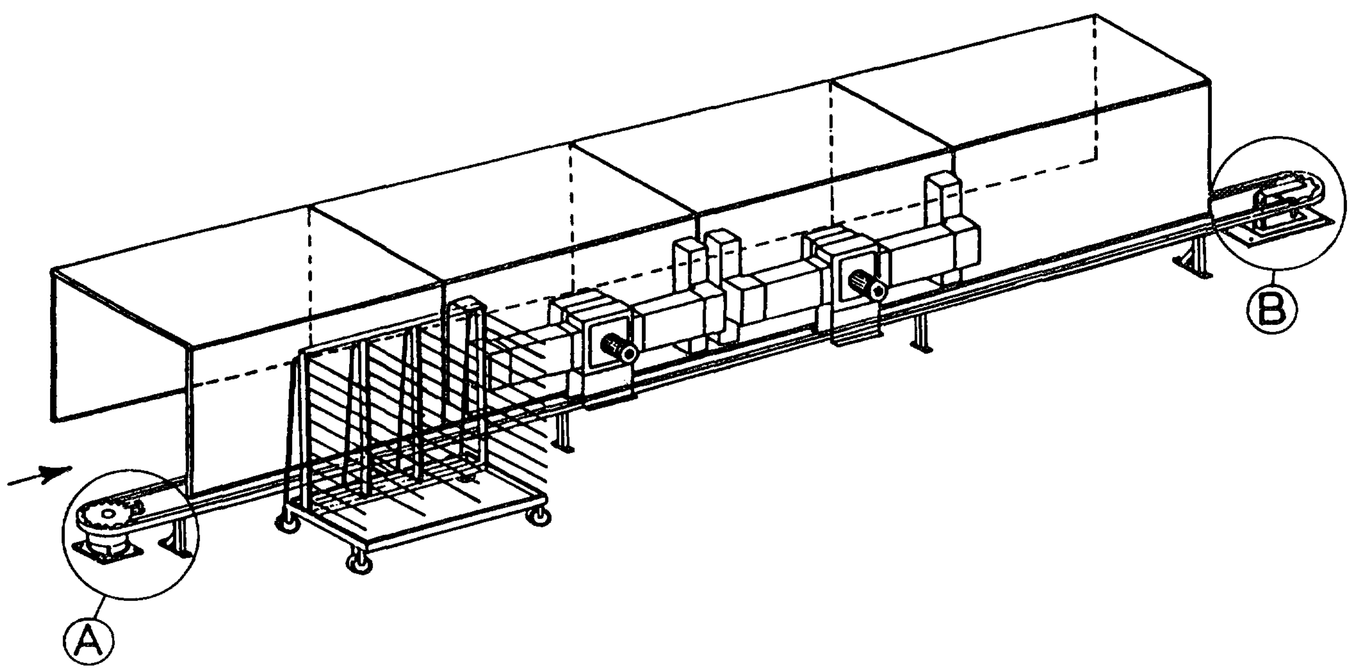


Figure A.VII.11. Typical conveyor details

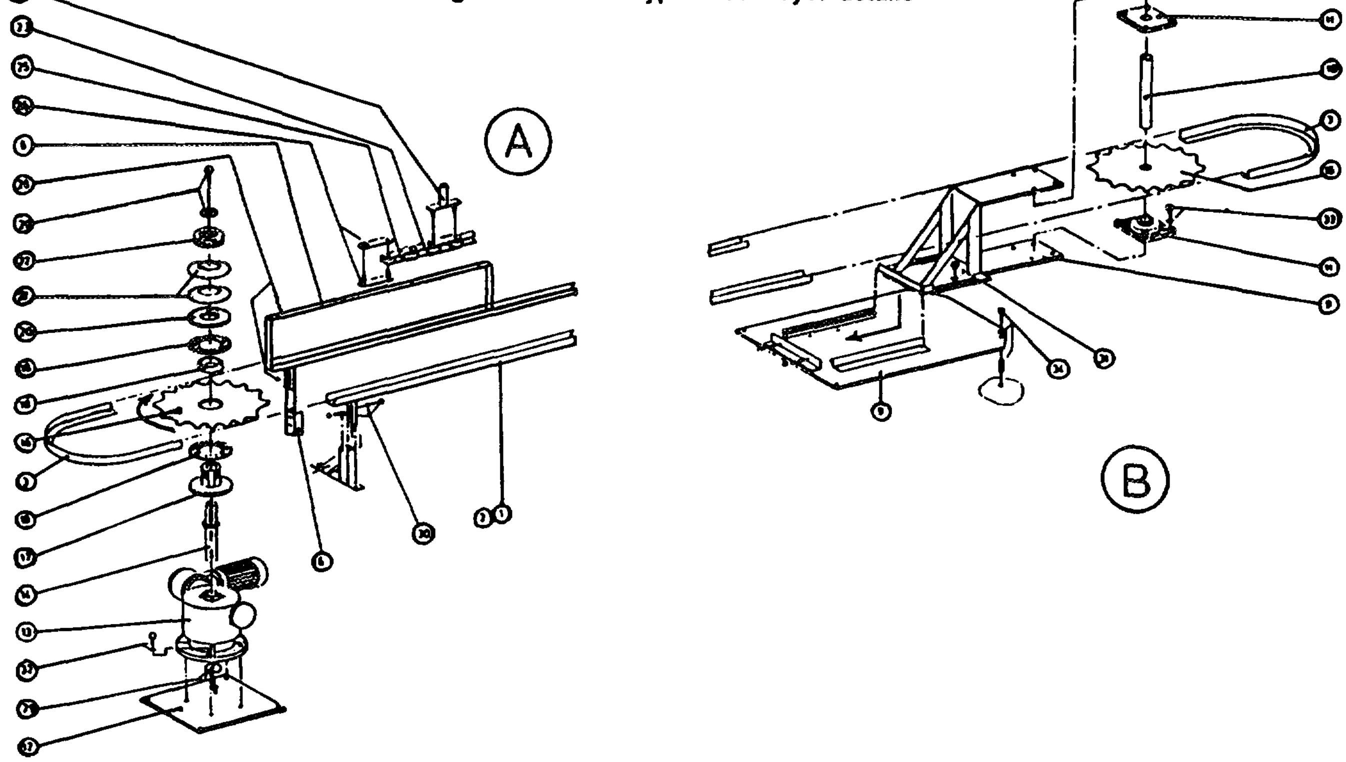


Figure A.VII.12. Overall layout drawing

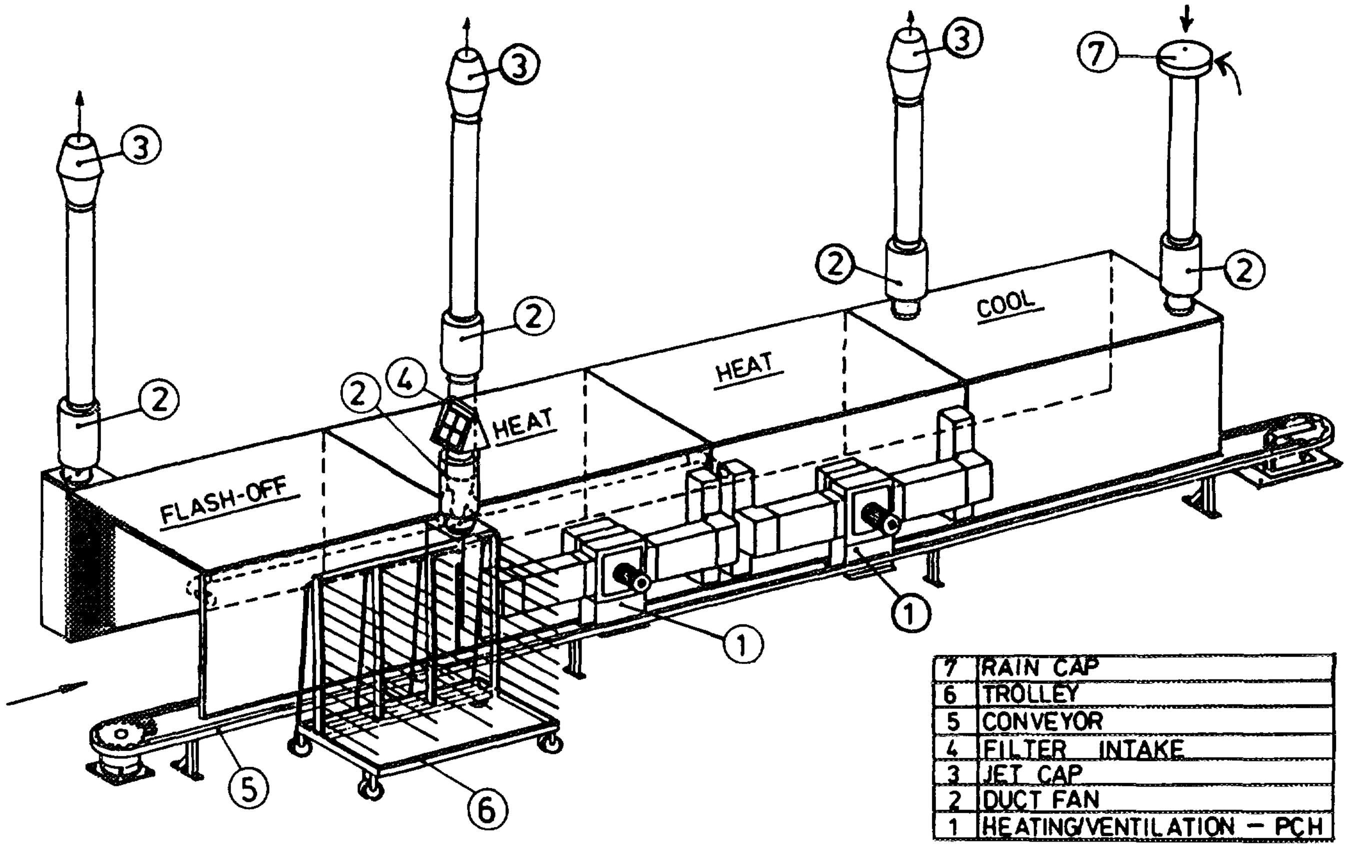
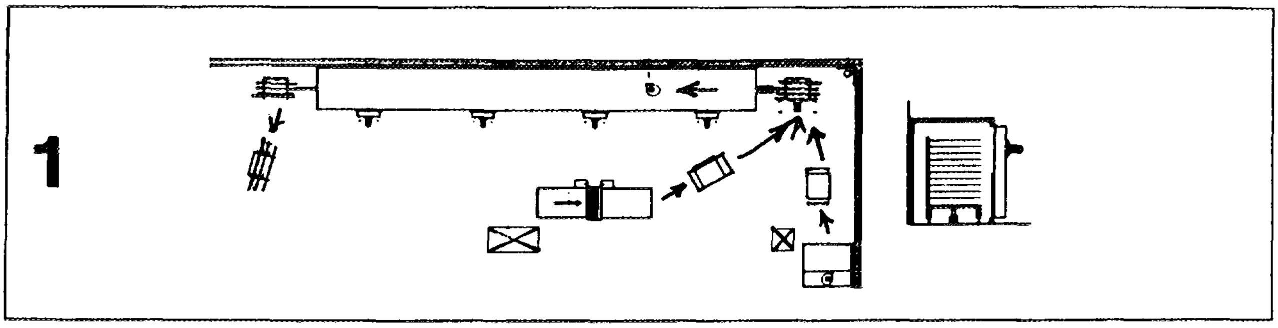
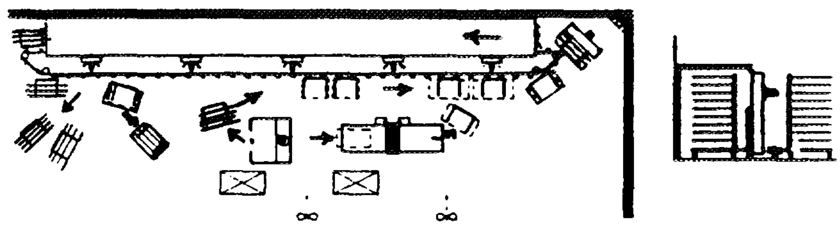


