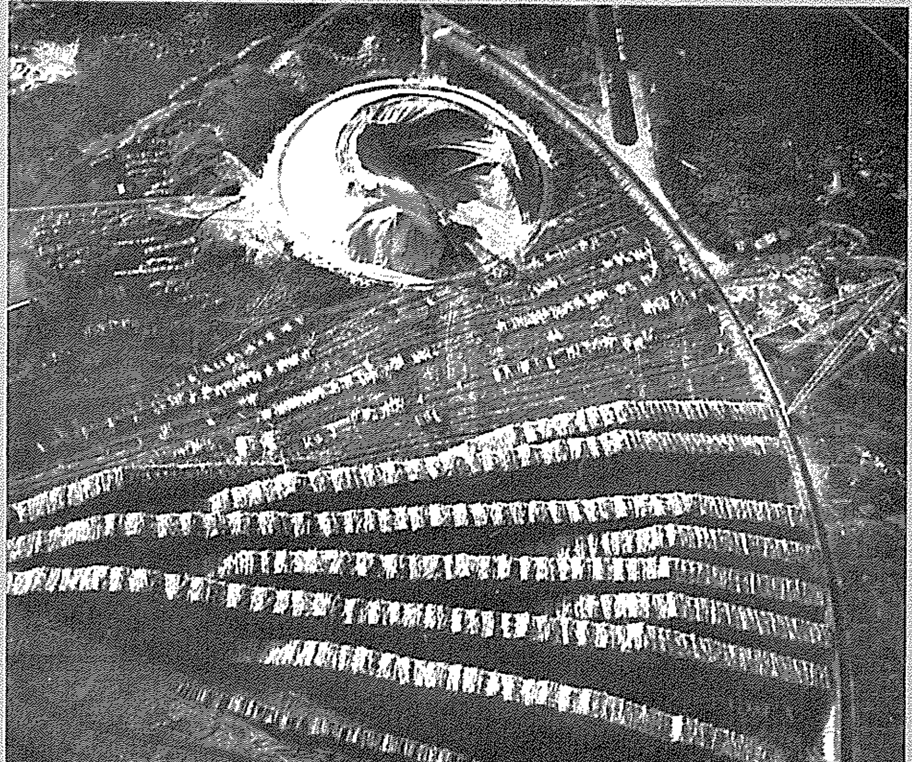
wood chips

production
handling
transport



FOOD AND AGRICULTURE ORGANIZATION
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WOOD CHIPS

PRODUCTION, HANDLING, TRANSPORT

Second (updated) edition

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
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C O N T E N T S

I. PREFACE

During the last ten years, there have been considerable development and radical changes in the production and long-distance transport of wood chips, making it possible to supply mills all over the world with wood as a raw material. It is no longer imperative to establish the mill close to the forest resources, and new techniques are not only helping producers to deliver the product faster and in better condition, but assisting in better forest management.

The FAO Forestry Department considered that the existing knowledge of and experience in production, handling and transport of wood chips was of great interest to many member countries, in particular those in developing regions. On FAO's request, NORAD (the Norwegian Agency for International Development) generously agreed to give financial support to the organizing of a symposium, in which a review-in-depth of the state of the wood chips industry could be made.

The symposium was held at Hurdal in Norway in 1972. A complete report (FAO/NOR/TF 83) including all the papers presented there was published a few months later.

Participants in the symposium felt that to make the findings more easily accessible and to ensure wider dissemination of the information a condensed version should be issued, and Messrs Dieter Oswald and Olav Gislerud, Norwegian Forest Research Institute, were asked to undertake this task in collaboration with the Logging and Transport Branch of the FAO Forestry Department. The condensed report was published in 1973.

In 1975/76 the report was revised by Mr. Olav Gislerud. The draft was reviewed by Professor Pentti Hakkila of the Finnish Forest Research Institute. The chapter on bark removal and chip upgrading was also reviewed by Mr. John Erickson, USDA Forest Service. The chapters dealing with shipping were reviewed by R.S. Platou A/S and by Scandinavian Bulk Traders A/S. Cost figures given in the report are as of 1975/76 unless otherwise stated or cited from other reports. Mention of companies and trade names is for the reader's convenience only and does not express any endorsement by FAO.

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The Organization's warmest thanks go to all, including the original authors, who have contributed to this report.

II. FORESTRY RESOURCES

II. 1 The Supply and Demand of Raw Materials from the Forest

Forests are one of the world's most beautiful and valuable resources. The benefits to the environment and to man are numerous - water conservation, oxygen production, climatic improvement, forest wildlife, recreation possibilities and wood products, just to mention a few. Products from trees - a renewable resource - are likely to increase in importance as the supply of other, non-renewable resources becomes less and more expensive. In addition, many wood products have the advantage of being energy-efficient, requiring less energy to process to finished products than competing materials.

During the last decade consumption of wood for fuel has expanded by one percent annually; in 1973 about 46 percent of the roundwood consumption was fuelwood and charcoal (FAO 1975a). In most industrialized countries, fuelwood consumption has declined, and in 1973 was as low as three percent of roundwood removal in some countries, including Japan and North America. In developing countries wood is often the only economically available fuel, with about 80 percent of the roundwood removal in these countries being used for fuel. A projection by Stone and Saeman (1976) indicates that fuelwood consumption will rise from the present level of 1 150 million cu m to 1 300 million cu m by the year 2000. The need for heat and energy is a basic one, and in each case the role of wood as a fuel should be carefully considered. With the present fossil fuel costs, particularly forest industry mills find it economical to recover energy from mill residue and sometimes from forest residue. In the future it may even become feasible to grow short-rotation wood for fuel of power plants (energy plantations). Wood for fuel has so far been supplied mainly by local sources and world trade of fuelwood and charcoal has been limited in scale.

Housing and related needs use the major share of wood-based panel products, products that more or less may be substituted for each other. The world consumption of sawnwood is expected to rise from 443 million cu m in 1973 to about 600 million cu m by the year 2000. Use of wood-based panels (plywood, particle board and fibreboard) are expected to rise during the same period from 96 million cu m to 200 million cu m (Stone and Saeman 1976). Keays (1975) predicts a considerably more rapid growth of the demand for particle board and fibreboard, reaching 400 million cu m by year 2000.

From 1950 to 1974 the world production of paper and paperboard more than trebled, from 40 to almost 150 million tons. Keays (1975) and Stone and Saeman (1976) estimate the demand to reach the magnitude of 400 million tons by the year 2000. The increasing need for paper products seems obvious, considering the population increase and the large number of wood-pulp based products needed for man's learning, communication, comfort and pleasure. Among factors more critical than the potential need for paper products may be how much consumers can afford to buy of such products, and the large capital necessary and other constraints limiting investment in pulp production. FAO (1975b) predicts a paper shortage of some 6 million tons in 1978 and 9 million tons in 1979.

During and after World War II, trees were the raw material for a rather well developed chemical and biochemical industry (see e.g. Glesinger 1949). Mainly on the basis of price, petrochemicals won the competition. Both mill and forest residue have recently again been brought increased attention for conversion to chemicals and food.

Present trends and forecasts conservatively indicate that by year 2000 the total demand for forest products will require about 4 000 million cu m compared to the present demand of 2 500 million cu m.

Knowledge about the world's forest resources is incomplete, the most recent and complete reviews are by Persson (1974, 1975). Present annual growth of merchantable timber is estimated by FAO at 3 000 million cu m. The amount of wood that can be removed under sustained yield has of course an upper limit, however, this limit is expandable and depends considerably on forest policy and management.

There are many possible roads leading towards meeting the expected demand for forest products in the nearest century, including:

- Increased forest area, however, this may not be possible;
- Utilization of presently unused coniferous forests (USSR and North America);
- Utilization of presently unused hardwood forests (South America, North America, USSR, Asia, Africa);
- Increased plantation area (fast-growing forests);
- Improved silviculture practices leading to higher forest yield;
- Reduced unwanted wood loss due to fires, insects and microorganisms;
- Harvesting and utilization of more biomass from the forests;
- Better utilization of the biomass by mill processing (higher technical yield) and to some degree by more durable products;
- Use of fibre sources other than trees;
- Increased recycling of forest products.

The interest in utilization of waste paper has increased during recent years. Paper recycling has been especially significant for highly industrialized countries with a high population density and a scarcity of forest fiber resources. The ratio of recycled waste paper to apparent consumption in the EEC countries averaged 28 percent in 1973, totaling 8.5 million tons. Japan and the Netherlands have reached a recycling rate slightly above 40 percent.

A combination of several of the above-mentioned methods of increasing the supply is likely. Considerable integrated biological, technical and economical studies are needed, as are political discussions and decisions, to reach the best ways.

Canadian studies (Keays 1975, Keays and Hatton 1975) indicate a possible shortfall of wood fibre of 200 million cu m by year 2000. This can easily be avoided by using a larger part of the forest biomass. Since 1964 the complete-tree concept has been advocated by Harold Young (Young 1974).

Major regions with a wood deficit are Europe and Japan. Regions with a considerable present and future wood surplus include mainly North America, but also USSR and parts of South America. The Scandinavian countries have for many centuries been Western Europe's natural timber reserve, but now mill capacity has reached present sustained yield from the forests and future volume expansion of forest products will be slow.

Some of the major trade flows of forest products between regions are:

Coniferous sawnwood and pulp and paper products from North America to EEC;

Coniferous sawnwood and pulp and paper products from Scandinavia, and of sawnwood from USSR to EEC;

Coniferous logs and chips from the West Coast of North America to Japan;

Tropical and subtropical logs and chips, mainly from Southeast Asia to Japan;

Tropical logs, sawnwood, veneer, and plywood from Asia and West Africa to Europe, and from Asia and South America to North America.

In 1973 forest products accounted for an export value of almost $ 22 000 million versus $ 6 000 in 1962. As a comparison the total world exports in 1973 were $ 560 000 million.

A feature in the forest trade worthy of note has been the particularly rapid rise of exports from developing countries - in 1973 being six times that of 1962. However, total exports of developing countries and centrally planned countries are low compared with those of the developed countries, which in 1973 formed about 74 percent of the total world export of forest products.

II. 2 Forest Resources

Resources for the wood processing industries may be classified as follows:

Cool coniferous forests (boreal forests)

Temperate forests

Subtropical forests

Tropical forests

Man-made forests

The cool coniferous forests exist principally in the northern cool temperate zone in a broad belt south of the tundra (Fig. 1). The USSR and North America together have more than 80 percent of the world's total area of these forests. They are composed of a small number of species in which conifers dominate - spruce, pine, fir and larch, growing mostly on grounds which are frozen in winter. The trees are of fairly uniform size with relatively homogeneous, long-fibred wood. A rotation period of 70 - 100 years is normal. Economically the coniferous forests are today incomparably the most important. However, geographical and climatic conditions make it difficult to reach a lot of them; and, owing to their slight volume per hectare it is sometimes not feasible to exploit them commercially.

The temperate forests, mainly in the middle latitude of the northern hemisphere, contain considerably more species and are comprised of a large number of sub-types ranging from mixed coniferous to pure broadleaved types (Fig. 2). Many of these forests are located in the most highly populated parts of the world and have to a great extent been subject to man's activities. Clearing for agriculture has been widespread; heavy cutting of fuel wood or cattle grazing have in many areas resulted in a brush forest of low quality. Besides conifers, these forests supply most of the world's beech, birch, oak and many other well-known woods.

Fig. 1. Cool coniferous forest in Norway.

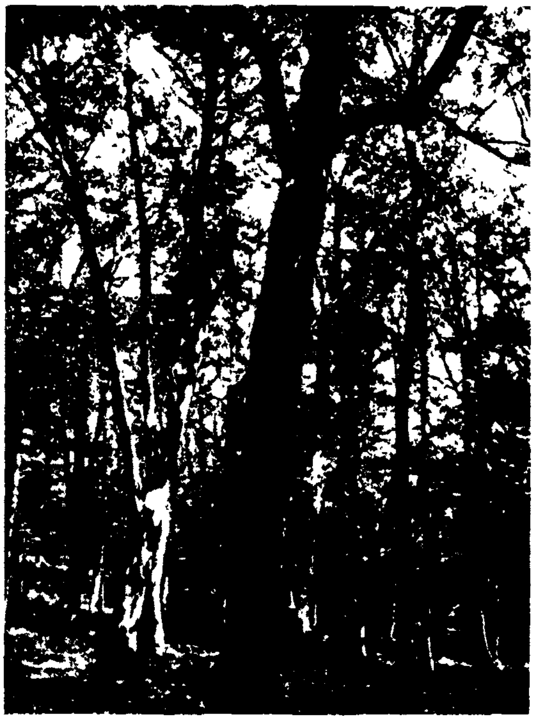


Fig. 2. A temperate broadleaved forest in Central Europe.

The subtropical forests are found at the tropical margins of the temperate forests. Areas with such forests include e.g. the south-eastern part of USA, parts of South America, New Zealand, and the south-eastern part of Australia.

Tropical forests are found all trough the tropical regions. Wherever rainfall is abundant the number of broadleaved species is normally very high, but most of the trees have so far been without commercial significance (Fig. 3). Their heterogeneity causes problems in processing for industrial purposes. Shifting cultivation, clearing for permanent agriculture, and wood exploitation are decreasing the rain forests at a growing speed.

In regions with a longer dry season all kinds of sub-types are found, variants of tropical forests, that range from rain forest to savanna-like areas.

Man-made forests. The area of man-made forests in the world is probably about 100 million ha of the total forest land area of about 4000 million ha. Plantations in North America and Europe are usually replacing exploited forests of the same species, while the intensive plantations of the tropics and subtropics normally differ completely from the original forests. The area covered by fast-growing plantations outside of China, Japan, Europe, and North America is perhaps only 8 million ha (Persson 1974) and thus very small in comparison with the available natural forest area.

Fig. 3.

Tropical rain forest in Latin America.

Fig. 4.

An eucalyptus plantation in Cyprus.

A part of these fast-growing plantations are protection forests and if exploited, it will be under special regulations. As sources of industrial wood, these plantations have considerable and growing importance for some countries, but from a world viewpoint the production is not yet very important. The manufacture of pulp from intensive plantations is only about 2 percent of the total world production, which is more than 100 million tons per year. According to the most optimistic FAO forecasts, the total area of intensive plantations in Africa, Central and South America, Asia (except China and Japan), and the Pacific area may reach about 17 million ha in 1980. Even with this increase, it is estimated that only 3 to 5 percent of the total consumption of pulp and paper will be from wood from fast-growing plantations by the end of 1980, when consumption is expected to amount to 200 million tons.

Some of the more successful intensive plantations are mentioned below:

Southeastern USA - Large pine plantations combined with an intensive tree breeding programme.

Cuba - Plantations of eucalyptus and other broadleaved and coniferous species.

Argentina, Brazil, Chile, Uruguay - About 3 million ha mainly of eucalyptus, poplars, and pines.

Algeria, Morocco - About 0.5 million ha of eucalyptus and pines.

Kenya, Malawi, Tanzania, Uganda - About 0.25 million ha mainly of pines and cupressus.

Madagascar - About 0.25 million ha of eucalyptus and pines.

South Africa - Over one million ha of eucalyptus, wattle, and pines.

Europe - Fast-growing poplars in Italy; eucalyptus and pines in Spain and Portugal; large areas of spruce, pine, and fir in Great Britain.

Indonesia, Thailand, Burma and the Phillippines - Teak, acacia and pines.

New Zealand and Australia - More than one million ha of pines and eucalyptus of good quality.

The concentration of volumes, the uniform size of the trees, the homogeneous properties of the wood, all contribute to a considerable saving in harvesting, transport and manufacturing costs. The yields from these intensive forms of plantation can be surprisingly high.

Growth figures of between 20 and 30 cu m ha/a are not unusual in the Far East, Africa or Latin America. This is about 5 times the average in Scandinavian plantations.

Regarding regeneration the difference between forestry in cool coniferous regions and plantation forestry of eucalyptus, for example, seems above all to lie in the required intensity of cultivation and the time element. An eucalyptus plantation needs a lot of capital for items such as earth moving, planting, truck roads, machines and training of labour.

The short rotation periods in eucalyptus plantations mean that all steps in forestry must have a definite aim right up to the time of the final cut. In cool coniferous zones with rotations of between 70 and 100 years, the outcome is very uncertain. Predictions for the future of the stands will be more or less qualified guesses. What kind of raw material will be demanded at the time of cutting in these forests? Which techniques will be applied? Therefore, new stands are established in a way which allows alternatives in determining the final aim of production.

In fast-growing plantations like eucalyptus with rotations of between 10 and 15 years it is otherwise. These rotations coincide rather well with the times of planning and "writing-off" nowadays used in modern wood industries. At the time of deciding on planting, spacing techniques and so on, it is possible to take the future cut into consideration, and so to base on economic foundations the techniques chosen to establish the new forest.

Here again it should be stated that forests cannot be regarded merely as so many cubic metres of wood. They are necessary in water control, they play a major role in the protection of the irrigation systems upon which agriculture often is based, they prevent soil erosion, they support wildlife and their importance as a recreation factor is constantly increasing. Thus the forest policy must be linked to other policies, and forestry should be seen as one of the elements in effective land use.

II. 3 Developing Countries as Potential Fibre Suppliers

More than half of the world's wealth of forests are tropical forests of different types. One third of these alone - the rain forests - probably contain at least as much in timber volume as all those of the northern temperate zone, a much larger area. Nevertheless the total annual removals from them constitute less than 10 percent of the cut in the northern forests. It is evident that the world has a great dormant asset of wood in the tropical forests. However, they present some problems when it comes to their industrial utilization:

They contain a large number of species with widely varying characteristics;

Not only individual species, but also the character of forests of the tropics differ widely, ranging in density from almost impenetrable rain forests to the sparse and lowyielding forests of the savanna;

Logging conditions are often difficult because of undergrowth, seasonal swamps, unstable soils and unfavourable gradients;

There is a lack of a transport network and other infra-structural assets;

Tropical forests often occur in areas of the world where the standard of living is poorest.

To these drawbacks it is necessary to add the difficulties observed in most developing countries:

Even if the mills are of minimum size the local market is as a rule not sufficient to support them, but export is needed;

The national ambition for self reliance is generally strong, sometimes limiting the possibilities of regional cooperation or joint ventures with developed countries on a profit basis;

There is a low level of efficiency in the whole industrial sector, lack of skilled personnel at all levels, and lack of educational and training facilities;

Marketing is not organized and knowledge of the quantities and qualities the market demands inadequate.

In order to get developing countries more involved in the world's trade of wood and wood products, production and transport systems should be more diversified and less conventional. The labour-intensive primary wood production and logging operations, timber transports, sawing, chipping and sometimes even pulping could be located in developing countries, while later links in production and marketing could be placed nearer the already well-developed markets.

In many places, particularly in developing countries, chip export appears to offer a way of financing the operations needed in good forest management. It may offer an outlet for species and trees which, from the management point of view, should be removed and which do not have any value or use except when exported in chip form. It would be unrealistic to expect large profits unless the species were as uniform or valuable as, for example, those now exported from the north-west Pacific, Australia and New Zealand, but at least the income from chip export might support, or at least strongly subsidize, desirable forestry operations. Having learned the techniques and economics of harvesting forests, the country concerned could then weigh the economic advantages of continuing chip export against establishing its own forest industry and exporting more processed products. The chip importer too, might well have an interest in or an incentive toward participation in the establishment of such an industry.

It is of some interest to recall the history of international trade in solid pulpwood. As pulp and paper production in some of the leading industrialized countries expanded, taxing native wood resources, trade in pulpwood steadily grew. Later on, as industry expanded in the countries with a wood surplus, exports were curbed and further expansion of the paper industry in countries with a wood deficit came to be based on rising imports of pulp. Thus international trade in solid pulpwood levelled out and subsequently declined. It would be logical to envisage a similar evolution of the long-distance trade in wood chips.

There is undoubtedly growing interest in wood chip export, particularly in some of the developing countries with ample wood resources. The argument can be summarized as follows:

It will enable forests which are at present stagnant, not being used or not able to be used, to be rehabilitated;

It will provide an outlet for wood which is not suitable for other purposes;

The resulting revenue obtained by forest authorities will assist in the production management of forest;

It will assist in the clearing of lands scheduled for agricultural and plantation development;

It will assist in social and economic development by introducing job opportunities, training facilities and infrastructural developments, and by increasing forest exchange earnings;

It will provide an outlet for waste from other forest industries;

A substantial wood-chip installation could be an exceptionally good first stage in the establishment of a pulp and paper industry.

All these arguments have a great deal of general validity, but the approach of any country to a particular project must necessarily be circumspect, tempered by several considerations, and with the question marks which hang over the future development of this trade borne in mind.

III. INTERNATIONAL TRADE IN WOOD CHIPS

III. 1 History and Some Policy Aspects of the Wood Chip Trade

The first transocean shipment of wood chips was made in 1964 from Oregon to Japan. In 1967 Japan imported 1.4 solid million cu m of wood chips, almost entirely from the USA. In 1971 the amount was increased to about 6 million cu m which came mostly from the USA, Canada, Australia, New Zealand and southeast Asia (Fig. 5). For 1975 the import of wood chips was estimated to be 15 million cu m, and by 1980 it is expected to rise to 30 million cu m (Warner 1975).

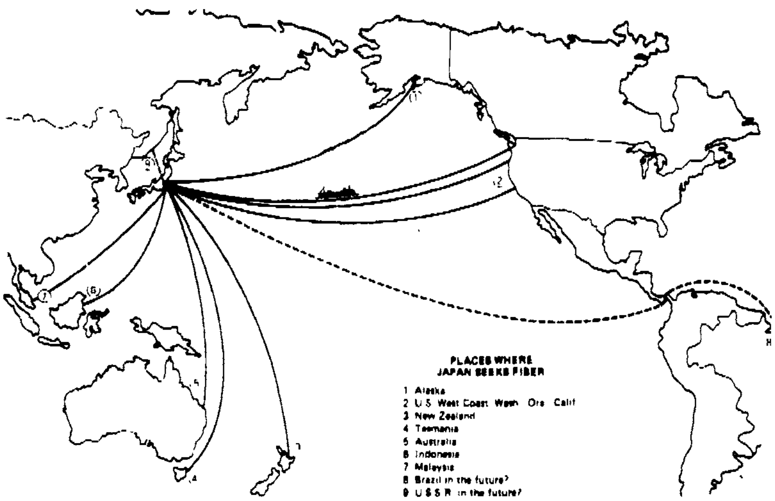


Fig. 5. Places where Japan seeks fibre (White 1972).

Fig. 6 shows the quantity and average value of chips exported from the West Coast of USA to Japan (Ruderman 1976). Most of the chips are from softwoods. Some whole-tree chips from alder were exported in 1974, but this ceased, at least temporarily, in 1975. As of January 1, 1976, the following chip prices (FOB ship) were reported:

Fir	\$ 51 - 54 per Bone Dry Unit
Hemlock	\$ 55 - 58 " " " "
Hardwood	\$ 51 - 54 per Bone Dry Unit

Some of the chip quality requirements were:

Chip fraction:	Maximum content, percent:
1 1/8 inch	4
7/8 "	18
3/8 "	18
Pan	4
Bark	0.5
Brown rot	0.15

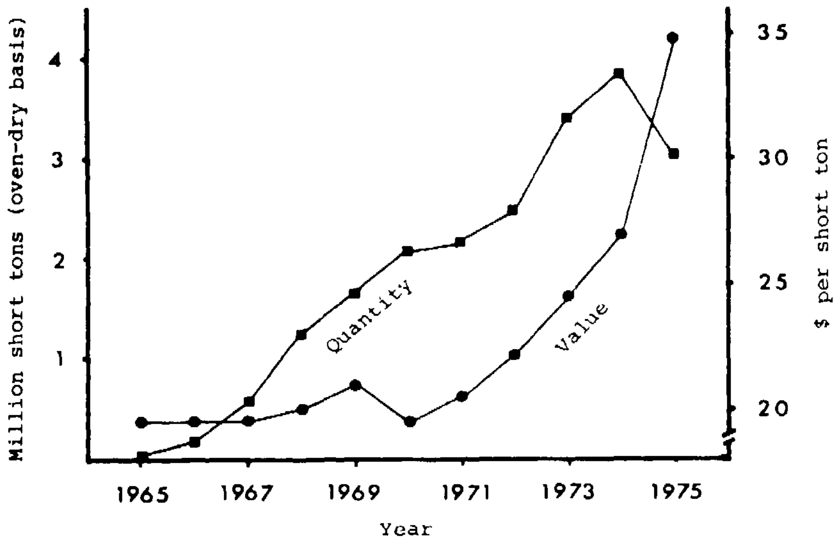


Fig. 6. Quantity and average value of chips exported from US West Coast seaports.

The trade in chips of rubber-tree wood wastes from sawmill and plywood mills from West Malaysia to Japan is an interesting case, for the replacement of Hevea by the new higher-yielding varieties is facilitated by this outlet for the wood from older plantations (Nordin and Ismail 1970).

Tasmania has emerged as one of the world's most important sources of wood chips, especially eucalyptus. A chipmill on the Tamar River in northern Tasmania, belonging to Associated Pulp and Paper Mills Ltd., will be shipping 900 000 tons annually to Japan. This mill is expected to have a life of not much more than ten years, being displaced at that stage by the development of a pulpmill to provide both local pulp requirements and eucalyptus pulp for export. The capital investment in this modern chip plant and the port including all handling equipment is reported to amount to 14 million Australian dollars (Fig. 7).

Following a pulpwood import agreement in 1970, the Japanese and the Russians have negotiated a contract for the supply of wood chips. According to the terms of the agreement, a total of 3.65 million cu m of chips

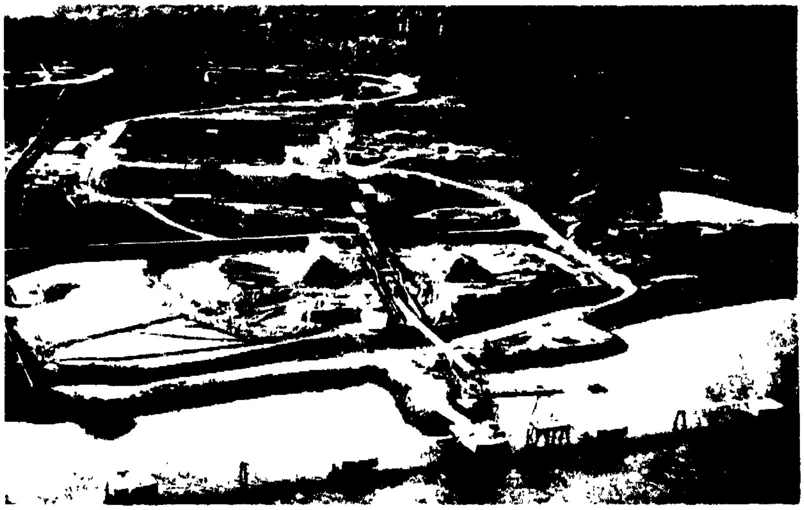


Fig. 7. The Tamar chip plant and port for transocean shipment of wood chips (Anon. 1972).

will be imported during the six-year period 1972-77. The prices, although not disclosed, are reportedly based on the international levels, thus the softwood chip price will be based on the rate for North American chips and the hardwood on that for Australian chips.

The world's first mixed-tropical chip export project, was officially opened in June 1974. Some information on this project, the Jant Pty. Ltd. at Madang, Papua New Guinea, is mentioned below; more details are reported by Lembke (1974). The main shareholder is Honshu Paper Co. Ltd., and the PNG Government has an option to acquire up to 20 percent equity.

The forest areas included in the timber permit cover 83 000 ha. The main species are kwila, celtis, terminalia, spondias, pometia and about 200 other mixed rain forest species. Only about 20 percent of the timber volume is veneer and saw logs, which led to thinking in terms of a woodchip project. The proposed integrated forest industry at Madang included a chipmill, a sawmill and a veneer mill - the latter not yet built - with an annual intake of almost 0.4 million cu m. The existing rain forest is expected to sustain this cut for about 20 years.

A very intensive land use study and environmental impact study was carried out, allocating land for water catchment areas; an adequate area of existing forest for each village, providing fuel wood, timber, etc.; land for small- and large-scale agricultural development; reserves of existing vegetation; and, finally, areas for logging and reforestation programs. When planting the major pulpwood species kamarere (*Eucalyptus deglupta*), clear felling and planting has proved more satisfactory than felling, burning and replanting.

Foothill forests will be managed on a selective logging basis for saw and veneer logs, and reforestation will be on a line-enrichment planting basis using fast growing hardwoods and some exotic hardwoods. The whole project, including forestry and mill operations, employed about 700 in 1975 and the number of employees is expected to be about 1 200 by 1977.

The chipmill is flexible and simple in design (see Fig. 59). Logs from the bush are measured, stockpiled, and then barked and chipped with Nicholson equipment. Sawlogs are culled out at the chipmill and sold to a nearby sawmill. The chips are screened and discharged onto the chip pile with a belt conveyor. Chip transport from the pile is also carried out by a belt conveyor, leading to a loading tower with a telescopic boom conveyor. The chip carrier is Madang, with a load capacity of about 55 000 loose cu m, making one round trip to Japan every 25 days.

The total investment cost of the project by 1975 was about $ 12 million of which about half was spent on roadbuilding, logging equipment and housing, and the other half on chipmill, stockpiling and wharf.

The Honshu Paper Co. Ltd. could in 1974 use up to 30 percent of the mixed tropical hardwood chips in their raw material mix. The cost of domestic hardwood chips at the mill was about $ 90 per bone dry metric ton in 1975. The value of the tropical mixed hardwood chips was lower, due to lower yield, reduced pulp quality and certain problems in the pulp and paper production process. From data reported by the company, one may surmise that the value of the mixed hardwood chips may range from 85 percent down to about 60 percent of Japan's domestic hardwood chips. The value reduction being caused by reduction in processing capacity and processing problems is difficult to estimate. Imported eucalyptus chips from Australia, however, have a value only slightly lower than the domestic mixed hardwood chips.

Trial deliveries of 8 carrier loads of pine chips from North Carolina to Europe, mainly to Swedish pulp mills, took place in 1975 via a Norwegian company trading in forest raw materials. Recently longterm chip trade contracts are agreed on opening up for export of chips from South-East USA to Sweden. Two chip carriers, each of 41 000 ton deadweight will be built for delivery in 1977. Southern pine chips will dominate the trade as hardwood chips are difficult to market in Europe. The CIF price is about $ 80 per bone dry metric ton for deliveries in 1975/76. The volume of this trade is not expected to reach the volume of the chip trade between the US West Coast and Japan. The 5-year CIF value of the contracts agreed on by 1976 is about 150 million dollars.

For both political and economic reasons, the FOB-prices of chips are not, as a rule, by any means low. In fact, the cost of some of the chips delivered to consumers is equal to the highest prices being paid for its wood raw material by the pulp and paper industry. However, if imported chips are used for "topping" local wood, or if pulp and paper production is subsidized or protected, it can be economically justifiable to import expensive chips, at least for short periods.

The sale value of chips naturally varies with the species. Coniferous chips fetch higher prices than deciduous ones, but the margin is declining. In bulk shipping, a given volume of normally dense hardwood chips contains substantially more wood than the same volume of less dense softwood chips. Furthermore, for some products the processing yield from hardwoods is higher than that from softwoods. Not only the quantity of wood and the uniformity of the chip mixture, but also the quality of the chips (in terms of size, shape and cleanness) determines their value. Normally the chip contracts run over long periods with annual or periodic price adjustment.

General problems of the wood-chips trade include the cost of long-distance transport and technical difficulties in maintaining the chip quality.

IV. C O N V E R S I O N T O C H I P S

IV. 1 Introduction, History and Terminology

Mills producing particle boards, fibreboards, refiner mechanical pulps, semichemical pulps or chemical pulps have traditionally received most of their raw material in the form of logs, and more recently also the part of the logs not utilized by the sawmills and veneer mills. Only the merchantable bole has been utilized, although this concept has changed considerably over the years, generally towards a larger part of the bole being accepted. Hardwoods have to an increasing degree become an accepted raw material. In many countries it has become economical to transfer the debarking from the forest to the mills; however, only board mills have generally utilized bark as a part of the raw material. The conversion of bolewood to chips has normally been a mill operation. As this type of production at the mill site is well known, what follows will deal mainly with chipping closer to the forest, and chipping a larger part of the tree.

In the beginning of the 1970's several factors led to a rapid development in the use of whole-tree chips - particularly in North-America - as an industrial raw material:

A rapid growth in demand for chips and local shortages of fibre sources, partly due to labour shortage;

Environmental concerns for wasting natural resources and concerns over the slash and slash treatment methods such as burning;

The search for raw material delivered mill at the lowest cost possible;

The advent of equipment for whole-tree handling and chipping.

By the end of 1975 almost 500 mobile whole-tree chippers were sold in North America, of which 300 were for field chipping and the others were for stationary use on terminals or for urban use. However, with the slower market situation from the end of 1974 to 1976, most mills had an adequate supply of high quality chips, and as whole tree chips and chips from forest residue in many mills created certain production problems, the use of such chips declined. Considerable research acitvities, however, are in progress to overcome the problems and to assess the feasibility of utilizing more of the forest biomass.

In Scandinavia there is a general shortage of bolewood raw material in relation to the consumption capacity of the forest industry, and, furthermore, increasing areas of forest are reaching the age when the first thinning operation is required. Alternatives to the traditional labour-consuming thinning methods are needed in high-cost countries. For these reasons, whole-tree utilization research projects started about 1970. Contrary to North America, it seems that relatively much research and many trials have taken and are taking place in Scandinavia, but whole-tree operations on a practical scale are so far carried out only to a very limited extent. It is predicted, however, that the next boom in forest industries will increase the use of whole-tree chips considerably, at least in Finland.

There is need to know more about the forest biomass - its harvesting and processing techniques, its potential uses, and the effects on the total ecology. The potential of using more of the forest biomass seems high, but a large number of too little known or unknown variables will decide the future development.

The terminology, for example describing biomass, tree components, methods of harvesting, and the resultant raw material is not yet consistent. "Complete tree utilization, whole-tree utilization, total tree utilization, full tree utilization" are some of the terms used; the word "forest" may be used instead of "tree". A more standardized nomenclature would be useful.

One concept applied by Young (1975) is the complete forest, emphasizing that all tree and wood shrub species - from the root tips to the leaf tips - should be investigated in their entirety with a view to using everything. Economic factors would then determine, for a given locality, the specific products that should be made or the specific use of each component. Within the complete forest concept, the harvesting practice can vary considerably from no harvesting at all to a possible future harvesting and use of all components.

The common and almost opposite concept is to regard more or less of the tree - depending on location and time - as a useful raw material, and what remains is considered either as forest residue or as mill residue.

Major practical approaches for harvesting more forest biomass have been:

Harvesting of stump and root-wood;

Harvesting of residue (slash) left after conventional logging;

Chipping more or less of the above-ground part of the trees.

Stump harvesting experiments and practice in Scandinavia are mainly based on the Pallari Stumparvester but other equipment is also being tried. In USA the Rome Puller-buncher is one of the machines being developed for stump-root harvesting; with this particular equipment southern pine trees are jacked free of the ground with taproot attached.

At many localities the forest residue left after logging (remaining trees, cull logs, tops, and branches) is viewed as a huge disposal problem. Different slash treatments are carried out, one alternative being conversion to chips usable for energy or forest products. Considerable research and feasibility studies have been and are being carried out, for example, in USA and Scandinavia (USDA 1972, Grantham 1974, Grantham et al. 1974, Harrison 1975, USDA 1975). Although there are several methods and possibilities for residue utilization, only a local evaluation can determine the feasibility.

A method commonly tried in the effort to get more wood out of the forest and to reduce costs, has been chipping all the above-ground tree parts. This method is often termed as whole-tree utilization or whole-tree chipping.

IV. 2 Whole-tree Chipping

Depending on conditions and equipment, whole-tree chipping can be done directly at the stump, on the strip road, at the landing along a forest road, or at a terminal or mill wood-yard. Chipping in the stand by harvester-type machines is being developed for harvesting of small-sized trees in Finland, in France, and probably in North America. Chipping of whole trees at terminals or mill-yard has been tried several places, but external transport is a bottleneck - truck transport of softwood trees from thinnings is estimated to be almost twice as expensive as chip transport, even on distances as short as 30-40 km. For the time being, and with present equipment, chipping at the landing along a forest truck road is most common and seems in many cases to be the best alternative.