Figure A.VII.13. Conveyor systems for use in drying tunnels

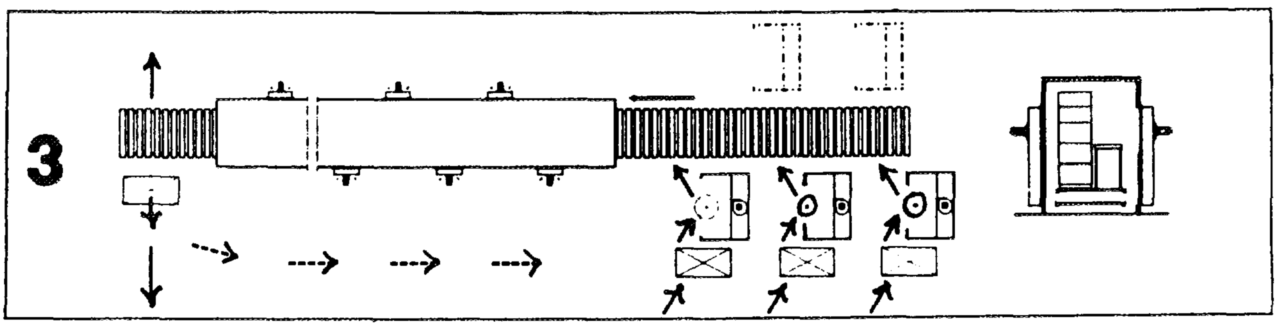


Drying tunnel oven with pusher for mobile racks - manual return transport.

2



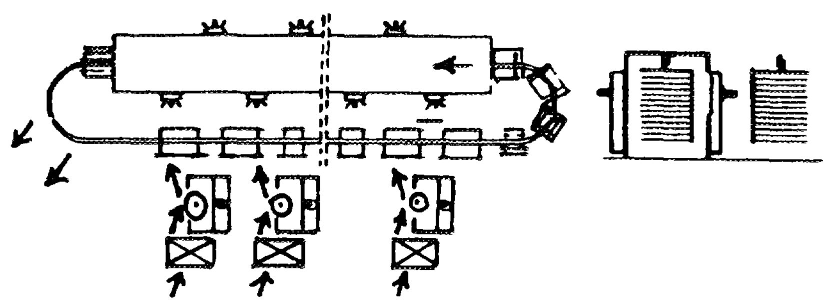
Drying tunnel oven for mobile racks with floor conveyor. Concentration area for coupling on- and off of mobile racks.



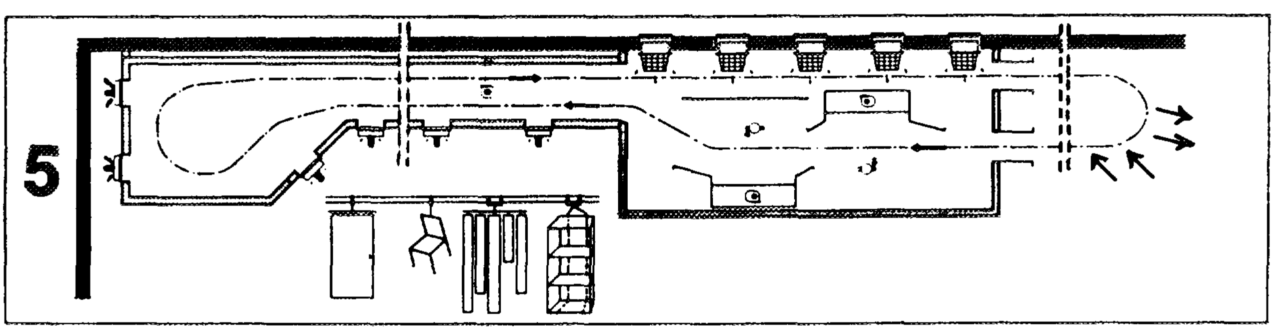
Drying tunnel oven with slat conveyor.

4

Drying tunnel oven for overhead conveyor with suspension racks.



Drying reversing oven and paint spraying box in dustfree room, operated with overhead conveyor with suspension tools for the workpieces.



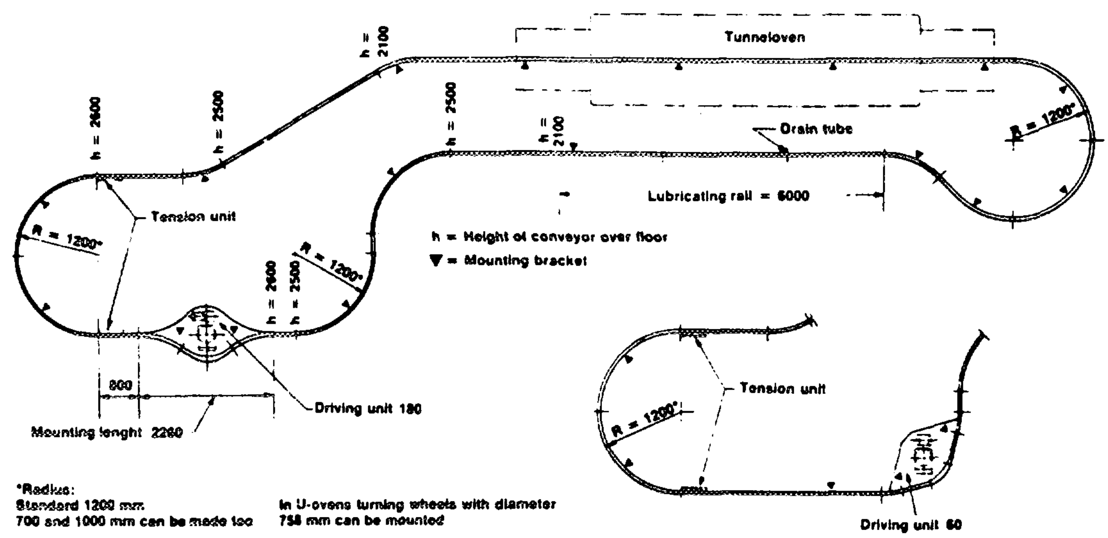
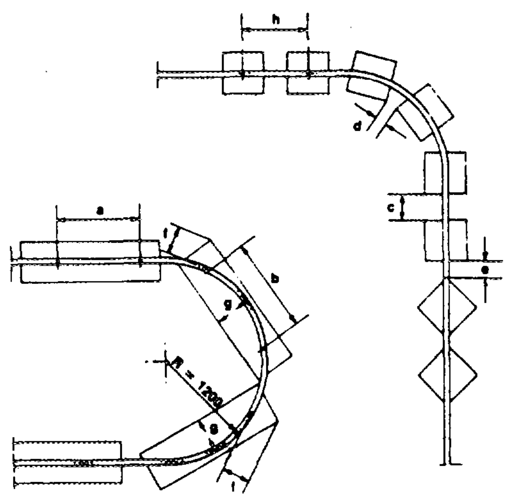
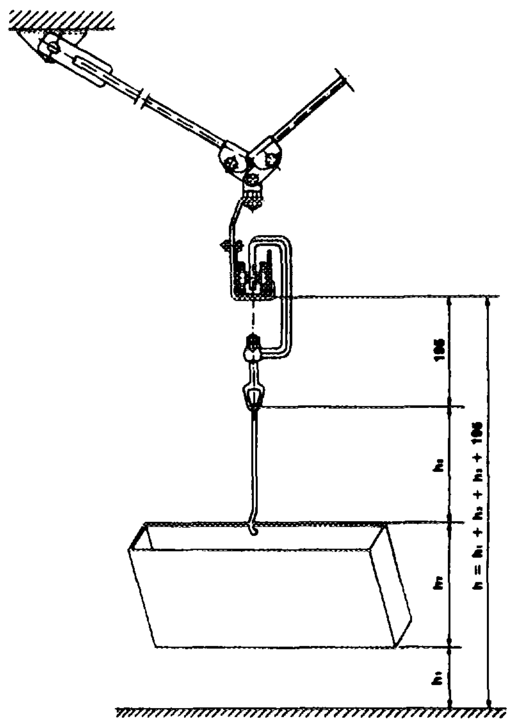


Figure A.VII.14. Typical suspended conveyor layout

Figure A.VII.15. Distance between goods in curves





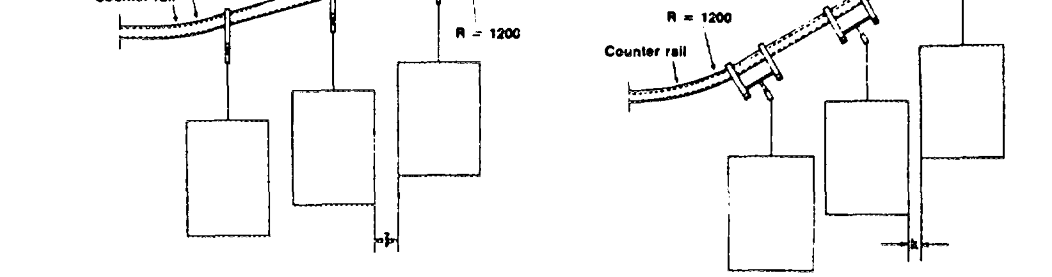


Figure A.VII.16. Distance between goods rising

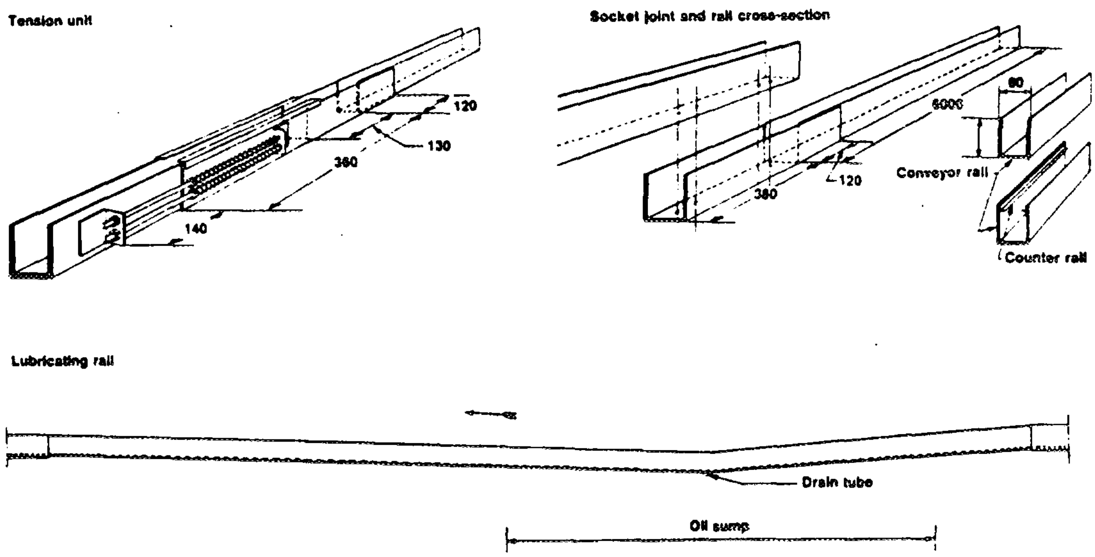


Figure A.VII.17. Tensioning and lubrication of conveyor rail

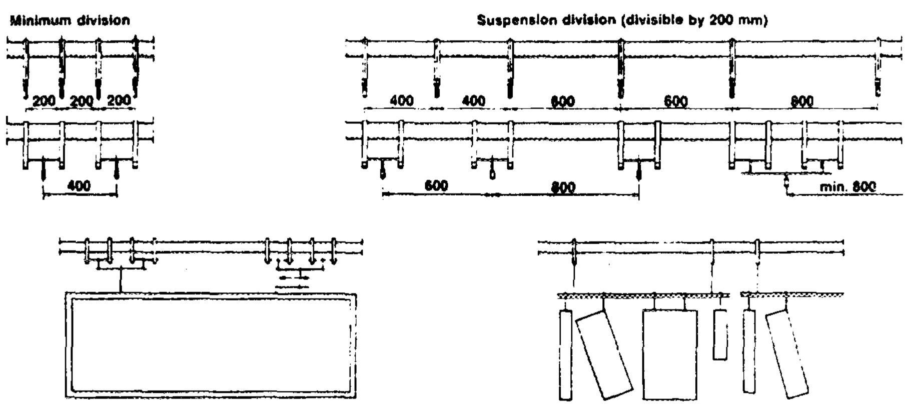


Figure A.VII.18. Positioning of hooks

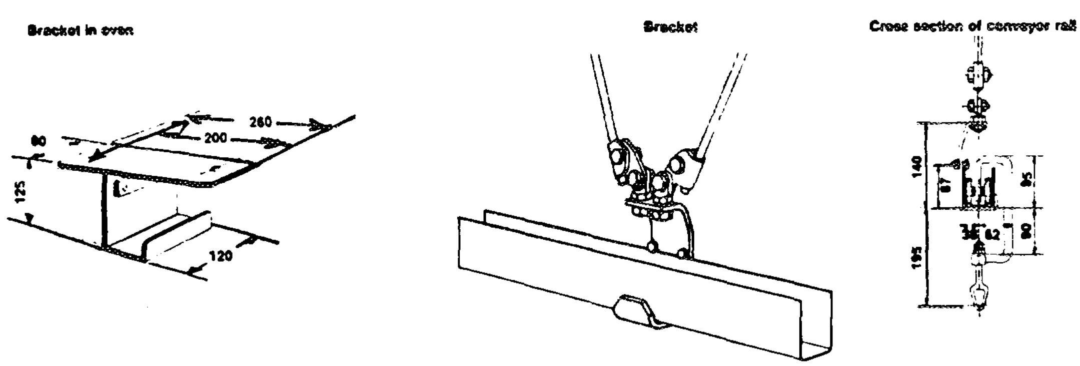
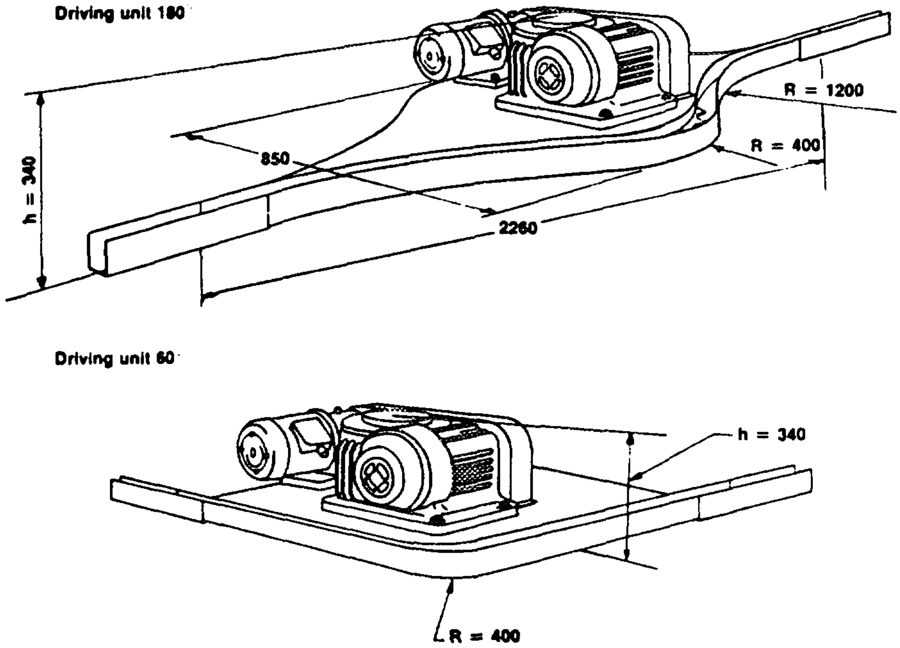


Figure A.VII.19. Mounting bracket

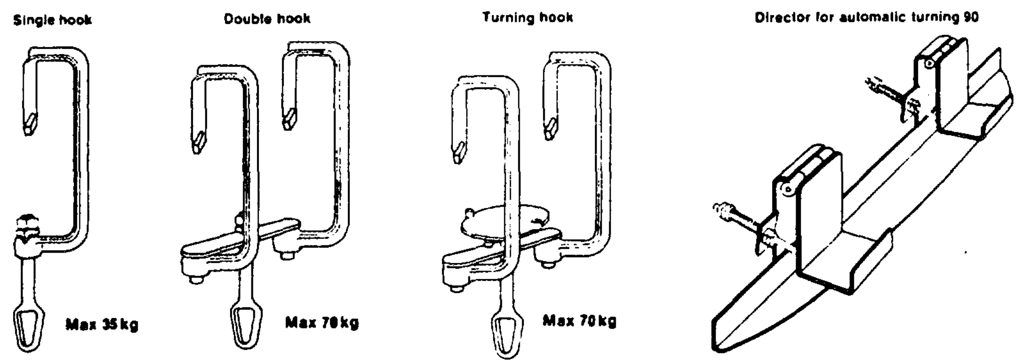
Figure A.VII.20. Location of driving unit

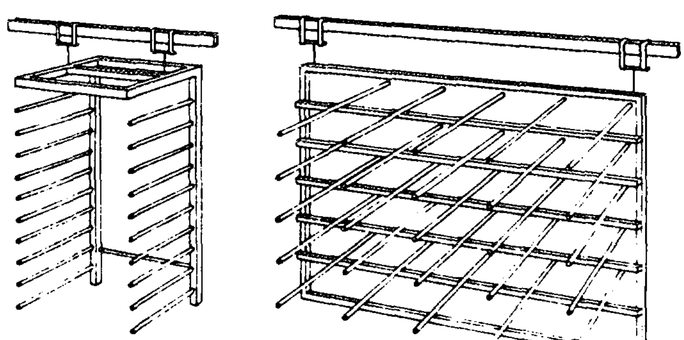


A gear motor is via a friction clutch and chain drive transferring power to a worm gear.
On the output shaft of the worm gear is mounted a 12 toothed chain wheel, which is gearing into and conveying the conveyor chain.
The driving unit can be supplied for placement on a straight piece of rail, or in a curve.