A successful field-chipping system must meet the following requirements:

- Portable and reliable chippers;
- Suitable handling and transport equipment;
- Production of chips of a quality acceptable to the industry;
- Returns that compare favourably with other stump-to-mill systems.

Field chipping can be of pulpwood, the bole, or the whole tree. It may also include chipping of residue left after logging, such as shrubs, brush and unused tree parts like the cull, tops and branches.

The purpose of the chipping may be:

- Disposal of slash as an alternative to burning;
- Production of chips for such purposes as mulch, soil improvement, or fuel;
- Production of chips as a raw material for forest industries.

In the following, discussion of field chipping will be limited mainly to whole-tree chipping to produce raw material for the forest industries.

Whole-tree chipping is most common in hardwood stands. Veneer and sawlogs may be logged separately or, more commonly, culled out at the landing. In North America, presently, whole-tree chips from conifers are only occasionally accepted, and in some softwood thinning operations most of the branches are removed before field chipping. Logging operations in mixed stands may include two different production lines, one for hardwoods and one for softwoods, and this is a complicating factor.

The whole-tree chipping may be as a part of clear-cutting, selective cutting or thinning operations. Particularly in stands with low volume per hectare, small-sized trees or poor form and quality, whole-tree chipping has been the only logging method economically feasible.

Some of the major advantages and disadvantages of whole-tree chipping are:

Advantages

The method increases the quantity of wood obtainable from each hectare of forest, because it uses tops and branches and trees that were formerly not commercially useful. There is a potential for allocating cleaned chips to processes requiring high-quality chips, and lower quality chips to less demanding processes, to fodder and chemical recovery processes, or to fuel;

It might turn some presently unusable forests into commercially useful ones;

The system allows a high degree of mechanization and low input of manual work;

It is an elegant stump-to-mill system allowing a rapid wood flow;

It may make forest cultivation easier and cheaper as logging residue problems become reduced or avoided;

The site is more pleasing to the public when clear of logging debris.

Disadvantages

Organic matter and nutrients are removed from the soil. Leaves, bark and branches are the wood-components highest in nutrients. Removal of these components may cause reduced future production, make fertilization necessary and possibly increase the danger of soil erosion;

The industry in most cases gets a less desirable raw material because of the content of leaves, bark and other impurities. Removal of these with conventional screens is difficult and creates a need for additional chip cleaning equipment;

If the chips are not cleaned before the processing, increased water pollution from the mill is probable, particularly in some wet processes, unless ample precautions are taken;

A highly mechanized system for whole-tree chipping is expensive;

Small contractors and possibly forest owners may be excluded from logging work and fewer workers are needed;

The system requires careful planning and coordination to operate efficiently, e.g., between chipping and chip transport;

The method may have adverse influences on the forest ecosystem including climate, wildlife, birds, insects and microorganisms.

Two of these factors are briefly discussed below.

IV. 2.1 Increased Harvest of Dry Matter

The increased amount of forest dry matter harvested from a given land area by whole-tree chipping methods, as compared to conventional harvesting, varies widely due to differences in species, age, stand type, and conventional harvesting practice. In the case of conifers a 10-40 percent increase is normal; in hardwood stands the increase may be considerably higher. To obtain precise and reliable data for each specific case and locality, several single tree and stand biomass studies and reviews have already been carried out, e.g. by Young and Carpenter (1967), Keays (1971 a-e), Hakkila (1969, 1971), Ribe (1973), Gislerud (1974), Young (1976).

The amount and proportion of the different tree or stand components, e.g. wood, bark, and foliage, will of course be reflected in the whole-tree chips, although the content of foliage and bark may be somewhat reduced during the transport and chipping operations. On the other hand, the content of contaminants and abrasive material will often increase during the handling.

IV. 2.2 Removal of Plant Nutrients

Sunlight, water and nutrients are essential factors for tree growth. Within the global nutrient cycle, which often requires geologic eras for completion, there are secondary nutrient cycles very important for growth, Fig. 8 (Jorgensen et al. 1975). Additional nutrient input may come from fertilization, and other nutrient losses from harvesting, forest fires, etc.

In general the concentration of plant nutrients decreases in the following tree components, respectively: Leaves (needles), branchbark, stembark, branchwood, and stemwood. When thin roots are excluded, the nutrient concentration of stumps and roots does not differ much from that of the bole.

Considerably more nutrients are thus removed from the forest by whole-tree utilization than by removal of the marketable bole only. The increase in nitrogen and other macronutrient removal will be from 1.5 to 5 times that of conventional harvesting. The removal of nutrients by whole-tree utilization in thinning stands is of course less than at final cut, but the

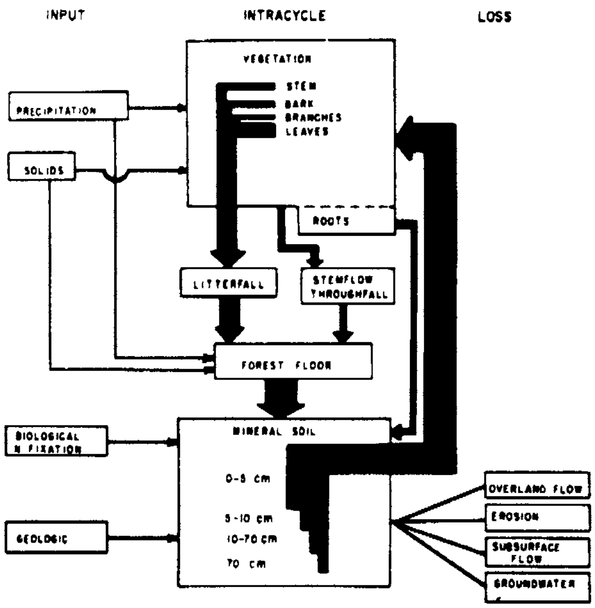


Fig. 8. The nutrient cycle.

thinning occurs when the stand's need for nutrients is greatest.

The impact of whole-tree utilization on the nutrient balance depends on such local conditions as the nutrient quantities in the soil and inputs from precipitation, air-borne solid particles, mineralization and weathering. No simple, general conclusions can be given, but some preliminary regional viewpoints are:

In Scandinavia nutrient depletion is not regarded as serious on normal and good sites, but fertilization, particularly with nitrogen, may be necessary to compensate for nutrient losses. It is advised against whole-tree utilization on peatland and on poor, sandy soils.

In Central Europe it has been estimated that whole-tree utilization in the long run will require compensatory fertilization, mainly of P, K, Ca, and Mg, to maintain growth.

Nutrient balance studies in USA show that the amount and number of times that the forest biomass can be removed before productivity becomes greatly reduced will vary considerably by site.

In the tropics and subtropics the soil usually possesses low nutrient reserves and there is often little or no chemical weathering to replace nutrients lost by logging or leaching. The major part of the nutrients is held in the vegetation itself, in the litter or in the soil organic matter. For these reasons, harvesting techniques that lead to the removal of considerable amounts of plant nutrients from a system already low in chemical reserves, should be carefully evaluated.

The shorter the rotation between each whole-tree harvesting, the more nutrients are generally removed. In intensive short-rotation forestry where most of the above-ground biomass will be frequently removed, fertilization will probably become a necessity and a normal practice as in agriculture.

A more intense utilization of the forest biomass means that more care must be given to the site nutrients and nutrient cycle, and considerable research activities are under way. Only as an exception may forest residue be regarded as a potential raw material free of expenses, because of its content of plant nutrients.

Information and literature references on nutrient content of different tree components and nutrient removal by whole-tree utilization are given by, for instance, Young and Guinn (1966), Boyle et al. (1973), Gislerud and Tveite (1973), Nykvist (1974), Binns (1975), Jorgensen et al. (1975), Kreutzer (1975, 1976), Mälkönen (1975, 1976), Tamm (1975) and Boyle (1976).

IV. 3 Logging Equipment and Organization for Whole-tree Utilization

A common version of the whole-tree harvesting system can briefly be outlined in the following steps: felling, bunching, skidding, chipping, blowing into van or containers, hauling to mill, scaling, and unloading.

Whole-tree utilization logging crew sizes and equipment in North America will vary from operation to operation, depending on factors such as tree sizes, terrain, climate, and whether clearcutting or thinning.

A typical operation might consist of:

Crew:	Equipment:
1 working foreman	
2 operators	2 feller bunchers with hydraulic shears
2 "	2 skidders
1 operator	1 chipper
	1 shop van with tools
	Additional equipment may include dozer, van spotter tractor, crew car, chain saws, chip screen, and trucks and vans.

Some crew sizes are smaller, other considerably larger, e.g. running two chippers, culling out the most valuable logs, or also running softwood harvesting in the same operation. In a few operations two shifts are working per day for better utilization of the expensive equipment.

In the North American operations cutting is usually done with feller-bunchers (e.g. Caterpillar, Drott, International, John Deere, Melroe Bobcat) that put the trees in piles ready for pick-up by articulated grapple skidders. In steep or muddy terrain track skidders may be used (e.g. FMC 200). Forwarders carrying all or most of the load are also considered, normally giving less dirt contamination. The trees are dropped at the landing where the chipper is located. The trees can if necessary be stock-piled, but normally the trees are fed almost directly into the chipper and the chips blown into a waiting van. In some cases a screen is installed between the chipper and the van, but field screening has so far been a bottleneck; the available screens are either too large or have a too low capacity. Moreover, the fuel value of the fines well covers the cost of transportation to the mill. The trucks and vans are conventional types; some operations use a spotter tractor to move the vans from the landing to the main road where regular highway trucks take over. The trucks and chip vans may be included in the operation or run by contractors.

The production capacity of a whole-tree chipping operation is very high. The actual overall production reached varies considerably between operations. Many operations have rather high nonproductive time records - averaging about 50 percent of total time - while other operations show very good productive time figures. Major reasons for down-time are bad weather, moving, no vans available, spotting vans, changing chipper knives, repair and maintenance. Knife changing may be necessary about twice a day, but under difficult conditions considerably more often, with each complete knife change taking 10-20 minutes. Field chipping during severe winter conditions is difficult.

The average production of chips delivered to mill of a 7-9 man crew operation often ranges between 100 and 300 green tons per day, or about half that weight expressed as oven-dry tons.

The personnel on whole-tree chipping jobs need considerable skill in operating and maintaining the equipment. In many operations the equipment operators rotate so they are familiar with all the equipment. Careful planning and co-ordination of whole-tree chipping operations is even more critical than for other logging methods to obtain a satisfactory result.

In Scandinavia, smaller and simpler equipment is under development for early thinning operations and for harvesting of small-sized trees. The methods and equipment include:

Combined felling-chipping in the stand by harvester-type machines and chip transport to the mill;

Felling with power saws or feller-bunchers, chipping at the stump or on strip-road, and chip transport to the mill;

Felling, hauling by skidders or forwarders to the landing, chipping with small tractor-powered chippers or larger, mobile chippers, and chip transport to the mill;

Logging and transport of whole trees from the stand to the mill yard where chipping takes place.

IV. 4 Landing Requirements for Field-Chipping

In the North American system a successful field chipping operation depends entirely on the landing or the field chipping terminal. Landings must be selected and prepared in advance. The landing should preferably be a large, relatively flat, but well-drained area. Bulldozing as well as filling with gravel may be necessary, particulary to ease van spotting at the chipper discharge spout and to remove the full chip vans.

Landing space requirements are:

The landing should accommodate adequate space for trouble-free turn-around for the truck-trailer unit;

The chipper should be located with the front toward the skidder entrance of the landing with a 15-25 m long space behind the chipper for parking the chip vans, preferably two vans positioned at an angle to each other so that when one van is filled, the chipper spout can be positioned to fill the empty one;

Adequate space for skidder turning away from the drop area on both sides adjacent to the chipper and space to swing the longest trees to the chipper infeed deck;

Parking space for an adequate number of empty and full chip vans and nearby parking space for the shop van;

If whole trees are to be stored, logs bucked and sorted out, and material handled with a front-end loader, considerably more landing space is required.

An example of a landing lay-out is shown in Fig. 9.

In most of the North European systems, however, the requirements for landing sites are not so strict, due to lighter equipment and more flexible logging schedules.

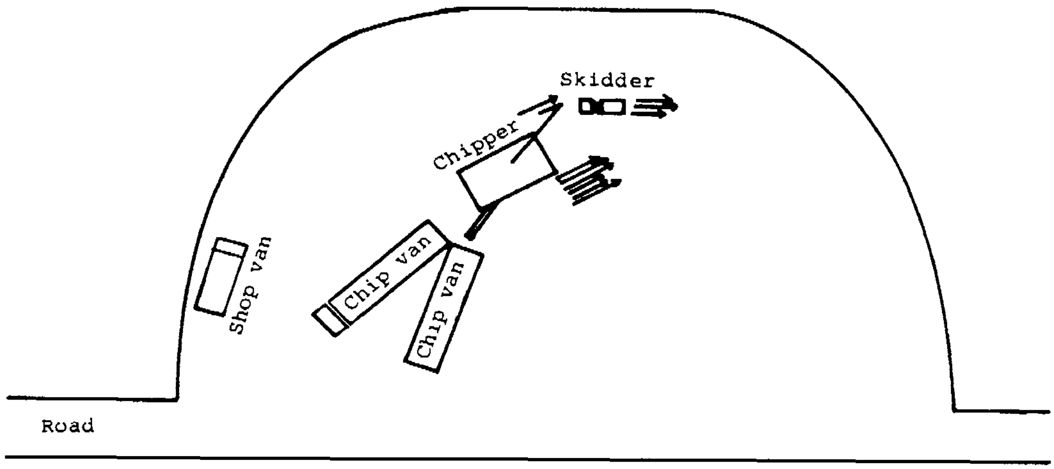


Fig. 9. A landing layout for field chipping.

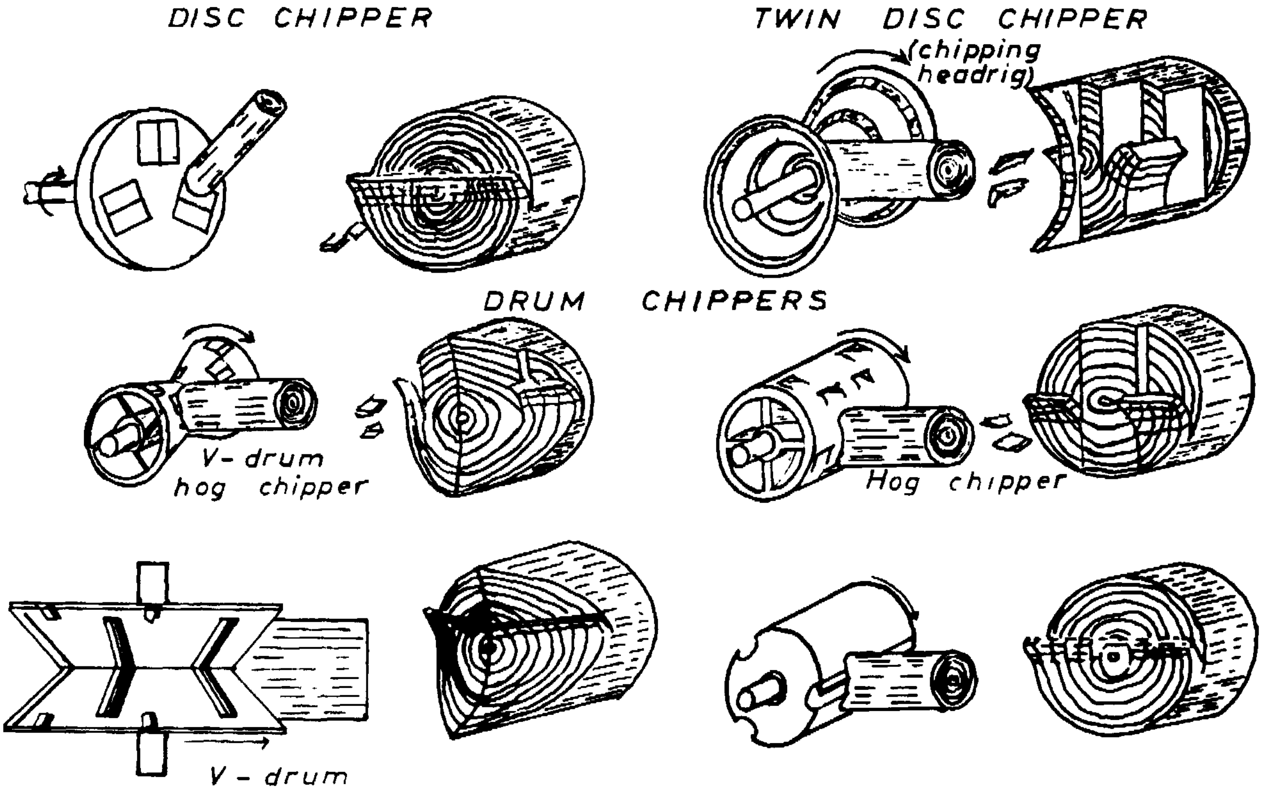
IV. 5 Mobile Chippers

There are several chipping principles currently in use (Fig. 10). A chipper must be of rugged design to withstand its tough job. Maintenance should be easy, it must produce chips of good quality, it should have a high production capacity in relation to its size, and a low power requirement per produced unit. In practice a chipper is a compromise between the different requirements, aiming at obtaining the best overall economy.

Pulpwood chipping at the industry is usually done with heavy, rugged disc chippers with 3-15 knives, although drum chippers are used to some extent.

Many sawmills now use chipping headrigs that produce pulpwood quality chips while producing smooth cant surfaces. Chipping of sawmill by-products such as slabs is usually done by disc chippers, often with horizontal infeed and live rollers. Different types of shredders (hammermills) with blunt- or dulledged cutters are also used, primarily for splits. The main advantage of shredders is the low maintenance cost, a disadvantage is the poorer chip quality. An example of chips from splits produced with a disc chipper and with a shredder is shown in Fig. 11.

Studies of portable and semi-portable chipping were published in 1959 (FAO 1959), in 1962 (FAO/ECE/LOG/98 1962) and in 1965 (FAO/ECE/LOG/161 1965). To give an idea of the wide range of mobile chippers presently available, data of some chippers are presented in Table 1 and Figs 12-37. The capacity figures given for the different chippers are very uncertain, depending as they do on wood species, the hardness of the wood, tree or log size, straightness, etcetera. In practice chipper feeding often is the most limiting factor. Prices are given as an indication only.



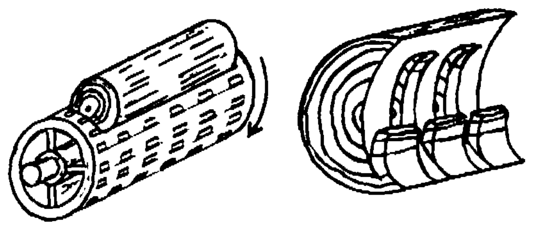


Fig. 10. Types of commercial chippers and typical cut face section produced by each type.

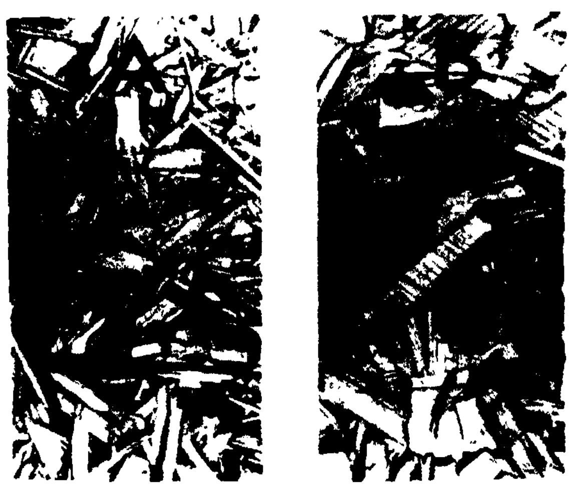


Fig. 11. Chips produced with shredder (A) and with disc (B).

Table 1. Features of some mobile chippers.

Chipper	Manufacturer	Approx max. tree diam. cm	Chipper type	Weight ton	Power requirement hp	Production ton/day	Approx. price ex. factory $	Remarks
Karhula 312 CS	A. Ahlström Oy Engineering Works Div. SF-48601 Karhula Finland	25	disc, 3 knives	2.6	75-115	15-40	21400	Chipping of roundwood and whole trees, without basic machine
AST (ASP)	Alavuden Tehdas Oy SF-63400 Alavus Finland	13	disc, 3 knives	0.2	30-75		1200	Chipping of smallsized trees and wood, without basic machine, 100 sold
ALGOL Multi-purpose Tree Chipper I	Oy ALGOL Ab Eteläranta 8 SF-00131 Helsinki 13 Finland	30	drum, 16 knives	18	300		100000	Chipping of whole trees and slash
ALGOL Multi-purpose Tree Chipper II	"	30	drum, 20 knives	21	350		125000	Chipping of whole trees and slash
Whisper Chipper	Asplundh Manufacturing Division, 50 East Hamilton Street, Chalfont, Pennsylvania 18914, USA	15	drum, 4 blades	1.6-1.9	50-110	10-15	5955-7120	Disposal of smallsized trees and brush, 4 models, 11000 sold
Bruks 720	Bruks Mekaniska AB P.O. Box 46 S-820 10 Arbrå, Sweden	20	disc, 4 knives	0.5	40			Mainly for production of fuel chips, without basic machine, 367 sold
Bruks 850	"	25	disc, 1-2 knives	1.5	40-75	15-40	7500-13000	Chipping of pulpwood and sawmill residue, equipped with feed conveyor and extra compress rollers for whole tree chipping, without basic machine, 76 sold

Chipper	Manufacturer	Approx max. tree diam. cm	Chipper type	Weight ton	Power requirement hp	Production ton/day	Approx. price ex. factory $	Remarks
Bruks 1300 MT	"	25	disc, 2 knives	3	70-100		10800-15000	Chipping of pulpwood and sawmill residue, equipped with extra compress rollers for whole-tree chipping, without basic machine
Bruks 1500 MT	"	28	disc, 3 knives	6.1 (+weight of trailer)	150-250	70-80 (sawmill residue)	from 70000	Chipping of pulpwood, sawmill residue and tree tops, several versions available
Bruks 1500 PT	"	33	disc, 5 knives	14	240-350	90 (sawmill residue)	100000	Chipping of pulpwood, sawmill residue and tree tops, several infeed designs available
Bruks 2000 RT	"	41	disc, 5-7 knives	18	340-600	140 (sawmill residue)	120000	Chipping of pulpwood, sawmill residue and tree tops, several infeed designs available
Bruks 800 CT	"	35	drum, 3 knives	4.9 (+weight of tractor or truck)	240	40-95		Chipping of whole trees and slash
Bruks 1200 CT	"	40	drum, 3 knives	16	350	70-130	125000	Chipping of whole trees and slash
Bush Harvest-master	Bush Manufacturing Co. Kockum Industries, Inc. 9220-B Parkway East Birmingham, Alabama 35206 USA	55	disc, 3 knives	30	about 500		116000	Chipping of whole trees

Chipper	Manufacturer	Approx max. tree diam. cm	Chipper type	Weight ton	Power requirement hp	Production ton/day	Approx. price ex. factory $	Remarks
ABC - 1000 M	AB Constructors S-285 00 Markaryd Sweden	25	disc, 2 knives	1.3	50-150	15-40	7500	Chipping of slabs, logs and whole trees, without basic machine, 40 sold
ABC - 1500 M	"	30	disc, 3 knives	3.2	50-150	15-40	from 18400	Chipping of slabs, pulpwood and whole trees, without basic machine
ABC - 1800 M	"	40	disc, 4 knives	11	250		57500	Chipping of slabs, pulpwood and whole trees
ABC - 8/60 RD	"	35	drum, 2 knives	3.8	60-150	40-60	32000	Chipping of slabs, logs, boles and whole trees
ABC - 10/80 RG	"	45	drum, 3 knives	12.2	350	180	103500	Chipping of slabs, logs, boles and whole trees
ABC - 8/60 RC	"	35	drum, 2 knives	24	365	180	195000	Chipping of logs, boles and whole trees, may work in terrain
Fulghum Whole Tree Chipper	Fulghum Industries Inc. S. Main Street Drawer "G", Wadley Georgia 30477, USA	56	disc, 4 knives	31.5	540		130000	Chipping of whole trees
Hedlunds type 460	Hedlunds Mekaniska Verkstads AB S-822 00 Alfta, Sweden	29	disc, 3-5 knives		75-220			Chipping of pulpwood
Morbark Total Chiparvestor Model 12	Morbark Industries, Inc. Box 1000, Winn Michigan 48896, USA	29	disc, 2 knives	5.3	190	150	35400	Chipping of whole trees

Chipper	Manufacturer	Approx max. tree diam. cm	Chipper type	Weight ton	Power require-ment hp	Produc-tion ton/day	Approx. price ex. factory $	Remarks
Morbark Total Chiparvestor Model 18	"	45	disc, 3 knives	12	310		72000	Chipping of whole trees
Morbark Total Chiparvestor Model 22	"	56	disc, 3 knives	26	380	200-300	114000	Chipping of whole trees, about 400 sold
Nicholson Logger Utilizer	Nicholson Manufacturing Co., 3670 East Marginal Way S, Seattle Washington 98134, USA	44-69	V-drum, 3 knives	42-78	850-1250			Debarks and chips logs and boles, 3 models
Nicholson Complete Tree Utilizer 22"	"	56	V-drum, 3 knives	32	600	250	from 184000	Chipping of whole trees, a larger model available
Nicholson Ecolo Chipper	"	46-69	drum, 4-14 segments, 4-28 knives	27	600	from 100	from 118000	Residue chipping, max. in-feed width 69-246 cm, 5 models available
Precision 58" Tree Harvester	Precision Chipper Corporation, Leeds P.O. Box 360 Alabama 35094, USA	45	disc, 3-4 knives	15.8	260		61000	Chipping of whole trees
Precision 75" Tree Harvester	"	55	disc, 3-4 knives	27.2	from 325	200-300	from 103250	Chipping of whole trees
Precision 84" Tree Harvester Twin Engine	"	64	disc, 3-4 knives	31.3	from 500		from 115250	Chipping of whole trees, about 30 sold (all models)

Chipper	Manufacturer	Approx max. tree diam. cm	Chipper type	Weight ton	Power require-ment hp	Produc-tión ton/day	Approx. price ex. factory $	Remarks
Wood/Chuck	Safety Test & Equip. Co. P.O. Drawer 400, Shelby, N.C. 28150, USA	25	drum, 4 knives	2.1	100-200	12-15	9095	Disposal of smallsized trees and brush, 200 sold
Skogma-huggen	Skogsmateriel AB Box 121 99 S-102 25 Stockholm 12 Sweden	24	disc, 3 knives	0.8	60		4500	Chipping of sawmill residue, pulpwood, and smallsized whole trees, without basic machine
Trelan	Strong Manufacturing Co. 498 8 Mile Rd., Remus Michigan 49340, USA	43	disc, 2 knives	8	185	125-150	38700	Chipping of whole trees, about 30 sold
Pallari Busharvester	Tervolan Konepaja SF-95385 Tervola Finland	15	drum	10	300-350	15-40	130000-155000	Felling and chipping of smallsized trees and bushes, prototype
TT Terrain Chipper 1000 F	Työväline Oy Sulkapolku 3 SF-00370 Helsinki 37 Finland	25	disc, 2 knives	18.5	150		137500	Chipping of whole trees
TT Terrain Chipper 1000 T	"	25	disc, 2 knives	16	150		125000	Chipping of whole trees
TT Landing Chipper 1500 L	"	40	disc, 3 knives	22	300		125000	Chipping of whole trees, slash and slabs
TT Landing Chipper 1500 T	"	40	disc, 3 knives	23	300		150000	Chipping of whole trees, slash and slabs

Chipper	Manufacturer	Approx. max. tree diam. cm	Chipper type	Weight ton	Power requirement hp	Production ton/day	Approx. price ex. factory $	Remarks
Diadem Brush Chipper	Vandermolen Corp. 119 Dorsa Avenue Livingstone N.J. 07039, USA	8	drum, 2 knives	0.1	8-12		650-889	Brush disposal, also farm tractor PTO model available
Vecoplan type 45/20/4	Vecoplan GmbH + Co. D-5439 Bad Mariénbad Postfach 1245 W. Germany	20	drum, 2 knives	12.5	240		63000	Chipping of slabs and logs
Vecoplan type 75/26/7	"	26	drum, 2 knives	20	200-300		135000	Chipping of slabs and logs
Veco-Mobil-Chipper type 55/20/4	"	25	drum, 2 knives		200		117500	Whole-tree chipping
Wayne 16"	Wayne Manufacturing Co. 1201 E Lexington Street Pomona California 91766, USA	15	drum, 4 knives		210			Disposal of smallsized trees and brush

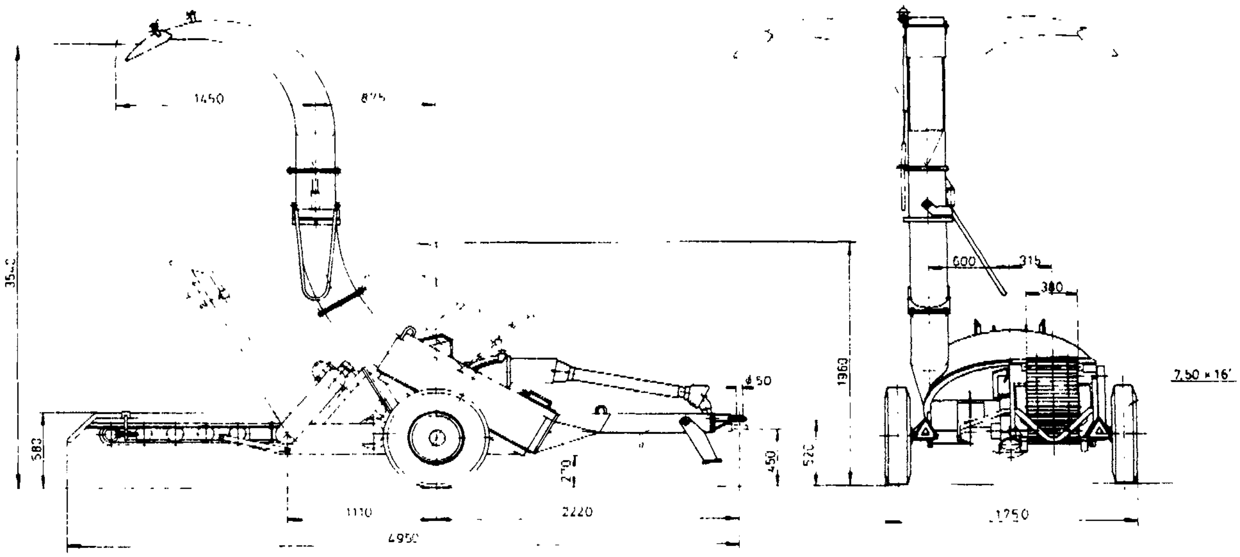


Fig. 12. Karhula 312 CS.

Fig. 13. ALGOL Multipurpose Tree Chipper II.

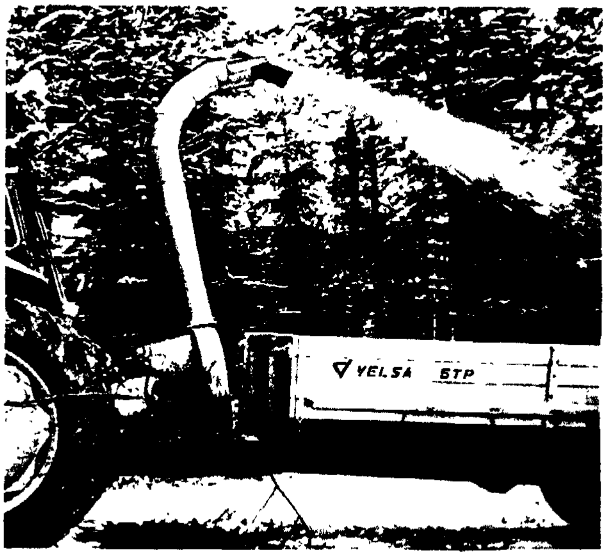


Fig. 14.
AST.

Fig. 15.
Whisper
Chipper.

Fig. 16. Bruks 850 M.

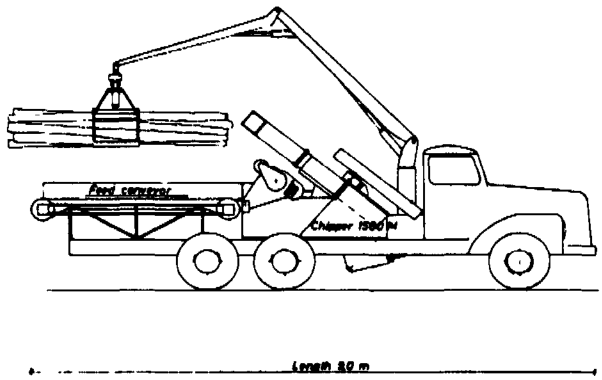


Fig. 17. Bruks 1500 M.

Fig. 18.
Bruks 800 CT.

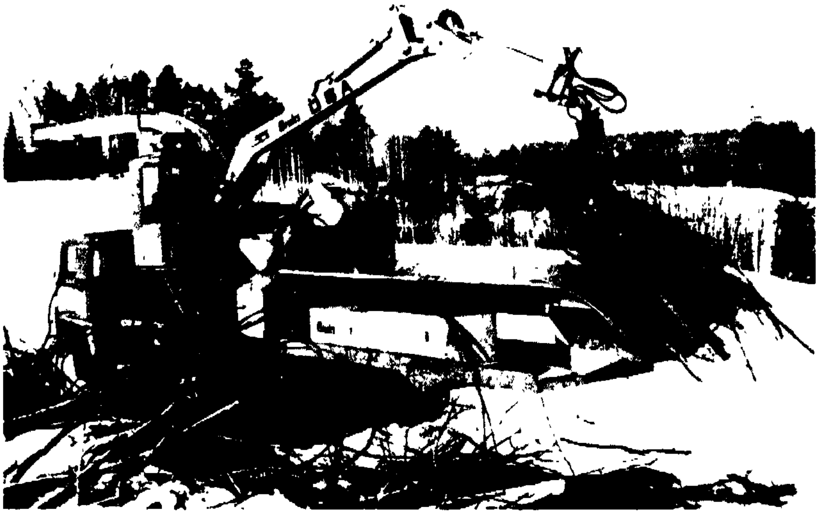


Fig. 19.
Bruks 1200 CT.

Fig. 20. Bush Harvestmaster.

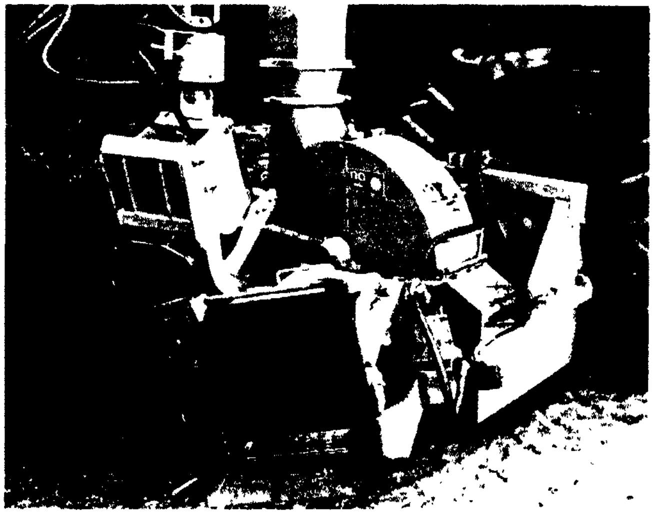


Fig. 21.

ABC - 1000 M.

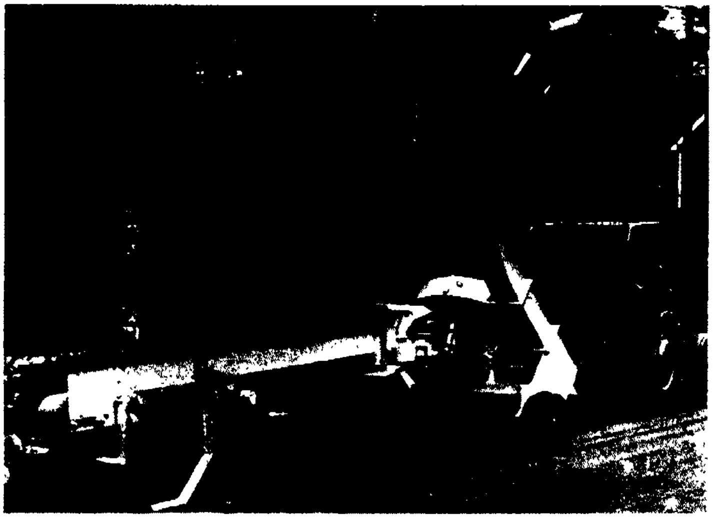


Fig. 22. ABC - 1500 M.