Speed ranges:
The driving unit can be supplied with fixed number of revolutions or variable maximum 1:9 within the range 0.01–40 metres/minute conveyor speed.
For extra long conveyor plants several driving units with hydraulic synchronizing are used.

Figure A.VII.21. Various hooks for suspended conveyor systems

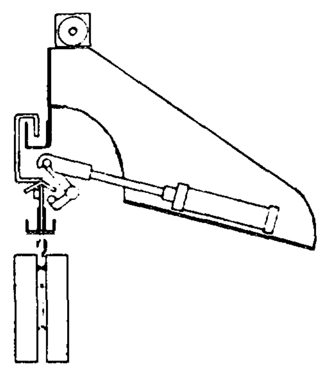




Besides, see leaflet for suspended shelves, and mobile racks

Figure A.VII.22. Examples of suspended shelves

Figure A.VII.23. Automatic hoist



Annex VIII

DIRECTIONS FOR ASSEMBLY AND USE OF THE FLADDER SYSTEM

To get full use of the Fladder 250/Mini and to avoid problems, it is advisable to study this brief description before starting to use it. Figures A.VIII.1 and A.VIII.2 show how the Fladder system works. Table A.VIII.1 presents technical specifications for the 250/Mini and another model, the 300/Air.

Connection

Connect the Fladder 250/Mini to a compressor with a capacity of 6 bar and 300 l/min via an air treatment device with pressure regulator, filter and lubricator. The fittings and couplings must be checked for sufficient though-flow of air.

The motor must always be lubricated during operation (about 2 drops/min, viscosity 10sec/20° C).

Table A.VIII.1. Technical specifications for two Fladder models[a]

	250/Mini	*300/Air*
Air motor (rev/min)	~1 400	~1 100
Air pressure (bar)	6	6
Air consumption (l/sec)	5	10
Output (W)	180	380
Spindle length (mm)	80	150
Number of blades	6	12
Working weight (kg)	1	3
Shipping weight (kg)	2.5	5
Volume (m^3)	0.02	0.05

[a]The air must be filtered and oiled.

Mounting of the blades

Unscrew the bottom flange from the shaft and remove the polystyrene spacers. Now place the Fladder blades and spacers alternately on the shaft until it is full. If the last flange can be depressed below the level of the shaft end, then use another spacer. It is very important that the blades and spacers are securely tightened as otherwise the blades will slide and wear down the spacers. It is not necessary to fill the drum with Fladder blades as long as they are tightened as described above.

Sealer sanding/denibbing

Operate with a light pressure so that the Fladder blades are pressed about an inch into the material. If you press harder, the sanding will not be so fine and you will lose some of the capacity as the number of revolutions will decrease.

It is important that you always sand away from an edge and not towards it, as otherwise the piece will be sanded too much and the lifetime of the Fladder blades will be shortened.

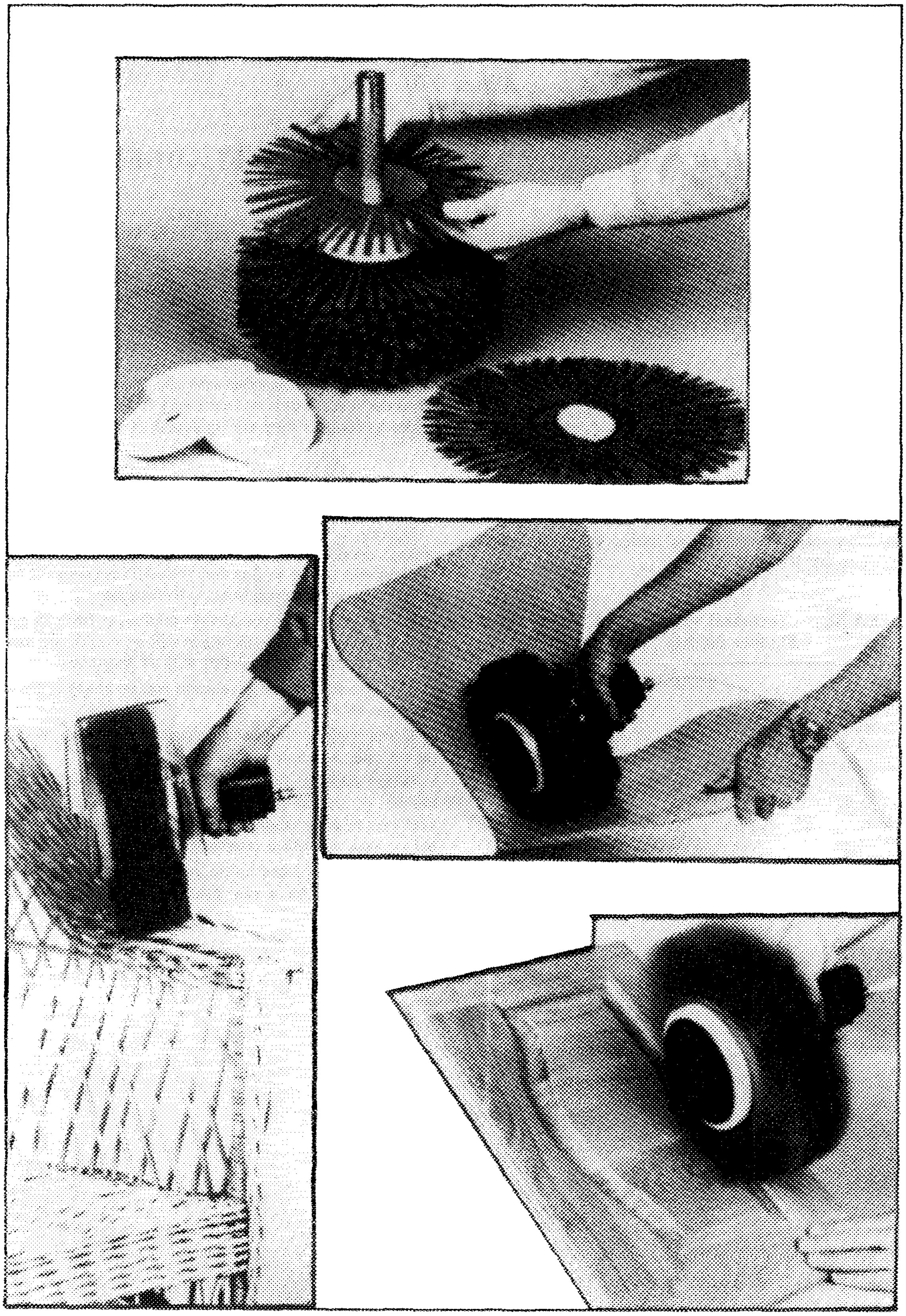
The direction of the revolution can be changed by turning the machine 180°.

If you wish to sand deeper than about an inch, it often pays to mount only a couple of Fladder blades.

When sanding difficult pieces, it is advisable to reduce the number of revolutions. That is done by reducing the pressure. If you want heavier sanding, first increase the number of revolutions before you try with a coarser grit size.

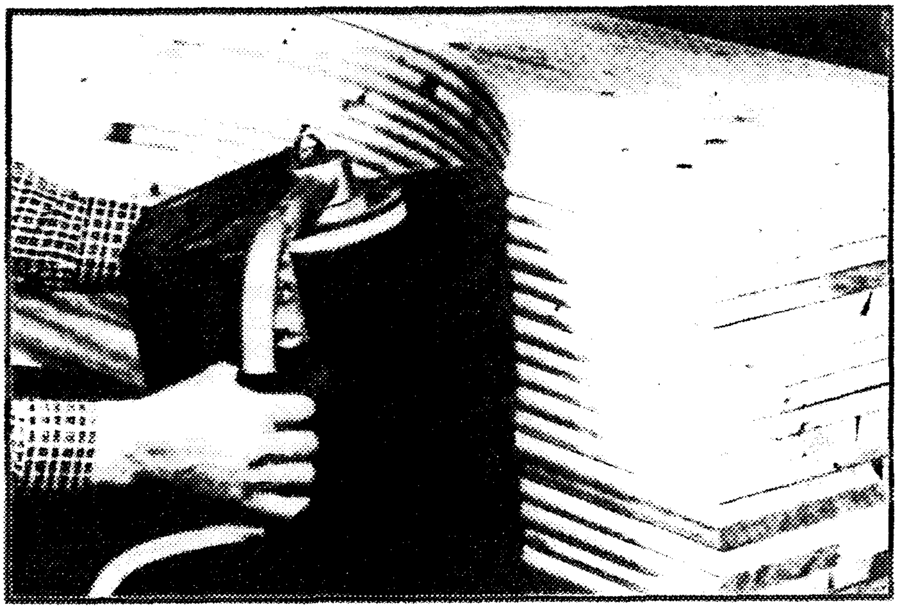
Before being placed in use, new Fladder blades should be well worked though on a raw piece of wood to make them more flexible.

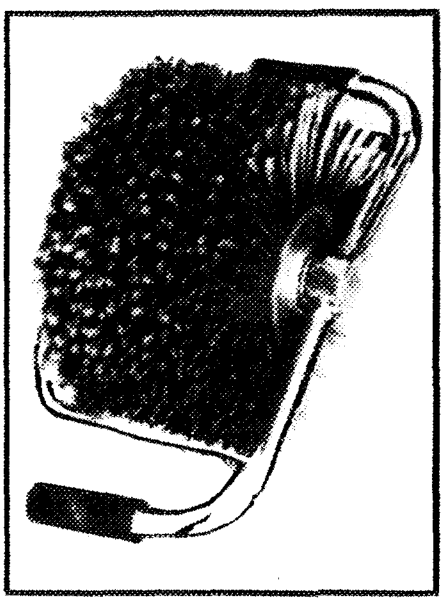
Figure A.VIII.1. How to load and hold the Fladder 250/Mini in use



Source: Siso, Denmark.

Figure A.VIII.2. Operation of Fladder 300/Air with 12 blades





FLADDER 300/AIR:

The air must be filtered and oiled:

Air motor	Approx. 1,100 RPM
Air pressure	6 bar
Air consumption	10 liters/sec.
Output	380 W
Spindle length	150 mm
Number of FLADDER blades	12
Weight, working	3 kg
Shipping weight	5 kg
Volumen	0.05 m^3

Source: Siso, Denmark.

IX. PACKAGING OF FURNITURE FOR EXPORT

John Salisbury*

Introduction

This chapter will concentrate on the question of potential damage to furniture during export, and how it can be minimized. The hazards that must be borne in mind when exporting furniture include the following:

(a) Compression damage;

(b) Impact damage;

(c) Vibration damage;

(d) Atmospheric damage.

The effects of these hazards can be minimized but not eliminated. Some damage will always take place, and the function of good packaging is to reduce it to levels that can be tolerated. If damage is being completely eliminated, almost certainly the packaging is costing too much.

The figures in this chapter are from the International Trade Centre (UNCTAD/GATT).

Compression damage

The export pack will pass through many warehouses during its journey. Because floor space in warehouses is becoming more expensive each day, pallets are stacked five or even six high. This can mean compressive forces of 6 tonnes or more on the bottom pallets.

In the hold of an aircraft, the stack load will not be high, but on touchdown the apparent weight pressing down on a crate can be increased by a factor of 5 (or 5 g, as this effect due to gravity is called).

The situation in an aircraft is bad enough, but consider a stack of pallets or crates in the hold of a ship. The bottom load can be supporting a load of many tonnes before the ship rolls or pitches; then, when the ship and the load change direction, the compressive forces can increase many times. This is especially serious in light of the small area over which the force is applied, which is the area of the skids on the pallet base. Exporters exacerbate the situation by reducing the area of the skids to minimize pallet costs.

The top crate of a unitized load may have resting on it a crate from a different shipper with different (smaller) dimensions. The resulting compressive forces would not be evenly distributed on the bottom.

The important thing to remember about damage caused by compression is the way it multiplies when the area gets smaller. The compressive forces must be distributed over as large an area as possible, and there are many occasions when this must be borne in mind.

Compression damage reduction

For travel by sea and warehouse storage, the crate must be sturdy enough to support up to 10 tonnes. Ideally, the area of the lower skids should equal at least one third of the area of the pallet base. Special attention should be paid to where the compression will fall on the top of the pallet, making sure that it is strong enough. The crate must be adequately braced and supported inside.

The transfer of these compression forces onto the finish can leave an imprint of any irregular surface, e.g. corrugated paper, woven materials, short flaps on a corrugated box, string etc., so the surface in contact with the finish must be as smooth as possible.

The best protection is to avoid high compressive forces altogether by using a freight container. These are rarely more than 2.5 m high, so the maximum compressive forces that can act on the export pack are limited. However, these forces are increased by as much as a factor of 5 by the rolling of the container ship.

Freight containers are usually 2.5 m high by 2.3 m wide, but the length can be 3 m, 6 m or 12 m. Remember that exporters do not have to fill the whole of even a 3 m freight container, as there are many companies who consolidate containers for sea travel.

Impact damage

A packed product is going to be dropped now and then during its export journey. The lighter it is, the more frequently it will be dropped and the greater will be the drop height. A lightweight pack, say up to 30 kg, is likely

*International Trade Centre (UNCTAD/GATT), packaging consultant at the Indonesian Packaging Institute.

to be manhandled and to suffer as many as 20 drops of between 0.3 m and 1 m.

A heavier pack, say over 100 kg, is too heavy to be manhandled, so it will be moved by forklift truck and crane. Drops will be rare, but the load can be put down heavily by forklife truck, and this can have the same effect as, say, a drop of between 0.3 and 0.5 m.

If the product goes by road it will be subjected to serious bumping and impacts as the wheels strike potholes. If it goes by rail, it will be subjected to severe impacts (up to 15 g) during shunting operations. If a sea journey is involved, there is the additional hazard of the load striking parts of the ship during loading and unloading.

If these impact forces acted only straight across the pack, the situation would be bad enough. In a rolling ship, however, they act obliquely, tending to shear the crate with forces that cause it to collapse sideways. The same high shear forces (up to 15 g, that is up to 15 times the weight of the pack) act when a railway truck is shunted or violently braked.

The effect of vertical and horizontal impacts can be studied in a transport packing laboratory. Figures 141 and 142 show the types of product-damaging forces encountered in road and sea transport.

Figure 141. Forces involved in road transport

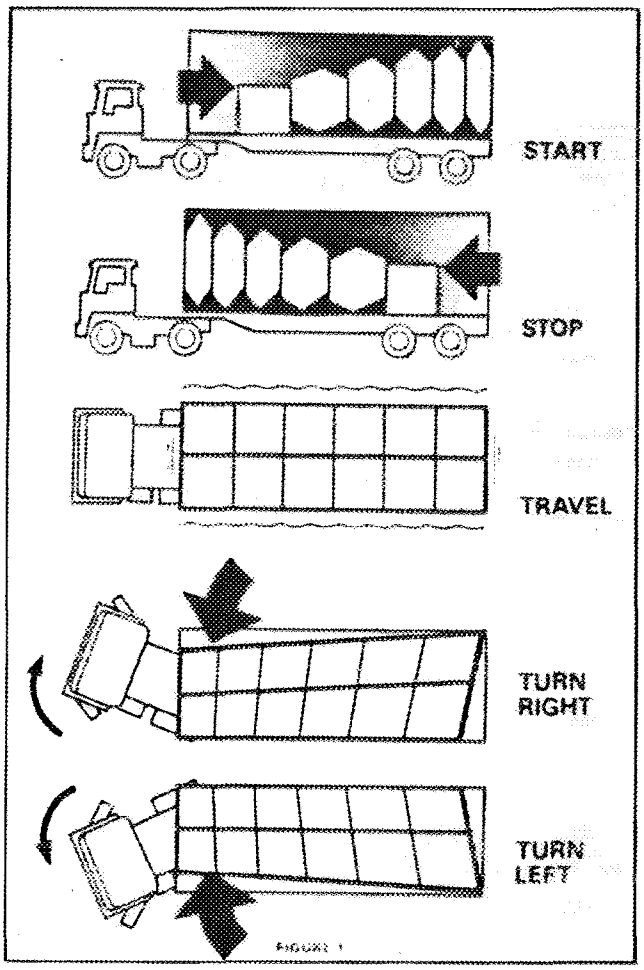
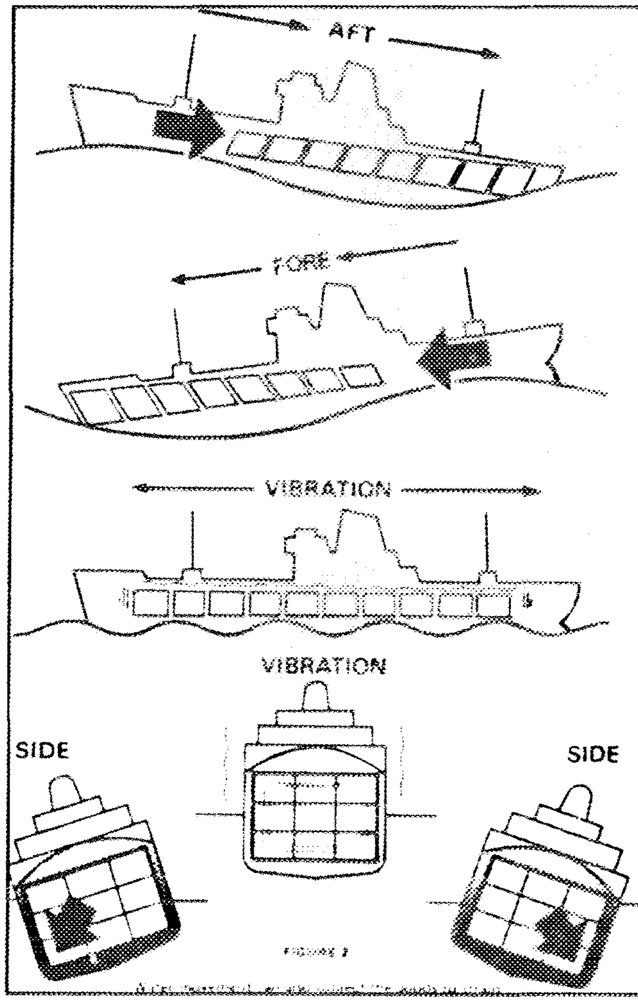


Figure 142. Forces involved in sea transport



Impact damage reduction

Projecting pieces like handles and knobs should be removed if possible and if acceptable to the customer. Export furniture should be designed with as few projections as possible.

Knockdown furniture greatly reduces the volume needed for packaging, in effect increasing packaging productivity (figure 143). However, it must be specially designed and it requires special fittings, not all of which are likely to be available. All small items must be very securely fastened in place.

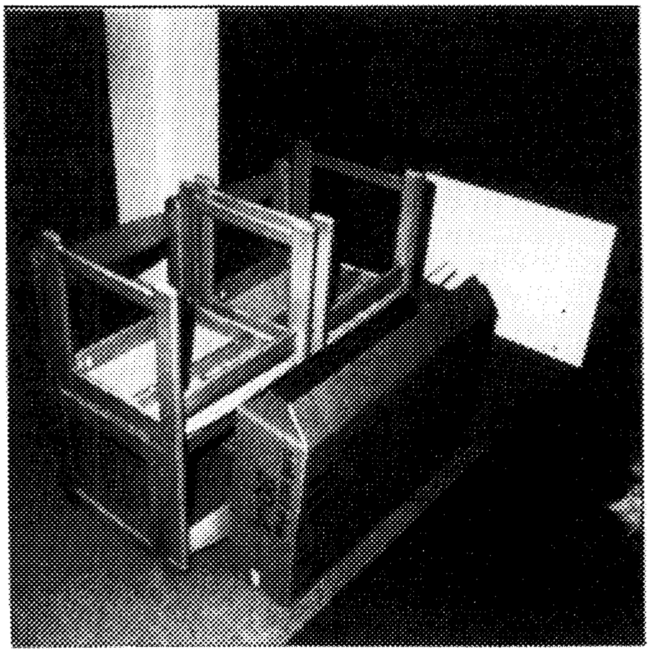
Holding furniture away from the sides and edges is very effective and can be done using fitments made from corrugated board, as shown in figures 144-147.