Fig. 23. ABC 10/80 RG.

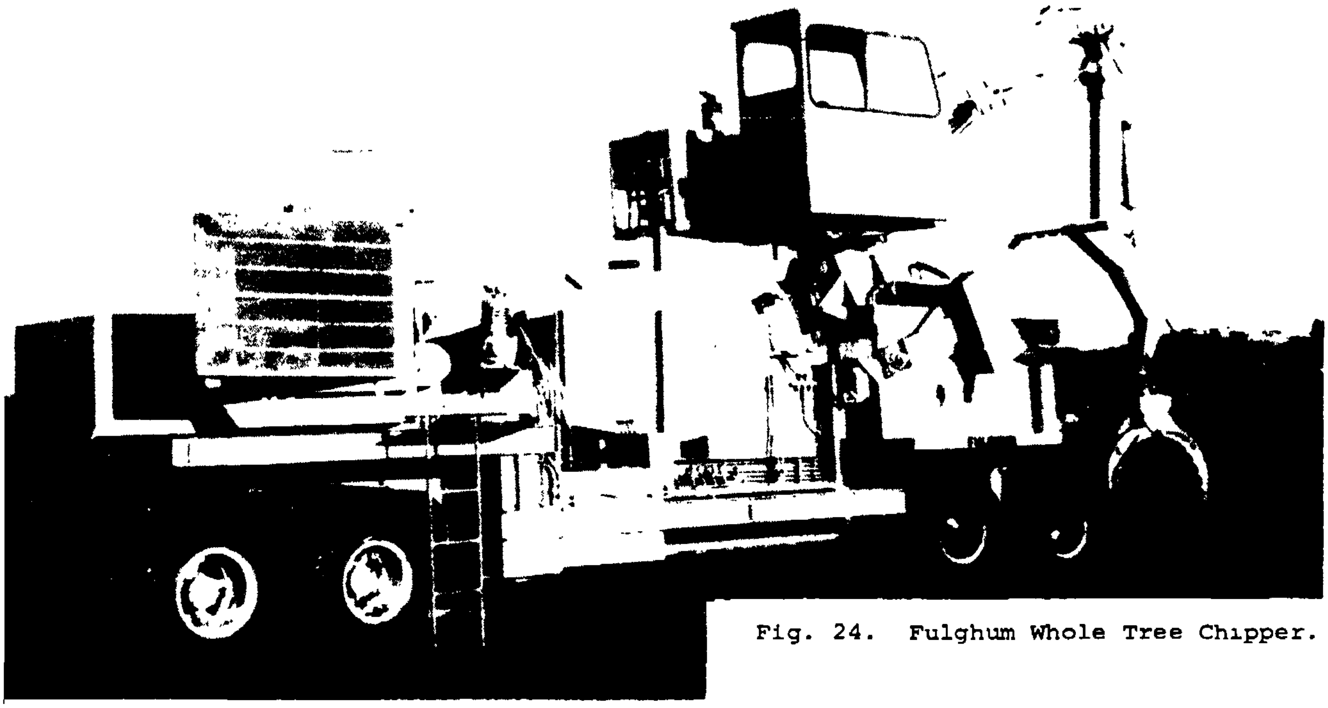


Fig. 24. Fulghum Whole Tree Chipper.

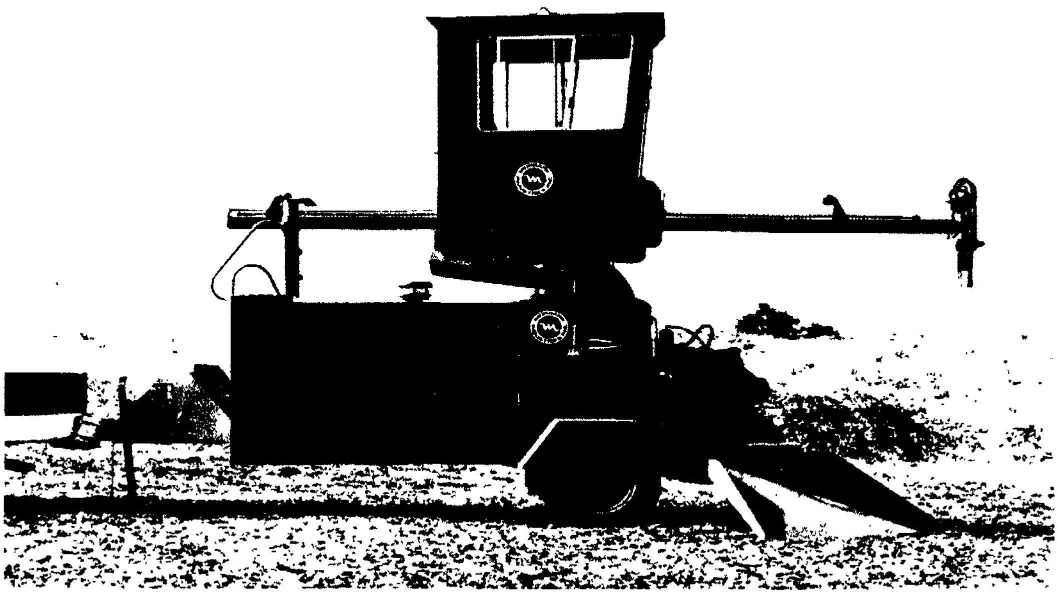


Fig. 25. Morbark Total Chiparvestor Model 12.

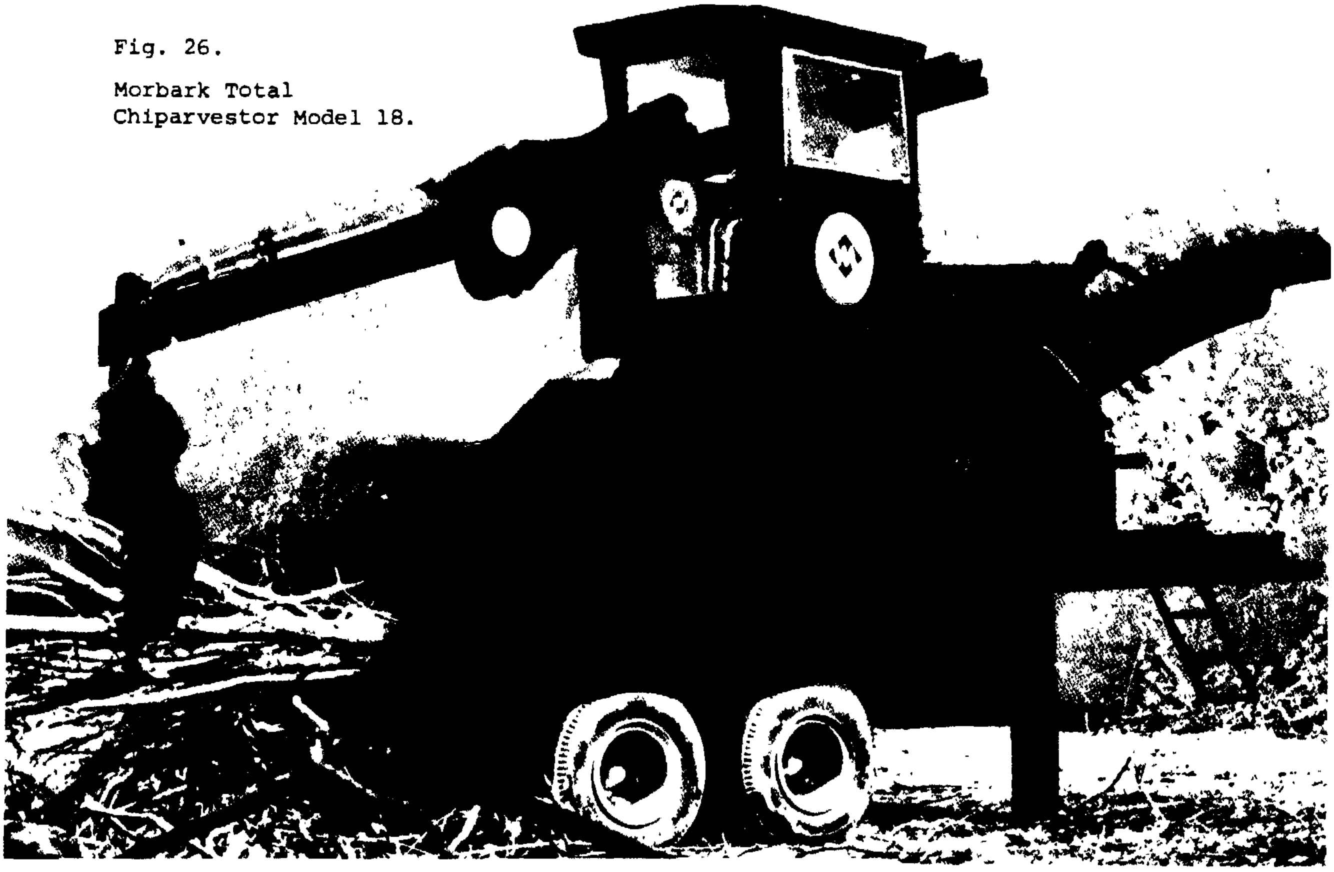


Fig. 26.

Morbark Total
Chiparvestor Model 18.

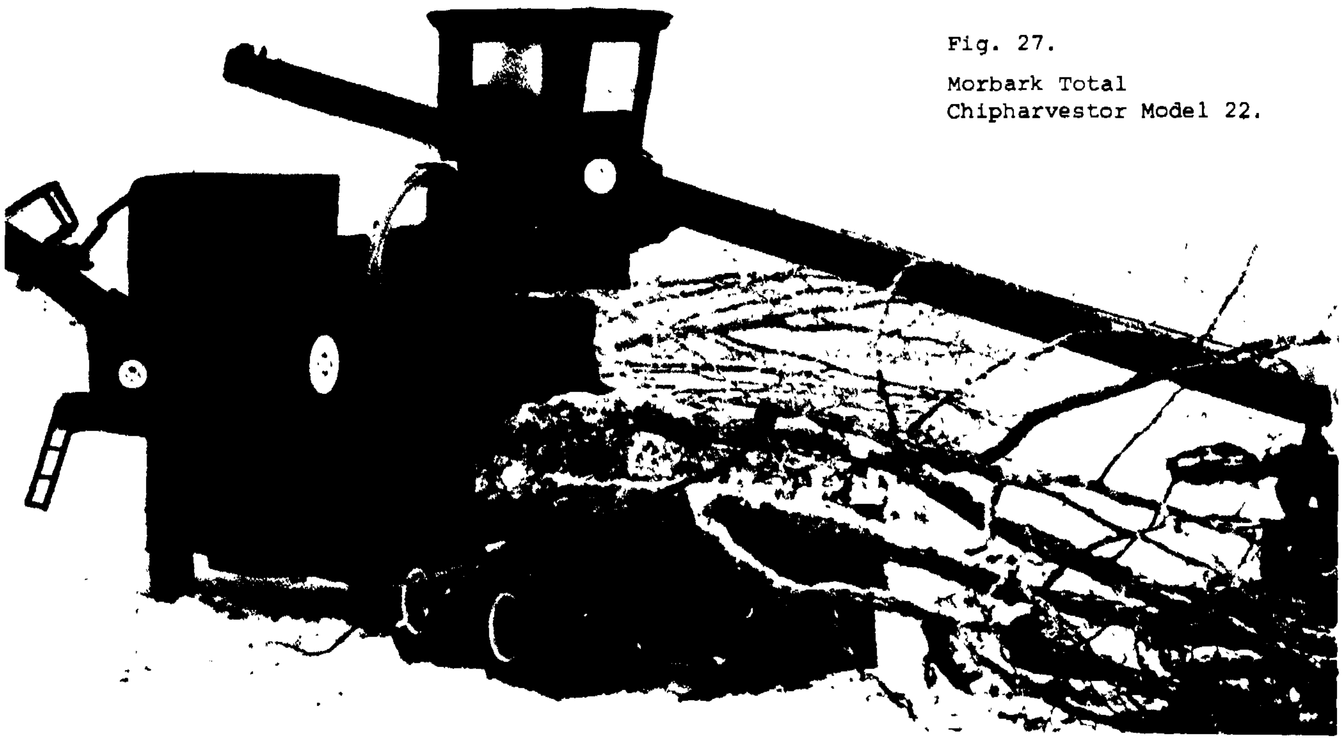


Fig. 27.

Morbark Total
Chipharvestor Model 22.

Fig. 28.

Nicholson Complete Tree Utilizer 22".

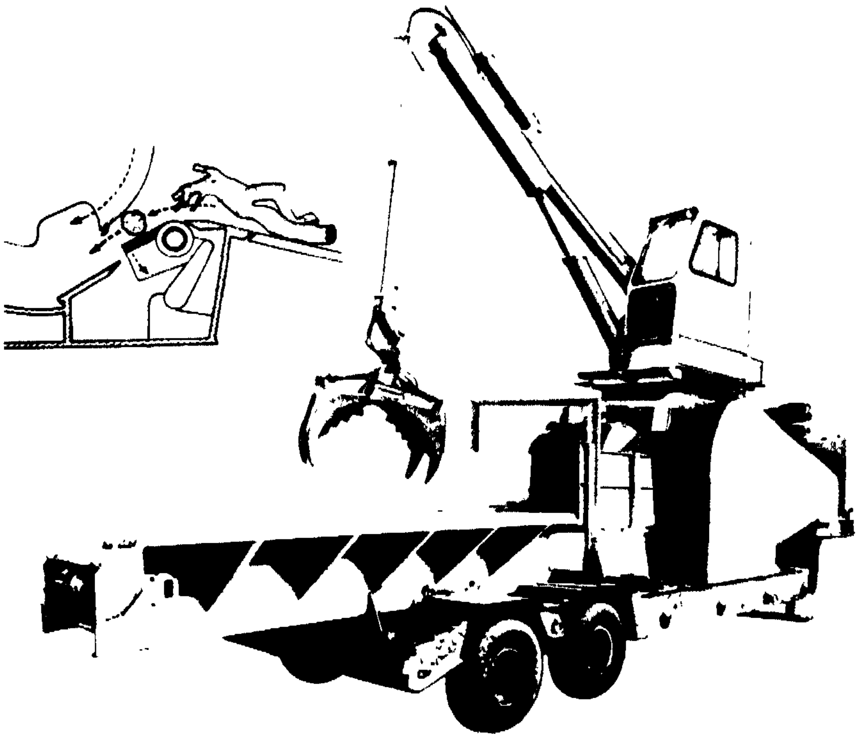


Fig. 29.

Nicholson. Ecolo Chipper.

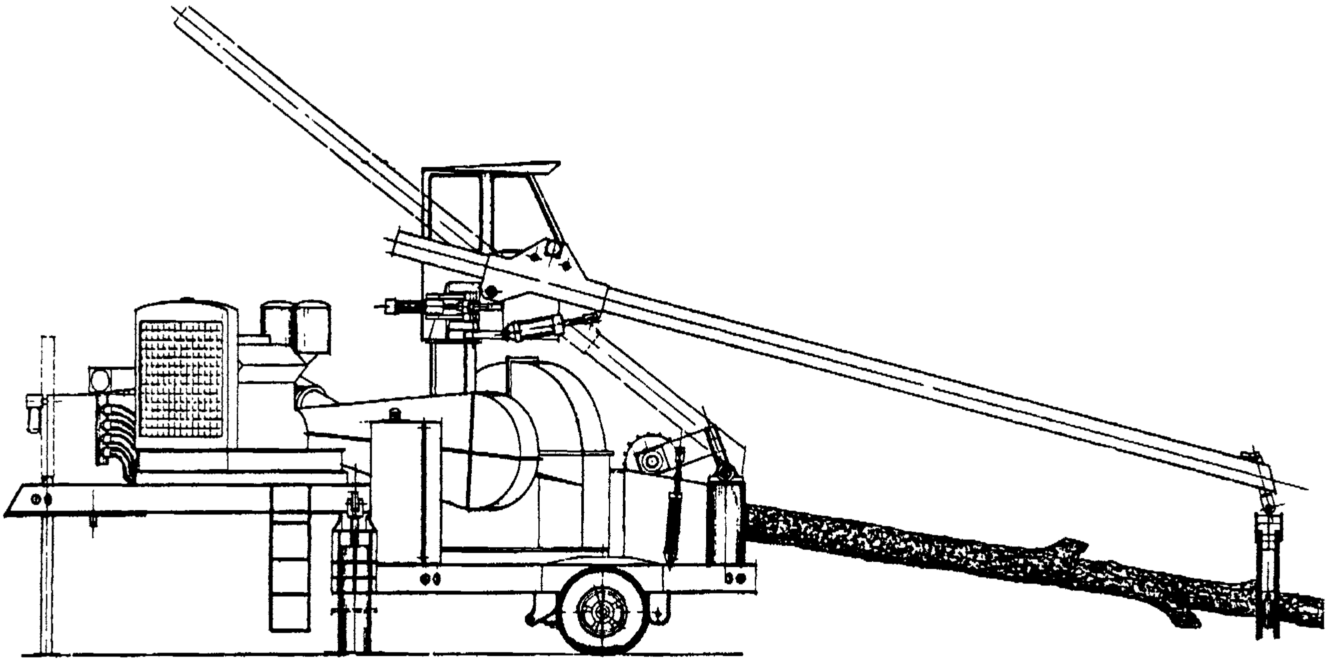


Fig. 30. Precision 58" Tree Harvester.

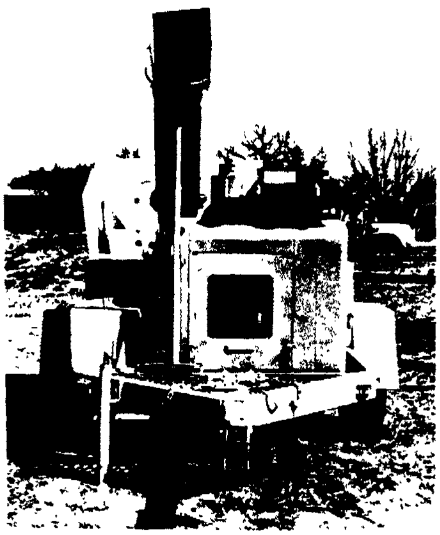


Fig. 31. Wood/Chuck.

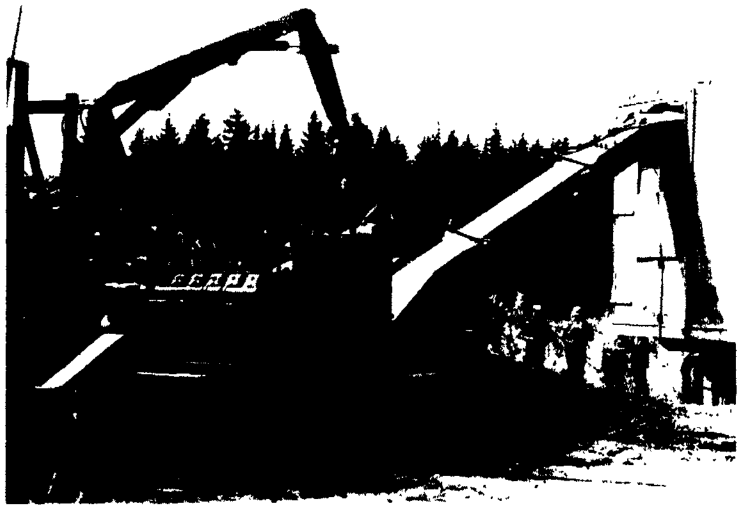


Fig. 32. Trelan.

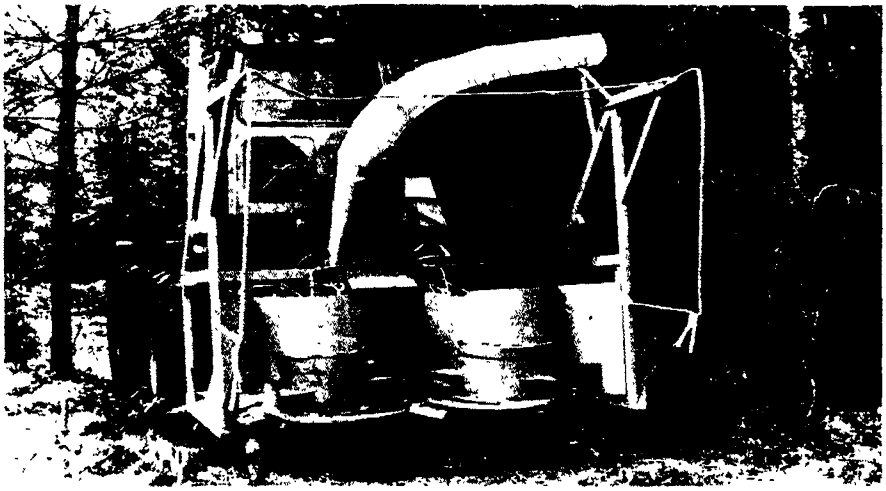


Fig. 33.
Pallari
Busharvester.

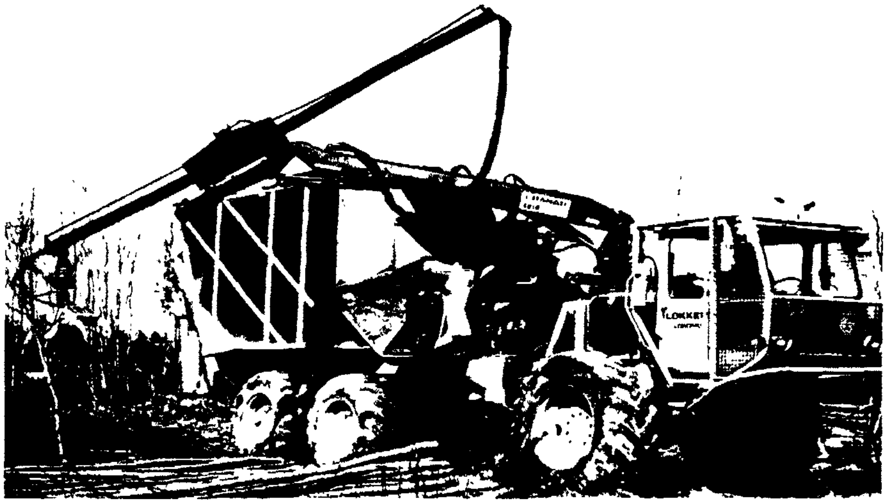


Fig. 34.
TT Terrain
Chipper 1000 F.

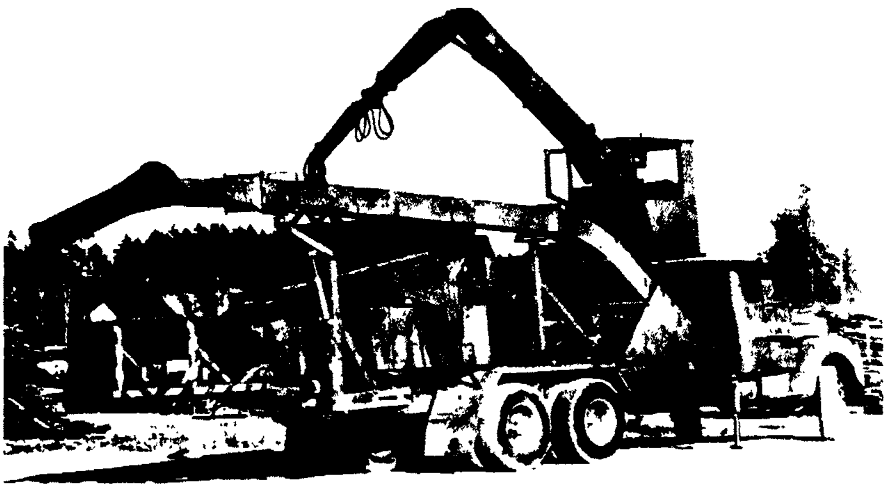


Fig. 35.
TT Landing
Chipper 1500 L.

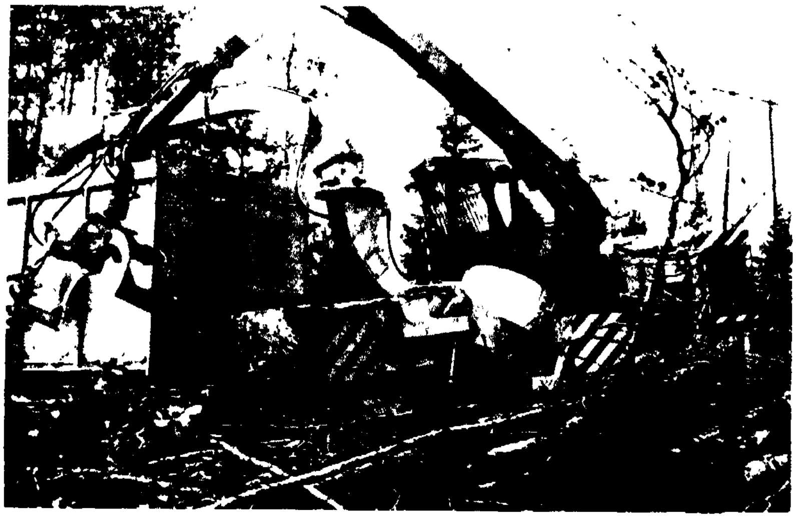


Fig. 36. TT Landing Chipper 1500 T.

Fig. 37. Diadem Brush Chipper.

Mobile chippers are generally lighter than stationary pulpmill chippers, but usually the chipping part seems to be adequately rugged. The disc is also lighter with less flywheel action, both slowing down and building up rpm more rapidly than a stationary chipper. When chipping whole trees and particularly slash, a relatively large infeed opening is required. In addition most mobile chippers have an infeed steel chain and compression and feeding rollers. Both disc chippers and different drum designs are used, the latter type allowing a larger infeed opening.

Two major problems are associated with whole-tree chipping and particularly with slash chipping. The material is fed into the chipper in non-uniform directions in relation to the knife, resulting in uneven chip lengths; and stones and sand often cause problems, giving delays and high knife maintenance cost.

The energy needed for chipping depends on several factors, such as wood basic density, moisture content, and chipper design and maintenance. Normally chipping requires 1.8 - 6 hp hours per solid cu m of wood.

Information and references on chipper design and power requirement are given by Papworth and Erickson (1966), McKenzie (1970), Erickson (1972a), Lapointe (1973), Ranhagen (1973, 1974), and Parker (1975).

IV. 6 Maintenance of Chippers

The following is based mainly on a paper by Hartler (1972). It refers to stationary disc chippers, but should also be valid for portable ones.

The feeding of logs into the chipper is of great importance in achieving good quality. The log must be fed in with correct positioning of its axis and at a speed practically the same as that at which it will be sucked through the machine. The suction through the machine is also of importance and chippers should be designed in such a way that the suction is effective and constant, with the log moving at a steady speed through the chipper without jerky movements or, even worse, bouncing.

Much could be said about the arrangement of the spout in relation to the disc and the knives in it; but, briefly, both the cutting angle and the knife angle should be as small as possible. A small cutting angle means that the cutting surface will be large and this will limit the size of the largest log that can be fed into the machine. A small knife angle is hard to achieve because the smaller the angle the more exposed the edge is to wear. When a better material is found for the knives, a reduction in knife angle can be achieved.

Maintenance of the chipper is of course of the greatest importance in achieving optimum quality. The bed plate as well as the wear plates on the disc should not be allowed to become too worn and the distance between the bed plate and the knife should be carefully adjusted at frequent intervals. Most machines are not designed with this in mind, however, and it is often difficult to meet even nominal demands in this respect. Knife sharpness is another factor which has to be checked.

Besides cutting and knife angle, the cutting speed is one of the most important factors in determining chip quality. It should not be allowed to be too high. However, quality has to be balanced against production: high speed gives high production and low speed gives high quality. Chippers for sawmill residue and field chipping are often equipped with a feeding mechanism. If the motor is overloaded and the speed drops, feeding can be stopped or will stop automatically. If necessary, the feeder might also be put into reverse.

IV. 7 Bark Removal and Chip Upgrading

Some pulpwood debarking alternatives are shown in Fig. 38 (Erickson 1972b).

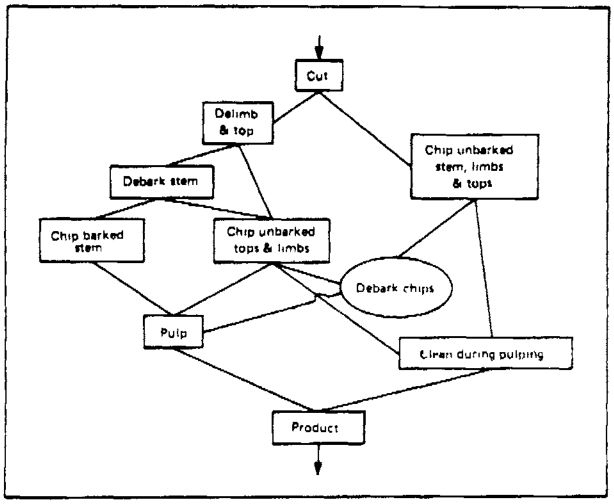


Fig. 38.

Pulpwood debarking alternatives.

At present almost all debarking of wood is done with conventional methods before chipping. Debarking may be done by manpower or by machines. At sawmills, cambium shear and rosser head barkers are commonly used, while pulp mills usually use drum barkers. Drum barking is performed according to two principles: 1) parallel barking for long wood (3-8 m), and 2) tumbler barking for short wood (1-3 m). Parallel barking is claimed to reduce wood loss through no or less bucking and also because less brooming takes place. In case of crooked logs and species difficult to debark, tumbler barking is preferred.

At a few pulp mills drum barking is done without adding water in order to reduce water pollution and to obtain bark with a low moisture content suitable for use as fuel. Mixed dry-wet drumbarkers are also available, where the major portion of the bark is removed in the dry inlet drum-section. The second drum section is a wet end, improving the log cleanliness. Another approach to reduce water pollution is to substitute steam for water. The technique of roundwood debarking is well known (see FO-FAO/ECE/LOG/162 1966, Weiner and Pollock 1972), and the following will mainly deal with the possibilities of bark removal after chipping, as this is a fairly new method.

Chips from whole trees and slash may be used as received by the mill, but are usually mixed with other clean chips. Clean chips are of course a considerably better raw material, and in some processes a necessity. The upgrading of the chips may include removal of foliage, of oversize chips, of fines and of abrasive material in addition to bark.

The purpose of the upgrading could also be to separate the whole-tree chip mass into different classes or components, each suited for different uses, ranging from pulp to fuel and chemicals.

The necessary degree of upgrading varies with the mill production process, production equipment, and end product. If the bark content were reduced to be 3-5 percent, several kraft mills could use large amounts of whole-tree chips.

Bark removal after chipping involves 1) breaking the bond between wood and bark (separation) and 2) removal of the bark particles from the chip mass.

Investigations by Erickson (1972a, b) show that a part of the bark is separated from the wood during chipping of unbarked boles. In the growing season the disc type of chipping resulted in 90-100 percent bark separation. In the dormant season, however, bark adhered closely to the wood (a situation most pronounced in the case of conifers) which gave separation results sometimes as low as 30-50 percent. It is thus not possible to rely entirely on chipping to separate bark from wood chips throughout the year.

Many principles like compression, screening or air or liquid flotation have been tried in wood-bark separation.

Several years of research at the Forest Engineering Laboratory (FEL), Houghton, Michigan, USA, has resulted in a technically feasible bark-chip separation-segregation process. The heart of the process is a compression debarker. The chips are passed in-between two opposing, hydraulically loaded steel rolls that maintain a nip spacing smaller than the chips. In this process a part of the bark adheres to the compression rolls and is scraped off or is crushed into small particles that can be screened out. Compression debarking alone may remove 40-70 percent of the bark content in the chip mass. Steaming the chip mass for 5 minutes before compression softens the bark and makes it tacky so that it adheres better to the compression rolls, from which it is then brushed or scraped off. Pre-steaming followed by compression debarking may remove 55-80 percent of the input bark. Whole-tree chips of quaking aspen, sugar maple, and jack pine with an input bark content of 9-21 percent had a residual bark content of 3 to 7.5 percent after the treatment. The wood recovery ranged from 80 to 97 percent. Most of the bark is in the chip fraction smaller than 10-15 mm. Screening this fraction out of the mill furnish will reduce the bark content to less than 3 percent, but increase the wood loss, and give more fuel. However, some of the wood in this chip fraction may be recovered by, e.g., a hammermill treatment and subsequent screening. Recent reports by Mattson (1975) and Erickson (1976) describe the FEL chip-debarking system.

One company, Parsons & Whittemore, has since the spring of 1975 operated the world's first mill-scale pilot chip-debarking plant at the St. Anne-Nackawic Pulp and Paper Company Limited, New Brunswick, Canada, based on the method developed by FEL. The whole-tree chips are screened to remove the fines, by which the original bark content of 11-15 percent is reduced by 20-30 percent. The chips are presteamed for 3-7 minutes and then metered onto a three-stage conveyor system feeding the compression rolls with a single-chip layer distributed across the full conveyor width. In general, the bark content of the hardwood species maple, aspen, beech, and birch seems to be reduced to about 3 percent with an acceptable wood loss when the upgrading process includes the following steps (Fig. 39).

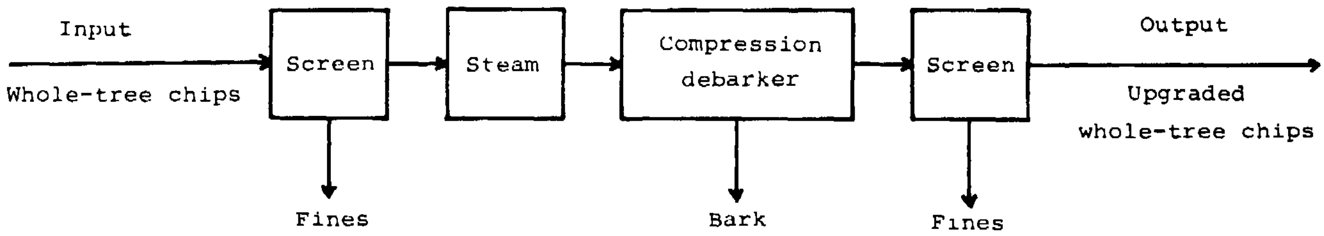


Fig. 39. The chip upgrading system at St. Anne-Nackawic.

The capacity of the compression debarker unit is about 10 tons of ovendry chips per hour. Compression debarking reduces the chip packing density, but also the cooking time, resulting in a certain possible net gain in digester capacity.

From experience gained up to the end of 1975, the process seems rather promising, but the compression unit requires further improvement before being made commercially available. In general, bark removal after chipping is not expected to be as effective as current roundwood debarking methods, but is nevertheless very attractive.

A different approach involving the use of water for separating and segregating bark and foliage from whole-tree softwood chips is pursued at the Forest Engineering Research Institute of Canada, Quebec (PPRIC 1975, FERIC 1975).

Of other chip upgrading methods and equipment the following may briefly be mentioned:

- Flat, usually inclined vibrating screens. Such screens have a relatively low efficiency;
- Gyratory (swinging, floating, rotary) screens have a circular or elliptical motion. Such screens give a better screening result than vibrating screens (Fig. 40);
- Perforated drum or rotary bar screens (Fig. 41). These rotation screens are mechanically simple and more or less selfcleaning. The screening capacity and efficiency is often relatively small in relation to screen size;
- Rotary disc screens (Fig. 42) carry the chips along on rotary discs and the undersized material drops through the spaces between the overlapping discs. The discs may be differently spaced along the screen and thus separate the chip mass into different fractions. Advantages of this screen type are high

capacity in relation to screen size, simplicity, self-cleaning, and low costs;

- Air classification techniques (Fig. 43);
- Chip washing.