Two chairs may be packed as shown in figures 148-150.

Foam polystyrene pads are often used (figure 151), especially for heavier furniture, including case goods, but for lightweight rattan chairs they would not be as appropriate.

Shrink film is increasingly being used to hold such fitments in place as well as to protect against water and dirt and to reduce scuffing of the surface (figures 152 and 153). Stretch film is also finding use because it does many of the

Figure 143. Reducing storage space via the use of knockdown design; all these items can be packed in the one box shown



things that shrink film does but is cheaper and does not require heat. Such an application is shown in figure 154.

Bubble cap film (figure 155) can be used to reduce impact damage on light articles, but it does not apply the pressure evenly, and it may leave a pattern, as well as lose its ability to protect after a sharp blow. Alternatively, the whole piece can be covered with a padded bag ("Jiffy bag"), which can absorb impacts (figures 156 and 157).

Corrugated boxes should be as rigid as possible, and gluing the flaps helps considerably. Taping is effective and seals against dirt entry and is often used together with gluing the flaps. Stapling is not recommended because it can cause damage during closing, during transit and during opening.

The most effective way to reduce damage from impacts is to increase the weight of the export pack by tightly packing the furniture into a unitized load with a pallet base or, best of all, to increase the weight to many tonnes by packing it tightly into a freight container.

Vibration damage

Vibration can come from the bumping of trucks along a normal road, from the engine of the truck or, much

Figure 144. Corrugated board fitments

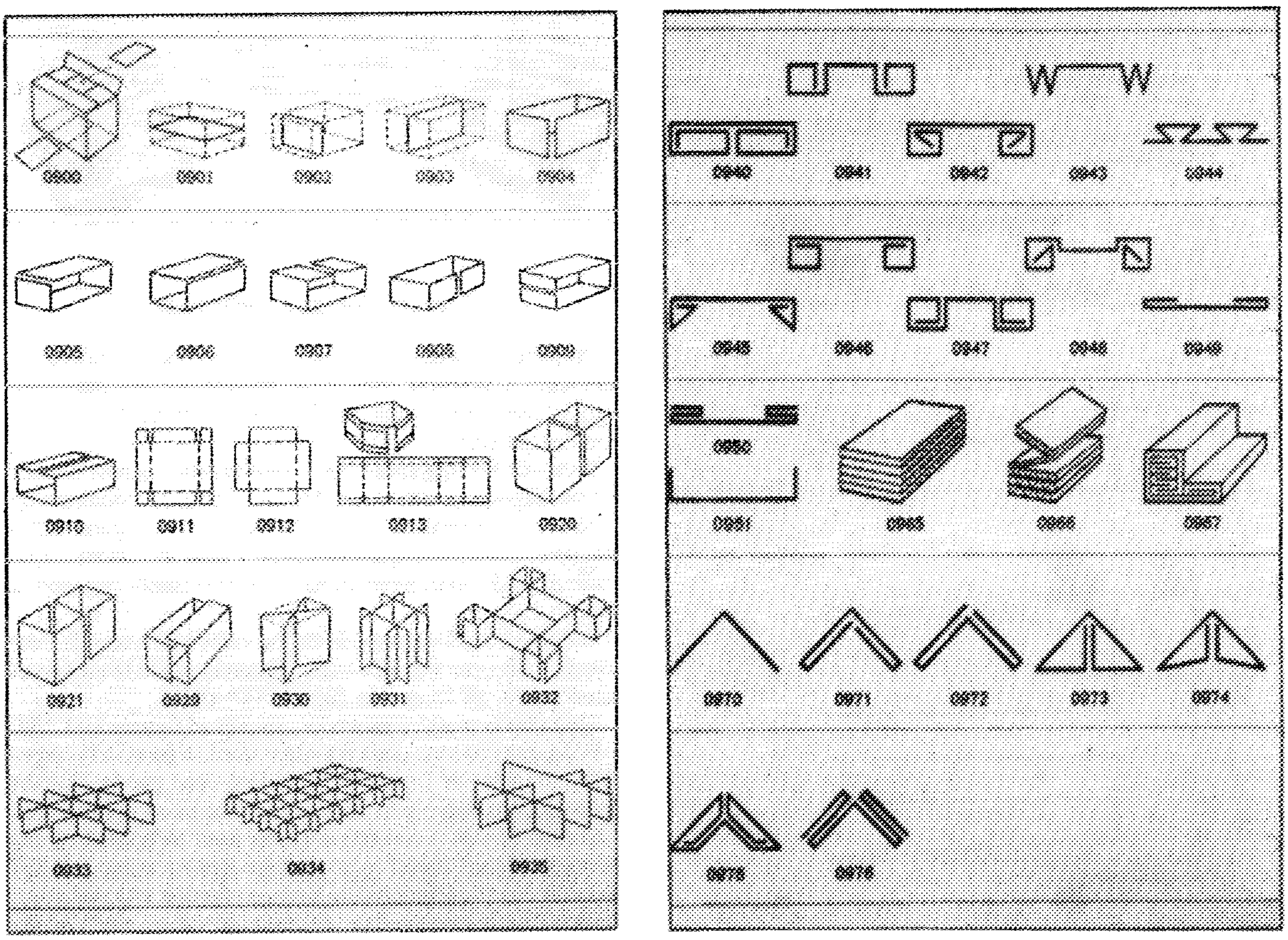
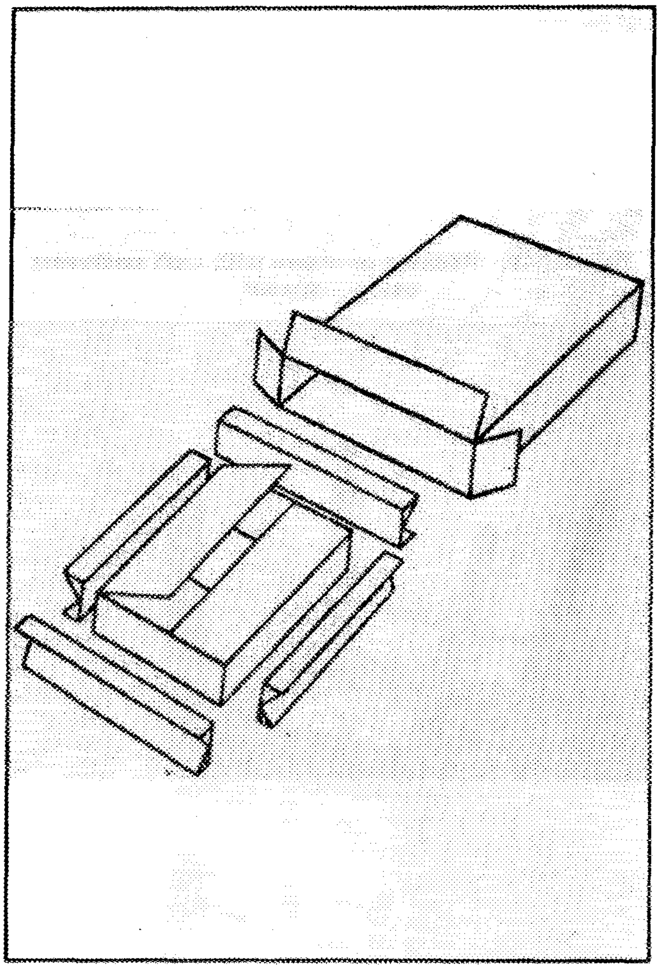


Figure 145. Positioning of inner box containing furniture item and four corrugated board spacers within external corrugated box



more commonly, from the vibration of ship or aircraft engines.

The damage caused is going to depend on the roughness of the surface in contact with the finish and the pressure between the two surfaces. The inside of a corrugated box is rough enough to seriously damage a surface rubbing against it for even a short time and can even damage the surface of upholstery fabrics. The edge of a corrugated board can be very abrasive when vibrating (it can even cut through a protective blanket), so inner flaps must not fall onto a delicate surface.

Freight containers can give marvelous protection against many transport hazards, e.g. compression, water and dirt, pilferage and loss, but the goods inside are *still* going to be subjected to a great deal of vibration during a journey. Vibration greatly increases the damage due to compression.

Vibration damage reduction

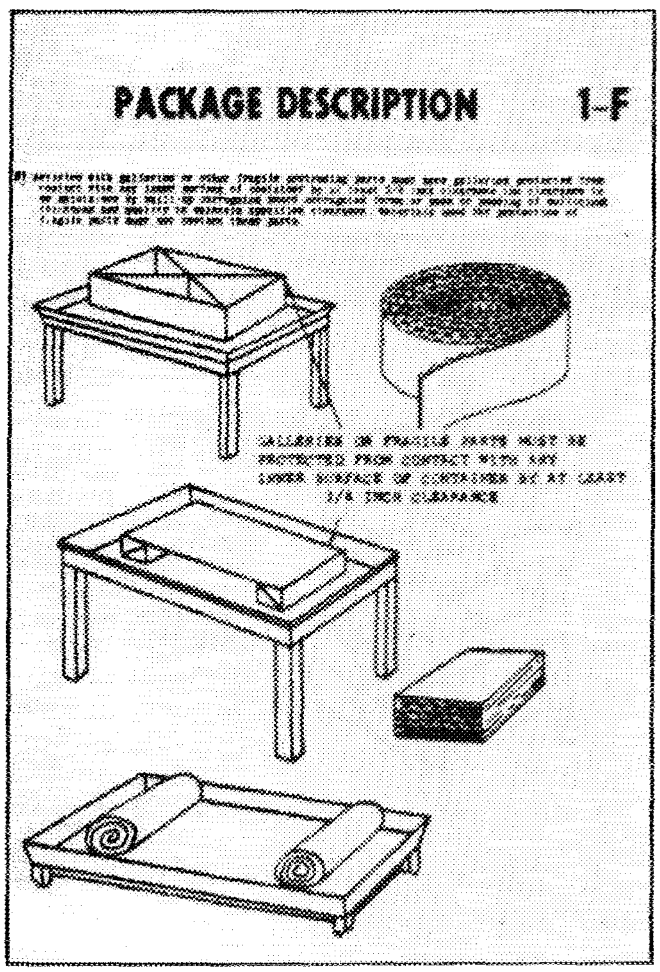
The furniture should be immobilized and packed in tightly, allowing as little movement as possible between the finish and any surface that contacts it. Ideally a gap should be left between the finished surface and the pack sides.