No individual, simple machine can be expected to perform complete chip upgrading, however by combining well-known screening or washing methods with recently developed chip-barking methods, very much of the job can be accomplished. It is probably economical to spend more money on chip upgrading and reduce costs incurred from mill production problems. The size and cost of the equipment seem to limit most steps of the upgrading to chip terminals or industry.

Recent reviews of chip upgrading methods and equipment are presented by Christensen (1976), Hartler (1975), Arola et al. (1976), Erickson (1976), and Snow (1976).

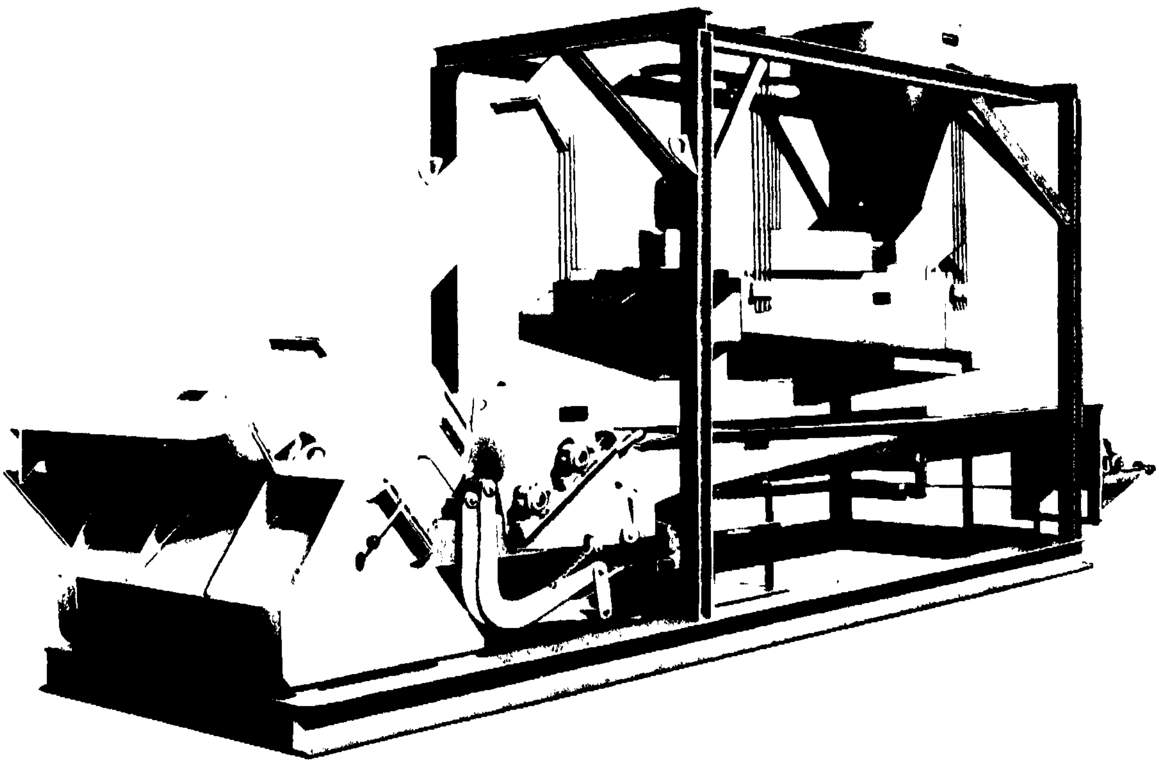


Fig. 40. An example of a chipper and a gyratory screen (Bruks Chip Pac).

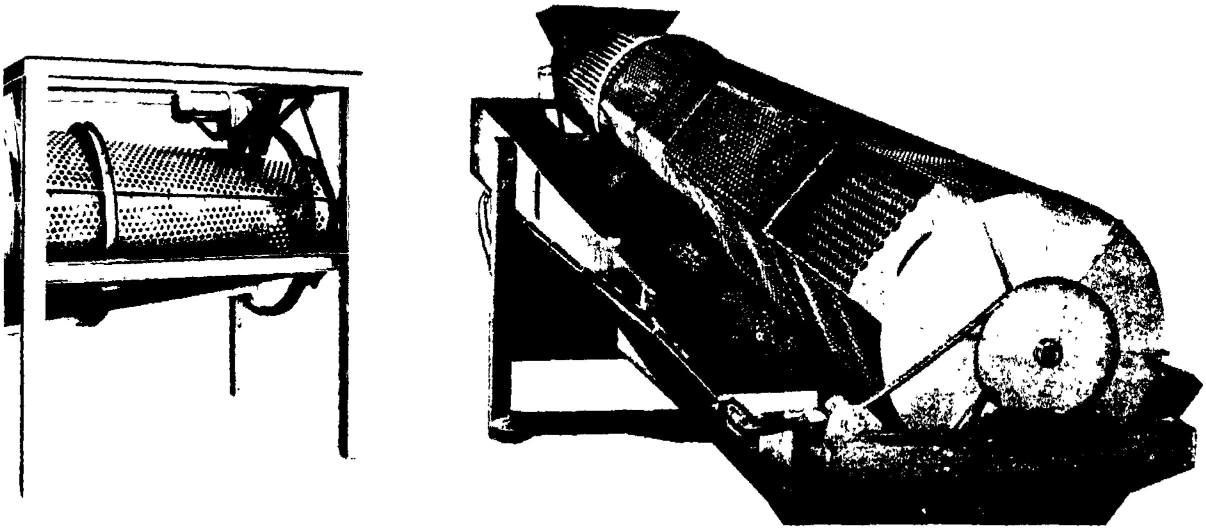


Fig. 41. A small rotary drum screen for separation of slivers from sawdust (Bruks), and a larger drum screen (Morbark Class-A-Fiber unit).

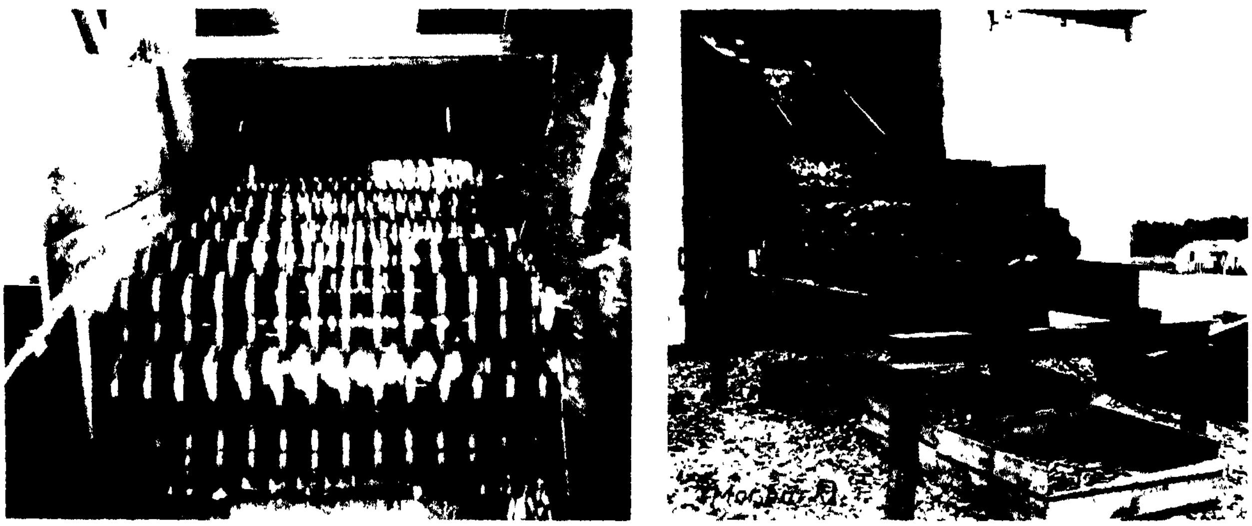


Fig. 42. Rotary disc screens.

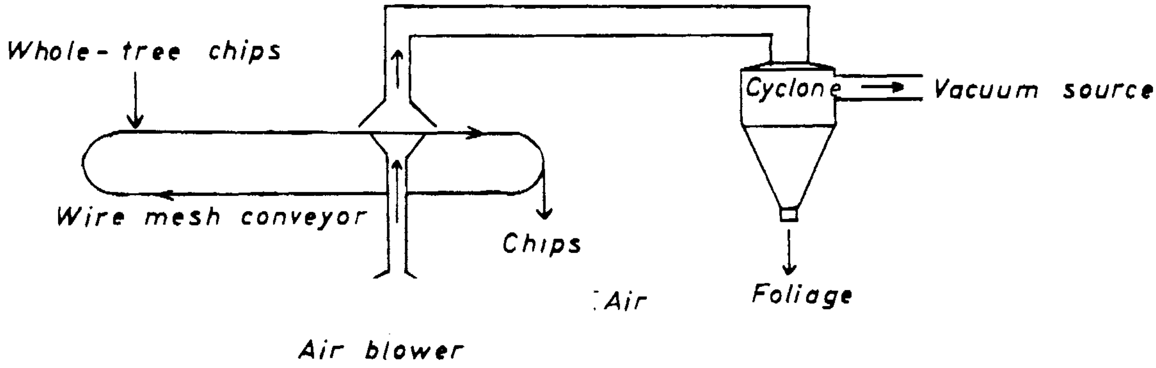


Fig. 43. A schematic drawing of single stage airlift-vacuum system for removing foliage from whole-tree chips. In practice single- or multi-stage air classification systems are likely equipment for chip upgrading combined with other equipment.

IV. 8 Some Economic Considerations

It is difficult even to give cost figures for traditional harvesting systems because of the wide variability encountered in different situations and also due to cost escalation. Cost analyses for whole-tree utilization systems are even more unreliable as this kind of logging is largely in the research and development phase. When the economics of different systems are evaluated, they should not merely be limited to calculations of the cost from the stump to the digester, but also take all the important consequences in consideration. Such evaluation programs are in progress, but results are not yet available.

Whole-tree harvesting as practiced in North America has some significant features:

The capital cost of the logging equipment is high. Equipping one operation for just chip production, including 2 feller-bunchers, 2-3 grapple skidders, 1 whole-tree chipper, and shop van with tools costs $ 330 000 - 550 000. Maintenance costs are also rather high. Hauler equipment for chip transport, 3-4 trucks with 4-10 vans, may also be added to the operation investment cost or may be run by contractors;

The production per man-day is higher than for most other logging systems, normally 12-35 tons of green chips delivered mill;

The cost of whole-tree chips delivered mill-yard varies considerably between operations. Normally the cost of chips is lower with a well-run whole-tree chipping operation than the cost of chips with conventional logging operations. Whole-tree chipping seems particularly competetive in stands with relatively small-sized trees and trees of low quality and value. On the other hand, whole-tree chips have a lower value and a more limited range of use than clean chips, unless after being upgraded - the technology of which is still in its infancy;

The importance of the increased dry matter yield per unit of land area may vary from nil where supply is ample to high where supply is scarce. One possible benefit of whole-tree utilization could be reduced transportation costs as the procurement area shrinks.

In Scandinavia, preliminary cost figures indicate that whole-tree utilization is a realistic possibility, particularly as more raw material can be recovered and there are potential harvesting and handling advantages. However, it is not seen as a general solution for more effective utilization of Scandinavian forest resources. Too little data is as yet available for reliable calculation of the end result of different harvesting and utilization methods. Beyond doubt, the present whole-tree utilization research and development projects will provide valuable knowledge as well as information necessary for proper decision making.

V. TRANSPORT SYSTEMS

V. 1 Introduction

The demand for a certain product depends not only on its price and quality, but also on its availability - the delivery date, quantity and location.

To deliver the right amount of goods to the right place at the right time, and thus give the customer complete satisfaction, a modern distribution system is necessary. Each link in the material-handling chain must be efficient, from the extraction of the raw material through the different processing stages to the customer. In the logistics of the fibre industry, the attempt to give the customer the best service at the lowest price covers all the links in the transport chain, from the time the growing tree is felled in the forest until the consumer's demand for lumber, pulp and paper is satisfied, and is concerned with the economics of the whole activity - storage, handling in terminals and place and time of delivery. The logistics of distribution of the finished product to the consumer is of growing importance as the increasing costs of distribution are closely related to the country's degree of development together with the costs of production (Fig. 44).

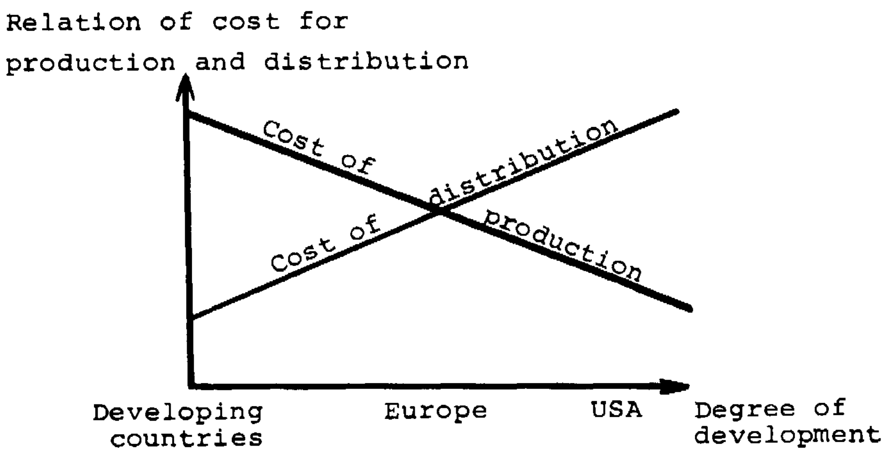


Fig. 44. How production and distribution costs vary according to degree of development.

The fibre flow from forest to customer is, at least before processing, in bulk form, either logs or wood chips. The following guidelines apply for rational bulk handling:

The loading and unloading should be concentrated in a few places;

Specialized tools and equipment should be used, as well as specialized carriers for the main products;

The goods should be arranged either in big quantities (bulk loads) or as standardized unit loads easy to handle and transport.

Wood chips have a low weight per unit of volume. When the load is limited by the volume and not by its weight, utilizing all available space and obtaining a good compaction become important for the transport economy. Adding a chip crown onto open cars and trailers often improves the economy. To avoid spilling during transport, special chip transport nets are often used. The compaction after loading expressed, for example, as the relative solid volume, will vary between 0.30 and 0.45, mainly depending on chip properties and loading method. Pneumatic loading has proved to give better compaction than free fall from loaders, silos, or mechanical conveyors, however, pneumatic conveying is not without disadvantages. Oscillating the car during loading increases the relative solid volume somewhat. Other means of vibrating the chips and also baling of the chips to obtain better compaction and handling economy are being investigated.

Transport of wood chips falls into two phases - internal and external. External applies to every phase which takes place outside the mill, whether it is a pulpmill, a chip plant or a sawmill. External transport means transport by truck, railway, pipeline or ocean carriers specially built to carry wood chips.

V. 2 External Transport

V. 2.1 Transport by Truck

The transport of wood chips from sawmills, plywood mills or field chipping operations to the receiving terminal or mill is commonly by trucks, provided the transport distance is reasonable. Usually the trucks are specially equipped for the job. The ideal truck transport equipment depends on transport volume, transport distance, loading time and equipment, unloading facilities, and not least, on truck and road regulations specific to each country. By combining a steel frame and an aluminium skin the weight of the chip trailer can be reduced and extra payload gained. However, in some field chipping operations thin aluminium skins have proved inadequate. In Scandinavia, for example, the ideal chip vehicle often consists of two fixed containers without unloading equipment and with five or six axles (Fig. 45). The maximum that the net payload can reach under Swedish conditions, for example (24 m total vehicle length, 10/16 t one axle/bogie pressure), is 33 t (100 cu m loose volume). Different container systems are being tried, particularly in field chipping operations (Fig. 46).

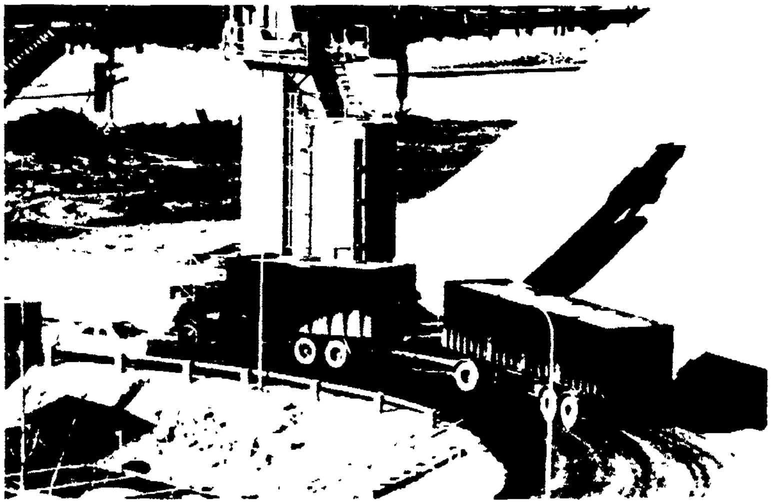


Fig. 45. Three-axled truck and three-axled trailer for wood chip transport.

In North America conventional semitrailers with capacities up to 90 cu m loose volume are common, chip trailers containing 110 cu m also being used in USA. In areas with cold winters the chip vans are often equipped with hoses for chip thawing by steam before unloading.

One of the most effective ways to decrease costs is to minimize loading and unloading times.

Fast loading can be achieved in many ways. Using big loader tractors or loading from silos by gravity (Fig. 47) are effective methods. With silos there is a problem that in a cold climate the chips would freeze together, but this may be overcome by providing the silos with heating cables and insulation. Loading can also be done by mechanical or pneumatic conveyors. Under field chipping, the chips are usually blown directly from the chipper into the van or container.

Unloading can be effected by tipping the containers with hydraulic devices mounted on the truck. This increases the versatility of the transport equipment, but results in reduced payload. Chip containers with hinged side walls can be unloaded by a tractor-mounted blade pushing the chips off. With large transport volumes, the best way of unloading is probably to have fixed bridges at the unloading station so that the whole truck load can be dumped, for which the total unloading time is roughly 10 minutes. Another method involves use of vacuum to suck up the chips from the container.

At some terminals mechanical chip diggers are used, normally combined with either mechanical or pneumatic conveyors, giving an unloading time per van of about 15 minutes. Some unloading systems are shown in Fig. 48.

Apart from terminal work and load capacity, other important parameters in the economics of wood chip transport by truck are the travel speed and the effective working time. Skill and motivation of the driver play a far more dominant role than might be expected.

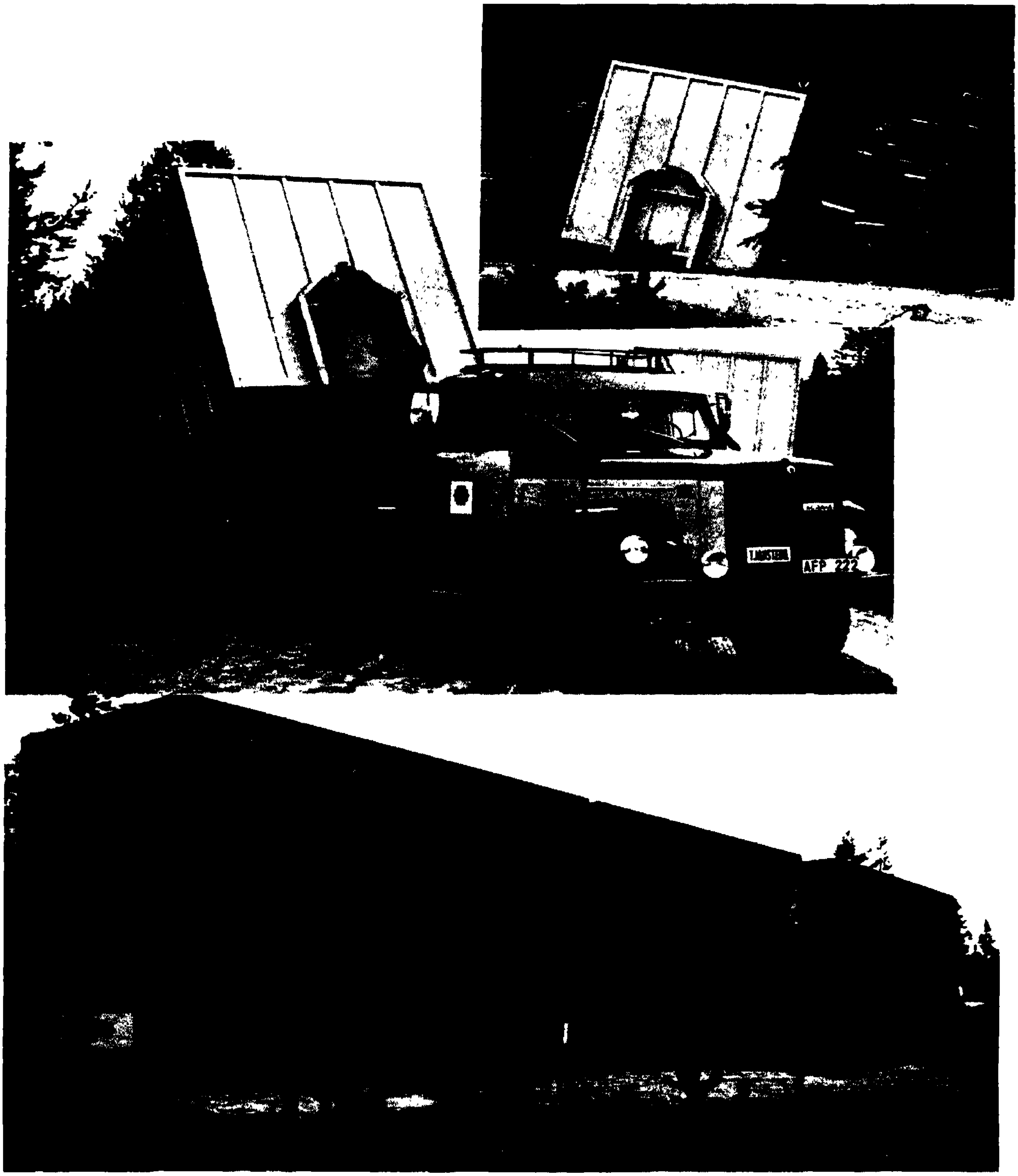


Fig. 46. Example of a container system (HIAB-FOCO), each container has in this case a volume of about 38 cu m.

Fig. 47. Different methods for loading chip trucks.

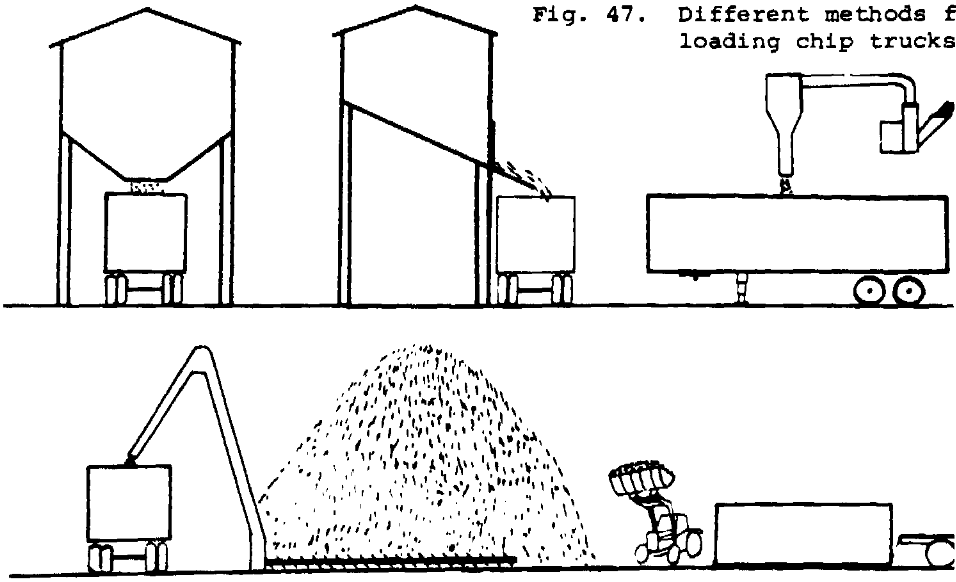
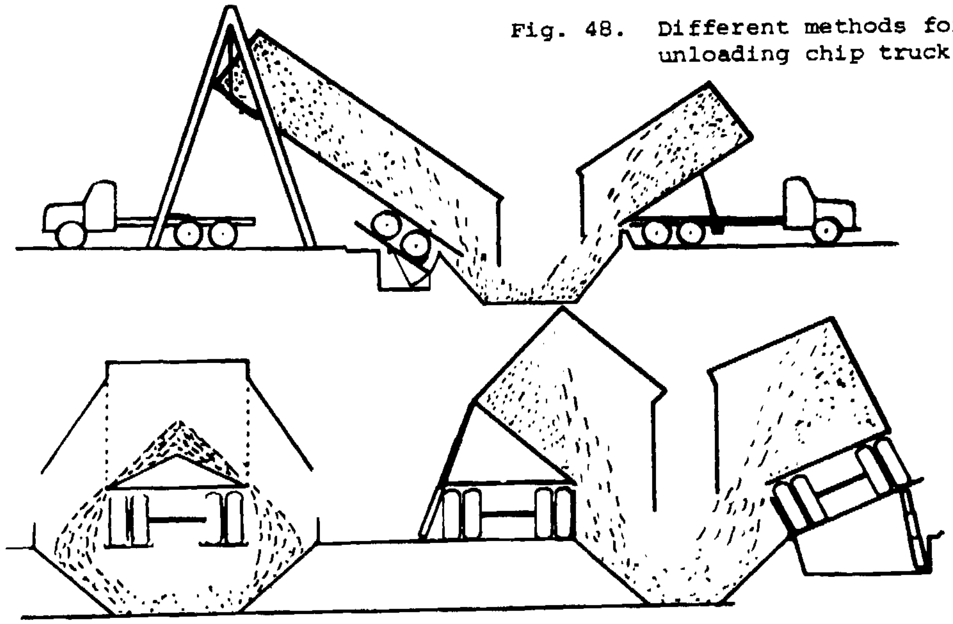
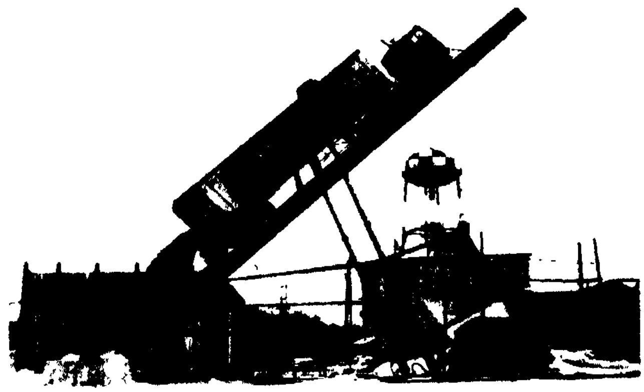


Fig. 48. Different methods for unloading chip trucks.





V. 2.2 Transport by Rail

Railway transport is very suitable for transport of great quantities of homogeneous material over long distances. It offers some important advantages such as regularity and high capacity and - if the transport is well planned - low costs. A close cooperation between the supplier, the receiver and the railway company is essential.

The rolling stock is usually provided by the railway company. The type and loading capacity of cars used for chip transport will of course vary from country to country and also within countries. Chip cars can be of the open top type or closed top type. Open top types facilitate the loading procedure and a crown of chips can also be added on the top (Fig. 49). However, in countries with severe winter conditions, roofless cars will result in snow and ice build-ups as well as the chips freezing more together. Open top chip cars can easily be unloaded by e.g. vacuum unloading with a digger head with agitators.

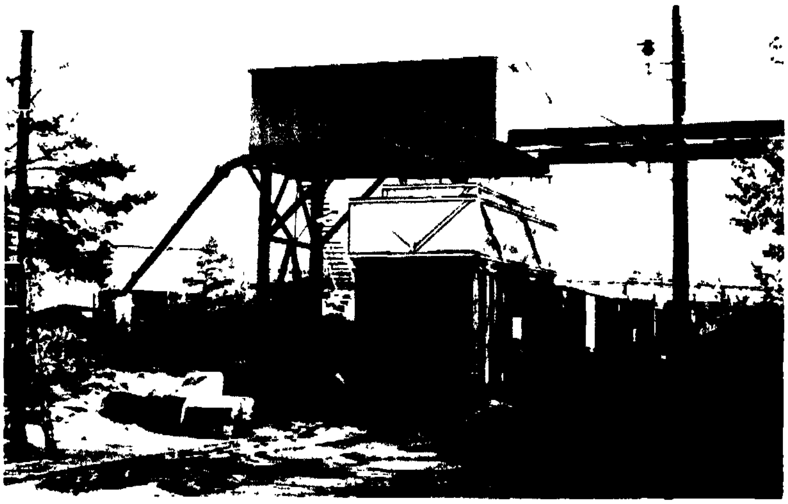


Fig. 49. Loading of an open top chip car.

If the sawmills delivering wood chips have no direct connection with the railway through a side rail, close cooperation between the trucking system and the railway promises good results. In this case specially built containers are loaded with chips at the sawmill site, then transported by trucks to the railway station where the containers are loaded directly onto open wagons (Fig. 50).

Another solution is provided by a terminal to which chips are transported by truck, unloaded and reloaded onto the railway wagons. In order to make the handling of wood chips at such terminals rational, great quantities are necessary. Before unloading, the volume and quality can be measured.

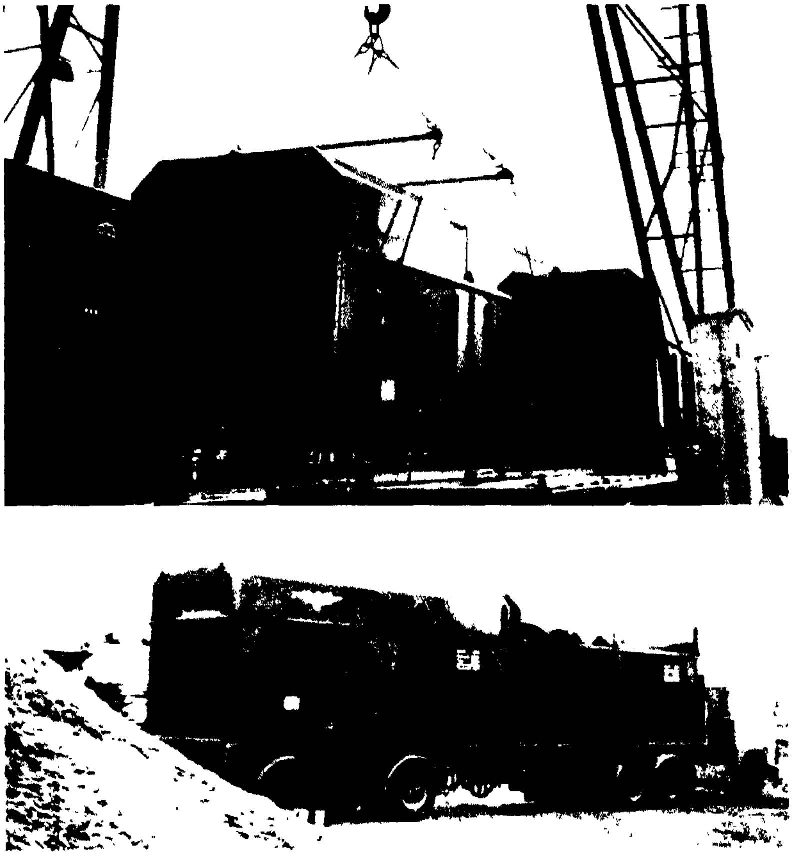


Fig. 50.

Loading of a chip container onto a flatcar holding 3 containers, each with a capacity of 33 cu m (upper figure). The same type of container loaded on a truck platform.

As with road transport, uniform loading and unloading methods cut costs. The providing and operating of loading and unloading equipment normally fall upon the sender and the receiver, or may often be provided in cooperation with the railway company.

The following methods are effective, singly or in combination: loading by belt conveyor, by gravity from silos, by wheel loaders, and pneumatic loading. The choice of the loading system to be installed depends mainly on the quantity transported, the location of the sawmill or chip plant in relation to the railway, and how fast the wagons should rotate between the loading and unloading station.

A simple and modest capital investment method to unload cars with side walls that can be swung open from below, is to use a tractor with a front end pushing blade (Fig. 51). By this method it takes about ten minutes to unload a wagon with a 65 cu m loose volume of wood chips. Another unloading method at a relative low capital investment is the use of a small tractor with scoop loader or bottom-dumping bucket which enters the chip car by the end-gate. Often a special portable chip handling unit with a grated platform is used together with the tractor. Self-propelled digger units combined with mechanical or pneumatic conveyors may also be applied, particularly when handling covered cars or frozen chips.

When handling large volumes of chips, tilting platforms are often used. Other methods applied are rotary car dumpers and overhead vacuum unloaders for open top rail cars (Fig. 52).

Fig. 51. Unloading of a rail car into a chip hopper by tractor.

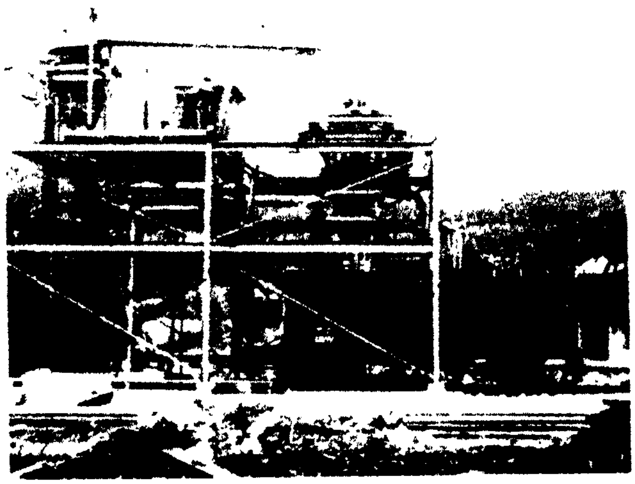


Fig. 52. Unloading of a rail car by overhead vacuum unloader.

V. 2.3 Transport by Pipeline

Transport by pipeline is achieved in two ways: by pneumatic transport, used mostly for shorter distances (see V. 3.2) or by hydraulic pipelines. In 1957 the first trials in transport of wood chips in hydraulic pipelines were carried out at the Pulp and Paper Research Institute of Canada.

A precise definition of hydraulic pipeline transport would be: sending through pipelines particles of solid matter floating in a liquid, in the present case, wood chips and water, see Fig. 53.

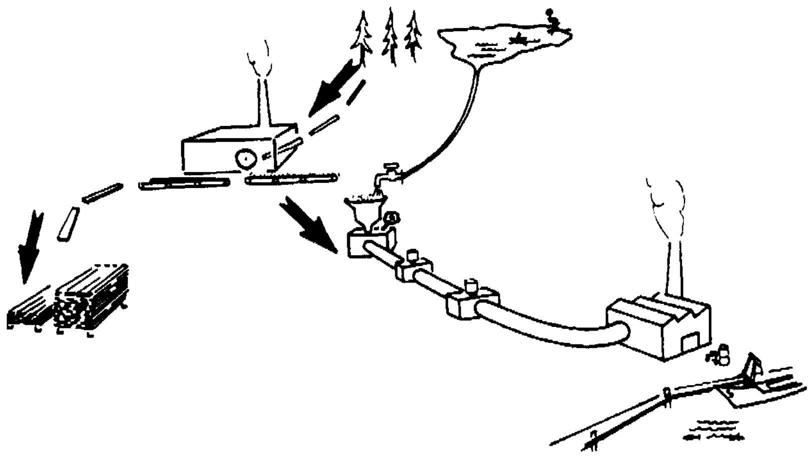


Fig. 53. Outline of arrangement of hydraulic transport of wood chips by pipeline.

Factors influencing the choice of equipment fall naturally into two groups. The first consists of factors over which there could be a certain degree of control (concentration, speed of flow, etcetera). The second group depends on such factors as quantity per annum, transport distances and topography, which determine the choice of method and dimension of the transport.

The concentration of the mixture can be defined as the volume-percentage of solid matter (10 cu m solid measure of wood chips mixed with 100 cu m of liquid is called a 10 percent mixture). It is not possible to obtain a higher concentration than 50 percent in the mixture, since the wood chips will not pack more tightly. The power need in the pumps increases considerably when the concentration of the mixture exceeds 35 percent. It is generally recommended that the concentration of wood chips be up to 30 percent. The most practical, as well as the economically correct, speed for water transport seems to lie between 1 and 3 m/sec.

Few experiments have been carried out on the quality of the chips after transport, but they show a slightly higher percentage of smaller chips, with deterioration caused mainly by the pumps. This situation would be improved through better construction of the pumps and mixing systems. No reduction in size occurs as a result of pipeline transport itself.

The annual quantity transported is the dominating factor when deciding whether this transport is economically feasible compared with other systems. The distance is not as decisive in pipeline transport as in other forms. Cost calculations for the pipeline method show that the cost per cu m/km may be only slightly reduced over distances of more than 30 - 40 km. It was found that the optimum economic distance under American conditions lies somewhere between 80 and 110 km.

Pipeline transport is a highly mechanized method requiring capital, which constitutes up to 60 - 70 percent of the cost of transport while power constitutes only 15 - 20 percent.

At present (1976) no hydraulic pipeline for wood chip transport is in commercial operation, but it is being considered. Theoretically, it is able to compete with existing methods, but this will have to be proved by detailed analysis of the economic factors in each case.

V. 2.4 Transocean Shipment

In 1974, ten years after the first transocean shipment of wood chips, there were about 50 Japanese chip carriers in service. Most of the carriers were in the deadweight class 20 000 - 40 000 ton carrying a chip volume of 40 000 - 100 000 cu m. Recent chip carriers provide from 1.9 - 2.3 cu m of cargo space per ton of designed deadweight.

V. 2.4.1 Compaction and Stowage Factor

The compaction rate for logs and for chips is often found to be about the same by ship transport. However, 20 - 30 percent of a vessel's intake of logs may be loaded on deck and thus the compaction rate appears better for roundwood as the compaction is commonly related to the volume of the vessel's holds. Thus the compaction rate for logs is normally considered to be 50 - 60 percent by ship transport compared to 40 - 44 percent for well compacted chips. In spite of this, transocean chip transport is normally considerably cheaper than log transport, the key factor is the gain in handling costs.

The stowage factor (cubic feet/long ton) of ore, for example, is about 20, but a bulk carrier usually has a designed stowage of 45 - 60. The stowage factor of chips is around 100 and this is reflected in the design of a chip carrier.

For transport of wood chips by ship the following stowage factors (cubic feet/long ton) may be used:

Chips from North America (softwood):	100 - 120 cf/LT
Chips from Malaysia (rubber tree):	100 cf/LT
Chips from Tasmania (eucalyptus):	80 cf/LT
Chips from New Zealand (pine):	100 - 110 cf/LT
Chips from New Zealand (beech):	80 - 90 cf/LT

The moisture content and stowage factor of chips depends entirely upon the kind of wood, site, season and weather conditions. Wood chips are a very bulky cargo compared with the other cargoes transported by the usual bulk carriers.

V. 2.4.2 Technical Features of Specialized Wood-chip Carriers

Like other industrial carriers, the size and design of the chip carriers depends on the shore facilities at the ports of call, such as chip loading or unloading facilities and conveyor systems. Some restrictions due to these loading and unloading facilities are imposed at each port of call; therefore when the vessel is designed, the shore facilities and location of the ports are considered the most important factors. Next to these, stability, volume of cargo space, stowage factors and speed are most important.

Endeavours to reduce the overall cost of the transocean shipment of wood chips have centred on the development of a ship design that would overcome the drawback of poor stowage. For this reason most chip carriers are wider and have a considerably higher moulded depth than an ore or bulk carrier of the same length.

Some approximate data of chip carriers with a hold capacity of 75 000 cu m are (see Fig. 54):

Length	185 - 195 m
Bredth	29 - 30 m
Depth	20 - 21 m
Main motor	11 000 - 12 000 hp

In 1974 the largest chip carrier in service had a hold capacity of about 115 000 cu m.

The carriers may be classified according to the existence of cargo handling gear on board into the following three groups:

Without cargo handling gear on board and entirely dependent on land facilities;

With unloading equipment only;

With loading and unloading equipment.

Of the 52 chip carriers built or constructed up to 1974, 15 were without chip handling equipment on deck. Such carriers can be assigned only to services between ports being well equipped with cargo handling gear ashore. Chip handling equipment on board is not affected by tides. It is effective relative to its small structure, and a part of the equipment is used both as loading and unloading gear. The quay can also be simpler and use of a mooring buoy system is also a possibility. Furthermore, shore-based cranes for unloading may be too small or have too small an outreach, considering the size and width of the chip carriers. For use of land-based equipment loading directly into the holds, the carrier usually will have to move along the wharf.

Chips are transported on board from the land-based pile by mechanical or pneumatic conveyors, often in combination with the on-board air trimmers

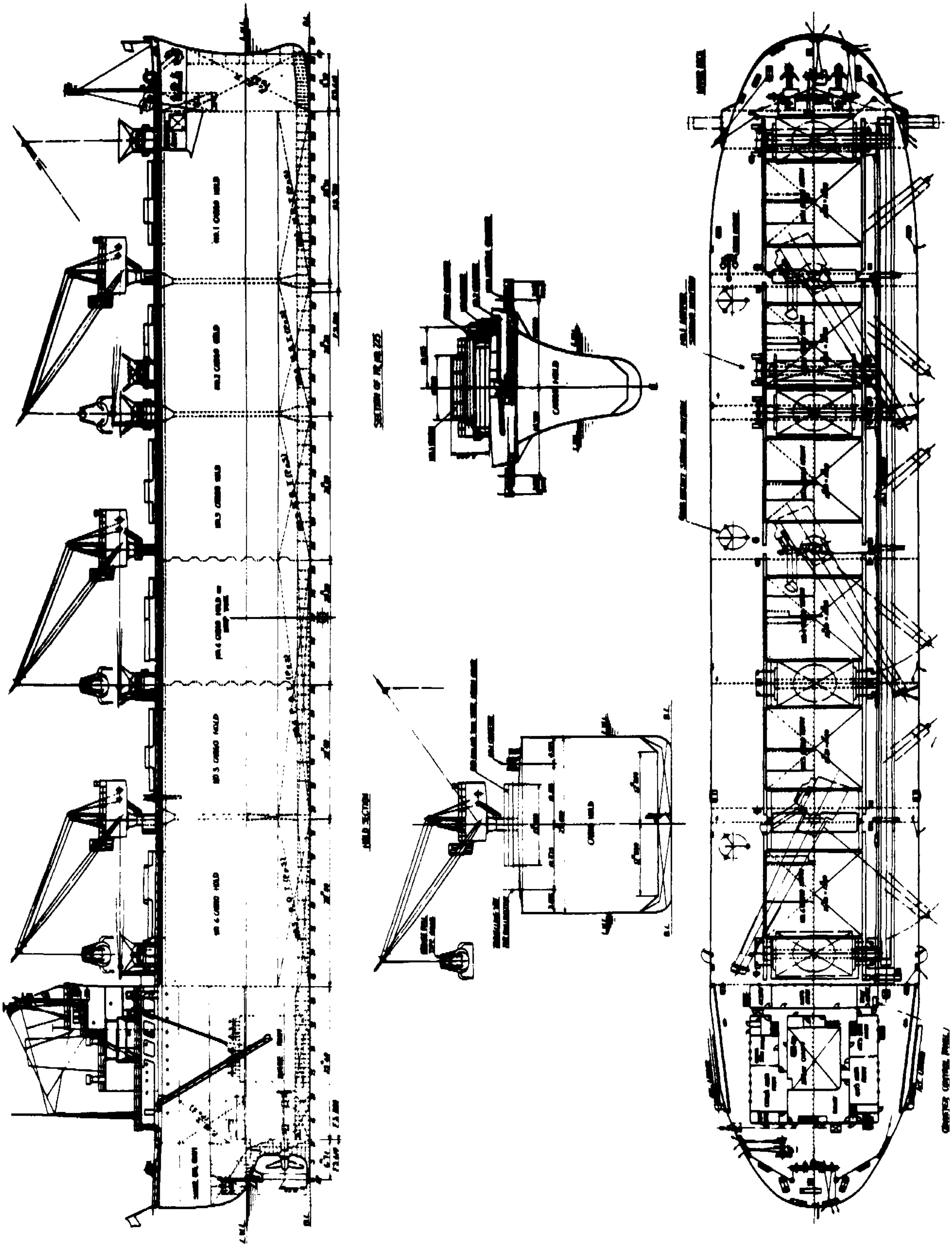


Fig. 54. An example of the design of a wood chip carrier (TAKAI MARU).

which can be moved along the hatch openings. Deflectors of different types that can be adjusted so that chips are well distributed in the hold with a high compaction rate, are used. The loading capacity may be as high as about 1 100 tons per hour.

However, it is possible to visualize an underwater pipe loading like those used for offshore loading of tankers. With such an installation a vessel taking say 150 000 - 200 000 cu m loose volume of chips should be loaded in two to three days. This would need planning on shore and on board by shippers and transporters with due respect for each others' problems and careful study of where investments should be made to achieve maximum transport economy.

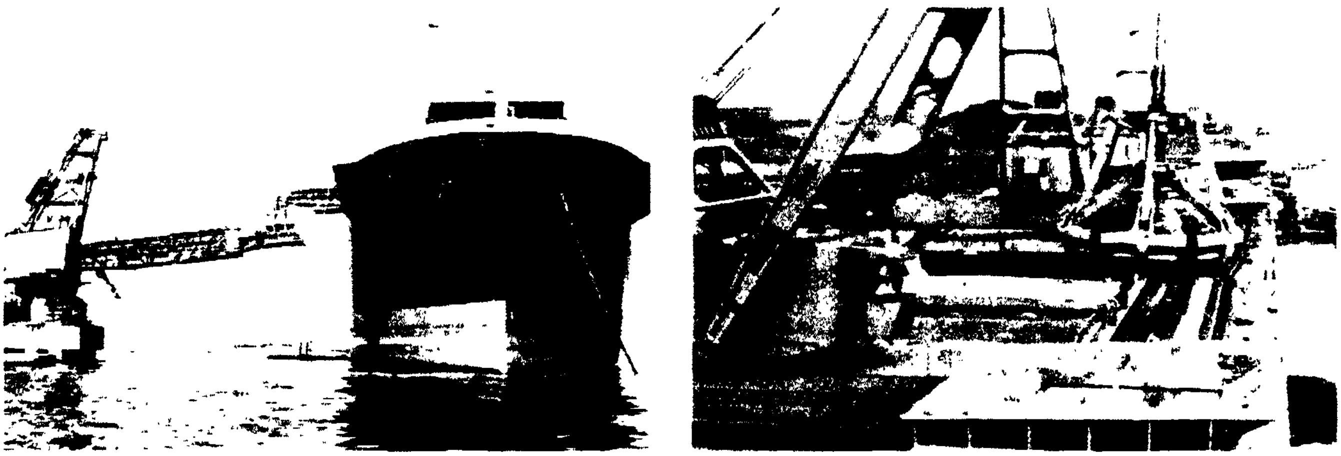


Fig. 55. Unloading operation with orange peel grab (right figure). Connection between discharging conveyor and shore conveyor (left figure).

Unloading is mainly done by ship-mounted cranes, equipped with so-called orange peel grabs, and main conveyors (Fig. 55), transporting the chips to the pile. The conveyor can also feed a hopper connected to a pneumatic system for conveying to the mill storage pile. In addition to the cranes a specially equipped bulldozer is necessary in the hold for moving chips from the corners to the centre where it can be reached by the grab. Unloading takes more time than loading. At present the capacity for unloading devices is nominally about 150 - 200 t/h per crane and most carriers are fitted with 2 - 4 cranes.

Pneumatic unloading systems have been developed for chip carriers, but the capacity and cost of the systems have not been reported, and may not yet be a realistic alternative.

More detailed technical information on chip carriers is given by e.g. Ishii (1972) and Hanaya (1975).

V. 2.4.3 Chip Port Terminals

In 1974 there were several chip export terminals in service, including 12 in USA, 3 in Canada, 3 in Tasmania, 3 in New Zealand, 3 in Malaysia; and 1 was opened in Papua New Guinea.

A terminal for chip export is often built particularly for chip handling, but terminals intended for other bulk cargoes may also by used. To justify establishment of a special-built chip terminal with rational handling equipment, large chip quantities are needed over several years. Long-term contracts where all parties involved - the wood raw material exporter, the transporter, and the chip user - have benefits are a pre-requisite for a successful chip export operation.

Essential factors for location of a chip export terminal are:

The port itself - adequate water depth, etc.;

The location of the terminal with regards to the wood producing area and the resultant transport costs from the woods to the chip terminal;

Terminal land area suited for handling and storage of the wood quantities in question.

The size and lay-out will of course vary, the wood may e.g., arrive as boles, logs, or as chips from sawmills or other chipping operations.

Basically the chip terminal will consist of:

Good transport facilities to the terminal, e.g. by road, railway or water (barges);

Facilities for assessment of the chip quantity and quality;

Unloading equipment (tipping bridges) and chip handling facilities. The chip handling and pile build-up is commonly done by mechanical conveyors, pneumatic conveyors or chip dozers, often in combination. Chip screens may also be included in the handling chains;

Adequate chip storing space, often for two or more separate piles. The storing and handling yard should have a top layer of asphalt or concrete on well-drained ground able to carry heavy loads;

Chip pile reclaiming equipment and conveyors from the pile to the wharf or dolphins with chip transfer to the carrier.

Most terminals use pneumatic systems - either shore-based or carrier-based - for loading the hold (Fig. 56), an exception is shown in Fig. 57.

Fig. 58 gives a view of a chip terminal in USA, and Fig. 59 shows a simplified lay-out of a mixed tropical hardwood chip project in Papua New Guinea. Further information on the latter project is given in chapter III.

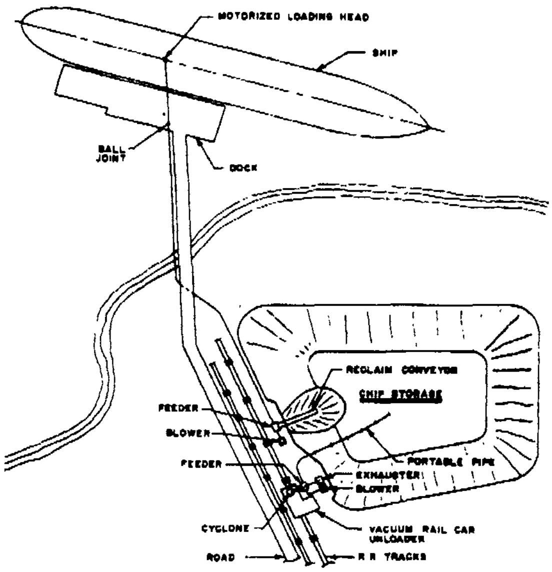


Fig. 56. Pneumatic loading of a wood chip carrier.

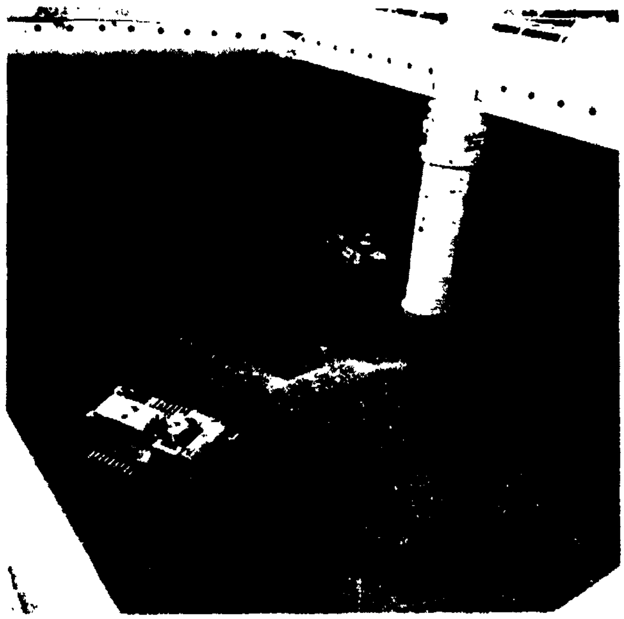


Fig. 57. Loading by gravity and bulldozers at Papua New Guinea (Lembke 1974)

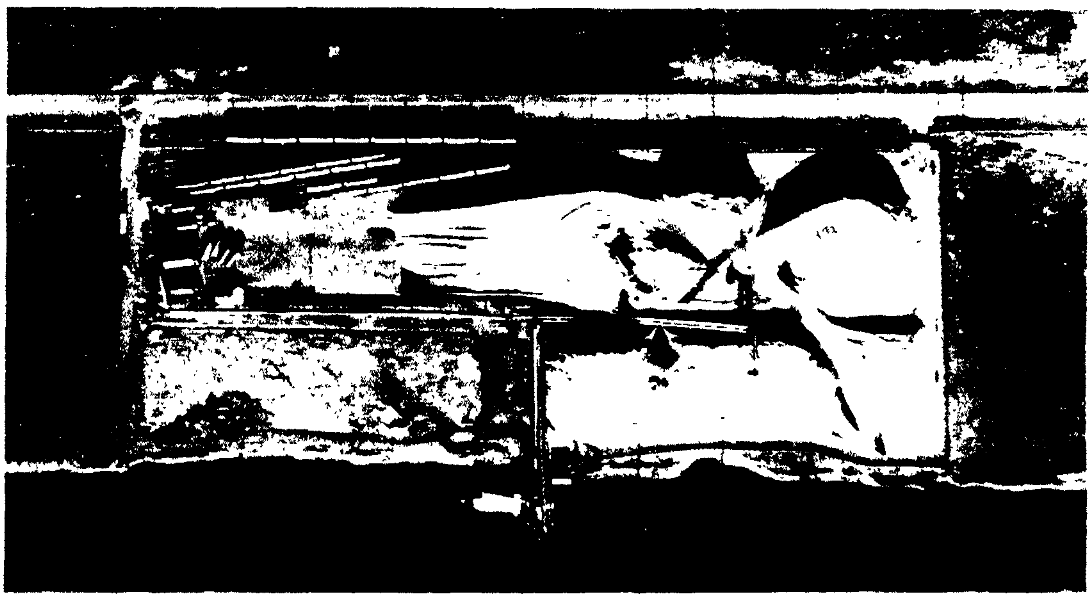


Fig. 58. A chip export terminal in USA.

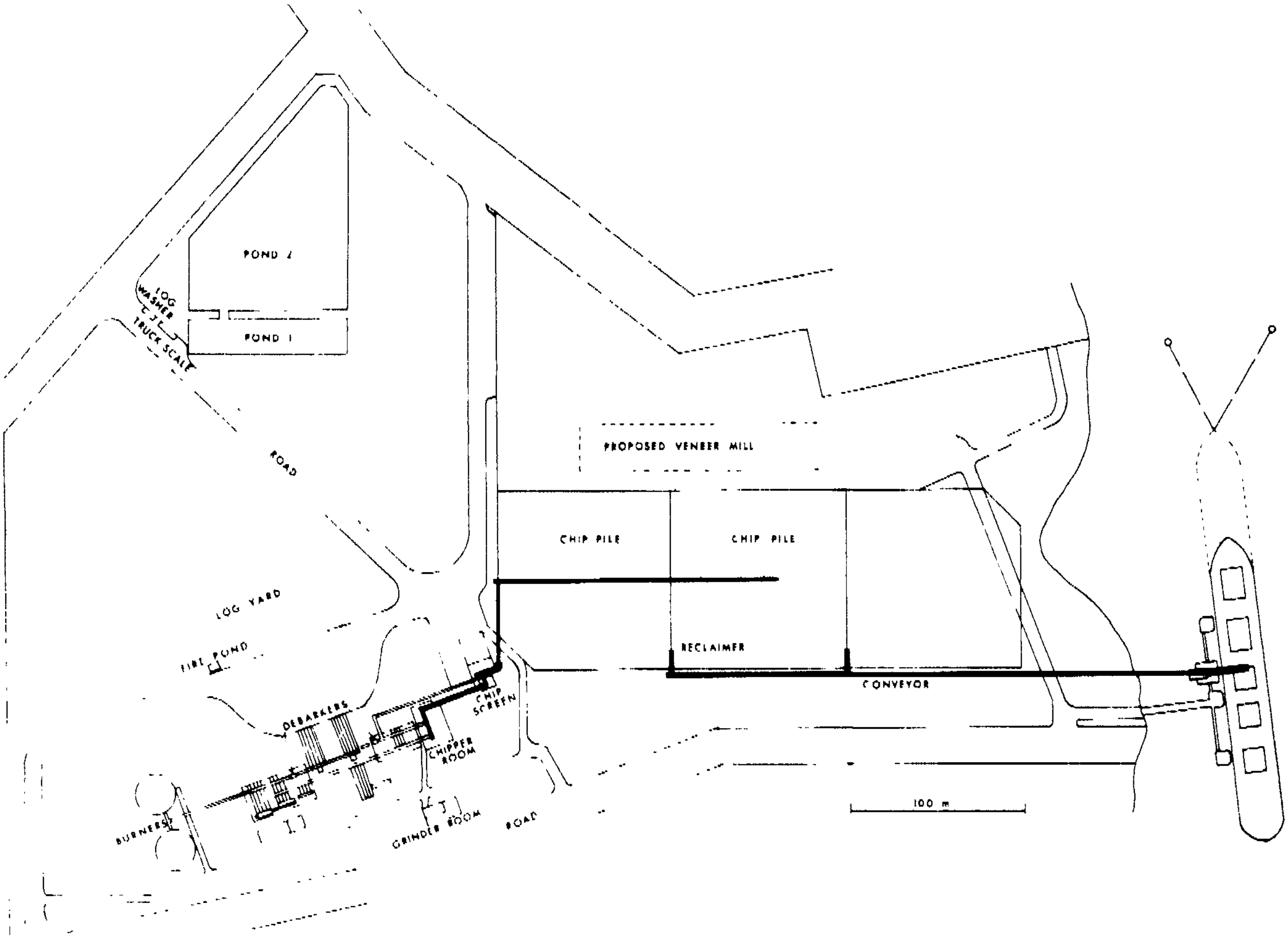


Fig. 59. Lay-out of the Jant Pty. Ltd. mixed tropical hardwood chip plant at Papua New Guinea.

The handling cost at chip export terminals will of course vary considerably between terminals. As a rough figure estimate, $ 3-7 per bone dry unit has been reported in USA.

The greatest number of chip receiving terminals is found in Japan, where 17 ports can accommodate chip carriers, of which 3 are directly connected to the storage yards of pulp mills (Hanaya 1975). Few terminals have large chip unloaders on shore, and most use belt conveying systems for chip handling.

V. 2.4.4 Economic Considerations

The cost of transport by sea has two basic elements, handling costs and underway costs.

The wood raw material for paper and paperboard may be transported as logs, chips or pulp. Logs are transported in normal bulk carriers in holds and on deck with a poor utilization of the vessel's deadweight capacity due to the low cubic/dw ratio of the bulk carrier. The special chip carrier can, however, almost utilize her designed deadweight, often resulting in a higher underway cost for logs. Present log handling methods (loading and unloading) are also slow and expensive, thus transport by specialized chip carriers is normally considerably more economical than log transport of pulpwood. However, present handling methods for logs are under close study and substantial economical gains may be achieved in this field. Baled pulp, on the other hand, is normally more economical to transport than wood chips, calculated per ton of pulp produced. One obvious reason for this is the fact that it takes about two bone dry tons or four green tons of chips to produce one ton of chemical pulp, or on volume basis, 7-10 loose cu m of chips to produce one cu m of baled chemical pulp.

A key factor for obtaining economical wood chip transport is the handling rate and not so much the speed of the carrier. This element is more pronounced for short voyages than for long voyages. On longer voyages larger ships are more effective than smaller ships, but the handling capacity necessary increases with an increase in carrier size. Hanaya (1975) presents interesting figures for relations between net freight cost per unit of hold capacity versus round-trip voyage distance, versus hold capacity, and versus handling capacity.

Modern port facilities involve adapting handling facilities to tonnage. Efficient carriers are likely to be highly specialized, and port and ship must fit hand in glove. Rational handling is probably not possible without longterm sales contracts. Even with rational terminal handling and modern chip carriers, overseas chip transport is not cheap. The handling and transport of chips may represent as much as 50 percent of the CIF value of the goods, depending of course, on the transport distance.

As examples of shipping costs it can be mentioned that in 1971 woodchip transport (softwood) from Vancouver to Japan, a transport distance of about 4 500 nautical miles, by a specially built chip carrier of about 28 000 ton dw was calculated at about $ 10 per long ton of green weight, excluding loading and unloading operations. Thus freight costs of chips per ton of pulp were calculated to be close to $ 50 per ton of pulp produced. In the same year transport costs of 1 ton of pulp from Eastcoast of Canada to Scandinavia with a bulk carrier of about 25 000 ton dw would amount to about $ 10 per ton.

In 1977 regular shipping transport of longfibred wood chips will commence from Eastcoast of USA to Scandinavia. Large, specialized, ice-strengthened chip carriers will be put into service, which will, on a long term basis, have an economy close to the one ruling in 1971. At the same time equivalent pulp freights on FIO basis from Eastcoast of Canada to Eastcoast of Sweden would probably amount to about $ 20 per ton.

There is still a cost gap between pulp transport and chip transport, but some of the gap has been bridged due to improved handling systems for wood chips as well as increase in size of tonnage.

One aspect of transocean shipment is costs arising due to chip deterioration. Outdoor chip storage is covered in chapter VI. 4. During sea transport no significant changes in chip properties are reported to take place. However, transocean shipment involves a large number of chip handling operations - maybe 20-30 - each resulting in mechanical breakdown of the chips with formation of dust, fines and pin chips. The effect of each handling operation is normally very small, but the effect is additive. This, combined with chip storage, results in a certain reduction in overall pulp yield and eventually in pulp quality. The price paid for the chips will of course reflect the value of the chips being fed into the buyer's pulp digester. All parties involved in a chip operation will thus directly or indirectly benefit from measures reducing unnecessary damage caused by handling and storage.

V. 2.4.5 CIF - FOB Sales

When selling wood chips, the producer - or seller - has usually only one aim: to sell at the best possible price. Handling and transport represent a considerable percentage of the CIF-value of the chips. If the chips were sold CIF the seller would, at least theoretically, be better able to influence and control the costs and thereby the revenue from chip sales. However, it has been common to sell wood chips delivered port terminal or carrier.

V. 3 Internal Transport

Internal chip handling, e.g. in a pulp mill, includes chip unloading from truck or railway car and chip transport to the digester, the latter normally being done by pneumatic or mechanical conveying systems. Batch digesters can also be filled by pneumatic digester charging (Fig. 60).

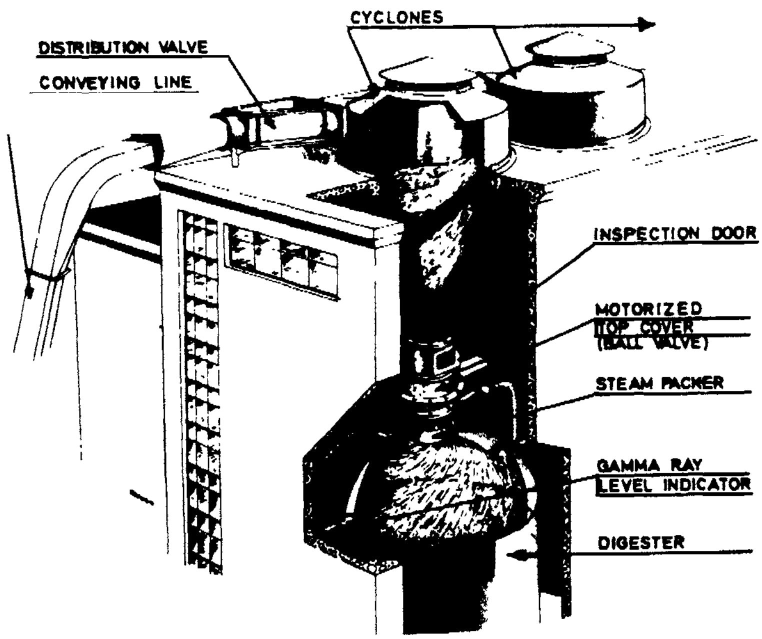


Fig. 60.

A fully automated pneumatic digester charging.

The chips may come directly from the chipper or from silos, and digester filling and other operations can be made fully automated. Apart from short retention times in silos or hoppers, some or all of the chips may also be stored, requiring handling to, in some cases on, and from the outside chip pile.

Tractors, pneumatic conveying systems, mechanical conveyors, unloading structures, and different types of bins and silos are common equipment for internal chip transport and handling.

V. 3.1 Tractors

Wheel chip loaders or carrying dozers are often the major chip handling eqipment at smaller and medium-sized mills, e.g. those used for chip pile build-up and reclaiming. Tractors are also commonly used in combination with conveyors for chip handling. Previously, crawler tractors pushing or carrying the chips were common.

This operation is critical with regard to chip damage and the generation of rejects. A good bulldozer operator is not necessarily a good chip-pile operator. He has to be trained to think that he is operating on plate glass, as an increase of rejects might cost the mill a 1 percent wood loss. The selection of tractor is of great importance. Many mills have found it advantageous to use a heavy rubber-tyred vehicle which travels relatively gently on the chip pile (Fig. 61).

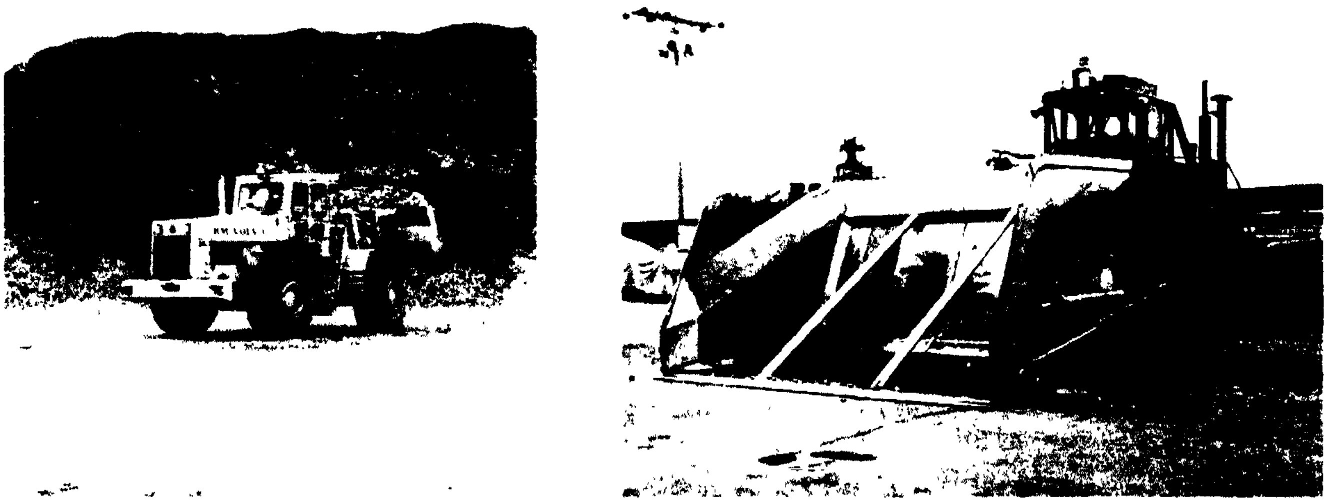


Fig. 61. Examples of wheel tractors for chip handling.

V. 3.2 Pneumatic Chip Handling

Pneumatic conveying can be described as a method of pumping solid particles in pipelines. The carrying medium is air, compressed by blowers; the material conveyed, in this case wood chips, is introduced into the air-stream by a rotary feeder.

A pneumatic conveying system (Fig. 62) consists of five basic elements as follows:

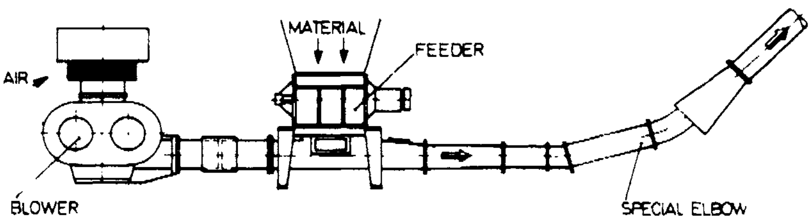


Fig. 62. Simplified pneumatic conveying system.

The blower, or positive air pump, supplies the air necessary to keep the material airborne in the conveyor tube. The working pressure of the blower is decided mainly by the conveying distance, the amount of material that is to be transported, the difference in height between chip inlet and outlet and finally the number of elbows in the pipe and their total angle. Usually the working pressure is in the range of 0.2 to 0.7 kp/sq. cm.

The feeder, or rotary air lock valve, is designed to receive the material to be conveyed from a chute and transfer it into the conveying tube with a minimum loss of air and pressure. The rotary valve feeder consists of a housing in which a rotor with radial blades is mounted. The material is fed from above into the "pockets" between the rotor blades and then passes into the conveying pipe upon operation of the rotor.

The tube, or pipeline, has a diameter selected to suit the volume and weight of material, as well as the conveying distance and the blower specifications. The diameter varies normally from 100 mm to 600 mm depending on the size of the installation.

The discharge device is located at the end of the tube. This can be a rotary distributor, an adjustable deflector, or a cyclone.

The controls consist of a specific electrical circuit for proper machinery interlock, and system protection through switches which are activated by the pipeline pressure.

In addition a pneumatic system may have silencers to reduce the noise, traps for removal of foreign material, and distribution valves.

The pneumatic conveyor is used for many different materials, over horizontal distances of up to about 2 000 m and for capacities of 1 to 1 100 tons of chips per hour. In a pneumatic conveying system the material velocity is very high - normally up to 40 m/sec. At one installation for carrier loading, the chip velocity is almost 80 m/sec at the discharge end.

The three main advantages of a pneumatic system compared with other bulk material handling systems are flexibility, low maintenance requirements and ease of installation.

Minimal floor space is required for the feeder unit and the piping can be located out of doors, thus saving valuable inside building space. The blower can be installed in some remote part of the building if necessary, as long as air piping is connected from it to the feeder.

Though pneumatic chip transport is a very convenient system to install and reliable in use, chip blowing is not without drawbacks. One is the high power consumption. In pulp mills motors from 50 to 1 000 hp are normally in use, and the power costs are considerable. As an example, the power needed to transport chips a distance of 100 m and 30 m up from a pile to a digester would cost ten times more than with a belt conveyor. Often the power demand of a pneumatic system is about 20 times that of belt conveying systems.

The cost of installation of a belt conveyor as compared with a pneumatic conveyor is shown in Fig. 63 (Croon and Frisk 1972). At a distance of about 100 m, the cost would be about the same. Extending the distance, the mechanical conveyor would be higher in investment costs but much lower in power costs, with a break-even at about 300 m distance (covering most practical purposes). Above this distance the total handling costs are lower for the pneumatic systems.

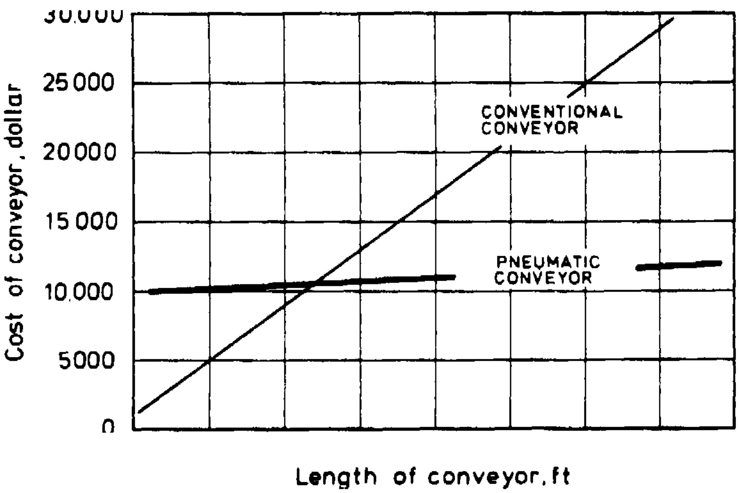


Fig. 63. Installation costs for pneumatic conveyor and conventional belt conveyor.

Because there are so many variables in every pneumatic installation, it is difficult to specify exact energy requirements, but as an example, to transport 90 cu m of wood chips per hour a horizontal distance of 165 m would require 60 - 70 hp.

Furthermore there are noise and dust problems, although these can to a great extent be eliminated.