The parts that are going to touch other surfaces should be covered with soft, smooth materials such as soft paper or machine-glazed kraft. Polyethylene is also used, but on many finishes it could stick, and as it may cause damage due to condensation it should be used with caution.

Any blanket material must be smooth and free of obvious pattern (such as a weave) and free of raised areas. It should be fastened with tape to avoid pressure points from string. It must be compatible with the finish. Staples are to be avoided.

A very good material is expanded polyethylene. It is smooth and gives some impact resistance, and some types (with small bubble size) are not easily torn, as is foam polystyrene. It is used for protecting high-quality finishes, but, again, great care is needed to ensure that the finish can survive contact with it in the heat and humidity of travel. In some countries it can be bought laminated to kraft paper.

Figure 146. Corrugated board spacers to protect galleries; they must be protected from contact with any inner surface of container by at least 0.25 in. clearance



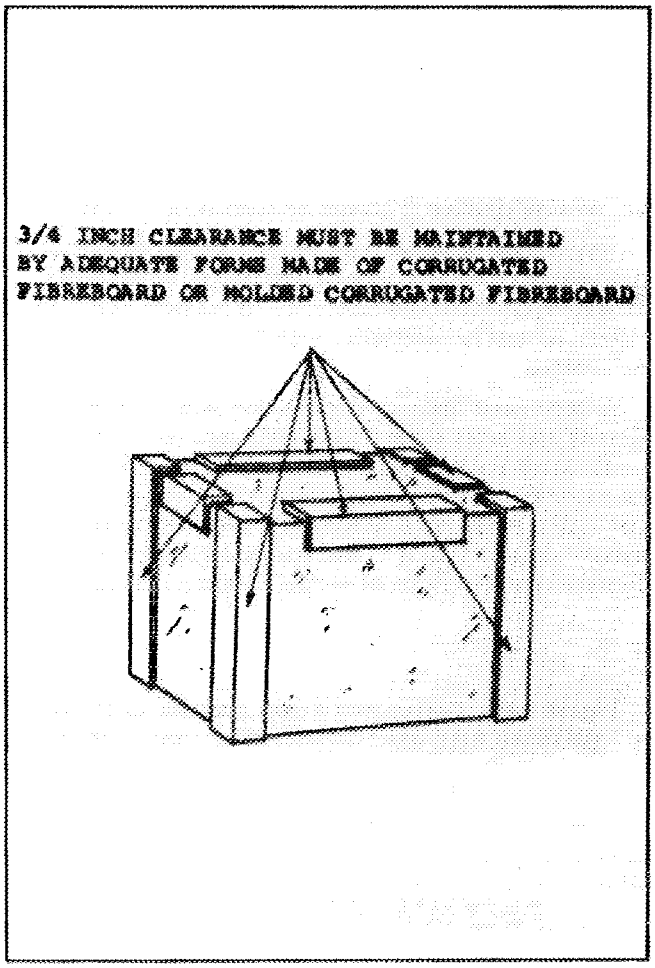
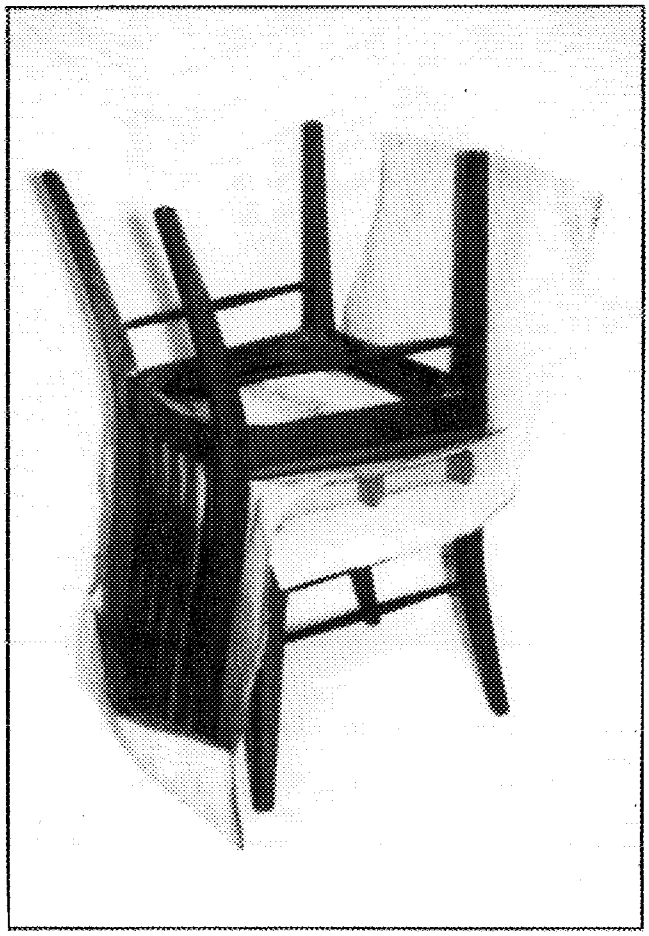


Figure 147.
Corrugated board fitments for edge protection; 0.75 in. clearance must be maintained

Figure 149. Packing of chairs with high backrests using a spacer



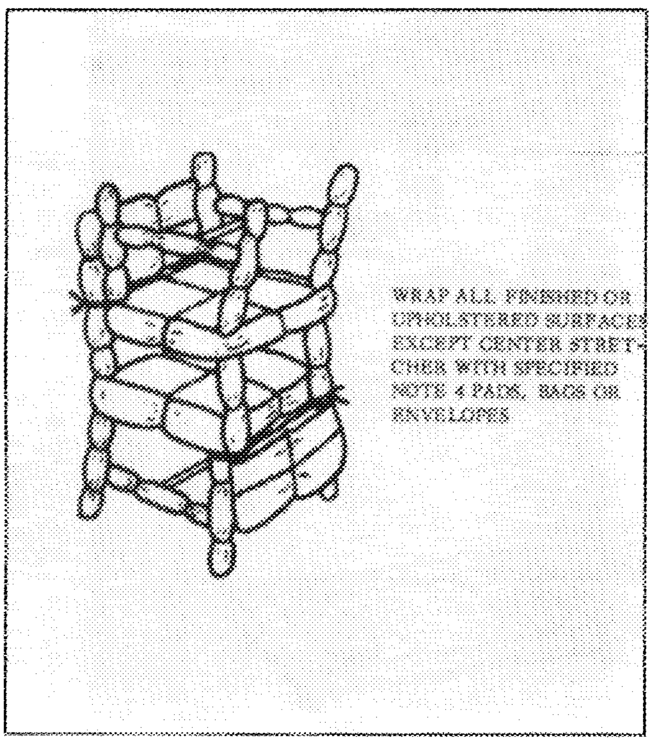


Figure 148.
Packing of chairs (individual wrapping of all finished or upholstered surfaces except centre stretcher with pads, bags or envelopes)