A good pneumatic transportation system to, on, and from a chip pile costs $ 250 000 - 450 000, depending on capacity and distance.

V. 3.3 Mechanical Conveyors

Belt conveyors - horizontal or inclined - are most common for mechanical chip transport, although scoop conveyors, for example, may be used for vertical transport. Other types of mechanical conveyors, often screw or stoker conveyors, are common in receiving bins and at chip pile reclaiming units.

V. 3.4 Chip Piling and Reclaiming

At every mill a certain amount of chips is stored for short or long periods. The storage as such and the methods used are perhaps the most important phase in the processing and handling chain. Controlled circulation of the store - normally on a first-in, first-out basis - is a basic condition for successful results.

An efficient way to control circulation of the inventory, chip distribution, compaction and particle size separation is the so-called Mo-Do system. This system is designed to build up the entire pile without bulldozing to distribute it. As can be seen in Fig. 64, the pile is

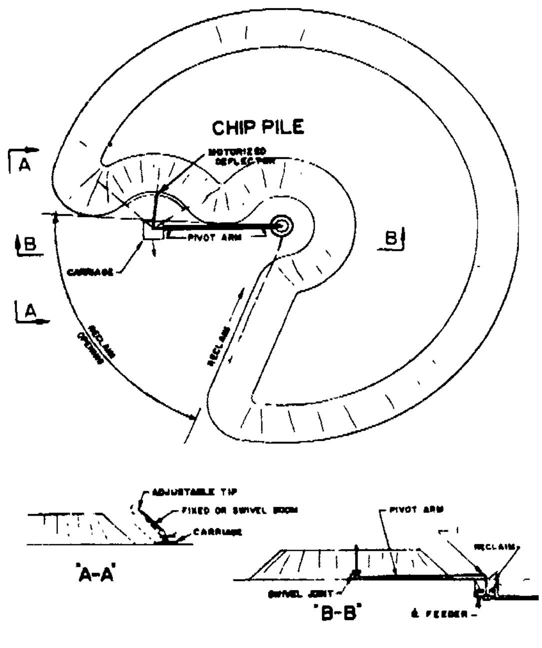


Fig. 64.

Round pile design (Mo-Do system).

circular. The discharge rig rotates around the centre and moves backward as the pile grows. The discharge pipe swings and is thus able to cover the entire width of the pile. This arrangement makes it possible to distribute the chips by pneumatic conveying only, resulting in a high and uniform compaction. The short travelling distance between the end of the discharge pipe and the pile also minimizes the separation of chip sizes. The reclaim pocket is located in the centre, feeding a pneumatic conveying system. This positioning simplifies bulldozing when the chips are reclaimed to production and results in higher efficiency and less chip breakage. The ring-shaped pile, with a small sector open between discharge and reclaim, makes it possible - or, actually, necessary to rotate the store and guarantees the ideal first-in, first-out method of circulation control.

Other equipment manufacturers make pneumatic control pivot pile builders, giving similar circular piles.

Reclaim of chips from outside chip storage is usually done with some kind of tractor or bulldozer, which pushes or carries the chips to the reclaim conveyor, usually a chain conveyor of some kind, although at a few installations a belt is used. A common characteristic of these reclaim conveyors is that they are quite narrow, which means that "arching" can easily occur if the load of chips is not kept low enough. For this reason, the bulldozer operator is forced to "spoon-feed" the conveyor to avoid delays and interruptions of the operation. As a result, the bulldozer is running more or less continuously but with only half a load each time, thus increasing the travelling on the pile. In order to reduce the number of runs over the pile, the reclaim conveyor should be of a design which eliminates the risk of arching or delays regardless of the volume of chips it is carrying. The basic condition for such a design is that the bottom area be large enough: another is low speed or movement and a large gate area to avoid arching within the pile.

One conveyor which seems to fulfil these conditions is the hydraulically operated stoker conveyor (Fig. 65). The standard bottom

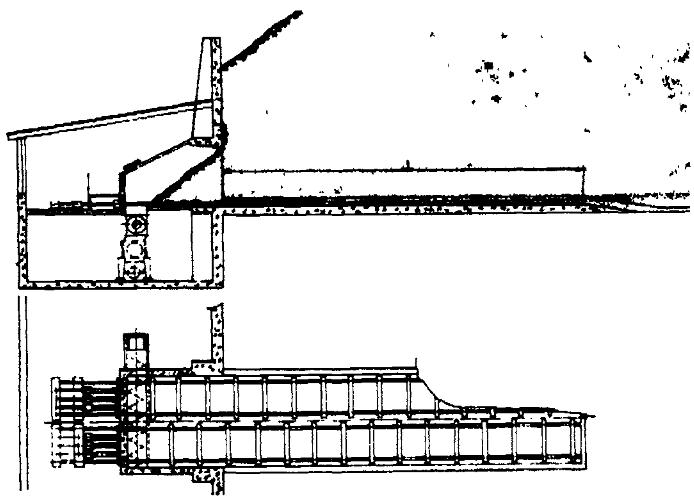


Fig. 65. Hydraulically operated stoker conveyor.

area for this unit is 12.0 × 4.5 m, the gate opening is up to 2 × 4.5 m, and the average material speed is about 0.1 m/sec. The alternating strokes of the stokers create a movement in the material several metres from the bottom level which effectively prevents bridging regardless of load. It is possible to store 2 000 loose cu m of chips over one reclaim unit. This makes it possible to utilize the bulldozer's full capacity on each run and thereby reduce the travelling on the pile.

Another system for controlled chip handling and storage is used by Weyerhaeuser's Valliant mill. The chips are conveyed on belts, travelling booms deposit the chips with a small free-fall distance. The reclaiming is also done by travelling mechanical reclaimers.

V. 3.5 Economic Considerations

Chip handling costs can be calculated relatively easily in each case: depreciation, interest, repair, energy, wages and miscellaneous. In addition considerable attention should be given to systems allowing a proper control of the handling and storage and to systems that give a minimum of chip damage. However, conditions and requirements vary considerably and each system must be investigated on an individual basis.

VI. WOOD CHIPS AS RAW MATERIAL FOR THE CHIP-USING INDUSTRIES

VI. 1 Wood Raw Materials

VI. 1.1 General Considerations

Almost any tree species can be utilized by the chip-using industries. The main question is whether it can be done profitably.

Within the chip-using industries, a modern kraft pulp and paper mill is a most complex and expensive plant with an annual wood consumption of, say, 1.5 million cu m. The investment cost is 200-300 million dollars. When development of infrastructure and forest plantations is necessary, the total investment cost may be more than doubled. The size and cost of a modern fibreboard or particle board mill vary, but they are generally considerably smaller and cheaper than a pulp and paper mill. A modern particle board mill in Scandinavia may, for instance, have an annual wood consumption of 100 000 - 400 000 cu m, and the investment cost would be in the range of 10-40 million dollars.

Vakomies (1972) suggests the following feasibility criteria for tropical timber for acceptance by the pulp and paper industry:

Markets for products

Type and quality of wood

Quantity and cost of wood

These three basic criteria are also generally valid for other timber species, other wood products, and other geographical regions.

VI. 1.2 Markets for the Products

Forecasting future markets is a well-established and relatively simple procedure. The domestic or regional markets in tropical countries are often relatively limited and can support only a type and size of pulp and paper plant which would not be internationally competitive. These markets are, however, often protected and can in some cases accept products of inferior quality.

VI. 1.3 Type and Quality of the Wood

The type and quality of wood which a pulp and paper mill can use depend largely on the market. Classifying the wood into either coniferous or deciduous types is sufficient to indicate broadly the pulp and paper categories for which it can be used. Regarding quality, an extremely important factor is uniformity of the wood in terms of density and fibre dimensions.

It should be noted that while softwood species have a wider and more versatile use for pulp and paper products than hardwood, "long fibred" softwood cannot be said to be of a better quality than "short fibred" hardwood without specifying for which product the wood is to be used and without considering product quality requirements and economics of operation (Vakomies 1972).

It is apparent that the morphological features of the fibres are, within a certain limit, considerably more important than the chemical variables. This is particularly true of softwood sulphate pulps, in which the chemical properties are relatively unimportant, while in sulphite pulps their significance is greater. In hardwood chemical and semi-chemical pulp, however, the chemical properties contribute considerably to the strength of the paper.

The three principal factors controlling strength of paper are fibre density (cell wall thickness or percentage of late wood), fibre length and fibre strength.

VI. 1.3.1 Softwoods

The cool temperate coniferous forests are dominated by a few species with relatively homogeneous long-fibred wood. The average fibre length is between 2.5 - 5.5 mm, depending on species.

Generally the temperate pine forests, as found in the south-eastern United States, produce pulp with a higher tear but lower burst and tensile strength than the more northern conifers.

For practical purposes pines are the only tropical conifers which need to be considered as raw material for pulp and paper. While limited in volume, the indigenous pines in any area have reasonably uniform density and fibre dimensions and are thus a good raw material for a wide range of pulp and paper products. It should be noted that the quality of pulps produced from these pines is similar to that produced from pines grown in sub-tropical and warm temperate climates. This means that the pulps have higher tear but lower tensile and burst values than are typical of pulps produced from conifers grown in cold temperate climates (Vakomies 1972).

Relatively little is known about the pulping qualities of exotic plantation-grown pines, but it appears that when climatic and soil conditions are similar to the native conditions of the pine, it produces pulp similar to that produced from indigenous trees. Low-altitude exotic plantations seem to produce pines which can have entirely different densities, fibre dimensions and resin contents from the indigenous trees and these can vary even within the same plantation. To evaluate the pulping quality of exotic pines grown in plantations, it is therefore necessary to determine carefully these variations and to carry out detailed pulping tests (Vakomies 1972). The wood properties of the exotic pines are dependent on tree age, changing considerably from the inner juvenile wood to the outer and more mature wood.

VI. 1.3.2 Hardwoods

While hardwoods cannot produce as wide a range of pulps and papers as softwoods, new technology has narrowed this difference. Furthermore, for certain grades of paper, particularly fine ones, pulps from hardwoods are superior to those from softwoods.

Some general advantages and disadvantages of hardwood pulps are:

Advantages	Disadvantages
Lower flow resistance and better formation	Lower tearing strength
Better surface properties	Lower folding endurance
Good mechanical properties (except tearing strength)	Lower wet web strength
Favourable strength-opacity relationship	Higher drainage resistance
Rapid strength development on beating	Surface picking problems
	Possible problems from extractives

For a paper mill it is often advantageous to have available pulps from both deciduous and coniferous woods to make blends in which the desirable properties of both can be combined. However, just how mixtures of fibres will work together is difficult to judge without making tests.

The vast majority of species available in the tropics is in mixed stands of a large number of deciduous species. One reason for the pulp and paper industry's very limited use of tropical deciduous species is the wide variation of densities, fibre dimensions and other characteristics of the sometimes hundreds of wood species in a stand.

The oven-dry density or specific gravity of these wood species vary from 0.2 to 1.2. Approximately one third of the species have a density outside, mainly above, the 0.3 - 0.8 specific gravity range normally considered suitable for pulping.

Fibre length is a poor criterion for evaluating the suitability of tropical hardwoods for pulp production. As a rule, these, like other deciduous species, have fewer and shorter fibres and more parenchymatic and vessel cells than coniferous species. The mean fibre length, depending on species, is usually between 0.6 and 1.7 mm. The length of the vessel elements is in the range of 0.2 - 1.2 mm. A factor of importance is the ratio between the tubular fibre wall thickness and lumen diameter. Expressed as Runkel-ratio, which is the ratio between twice the wall thickness and the lumen diameter (2W/L), the approximate limits of this ratio appear to be from 0.25 to 1.5 for species which produce pulp of reasonable quality (Vakomies 1972). Thick-walled fibres do not collapse easily, are stiff and retain their rounded shape during sheet formation and thus give poor bonding.

Many of the tropical hardwoods, particularly the heavier species, have a high content of extractives. If hot water or alcohol-benzene extractives exceed 10 percent it is very unlikely that the wood is suitable for pulp production.

The ash content of some tropical hardwoods may be as high as 4-5 percent whereas species growing in the temperate forests usually contain 0.2 - 1.0 percent ash. In addition to the mineral constituents necessary for plant growth, tropical hardwoods may contain silicate and oxalate crystals. Content of calcium oxalate and particularly silicate increases the hardness and durability of the wood, but causes a marked dulling of machine tools and may thus make the wood unsuited for industrial processing.

Heterogeneous tropical deciduous forests may be converted into plantations of selected species by:

Cleancutting existing stands;

Collecting and processing logs suitable for lumber and veneer production;

Collecting and processing logs suitable for pulping;

Disposing of the rest of the wood by mechanical means, by burning, or possibly by charcoal production;

Replanting with selected species.

In view of the lack of experience from such conversion operations, it is difficult to estimate the economics or to guarantee that the reforestation programme will be successful.

For a pulp mill, it should be possible - if it is economically sound - to accept, say 50 - 100 selected species of wood. Provided the volume distribution of these species is uniform all through the forest, the mill should be able to produce pulp of uniform quality. Another solution may be to reduce pulpwood selection to a few well-recognized species or groups of species whose percentages in the mixture of wood pulped can be controlled and kept constant at the mill. Both natural and artificially controlled "homogeneously heterogeneous" mixtures of wood have been pulped in laboratories or pilot plants and the pulps produced have been of good quality. The prospects of utilizing mixed tropical deciduous forests for pulp and paper production depend on technical, silvicultural and economic factors (Vakomies 1972). However, over the last years it has been shown that high-quality pulp can be produced on a practical commercial basis from mixed tropical hardwoods (King 1975).

There are samples of successful tropical plantations of hardwoods of both indigenous and exotic origin. Certain species of eucalyptus have produced very high yields in the tropics. While man-made forests of selected deciduous species are not yet common in tropical countries, they may be the best future source of wood raw material for pulp and paper in the tropics.

Also, more temperate climates like parts of South America and Africa, southern Europe, Australia and New Zealand have very successful hardwood plantations giving a high yield of homogeneous wood on short rotations. Eucalyptus species dominate in these plantations. Anatomy and characteristics of several eucalyptus species are described by Dadswell (1972). Among the 500-700 known species, a limited number have been selected, giving an ideal raw material for many paper grades.

VI. 1.4 Quantity and Cost of the Wood

To be competitive in international markets, a pulp and paper development normally needs large quantities of wood at relatively low cost.

The amount of wood available in any given year is naturally important for establishing the initial and ultimate sizes of the development. Particularly in mixed tropical hardwoods, more detailed and expensive inventories can be justified only after a preliminary appraisal of the project has indicated that the proposed project may be technically and economically feasible.

Since it is important to know at an early stage the approximate cost of wood delivered to possible mill sites, plans of preliminary management, planting or replanting, logging, transport and so on, must be drawn up and their capital and operating costs estimated. Particular attention must be paid, in this connection, to keeping the cost of the wood as low as possible during the initial years of harvesting when the newly established mill is going through its economically most difficult period (Vakomies 1972).

A useful guide for planning pulp and paper enterprises has been published by FAO (1973).

VI. 2 Chip Properties for Industrial Use

Consequences of a poor chip quality include losses of pulp yield and quality and increased production costs.

The following information on technical chip properties is based mainly on a paper by Hartler (1972).

VI. 2.1 Dimensional Requirements

Very little has been reported on the effect of chip dimensions on output variables by mechanical and semi-chemical pulping.

VI. 2.1.1 Kraft Cooking

In kraft cooking, diffusion is the predominant way in which the cooking chemicals are conveyed into the chips. The rate of diffusion is approximately the same in the three main directions of the wood, and therefore the critical dimension will be the smallest dimension, i.e. the thickness of the chip. Increasing thickness results in a more heterogeneous cook which means more screening rejects of partially delignified chips from which the fibre cannot be extracted.

The upper critical thickness limit depends somewhat on the wood species and also on the shape of the chip. Laboratory chips are solid, having fairly parallel, flat surfaces and no cracks (Fig. 66). Industrial chips have slight corrugations parallel with the grain on both of their largest faces (Fig. 67), which reduce the true chip thickness to a value somewhat below that of the nominal thickness.

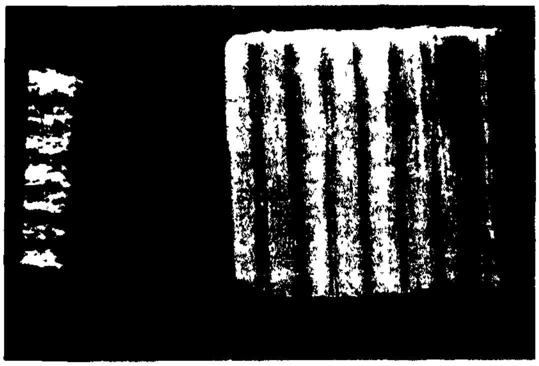


Fig. 66. Laboratory chips.

Fig. 67. Industrial chips with corrugated surfaces and fissures.

Of greater significance is that many chips, to a varying extent, contain cracks or fissures along the grain as shown in the figure. Whereas 4 mm is the upper limit for the thickness of laboratory chips, 6-7 mm is permissible for industrial chips.

The lower critical limit for chip thickness is determined by the fact that too-thin chips have very low mechanical stability and also that small-sized chips are difficult to process. In extreme cases they are also detrimental to the quality of the final product. In practice there is a distribution of thickness (Fig. 68) and the upper and lower end of the thickness distribution have to be kept under control.

Length is not so critical in kraft cooking and therefore restrictions are not usually placed on chip length. On the other hand, there is a linear relationship in commercial chippers between length and thickness with a factor of 5-7 times (the length is 5-7 times greater than the thickness). The chip length is usually between 15 and 30 mm when the chips are intended for kraft cooking.

A too high content or uneven distribution of pin chips and fines will cause non-uniform cooking and may also cause plugging of the liquor extraction screens, particularly in continuous digesters.

VI. 2.1.2 Sulphite Cooking

Chips for sulphite cooking do not have specified thickness requirements. In this case the length along the grain is more critical. There is a recognised relationship between chip length and resulting mean fibre length of the pulp: the shorter the chip in the grain direction, the higher the frequency of fibres cut during chipping and thus the shorter the mean fibre length (Fig. 69).

Since longer fibres contribute to stronger pulp, emphasis is put on longer chips for sulphite pulp, where strength properties are more of a bottleneck than in the case of kraft pulp. Furthermore, shorter chips contain a larger percentage of compression damage.

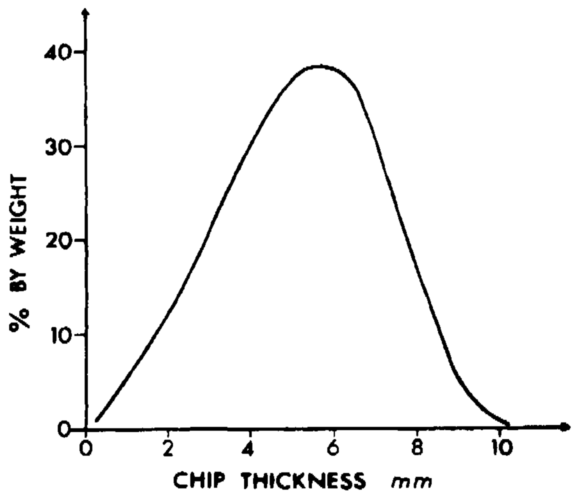


Fig. 68. Weight distribution of chip thickness for an industrial chip sample.

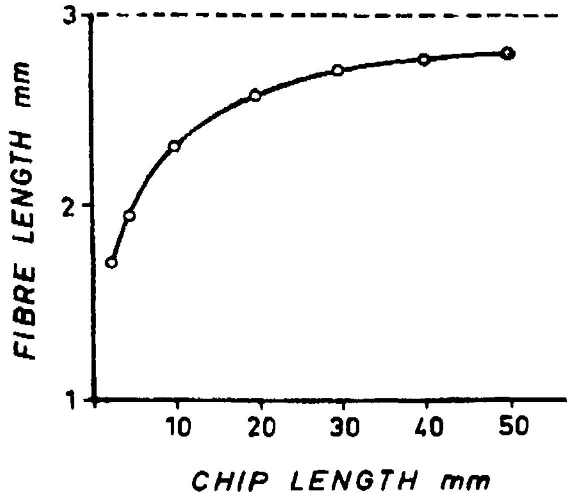


Fig. 69. Calculated relationship between average fibre length and chip length, assuming the average fibre length in the uncut wood to be 3.0 mm.

Often chip length is of the order of 35-40 mm in sulphite mills. Thi if probably an upper limit; longer chips would result in difficulties in penetration as sulphite cooking chemicals are conveyed mainly along the fibre axis.

VI. 2.2 Mechanical Stability

It is desirable to minimize the quantity of small-sized chips. Durin handling chips with low rigidity can easily be degraded into small sizes. Some industrial chips have severe cracks, resulting in a low rigidity perpendicular to the fibre axis. It is of great importance that chips hav a good mechanical stability.

VI. 2.3 Compression Damage

Softwood consists largely of fibres. In the main part of the fibre wall - the S2 layer - there is a helical alignment of the microfibrils, with an angle - the spiral angle - between the microfibrils and the axis o the fibre of 10 - 30° (Fig. 70). If this is prevalent throughout the wall it means that all the cellulose is arranged in a highly ordered state which means in turn that it has a low accessibility and a low reactivity towards pulping chemicals. This is a prerequisite in preserving the cellu lose from degradation during pulping operations in the mill, particularly under acidic sulphite cooking conditions. If this high degree of order ha not been the case, it would not have been possible to make strong pulps by the sulphite process. Severe compression of the wood unfortunately introduces misalignments in certain limited areas of the micro-fibrillar structure. In these areas the undesirable degradation of the cellulose will proceed at a high rate during acidic pulping operations, resulting in weak spots in the fibres and consequently a lower strength in the resulting paper. This phenomenon, which is a result of plastic flow in the wood during severe compression, is called compression damage.

Compression damage by conventional chipping occurs mainly as shown in Fig. 71. Springwood fibres are more sensitive to compression than summerwood fibres and the higher the density of the wood, the lower will the chip compression damage be. The moisture content of the wood also has a pronounced influence. Dry wood is favourable from the viewpoint of chip compression.

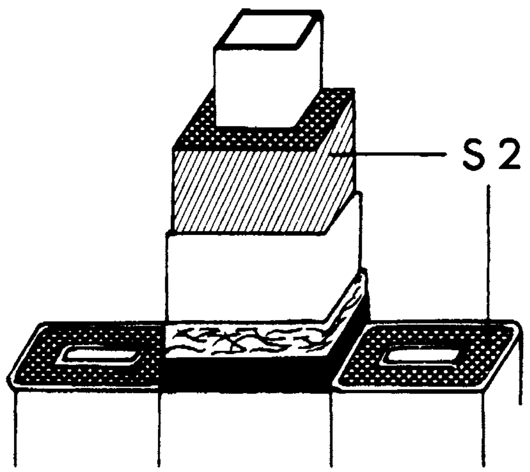


Fig. 70. A schematic drawing of the fibre wall of softwoods.

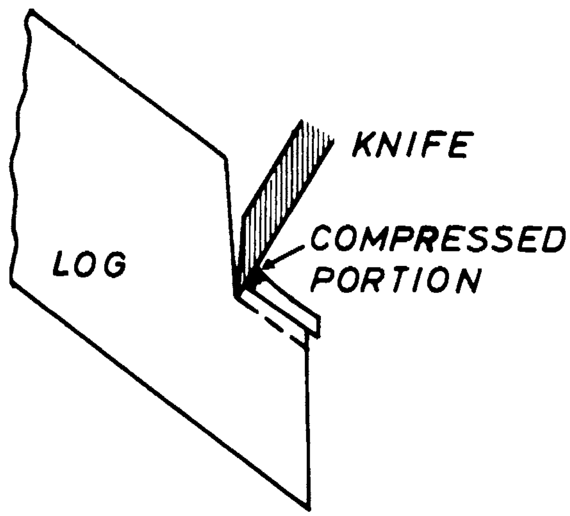


Fig. 71. Forming of compression damage.

Compression damage is of less importance when the chips are to be used for kraft cooking - the increasingly dominant cooking method in pulp mills - but it is of great importance in sulphite cooking.

VI. 2.4 Bulk Density

The degree of packing in the digester controls the amount of wood that can be charged to the digester. It also controls the filtration resistance of the large body of wood chips in the digester. Transfer of heat and cooking chemicals, which are of the greatest importance for the homogeneity of the cook, are usually achieved by circulating the cooking liquor. An even circulation in all parts of the digester is, therefore, of the greatest importance for a homogeneous cook. One of the factors that controls an even circulation is the filtration resistance which has to be the same throughout the body of chips in the digester.

The chip parameters that control the bulk density are:

a) the ratio of the largest to the smallest dimension, taken as the average diagonal of the chip and the average chip thickness;

b) the heterogeneity of the chips.

For fairly homogeneous samples the bulk density is uniquely determined by the ratio of the two chip dimensions, as seen from Fig. 72. The larger the ratio the lower the bulk density. Theoretical analyses have shown that for fairly homogeneous samples the densest packing is achieved when each particle has the form of a sphere. This corresponds to the ratio 1, whereas for most industrial chip samples the ratio is about 10 or even somewhat higher.

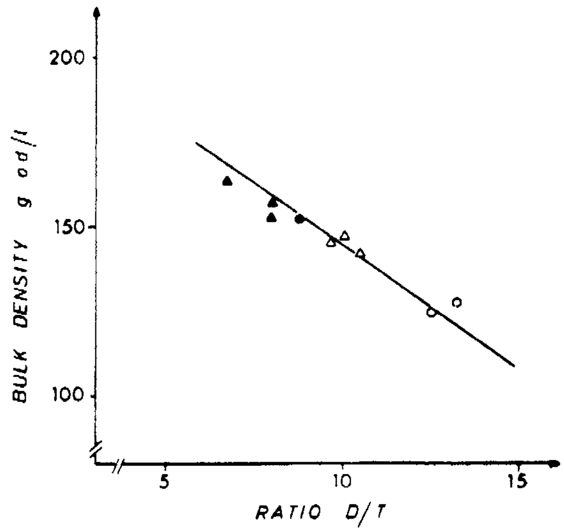


Fig. 72. Bulk density according to a standard laboratory procedure in relation to the ratio between average diagonal (D) and thickness (T) for some different industrial chip samples.

When fairly large quantities of oversized or small-sized chips are introduced, there will be to some extent a filling of the voids between the chips leading to an increase in the bulk density.

As seen in Fig. 73, the addition of 40 percent of oversized chips increases the bulk density of the body of the chips by about 10 percent. The addition of sawdust under similar conditions, on the other hand, increases the bulk density by nearly 20 percent. In the first case the bulk density increases because an oversized chip replaces several smaller, relatively loosely packed chips without disturbing the gross packing, whereas in the second case, the sawdust actually fills the voids between the chips.

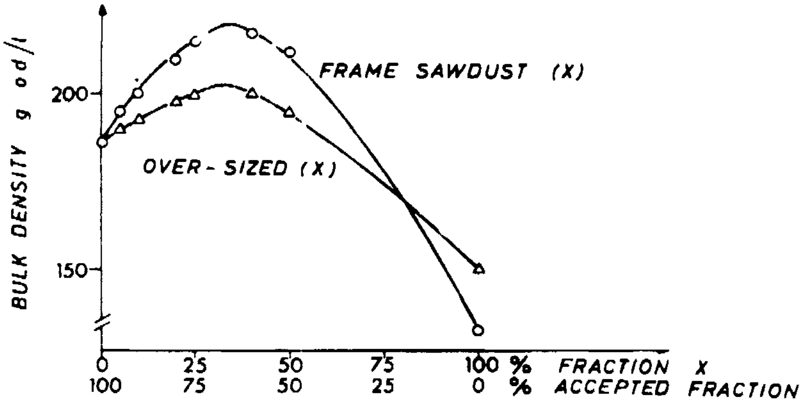


Fig. 73. Bulk density according to a standard laboratory procedure in relation to quantity of extra chips added to a sample of fairly homogeneous chips.

VI. 2.5 Moisture Content

Wet or fairly wet wood - with a 40-50 percent moisture content - is better than dry as regards the impregnation of cooking chemicals which to a large extent influences the homogeneity of the cook. Rewetting of dry wood by steaming implies certain limitations. A laboratory investigation (Hatton and Keays 1973) shows that the kraft pulp yields were the same for green and air-dry softwood chips, however, ovendried chips gave lower screened yield.

In softwoods some of the pores in the wood structure are irreversibly closed upon drying to high degrees of dryness. Furthermore, tanks and retention times for steaming in the mill are usually not designed for such an extensive steaming as would be required to add large quantities of moisture to very dry chips. Chips dried to moisture contents far below the saturation point have deteriorated somewhat in quality for pulp production, and high degrees of dryness cannot, in general, be compensated for in mills by extensive steaming.

Use of green, fresh chips is regarded as an advantage in the production of mechanical pulps.

There is only one factor in favour of dried chips and that is the accompanying stability as regards microbiological deterioration. This factor is, however, not a serious matter when the chips are stored in the mills for only short periods.

VI. 2.6 Purity and Some Brief Comments on Heterogeneity in Wood Properties

Wood chips for industrial use must, of course, be free from impurities such as sand and metallic particles, which, if they were present, would usually cause production disturbances in the pulp mill. Normally, wood chips have a sufficiently low content of such impurities. A too high content of abrasive material has been a major problem when processing whole-tree chips or chips from slash.

Furthermore, it is of the greatest importance to reduce decayed wood and bark to a minimum. They not only give lower yields and cause production disturbances but also affect the pulp quality negatively. Severe decay and large quantities of bark will not only be detrimental in the above mentioned aspects and thus cause a reduction in price, but will also in many cases result in an absolute rejection by the mill.

When the wood chips contain a mixture of various wood species or a mixture of woods coming from different sources, it is of the greatest importance that the mixture be kept constant so as to avoid any change in pulp quality. The difference between, for example, spruce and pine is so great that it has a pronounced effect on the resultant pulp quality after kraft cooking. When wood chips show differences in composition upon delivery, suitable measures must be taken prior to pulping to ensure proper mixing.

VI. 2.7 Chips from Chipping Headrigs and Chipper Canters

Chips produced by chipping headrigs and chipper canters show large variations between different machines and installations. In some cases a high content of fines is produced, but generally the chips, although showing a different geometry from traditional chips, have a percentage of chip accepts comparable to chips produced from disc chippers. The chips are often thinner and cook faster than traditional chips. On the other hand, such chips have a lower packing density and are more susceptible to handling damage, with a resultant increase in pin chips and fines.

VI. 2.8 Chips from Residue

As long as the wood supply exceeds demand, the stumpage price remains low and utilization is limited to only the best timber. When consumption grows, stumpage rises, and industry must broaden its raw material base to smaller-sized or quantitatively poorer wood.

Industrial processing of residue generally begins in a situation in which its price is low compared with the traditional wood raw material. The industrial plant which is first to venture into conversion of residue, previously regarded as unsaleable, often finds that it has made a truly advantageous decision. When the activity proves profitable, more and more companies follow suit. Demand grows and the price gradually settles at a level which corresponds to the true value and much higher than the original level.

Wood raw material is most completely used where the proportion of stumpage in the mill price of wood is high. Only in conditions where the wood price is high, is it usually worth utilizing wood thoroughly (Hakkila 1972a).

Residue is divided in two main groups: 1) residue of the mechanical wood processing industry and 2) forest residue. The former, particularly, has risen so much in importance and value that it in many countries is more correct to speak of it as by-products.

VI. 2.8.1 Sawmill Chips

The main by-products from sawmilling are slabs and trimmings. These are usually chipped at the sawmill in residue chippers, and to some degree the outer part of the log is directly converted to chips. In Scandinavia chips from slabs and trimmings constitute 20-25 percent of the solid volume of the log and contribute 10-15 percent of the sawmill's total sales. This income often equals the total cost of labour at the mill. For smaller sawmills it may be more economical to sell unbarked slabs or chips than to purchase an expensive debarking machine. The price of unbarked sawmill residue is about two-thirds compared to barked residue. Unbarked residue is used mainly in particle and fibreboard mills.

Chips from sawmills consist mainly of the outer parts of the logs, where the wood properties are excellent for pulping, even superior to traditional pulpwood. However, the yield of by-products in the sulphate process is low because of the low heartwood content. A too-high bark and fines percentage may also occur, especially in winter when frozen wood is processed.

As an example of the importance of sawmill chips, in Finland 20 percent of sulphate pulp and 10 percent of sulphite pulp is obtained from this material (Hakkila 1972a). About all the sawmill wood by-products are processed further as a raw material in the forest industry.

Also in many other countries, by-products, particularly from saw-mills and veneer mills, have become important raw materials for board and pulp mills. To maintain or improve the chip quality, the chip buyer may own and run the residue chipper, provide the maintenance, or otherwise inform and motivate.

In Sweden, sawmills have founded a powerful organization for marketing of sawmill by-products (Appert 1972).

Sawdust

In typical sawmills in Scandinavia, equipped with gang saws or double slabber circular saws, 11-13 percent of the log is turned into sawdust.

A disadvantage of sawdust for the pulp industry is its small particle size and consequent short fibre. The fibre length in chips of northern conifers is over 3 mm, while sawdust fibres average only 1.15 mm in length and are even shorter from circular saws.

Sawdust was first accepted as a raw material for particle and fibreboard. Since the middle of the 1950s, short-fibred sulphate pulp has also been made of sawdust. Although some sawdust may be carefully metered together with other chips, separate sawdust pulping is preferable to avoid digestion problems and to increase yield. When adding a separate continuous sawdust digester to an existing pulp mill, the production capacity, for economical reasons, should not be less than about 100 tons of pulp per day under Scandinavian conditions. The pulp properties in many respects ressemble those of hardwood pulps.

Production of thermomechanical refiner pulp from sawdust has recently begun. The pulp has strength properties lower than that of groundwood pulp, but it is adequate for certain paper and paperboard qualities.

Both in Sweden and Finland the major share of sawdust is utilized industrially, Finland even imports sawdust. Finnish sawdust digesters have an annual total production capacity requiring about 3 million solid cu m of sawdust. Thermomechanical refiner pulping there will within a short time consume more than 0.3 million cu m of sawdust.

VI. 2.8.2 Forest Residue

Forest residue is usually less economic to use than residue of the mechanical wood processing industry. It suffers from high harvesting costs, and it is often a poor raw material. But increased demand for raw material and the development of harvesting and processing techniques certainly leads to utilization of forest biomass previously regarded as unusable.
On the other hand, in recession periods with reduced demand and prices, forest residue such as slash is probably the first wood raw material that becomes unattractive.

Stump- and Rootwood

One of the important reserves of wood - 15 to 35 percent of the bole weight - consists of stump and roots. Their wood properties differ relatively little from those of bole wood, the most remarkable features being the high content of extractives in pine stumps.

Sulphate cook yields for stump and coarse roots from softwood are in most cases 2-3 percentage units lower than those of bolewood. However, due to the higher basic density, the consumption of stump- and rootwood from pine in cu m per ton of pulp is actually lower than that of conventional pulpwood. The pulp quality may range from comparable to bolewood to a 10-15 percent decrease in strength properties. The behaviour of the hardwood root system in sulphate cooking is more variable than the root system of softwoods.

The main impediment to utilization of stumps and rootwood has been the high cost of logging, transport, and conversion to chips free of soil contaminants.

About one million solid cu m of mature pine stumps are annually utilized in Poland, USA and USSR for production of naval stores. The wood remaining is often used as fuel or for fibreboard. In USA, one company has several years' experience in using stump wood after the extraction of chemicals for pulping (Stewart and Diaz 1972). A harvester-buncher prototype under development that pulls southern pine trees with taproot attached from the ground like carrots will probably increase the use of stumps and rootwood. In Scandinavia, comprehensive research programs have been directed towards the utilization of stumps and rootwood as an additional raw material. In Finland a commercial stump crushing, washing, and screening operation (Fig. 74) started in 1975 with an annual capacity of about 300 000 loose cu m of chips. From 10 to 20 percent of the crushed chips can be added to ordinary chips without significant effects on the kraft pulp quality. A positive factor is, of course, the higher yield of turpentine and tall oil.

Further information and references on stump- and rootwood utilization are given in reports by Keays (1971e), Hakkila (1972b, 1974, 1975a), Eskilsson and Hartler (1973), Koch and Coughran (1975), Stade (1975), Koch (1976), Nyholm (1976), and Projekt Helträdsutnyttjande (1976).

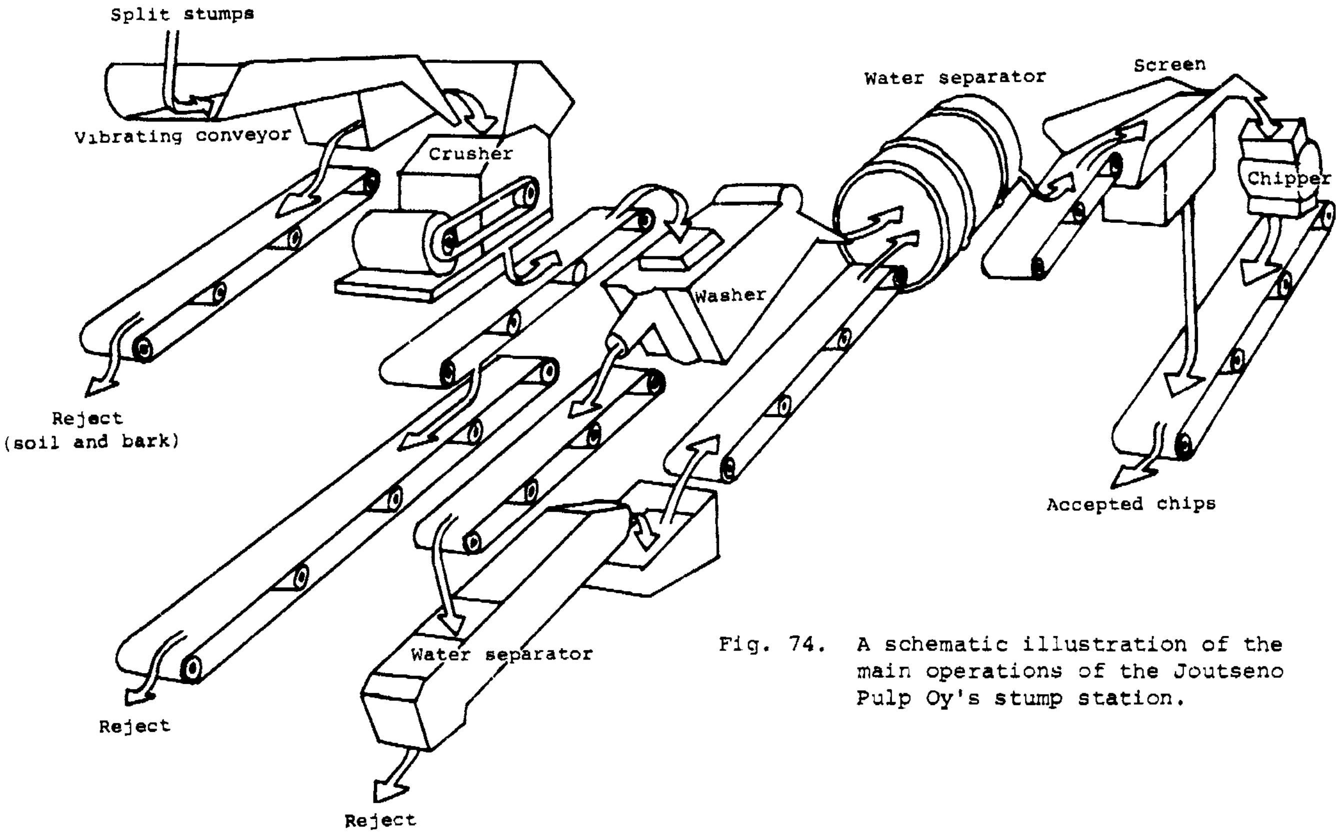


Fig. 74. A schematic illustration of the main operations of the Joutseno Pulp Oy's stump station.

Bolewood Residue

A fairly small proportion of bolewood is left unutilized in Europe. In Scandinavia the minimum diameter of wood used for making pulp is generally 5-7 cm. However, it appears to be difficult to maintain these minimum dimensions with traditional logging methods as the cost pressure is particularly heavy when using small-sized timber.

Even the top of the tree and young stems are perfectly utilizable raw material for the pulp and board industries. Both differ from regular stemwood mainly as far as fibre dimensions are concerned. Chemical composition and pulping behaviour show only minor deviations. The pulp yield is reported to be 1-2 percent lower compared with regular stemwood (Eskilsson and Hartler 1973).

Branchwood

Branches constitute a quantitatively great potential raw material source. If the dry weight of debarked bolewood is denoted by 100, the relative quantity of wood in the branches is 13 for Scots pine and 22 for Norway spruce under Finnish conditions. The total biomass of branches and top including the bark and needles, compared with the dry weight of wood and bark in bole, is 25 for pine and 50 for spruce (Hakkila 1972a). These figures are, of course, dependent on crown percentage and also on tree size; increasing with decreasing D.B.H. (Hakkila 1971).

Branchwood generally has a somewhat higher basic density than stemwood, while fibres are shorter. The basic density and chemical content are determined mainly by the high percentage of reaction wood. Softwood branches, which are rich in compression wood, have a relatively higher content of lignin, galactan and extractives than the corresponding stemwood. Hardwood branches are influenced by tension wood formation, leading to a higher cellulose and lower lignin content than stemwood.

Laboratory assessments indicate that up to about 50 percent of logging slash could be used to manufacture commercially acceptable particle boards with only little increase in resin content or board density.

Finnish, Canadian and Swedish experiments show that branchwood of conifers gives low pulp yield and most pulp properties are inferior compared to pulp from bolewood (Hosia et al. 1971, Keays and Hatton 1971, and Eskilsson 1974). The presence of bark and needles reduced the strength properties somewhat, but less than was feared. This is probably due to the low yield of these components. On the other hand, pulps from hardwood branches in most cases do not differ much from the corresponding bole pulp.

In Sweden, the presently prevailing view is that logging slash is of little interest as a raw material for pulping, but it may possibly become a raw material for board production.

<u>Bark and Needles</u>

Bark and needles are the least wanted tree components in board and particularly in pulp production.

In wet-process fibreboard mills, a bark content of up to 20 to 30 percent may be accepted. One of the major disadvantages of a high bark content is the increased amount of dissolved material which increases costs for water pollution abatement.

The proportion of bark that can be accepted in dry-process boards, depends on the production equipment, type of boards produced, binder content, and the required board quality. A literature survey on board production from bark and bark-containing raw material is summarized by Back and Lundqvist (1975).

In pulp production, the accepted bark content usually ranges from 0 to 4 percent, in some cases higher, depending on production process and products, but also on tree species and wood cost. As a rule, bark from young trees is less harmful than bark from old trees.

Under normal conditions for chemical pulps, most barks give a yield of some 20-25 percent and the consumption of chemicals is considerably higher than for wood. Problems are caused by dark colour, dirt specks, undigested bark flakes and pitch. In this connection it is worth noting that it is possible to use the unbarked wood of eucalyptus for cellulose. In the CELBI mill in Portugal, 10-15 year-old unbarked *Eucalyptus globulus* trees are used in the sulphate cellulose process (bark volume about 20 percent). Bark of young eucalyptus trees has a morphological appearance and chemical composition which is, however, rather similar to that of the wood (Thune-Larsen and Luhr 1972).

Also in Central Europe, kraft pulping of stored and screened chips from unbarked, small-sized hardwoods has given promising results (Wiedermann 1972). Kraft pulping of beech bark and bark-containing beech chips is described by Farkas and Farkasova (1975a, b). The pulp properties are in most respects relatively little influenced when the bark content of the chips is kept lower than 10 percent. However, to maintain production and pulp quality properties as brightness and cleanliness, each mill must decide the amount of bark that can be absorbed (Wawer 1975).

Kraft pulping studies of chips from unbarked softwoods indicate that acceptable bleached and unbleached pulps can be obtained (Horn and Auchter 1972, Vethe 1973). Digester yield and production capacity is lower, but the overall pulp yield is higher as the wood loss usually associated with the barking operation is avoided, and furthermore, there is also some pulp yield from the bark. Up to about 10 percent bark may be accepted in the chips without significant changes in pulp strength properties, however, more cooking and bleaching chemicals are consumed and an efficient centrifugal cleaning system is probably required.

Boards made of 100 percent slash pine needles are found not to have satisfactory properties for conventional uses (Howard 1974).

Needles give about the same pulp yield and have the same high chemical consumption as bark (Eskilsson and Hartler 1973).

The most extensive efforts toward foliage utilization have been made in the USSR. The main product is dried and milled technical foliage (muka), for use as an additive to poultry and cattle food. Since the first plant was built in 1956, muka production in the USSR has reached about 140 000 tons per year and further expansion of the production capacity is planned. Other products obtained from foliage include chemical goods like chlorophyll-carotene paste, sodium chlorophyll, provitamin-concentrate, conifer wax and several essential oils. The annual output of such dendrochemicals in the USSR is about 200 tons.

Research and development are needed to assess the feasibility of combining foliage utilization with whole-tree chipping where removal of the technical foliage would also improve the quality of the chip raw material when processing to conventional forest products.

For literature on foliage and foliage utilization, readers are referred to Hannus and Pensar (1970, 1973), Keays (1971b, 1975), Alestalo (1973), Ievins et al. (1973), Latvian Scientific Research Institute of Forestry Problems and Problem Laboratory for Utilization of tree living elements, Leningrad Forest-Technical Academy (1973), Barton (1975), Ievins (1975), and Ministry of Forestry and Forest Industry in the Latvian SSR, Latvian Scientific Research Institute of Forestry Problems (1975).

VI. 2.9 Whole-tree Chips as an Industrial Raw Material

Production and industrial utilization of whole-tree chips developed very rapidly in North America from the first full-scale trials in 1971, to 1975, when 4-5 percent of the total chip consumption in USA came from whole-tree chipping operations. However, during 1975, production of whole-tree chips declined as a result of the general recession with a difficult market situation for forest products.

In addition to being a raw material in the forest industries, whole tree chips may possibly find an outlet as a reduction medium together with coal and coke in the ferrosilicon industry and especially as a source of energy.

Particle Boards

In particle board production, a large quantity of needles seems to reduce the ability of the particles to be glued and the tensile strength perpendicular to the board surface. The more wood material and fewer needles the chips contain, the more suitable they are as raw material for the middle layer. A Finnish investigation shows that if particle boards are manufactured to a specific gravity of not less than 0.70 g/cu cm, whole-tree chips of pine, birch and spruce can be used in the middle layer up to 100 percent. The tensile strength perpendicular to the surface still meets the strength requirements. Whole-tree chips from pine and birch are better than those of spruce. When chips from branches are used, pine and birch can be used up to 100 percent in the middle layer, while not more than 25 percent of spruce branch chips can be used (Liiri et al. 1972).

Whole-tree chips from spruce thinnings, in a German experiment, were found not suitable in one-layer boards and in the outer layers of multi-layer boards. In the middle layer, however, a mixture of about 50 percent whole-tree chips was possible, giving particle boards of acceptable standard (Chen et al. 1972).

In Norway, whole-tree chips from birch (without leaves) have given one-layer particle boards with about the same properties as boards from unbarked bole chips (Sellæg et al. 1972). Many other experiments have also shown that whole-tree chips can be used for production of particle boards; however, in many countries, e.g. in Germany, Norway and Switzerland, whole-tree chips are not yet a competitive raw material (Götze et al. 1972, Günther et al. 1972, Paulitsch 1976, Peters 1976, Wolf 1976). On the other hand, some mills in Finland use whole-tree chips of pine and hardwoods as a small but increasing mixture for manufacturing of particle boards.

In USA a few particle board mills have been using whole-tree chips, mainly from hardwoods, as a minor part of the wood raw material without serious technical production problems. One mill under construction is supposed to be able to run with up to 100 percent whole-tree chips as wood raw material.

Fibreboards

In Finland, laboratory and mill investigations have shown that hard fibreboards can be made of softwood branch material. The yield of bark, needles and fines is lower than that of wood (Fig. 75). The laboratory boards made of branches had about equal bending strength but improved water resistance compared with hardboards made of bole chips. In the mill scale trial, it was shown that the hardboards made from branches had somewhat poorer strength properties than hardboard made from normal raw material, while the water resistance properties were of the same magnitude. Except for some handling and transportation difficulties, branch chips did not cause any difficulties in the mill production (Hosia and Kortelainen 1971). However, use of bark and needles increases pollution from waste water unless ample measures are taken.

In a Norwegian mill, a mixture of about 20 percent whole-tree chips from spruce thinnings in the ordinary raw material did not significantly influence either the insulating fibreboard quality nor the production process (Sellæg and Gislerud 1972).

Short-term mill trials with wet-process production of hardboard with a rather high proportion of whole-tree chips from mixed thinning stands

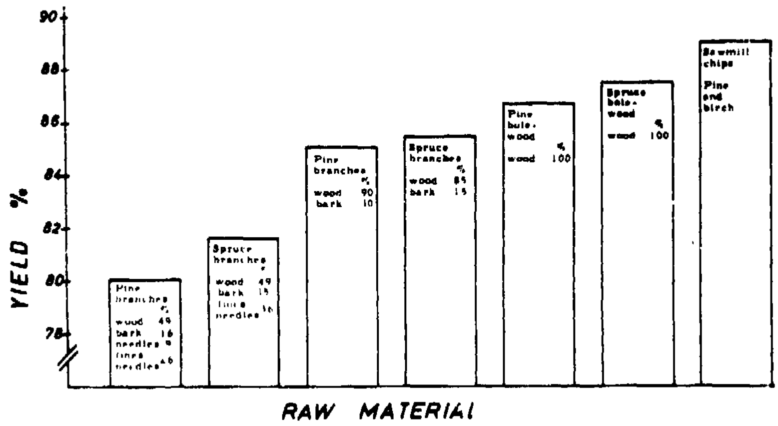


Fig. 75. Yield of different raw materials (laboratory defibration).

indicate that neither yield, nor biological oxygen demand, nor board strength differ appreciably to board produced from unbarked slabs. However, a high content of sand or other abrasive material caused production problems. Chip screening and removal of the fines is recommended (Helge 1976, Helge and Rødland 1976). A literature study by Nordlinder and Tufvesson (1975) shows that whole-tree chips, in addition, may cause some handling and screening problems and also blow-out in the defibrator, but otherwise the chips seem to be an acceptable raw material.

In North America some fibreboard mills use whole-tree chips as a part of the raw material. One company annually produces as a by-product more than 90 000 tons of hemicellulose extract for cattle feed (Hakkila 1975b, Galloway 1976).

In general it seems that the fibreboard industry can use whole-tree chips as raw material, but some minor equipment and process modifications may be necessary. The availability and cost of other raw materials compared with that of whole-tree chips will be decisive factors in its use.

Pulp and Paper

Pulp from whole-tree chips can be obtained by the kraft process and there are indications that a good grade of high yield (65-70 percent) pulp can also be obtained from some puckerbrush species. The screened yield of whole-tree chips depends on species and on the bark-to-wood proportion (Chase et al. 1971, 1973).

Regarding softwood, Fig. 76 shows the yield of different tree components for Scots pine. Similar results are obtained for Norway spruce. Contrary to pine needles, spruce needles are difficult to cook and defibre. The consumption of alkali (Fig. 77) is largely determined by the quantity of material dissolved (Eskilsson and Hartler 1973).

The strength properties of pulps from bark, twigs and needles are low, and moreover, these components give rise to specific problems of drainage, brightness and brightness stability. According to Eskilsson (1974) the positive value of these components is so small in pulping that it will not

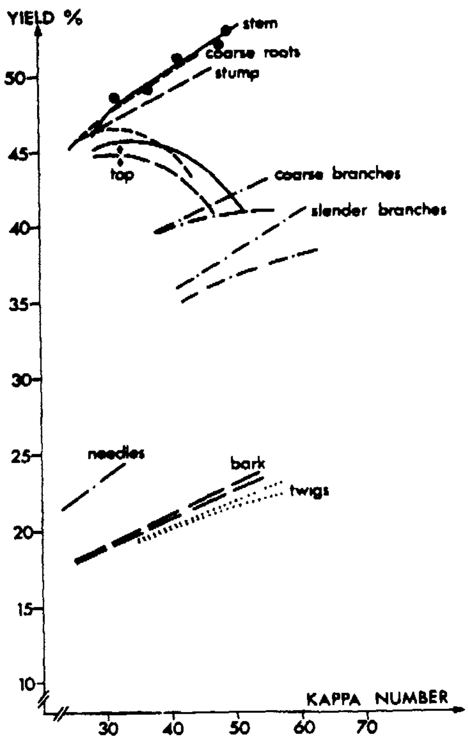


Fig. 76. Total and screened yield in sulphate cooking of different pine tree components. For each component, the upper curve represents the total yield and the lower curve the screened yield.

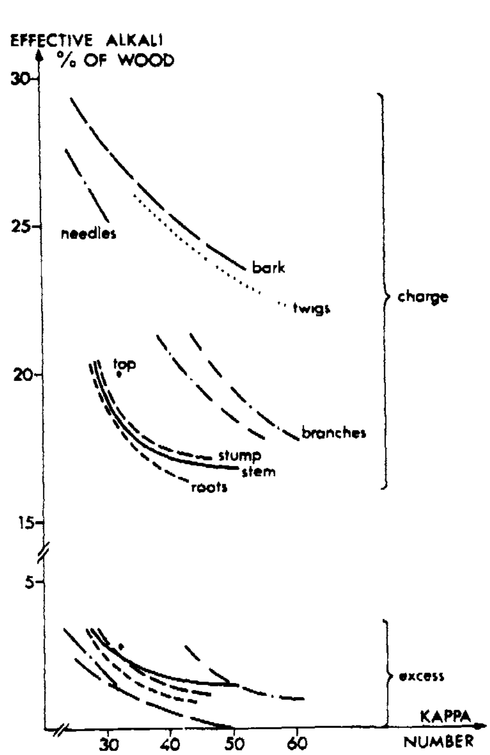


Fig. 77. Alkali consumption to reach a certain Kappa number in sulphate cooking of different pine tree components. The upper curves show the charge and the lower curves the excess of alkali.

cover the processing costs, and at least a partial removal will be a necessary feature.

Based on precise laboratory studies of red pine, loblolly pine and sugar maple, Marton et al. (1975) raises the question of whether it is worth using the twigs and thin branches, which contain a high proportion of bark. These components contribute only a small amount of pulp of an inferior quality, and furthermore, foliage and bark - particularly bark from thin branches - contain considerably more ash than the wood. Some of the ash minerals occur as abrasive crystals, probably causing increased wear of the chipper and the pulping equipment. The laboratory experiments also indicated that an oxygen-alkali two-stage cooking process might give higher whole-tree pulp yields than the kraft process. Except for tear strength of the pine pulps, oxygen cooking also produced pulps with comparable or somewhat better properties than the kraft process.

Based on detailed pulping studies, Virkola (1976a, b) also raises the question of using whole-tree chips and particularly softwood branches as a raw material for high quality pulps. High shrinkage of branchwood pulp is one of the major limitations for its use.

Experiments from laboratory pulping studies of different tree components and whole-tree chips, as well as mill experience with whole-tree chips are compiled by Stade (1975).

The major difficulties that arise or may arise in mills using whole-tree chips are:

Problems during handling and storage, hangups in bins and conveyors, and increased chip degradation during storage. The most severe problems are often experienced in connection with continuous digester operation, e.g. hangups and plugging of screens. Removal of fines and oversize chips by screening is often required to reduce these storage and handling problems;

Reduced yield and capacity. As the pulp yield of whole-tree chips based on digester charge is normally lower than that of ordinary chips, this will reduce the mill outputs. Other important factors limiting the output will often be the increased need for pulp cleaning and limitations in the recovery system;

Increased consumption of cooking and bleaching chemicals;

Increased scale formation in the digester system and increased pitch deposits, requiring more maintenance and chemicals;

Increased rate of equipment wear caused by sand or other abrasive material;

Reduced pulp quality resulting from higher dirt content and fibres giving less paper strength.

In general, whole-tree chips have up-to-now been commercially accepted only in North America, where about 80 pulpmills - mainly kraft mills, but also some semi-chemical mills - use this kind of raw material. The percentage of whole-tree chips ranges in most cases from a few percent up to 25-30 percent, only rarely being higher. Most whole-tree chips are from hardwoods. In Finland, three sulphate pulp mills started utilization of whole-tree chips in 1975.

The economics of using unbarked chips and whole-tree chips for pulp and paper production are discussed by Horn and Auchter (1972), Auchter and Horn (1973), Keays (1974), Keays and Hatton (1975), and Moran (1975). No simple, single conclusion can yet be given, but evaluation programs are under way. Some of the economic consequences can be assessed rather well on the basis of laboratory and mill experience while others can only be guessed. Very much depends on factors peculiar to the specific mill, such as production process and equipment, end products and not least, the supply/demand situation. The use of whole-tree chips may be profitable for some mills and in some situations while it may be very uneconomical for other mills.

Although whole-tree chips may be utilized as the sole raw material or blended with traditional chips, the future of whole-tree chips for pulping depends primarily on progress in the upgrading of chips before pulping.

VI. 2.9.1 Chips from Short-Rotation Forestry

Short-rotation forestry is one approach being explored as a way of increasing the supply of raw material for particle board, fibreboard, pulp, some chemical products, and fuel. This may involve both utilization of existing forest bushes and use of intensive management techniques approaching that of agriculture - selected species, improved trees, site preparation, row planting, fertilization, and whole-tree chipping. Hardwoods may be harvested after only a few years (mini-rotation) with highly mechanized silage methods, or trees may be grown for 6-20 years (midi-rotation) before harvesting. The greatest disadvantages of using young, small-sized trees for pulp and paper products lie in the high bark content and the rather short fibres. This is more pronounced the younger the trees are; however, variations are great between different species.

Pulp yield and most pulp strength properties are of course lower than with older trees, but may nevertheless be acceptable for a variety of uses. The economic aspects of short-rotation forestry - and in particular of intensive mini-rotation - are uncertain.

Viewpoints, data, and references on the use of chips from short-rotation forestry may be found in reports by e.g. Chase et al. (1971, 1973), Dutrow (1971), Ribe (1974), Jett and Zobel (1975), Lönnberg (1975a, b, 1976a, b, c), Lönnberg et al. (1975), Brown (1976), Einspahr (1976), and Rose (1976).

VI. 3 Assessment of Quantity and Quality of Wood Chips

When measuring wood chips, two main aspects must be kept in mind: 1) the accuracy of the value determination, and 2) the cost of the assessment. The most important factors determining the value to the fibre industry are the amount of dry matter and the general quality of the chips.

VI. 3.1 Quantity

Quantity can be determined by volume or by weight.

VI. 3.1.1 Volume

The loose volume determination is usually relatively simple. In truck or railroad transport, the base area of the transport container is usually known, so measuring is confined to estimating the average height of the chip load (or the distance from the container's top edge to chip level). The volume of chip piles can be determined either by direct measurement of the pile or from aerial photographs.

However, the loose volume gives only an approximate determination of the amount of dry matter of the chips. The variation in relative solid volume together with the variation in basic density make up the variation in dry matter per loose volume unit.

The relative solid volume is dependent upon several factors such as chip characteristics and chipping method, loading method, transport method and distance and climate.

By increasing chip thickness and length within certain limits (5 - 25 mm length) the relative solid volume increases somewhat (see also section VI. 2.4 concerning bulk density). Screened chips have a lower relative solid volume than unscreened chips, the difference being approximately 2 percent units. Variations occur too in chips from different chipper types. Chips from hammermills, chipping headrigs and chipper canters usually have the lowest relative solid volume; chips from disc chippers have the highest relative solid volume, while chips from spiral chippers are in between. Dull chipping knives reduce both chip quality and relative solid volume.

The relative solid volume is higher when the chips are loaded by blowing than by falling from a mechanical conveyor or silo. In free fall the compaction also varies with the height of the drop.

Settling during transport is usually computed in percent on basis of chip levels before and after transport. Fig. 78 gives an example of the settling (Uusvaara 1969). In truck transport the greatest amount of settling occurs during the first 20 - 40 km. Over a road transportation distance of 100 km the settling is of the magnitude of 4 - 10 percent. Settling is 1 - 3 percent greater in the trailer than in the truck and greater in road than in railway transport.

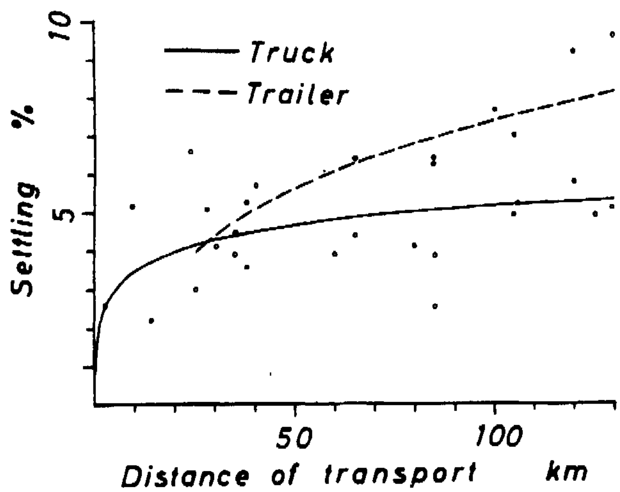


Fig. 78. Settling of chip loads as a consequence of the transport distance.

Climate also influences settling, which is usually greater during summer than winter, caused partly by chips freezing together in the silo or during transport (Uusvaara 1972). Even in the container settling is uneven, and it is greater at the sides than in the centre, Fig. 79 (Nylinder 1972). Settling increases the relative solid volume, and the average increase seems to be about 1.5 - 2.5 percent units by road transport, say, from 0.37 to 0.39.

The relative solid volume of sawdust is 2-5 percent units lower than the corresponding value for sawmill chips. Truckloads of sawdust are in Finland measured to have an average relative solid volume of 0.35 in winter and 0.387 in summer on arrival at the mill (Uusvaara 1974).

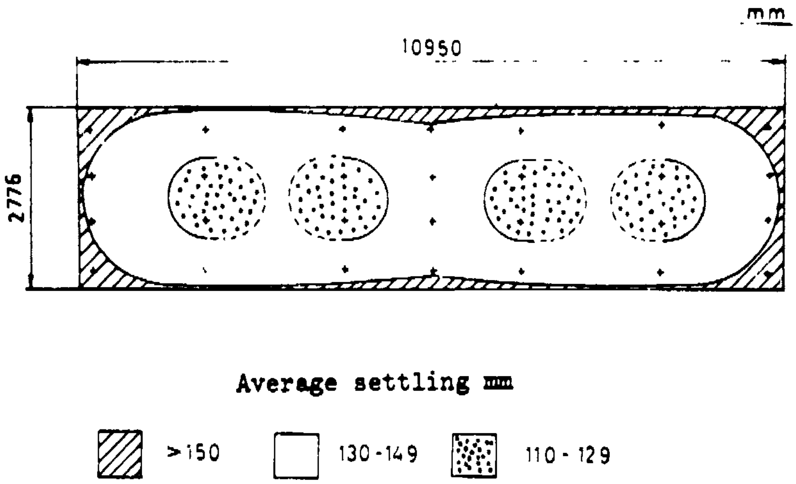


Fig. 79. Average settling after approximately 675 km transport in railway wagons.

Owing to the fact that many of the above-mentioned factors are specific to each supplier, the variations in the relative solid volume often are relatively small for each individual supplier, but can be quite considerable between different suppliers. Swedish investigations indicating the variation in relative solid volume of sawmill chips are shown in Table 2 (Nylinder 1972).

Table 2. The coefficient of variation within loads from the same supplier and between different suppliers (64 loads and 5 different suppliers).

	Within suppliers	Between suppliers
Relative solid volume (solid volume/loose volume)	0.4 - 2.8 %	5 - 6 %
Dry matter content (dry matter /loose volume)	0.4 - 2.9 %	6 - 9 %

In a chip pile, the relative solid volume of screened chips is usually 0.47 - 0.48 when pneumatically conveyed. Parts with more loosely packed chips will exist, especially at the edges where chips have been mechanically moved.

The chip basic density varies so widely with species and species mixture, tree age, growing rate and so on that it is not possible to give general, reliable figures.

VI. 3.1.2 Weight

With this method the transport unit is weighed before and after unloading and the difference constitutes the weight of the chip load (Fig. 80).

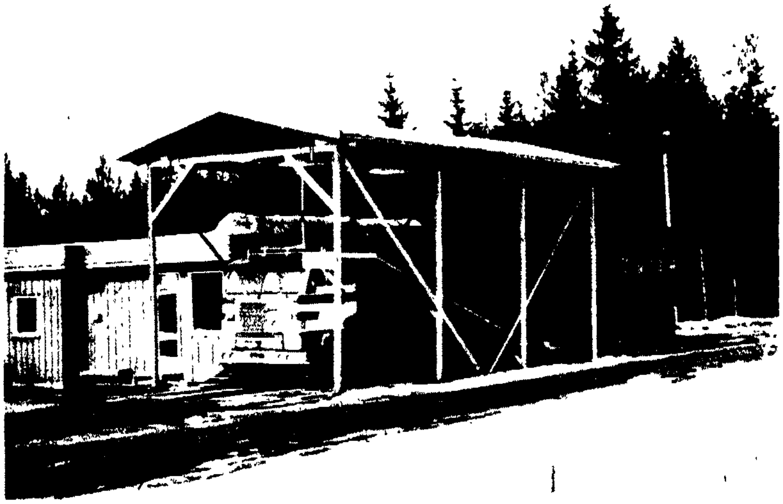


Fig. 80. Weighing a chip load.

In ship transport, the ship is surveyed before and after the cargo is loaded to determine the total green weight of chips. Certain deductions are made from this green weight for rainfall that enters the hold during loading, added water in the pneumatic conveying system, and excess of dust, bark and rotten wood (Warren 1972).

The moisture content of a chip load is dependent on wood species, season of logging and storing time and conditions. The variations in moisture content may thus become quite large both within and between different suppliers.

As it is impossible to determine the percentage of dry matter or moisture content of whole loads, sampling techniques are used.

For sawmill chips, if an average moisture value of a truckload with a 2 percent margin is desired, five to 15 two-litre samples should be taken from different parts of the load, mixed well and the moisture content determined on the basis of this general sample. In the case of large deliveries coming from one supplier, a number of random samples of the deliveries should be sufficient (Nylinder 1972).

In wood-chip shipments from New Zealand (mainly exotic softwood and native beeches), measurements are made at the time the ship is loaded. Every 15 minutes during the loading period of 50-60 hours, 5-kg samples of chips are taken, using for the purpose a sampling device which can be pushed in under the stream of chips falling into the feeder supplying the air conveying system. The samples are put in numbered plastic bags and sealed with rubber bands until required for testing. By means of a chip sample reducer (Fig. 81) subsamples of 500 g and 1250 g are obtained, the remainder being discarded.

The 500 g samples are used for determination of dry wood content while the 1250 g samples are used for assessing the chip quality.

There are, usually, in excess of 200 chip samples and these are oven-dried for 16 hours at 105^{o} in aluminium containers adjusted to the same weight to ease the weighing and calculating procedure. The coefficient of variation of dry wood content is about 4 percent, so that 90 percent confidence limits for the average of a shipment are about ± 0.5 percent of the mean result. Thus, because of the variation in dry wood content, the uncertainty in an individual shipment is of the order of ± 40 bone dry units (Warren 1972).

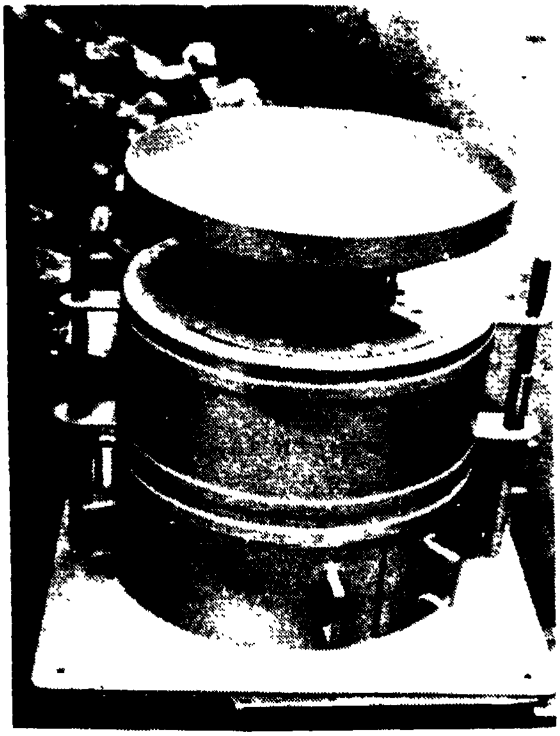


Fig. 81. Chip sample reducer.

Moisture determination by oven-drying and weighing is a simple and reliable method with an accuracy usually within + 1.5 and - 0.7 percent units. A major reason for over-estimation of the moisture content of chips very rich in extractives is due to evaporation of the most volatile components.

Among the many other principles and methods of moisture determination suited for chip trade, capacitance and nuclear methods (neutron and gamma radiation) seem most promising. At some pulpmills continuous chip scales and moisture meters are installed for better cost accounting and digester control. A discontinuous, but automatic, chip-moisture metering system approaching the accuracy of oven drying is described by Preikschat et al. (1974) and Wilhelmsen et al. (1976).

VI. 3.2 Quality

In the chip production and trade, quality is assessed more or less regularly. As test pulping is usually regarded as too tedious and expensive, routine testing of quality is mostly limited to investigations of the chip properties.

Analysis of chip dimensions is commonly done by screening. Different kinds of screening equipment are used, the most common method being screening through plates with circular holes (Fig. 82). The Willian chip classifier, although working by size, does not differentiate between chip length, thickness or width.

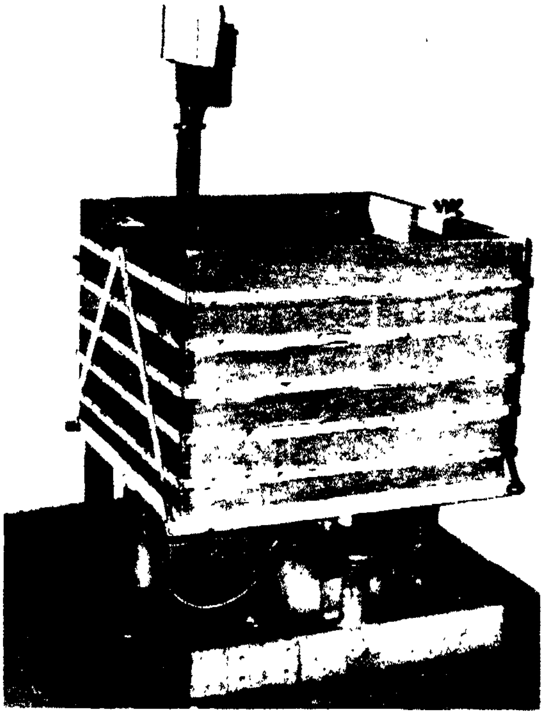
A Swedish method involving slot screening (Fig. 83) is regarded as more suitable, particularly for kraft chips, because it also separates the chips according to nominal chip thickness (Edberg et al. 1971, Hartler and Stade 1975). If the proportion of over-sized chips, pin chips or fines and dust is above agreed-upon limits, this will reduce the chip price. By other agreements the excess weight proportion of such fractions may be deducted from the load weight.

A Canadian chip quality analytical procedure is described by Hatton (1975a, b, 1976). The qualitative evaluation comprises two distinct stages: 1) Mechanical separation of chips into five size fractions (Fig. 84), and 2) Handsorting of the three largest fractions into five fractions. This gives altogether seven fractions: True overs, acceptable chips, bark, knots, decayed wood, pin chips, and fines. Each stage requires about 30-minutes' work; for analyses requiring only screening and bark separation, the time consumption is about 40 minutes.

Bark content and the content of decayed wood are by most analyses determined by hand sorting. Disregarding the inner bark that adheres to the chip, unless the same piece has some outer bark as well, simplifies and speeds up the bark determination. Content of bark and decay is in some places determined in percent of dry weight, in other places on a green weight basis. If the bark proportion exceeds certain specifications, say one percent, the weight proportion of the excess is deducted from the weight of the chips loaded. In other agreements, the price of the chips is reduced dependent upon the bark content. Similar systems are used for decayed chips.