Figure 150. Packing of chairs

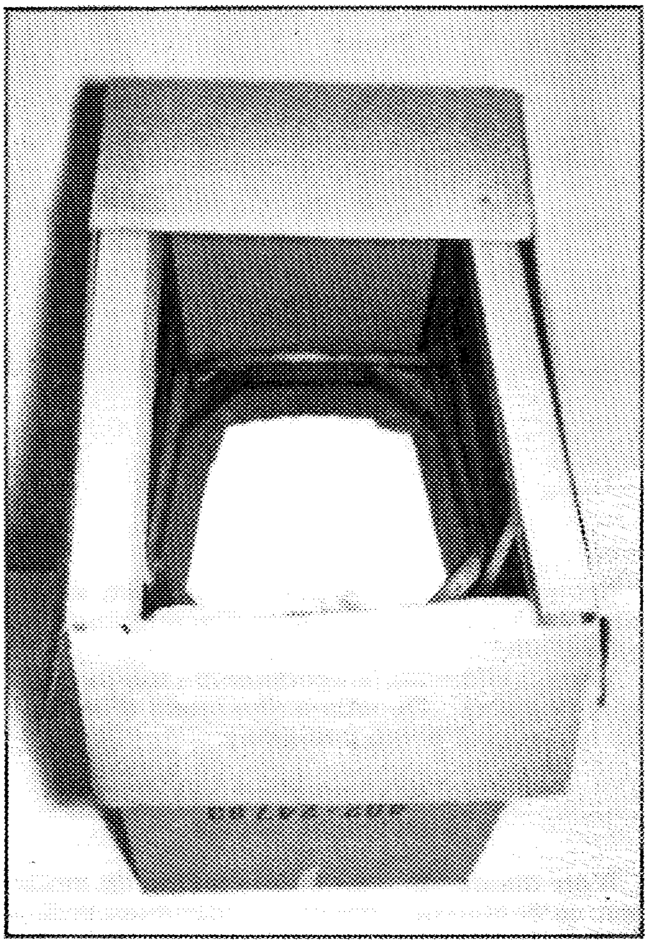


Figure 151. Foam polystyrene pads to protect edges

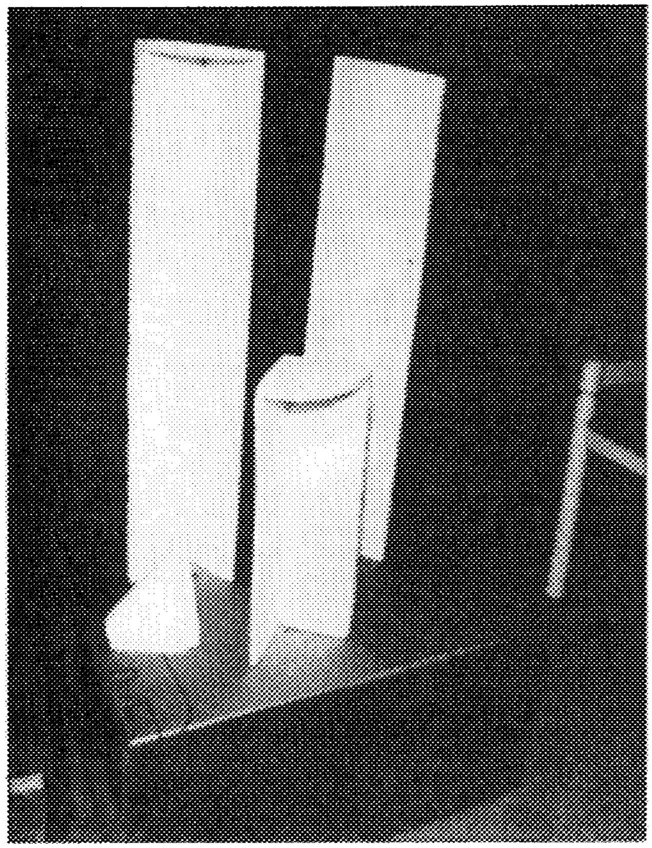


Figure 152. A shrink film application oven

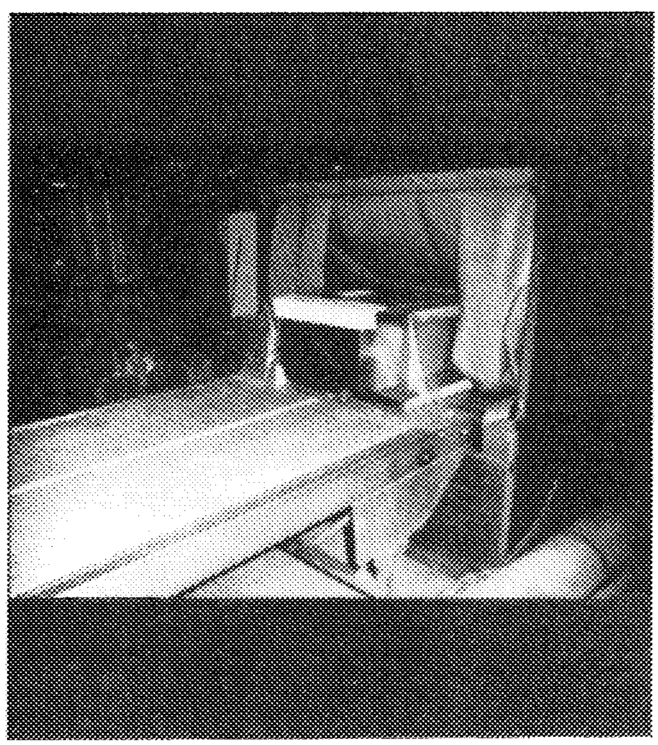


Figure 153. Use of shrink film

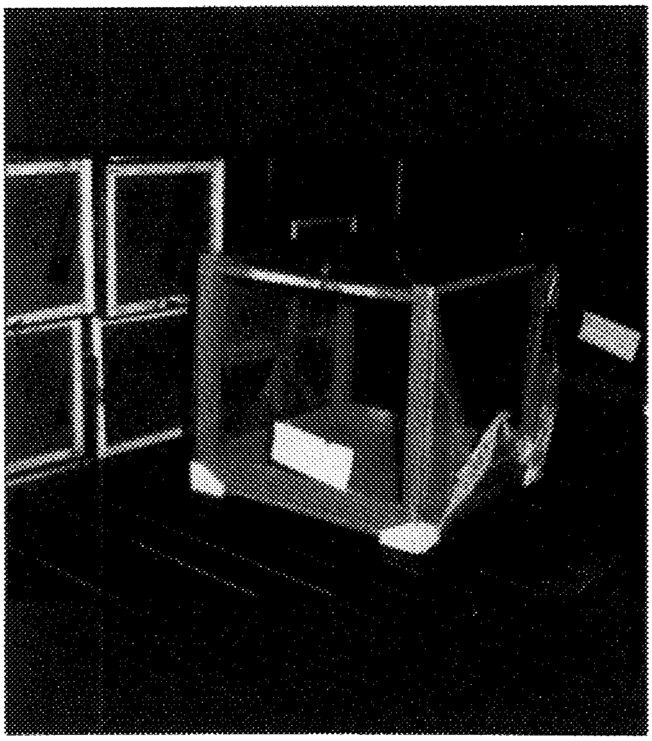
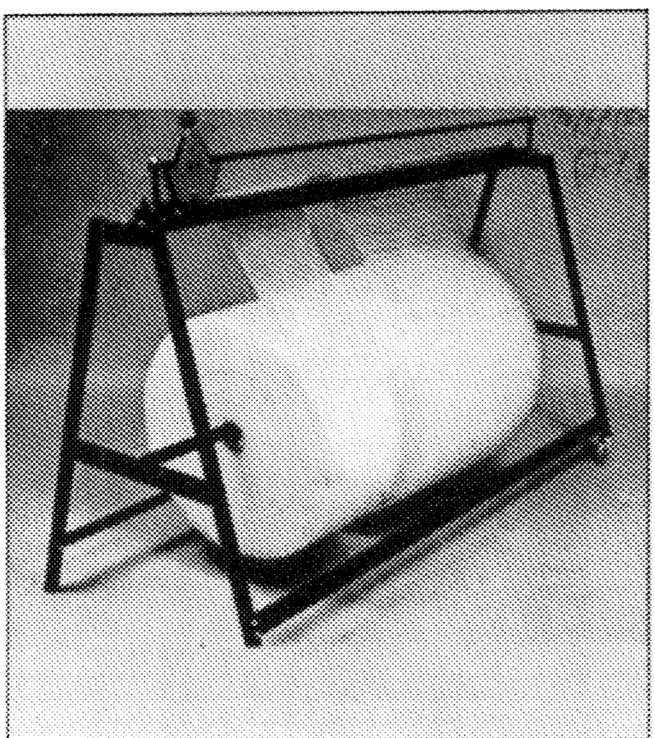


Figure 154. Use of stretch film

Figure 155. Bubble cap film



Newsprint is not suitable. It wears out quickly and can affect the finished surface, causing blotches, streaks and polished areas.

Vibration effects can be reproduced in a transport packaging laboratory. The relative abrasiveness of materials can be compared in such a laboratory.

Atmospheric damage

Water damage can come from rain while the product waits on the quayside or travels on an unprotected truck, or from condensation inside a pack or unitized load. It can mark the finish and encourage the growth of mould. Dust and dirt not only mar the appearance but also aggravate abrasion damage due to vibration. Diesel fumes can put a layer of grease on furniture. Sunlight can affect the finish and, if it strikes the surfaces unevenly, leave a pattern.

Atmospheric damage reduction

Export crates or boxes should be lined with bitumenized paper or polyethylene film. Leaving the bottom open will help avoid condensation problems. If the pack is to be tightly sealed, include a pack of moisture-absorbing solid, such as silica gel, to reduce condensation problems.

Figure 156. Use of a padded bag

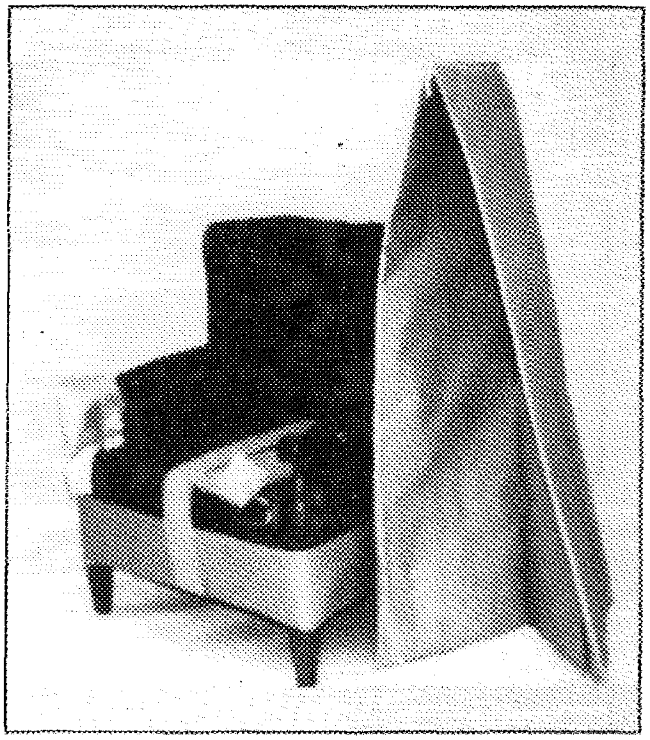


Figure 157. Use of a padded bag

The outer container of the unitized load should be shrink- or stretch-wrapped. Many finishes do not tolerate direct contact with polyethylene when the climate becomes hot and humid during transit.

If the freight container system is used, it should be remembered that containers can get very hot (up to 130° C) when exposed to the sun. Therefore, insulated containers may be necessary.

Conclusion

Each piece of furniture has its own packaging needs, and there is no substitute for experience in preparing furniture for export. However, the above principles should be of great help in determining the form an export pack will take.

Repairing damaged furniture can be relatively easy in a country like Indonesia, where there are low labour costs and readily available skills. The need for such repair is unlikely to be tolerated, however, when exporting to highly industrialized markets such as the United States, Europe and Japan, where labour costs are extremely high.

Information on packaging

The following sources of information are recommended:

Furniture Packaging Guide, published by Eastern Forest Products Laboratory, Montreal Road, Ottawa, Canada.

Packaging for Furniture, published by the Furniture Industry Research Association, Maxwell Rd., Stevenage (Herts.), United Kingdom.

Furniture Packaging Manual, published by Bohman Industrial Traffic Con-sultants, P.O. Box 889, Gardner, MA 01440, United States.

In the United States, packaging for furniture is strictly controlled. The approximately 100 recommended packing designs described in the last-mentioned manual are virtually obligatory. The manual gives detailed specifications for the outer pack and the pads or blankets to be used. If the pack does not conform to the requirements as laid down, carriers may refuse to carry it and insurance companies may refuse to pay out in the event of a claim.

A set of 80 slides on the export packaging of furniture is available from the International Trade Centre (UNCTAD/GATT).

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