Quality assessment of sawdust is normally done by screening. As an example, some Finnish pulp mills pay full price if the sawdust contains less than 35 percent of the screening fraction less than one mm. With increasing content of this fraction, the price is reduced until fuel value is paid when the fine fraction constitutes 60 percent or more. The price is also reduced with increasing content of bark and other impurities over a certain allowed limit.

In the storing of some unbarked wood such as spruce, tannins from the bark may cause troubles in the sulphite pulping process. Such tannin damage can be localized by colour reactions (methanol-sulphuric acid reaction, ferric sulphate reaction or nitrous reaction).



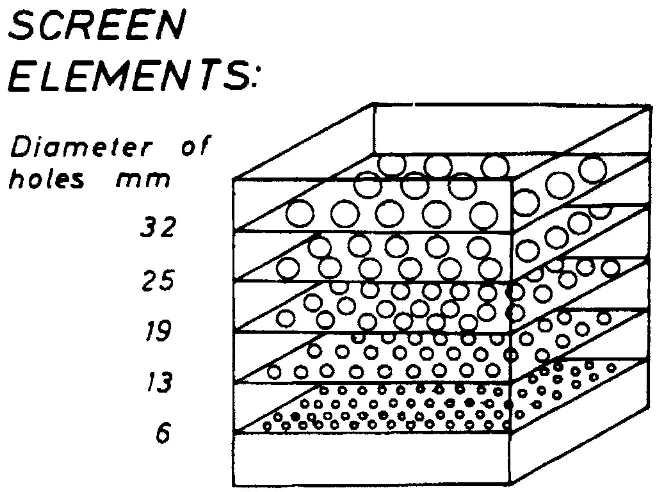


Fig. 82.

The William chip classifier with an illustration of the screen elements. Standardized screen elements with other hole diameters are also used, see TAPPI (1954).

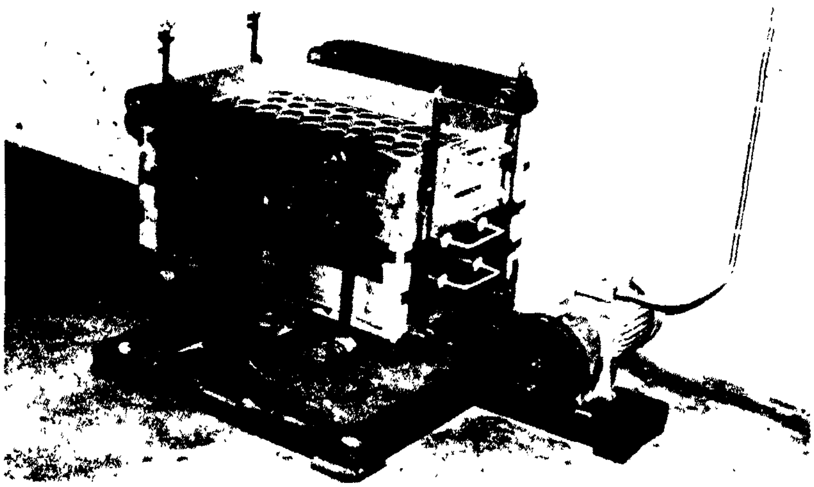
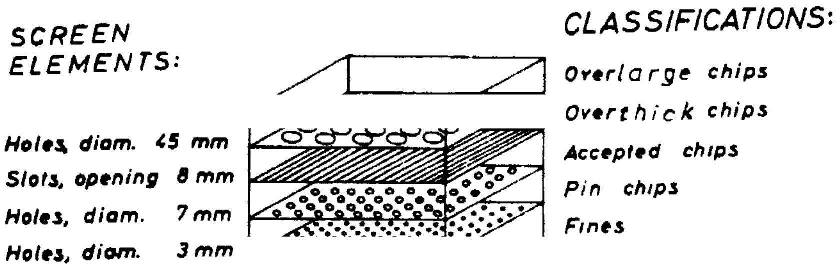


Fig. 83.

A Swedish chip classifier with slot screening. Screen elements and chip categories are illustrated.



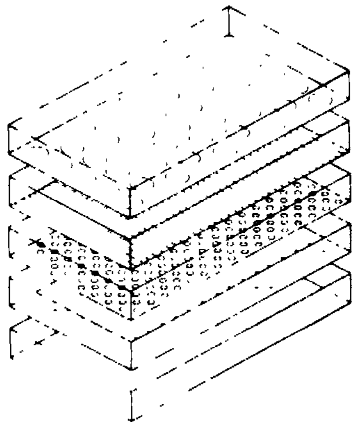


Fig. 84. The WFPL screen elements and chip fractions.

VI. 4 Chip Storing

VI. 4.1 Introduction

There are several factors, alone or in combination, which influence the need for wood storage, Fig. 85 (Wilhelmsen 1972). Some storage of wood may be desirable but usually not in too-large quantities and/or for too long a time.

Reasons for wood storage are:

Ease pressure on men and equipment compared to "hot operations";

Storing evens out differences between mill supply and demand;

The need to have reserves in case of shortage of supply. Uneven supply may be caused by seasonal or climatic limitations, limitations and breakdowns in the transport system, work conflicts, etcetera;

Storing may also be based on financial and economic reasons, to protect the producer against changes in wood prices, to hold the wood as an object of depreciation, to collect capital or else to obtain a more favourable structure of income over a certain period;

Quality improvement as, for example, in sulphite pulp production.

The disadvantages of wood storing are as follows:

Loss of wood substance and extractives;

Higher processing costs (chemicals, electric power);

Decrease of pulp and by-product yield;

Lower quality of the final products;

More handling and higher handling costs;

Tying up of capital and higher interest costs.

Outside chip storage in the pulping industry started on the west coast of the United States in the nineteen-fifties. Since then chip storage has steadily increased mainly because of economic advantages in handling (pneumatic conveying system) compared with roundwood, and also due to the increased use of chips from the mechanical wood industry (sawmills and veneer and plywood mills).

As this form of storage (Fig. 86) has gained acceptance, the accompanying problems and disadvantages have given rise to numerous investigations.

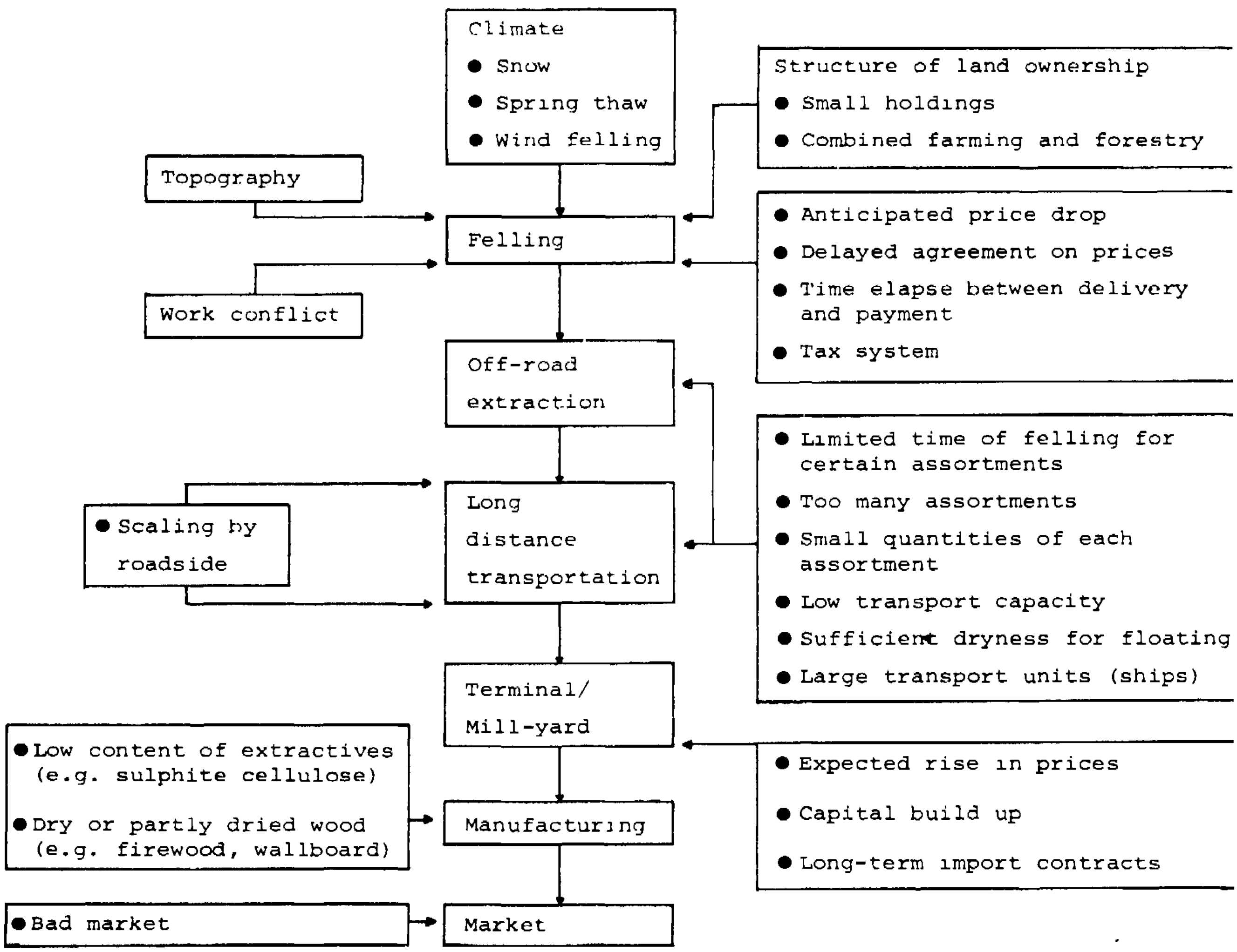


Fig. 85. Causes contributing to wood storage.

.g. 86. Outside chip storage at a Swedish sulphate pulp mill.

As wood units become reduced in size from logs to chips, the surface-to-volume ratio is considerably increased and the buffering effect of a solid wood mass is correspondingly reduced. This causes the environment to exercise a far more pronounced influence, mainly by microbiological and chemical activity.

Relatively little is known about storage of whole-tree chips, and, so far, few reports have dealt with chip storage in tropical conditions.

The storage effects discussed here will deal mostly with general trends. Large variations occur, due to different factors such as wood species, climate, pile size and method of building up the pile. A comprehensive bibliography on changes in wood raw material quality and value during harvesting, transport, and storage has been compiled by Weiner et al. (1974). Chip storage is reviewed by Hajny (1966).

VI. 4.2 Temperature

The temperature in a chip pile depends largely on the air temperature and precipitation, size and compaction of the pile, and the content and distribution of bark and fines. In the central parts of the pile the temperature normally rises 1 - 3°C a day during the first weeks of storage. With further storage it remains about constant for some time and then declines slowly. In chip piles investigated in Sweden and North America, a maximum temperature of between 60-70°C is normal for piles built up in summer. In those stored during winter, the maximum measured temperature has been about 50°C, and the temperature normally varies between 20 - 45°C. The temperature of the outer parts of a chip pile is lower than that of the central part, and is more influenced by the ambient temperature. Fig. 87 (Bergman 1972a) and Fig. 88 (Dillner 1972) show examples of chip pile temperatures. In tropical conditions, maximum temperature is reached soon after accumulation of the chip mass. Fig. 89 shows temperature recordings in chip piles stored in the northwest of Papua New Guinea. The wood was from lowland rain forests and each pile was conical, about 5 m high and with a base 12 m in diameter (Harries et al. 1973).

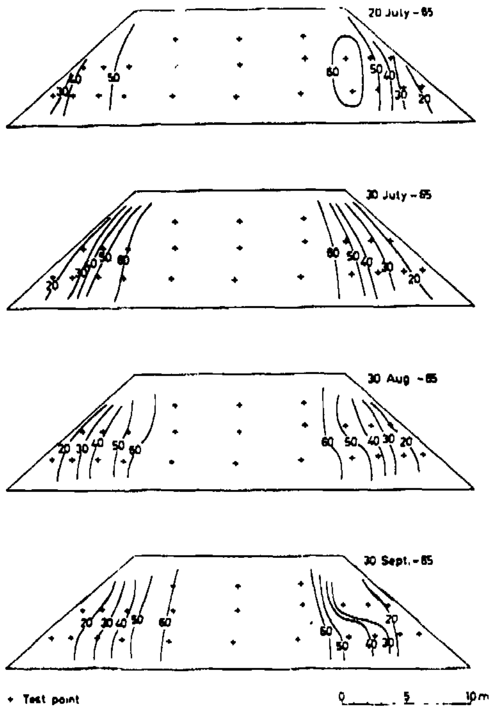


Fig. 87. Isotherms ($^{\circ}C$) in a well compacted pile of pine sawmill chips stored during three summer months in Sweden.

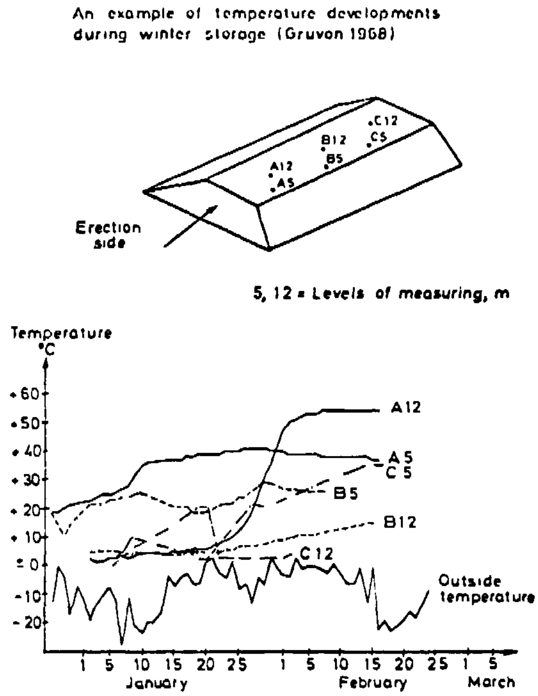


Fig. 88. An example of temperature development in a chip pile during winter storage in Sweden.

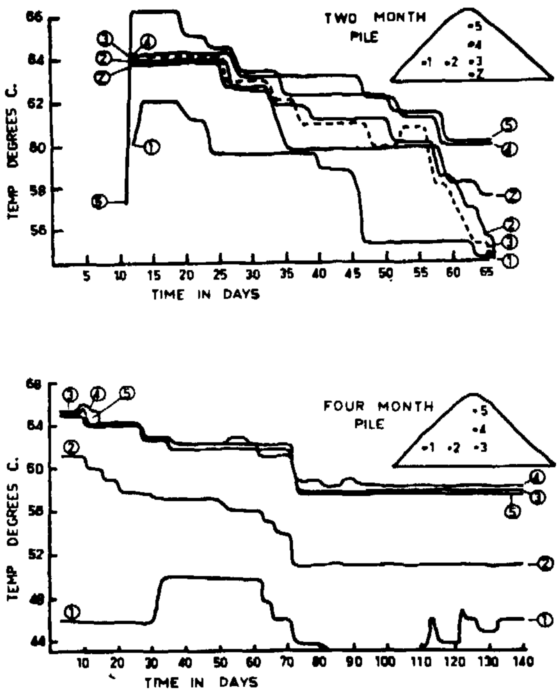


Fig. 89. Internal temperatures in small chip piles stored in tropical conditions.

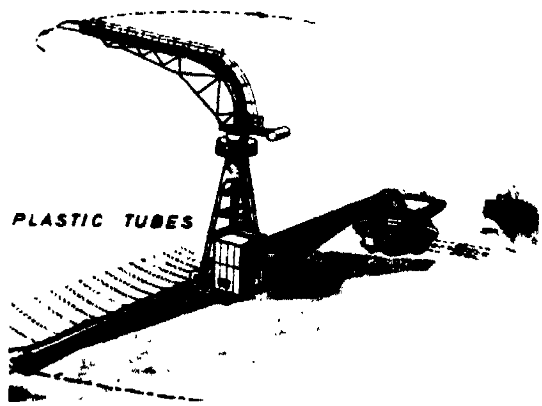


Fig. 90. Introduction of warm air into the pile through plastic tubes at the time of pile build-up.

In winter time in the northern cool temperate zone, large parts of the pile sides may be frozen. The best method of avoiding too extensive freezing of the chips is by introducing warm air (approximately + 35°C) at the bottom of the pile at the time it is built up (Fig. 90).

Some cases of charring or spontaneous ignition of chip piles have been reported (Bergman 1974). Such ignition is most likely to occur in large piles and starts in pockets of fines or bark. In winter 1971, a 250 000-cu m birch pile caught fire in Sweden and about 25 percent of the chips had to be rejected. However, it is regarded as almost impossible to ignite a pile from the outside, owing to the moist outer layers.

The thermogenetic reaction in wood chip piles has been variously attributed to:

The action of living parenchyma cells;

Biological activity of microorganisms (bacteria and fungi);

Chemical oxidation;

Acid hydrolysis of cellulose components.

All these factors have some influence. The initial heat release is caused mainly be respiration of the living parenchyma cells and more or less by bacterial growth. At temperatures above 40°C the living cells gradually die off. The long-term heat evolution is mainly caused by respiration of the fungi, but at temperatures above 45 - 50°C chemical heat-releasing reactions become more and more important.

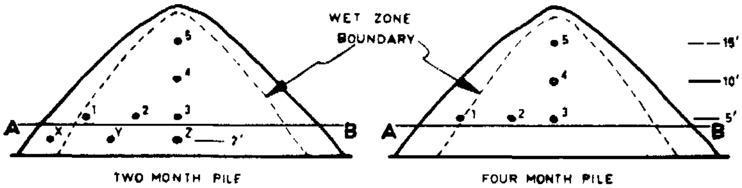
In a chip pile there is a "chimney" effect. Air from the outside is drawn in around the bottom edges of the pile, cools the chips, and is heated as it reaches the centre. The stream of air causes additional evaporation in the wood chips and the warm moist air rises in the pile. Thus both water and heat are transferred upward, giving both higher temperature and moisture content to the upper region of the pile. This air flow contains abundant airborne microorganisms that further accelerate the microbiological population and activity within the pile.

VI. 4.3 Moisture Content

Chips made of fresh wood normally have a moisture content of 40 - 60 percent based on wet weight. In piles stored during summer the chips in the lower part of the pile centre and in the sides become drier. The decrease in moisture is generally about 10 percent units after three months' storage. In piles stored during winter, the chips in the centre of the pile are the driest.

A layer of chips 1 - 2 m thick with a moisture content of about 65 percent usually covers the top of the pile. Much of the water in this layer comes from condensation of water vapour from the lower part of the pile, but precipitation also increases the moisture content. In the slopes of the piles the thickness is in the range of 0.5 - 1 m (Bergman 1972a).

Cases have occurred of small (about 1000 cu m) and uncompacted piles becoming wetter during storage as a result of precipitation (Bergman 1972a). Fig. 91 shows the moisture content in small hardwood chip piles stored in tropical conditions (Harries et al. 1973).



Position in pile	Moisture content (% wet weight basis)		
	Control	2 months	4 months
X	38.3	60.7 (+ 22.4)	—
Y	,,	25.5 (— 12.8)	—
Z	,,	29.6 (— 8.7)	—
1	,,	27.5 (— 10.9)	61.4 (+ 23.1)
2	,,	30.7 (— 7.7)	27.6 (— 10.7)
3	,,	30.4 (— 7.9)	32.0 (— 6.3)
4	,,	34.6 (— 3.7)	31.3 (— 7.0)
5	,,	36.0 (— 2.3)	30.6 (— 7.7)

Figures in brackets are moisture content changes at each position for a given storage period.

Fig. 91.

Moisture content of chip samples before and after storage.

VI. 4.4 Oxygen, Carbon Dioxide and pH

The biological and chemical reactions in chip piles need oxygen and give off carbon dioxide. In experimental chip piles of birch, spruce and pine, high contents of CO_2 and low contents of O_2 have been measured during the first days of storing. After some days, when a more stable air circulation is established, CO_2 content has decreased to about 1 - 6 percent and O_2 risen correspondingly (Fig. 92) (Bergman 1972a).

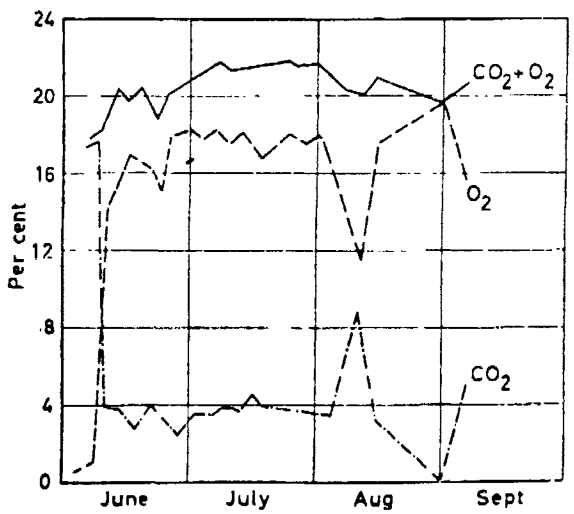


Fig. 92.

The percentage volume of CO_2, O_2 and CO_2 + O_2 measured at the lower centre inside a birch pile.

The pH of the chips often decreases somewhat during storing. Reduced pH is a qualitative indication of chip degradation, but whether a quantitative relationship of practical importance exists between pH and chip degradation is not known.

VI. 4.5 Chip Discoloration

Chips will be more or less discoloured during storage owing to microbiological activity and chemical reactions in the pile. Significant discoloration is caused both by bluestaining fungi, by brown-rotting fungi and also by some thermophilic ascomycetes. Discoloration is often extensive in the hotter areas of the pile with low pH. In addition discoloration may be caused by air pollution such as ash.

VI. 4.6 Microorganisms and Succession in a Chip Pile

The basic types of microorganisms isolated in wood chip piles are:

Bacteria

Yeasts

Stain and mould fungi

Rot fungi

Bacteria and yeasts are isolated in great number. As they are considered to have minor importance in loss of dry matter, they have not been studied in detail.

The staining and mould fungi found in chip piles are comprised of a great number of different ascomycetes, fungi imperfecti and phycomycetes. Several of these are able both to degrade wood and cause discoloration. Among the common isolates are: *Aspergillus fumigatus*, *Aureobasidium pullulans*, *Ceratocystis* spp., *Chaetomium* spp., *Penicillium* spp. and *Phialophora* spp.

The rot fungi are often divided into groups according to wood deterioration: white rots and brown rots. Some rot fungi, however, are difficult to place within these rough categories. Brown rot fungi, belonging to the basidiomycetes, have very rarely been isolated from chip piles within the normal storing period. White rot fungi, also basidiomycetes, are much more important in the decay of wood chips. The most common white rot fungus in Swedish chip piles is *Chrysosporium lignorum*, which can grow even at a temperature of about 50°C.

Detailed information and references regarding microorganisms in stored chip piles are given by Nilsson (1972) and Zielinski (1972).

Wood species, the history of the wood before chipping, size of chips, size of the chip pile, temperature, concentrations of CO_2 and O_2, and not least, interaction among different microorganisms, are all important factors determining the microflora. The chip pile is a complex system in which several of the factors are connected with one another.

Temperature is one of the most important variables. Fig. 93 shows the temperature relationships of different groups of fungi and also gives a rough idea of the distribution of fungi in a chip pile (Nilsson 1972).

It is certain that with increasing storage time and change of temperature, the chip pile undergoes a drastic change or succession in microflora (Smith 1972).

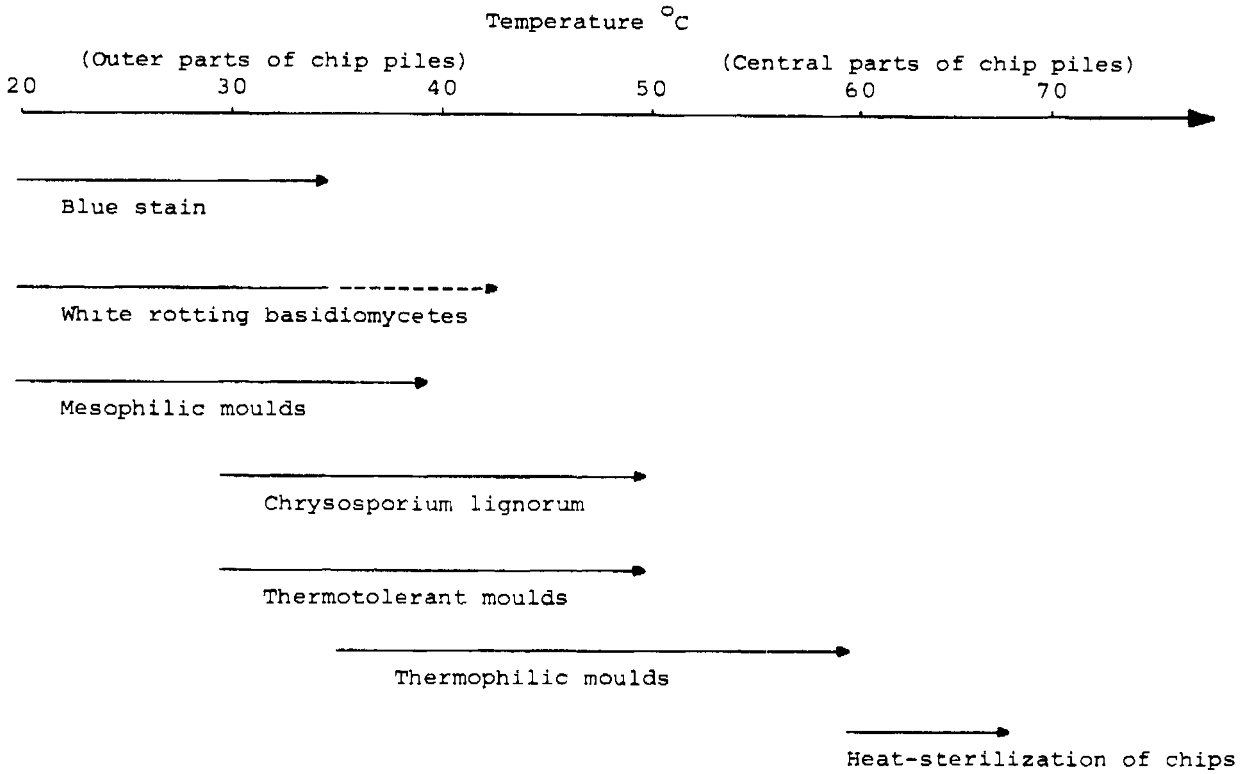


Fig. 93. Temperature relations of some groups of fungi isolated from chip piles.

VI. 4.7 Loss of Wood Substance and Resin

The enzymatic metabolism in the initial storing phase, the microbiological reactions and the chemical reactions at higher temperatures are responsible for most of the deterioration in chip piles.

Wood substance losses are determined as direct loss of dry weight or as loss of wood density. In experiments both methods are often applied, as both are subject to some error.

Chips stored in the temperature range of 20 - 50°C often show greater wood losses than those stored at 50 - 60°C. In summer storage in cool and temperate climates, the most extensively decayed parts are often found in the sides of the pile, while in winter the highest wood losses occur in the centre of the pile. If thermophilic wood-destroying fungi are involved - and they often are - then temperatures of about 50°C are ideal and high wood losses may be found in the warmer parts of the pile as well. Large wood loss variations are thus found within a pile, to a large extent depending on the degrading fungi in action. When the temperature rises above about 65°C, the fungal activity is almost nil; however high temperatures may cause chemical wood deterioration.

In general, the wood loss for the whole pile averages about 0.5 - 1.0 percent a month in cool and temperate climates. Prolonged storage or storage in warm and moist climates often leads to wood losses of 0.75 - 3.0 percent a month. Hardwoods (and particularly soft hardwoods) generally decompose more rapidly than softwoods, although various wood species exhibit different resistance to microbial deterioration. More detailed wood loss figures from different chip storage experiments in cool and temperate climates are given by Bergman (1972b).

Compaction of the chip pile has been reported to reduce the wood loss (Bois et al. 1962).

In Portugal, storage of eucalyptus chips has given the relatively modest wood loss of 4.3 percent after nine months of storage. Unbarked eucalyptus chips gave a remarkable lower wood loss, Fig. 94 (Dillner 1972). Storage of hardwood chips in small piles in a tropical climate (New Guinea) has resulted in average wood losses of approximately 2 and 3 percent after two and four months of storage respectively. Wood losses were much higher near the bottom and outer pile surface than in the central core of the piles (Harries et al. 1973).

Springer et al. (1975a) compared chips from unbarked and debarked red alder logs. Losses of wood substance, pulp yield and pulp strength were essentially the same for both types of chips. The losses after 6-months' storage in chip pile simulators were of such a magnitude that chip storage would probably be impractical without chemical treatment. Whole-tree chips are in some cases reported to have been more rapidly degraded than chips of debarked wood. Two Scandinavian storage experiments with whole-tree chips from young trees of spruce, birch and alder indicate that rather rapid chip degradation may occur. Foliage and bark showed considerably higher dry weight losses than wood (Gislerud 1974, 1976).

In general no changes or only minor relative changes are found in the cellulose, hemicelluloses or lignin content during normal chip storage. However, after 24 months' storage of pine and spruce chips, analyses show that arabinogalactan, xylan and glucomannan are most degraded. Chip samples giving low pulp yield had also considerably increased solubility in hot water and in 1 percent caustic soda (Hatton and Hunt 1972).

The resin content decreases significantly during outside chip storage, Fig. 95 (Dillner 1972). This decrease is greater in pine than in spruce and birch. One to two months of chip storage often give about the same resin seasoning as one year's roundwood storage. The resin decrease is partly explained as being a result of living cell respiration. The remaining resin components are hydrolyzed and furthermore oxidized, giving volatile products and heat. The greatest losses of resin are usually experienced from the hotter central parts of the piles. To a large extent the rapid resin seasoning is a result of temperature-dependent chemical reactions (Hemingway et al. 1971, Rogers et al. 1971). During chip storage fungi may easily be involved in the process of resin maturation, but their relative importance to other biochemical and chemical processes are not known (Smith 1972).

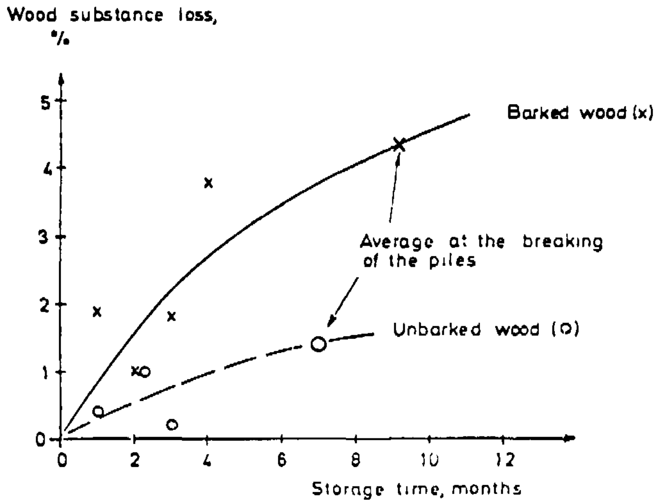


Fig. 94. The development of wood substance losses during storage of *Eucalyptus globulus*.

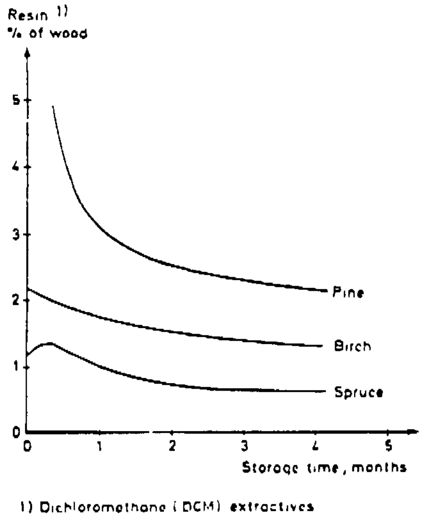


Fig. 95. Change of resin content of wood during outside chip storage.

VI. 4.8 Methods and Means of Reducing Chip Deterioration

Chip deterioration may be reduced by intensive control of chip storing and handling and by chemical and other preservative treatments.

VI. 4.8.1 Improved Chip Handling and Storing

Fines control Every handling of wood chips - more or less - increases the fines content and/or fibre loss and thus reduces the pulp yield. In general, chips are somewhat more friable after outside chip storage than when put into storage. Primarily, bulldozing and pneumatic conveying increase the fines content by physically breaking the chips into smaller pieces. The main factors in pneumatic conveying contributing to size breakdown are impact angle, air velocity and friction. By proper design and installation of the conveying system, the mechanical chip degradation can be brought to a minimum. An example of the alteration in size distribution by handling is illustrated in Fig. 96 (Warren 1972). Chip handling should thus be kept at a minimum.

At the discharge end of pneumatic conveyors the fines slow down more rapidly than the chips, particularly if wind is blowing against the discharge direction. The result is an uneven concentration of fines in the pile and even blankets or pockets of fines. This may lead to difficulties both in obtaining an even thermal distribution and in the digesting process.

Length of storage time Many recommendations are given as to length of storage time, depending on species, climate and pulping process. For kraft mills, storage time should be as short as possible or as few chips as

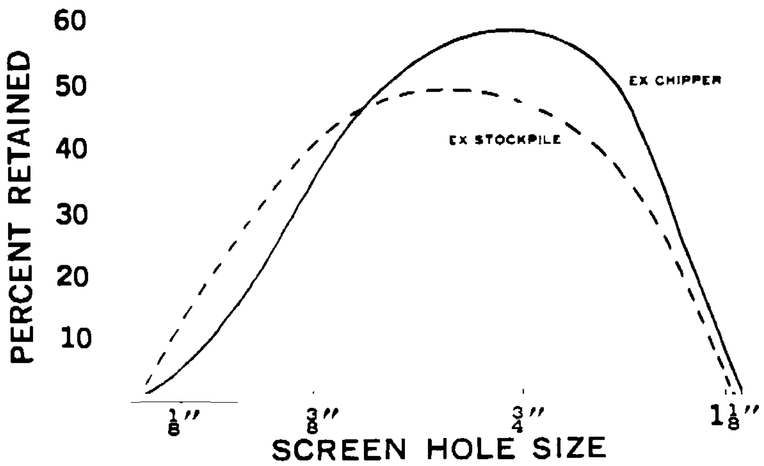


Fig. 96. Chip size distribution before and after handling. The chips are 1) screened immediately after chipping and 2) screened at the entry to the air conveyor during ship loading.

possible should be kept in storage. For a sulphite mill one to three months' storage is sufficient to avoid troubles with pitch.

To keep control of proper storing time for all chips, a first-in — first-out pile system should be applied; for example, chips are deposited at one of the open ends and reclaimed from the other. An example of such storing is the Mo-Do system (see Fig. 64).

VI. 4.8.2 Chemical and other Preservative Treatments

Anaerobic storage Inhibition of oxygen should be a logical method for reducing heat and deterioration in chip piles.

Both douglas-fir and aspen wood chips have been stored under water or in an atmosphere of 95 percent nitrogen and 5 percent carbon dioxide for periods of up to 26 months. Such laboratory storage did not essentially alter chip density or kraft pulp yields and quality (Eslyn and Laundrie 1973, 1975).

Covering the pile with a plastic sheet has proved fairly successful as an O_2 barrier (O_2 level about 1 percent). The temperature increase in the pile was only 2 - 3°C above ambient temperature and chip weight loss 2.3 percent after a 185-day storing period of aspen chips (Feist et al. 1971). Anaerobic conditions are probably fairly expensive to arrange by this method, and during build-up and reclamation, which may proceed over a long period of time, it is not possible to cover the chips.

Water spraying of chips Water spraying of sawlogs and pulpwood is a well-known protective method. The spraying of chip piles during storing is much less favourable. In the southern United States water spraying of chips has been found to offer no advantages over dry chip storage in preserving wood and pulp quality (Bois et al. 1962, Djerf and Volkman 1969). However, spray storage of chips for shorter storing times may reduce wood density loss and loss of pulp strength.

When weighing this against the cost of water spraying and increased processing costs due to the higher-than-normal moisture content of the chips, water spraying in chip storing seems doubtful. The reason why water spraying is less effective for chips than roundwood is probably the difference in microflora. The soft rot fungi which are common in chip piles can tolerate a considerably higher moisture level than the fungi which are common in roundwood (Bergman 1972a).

Chemical preservation Chemicals for prevention or reduction of chip deterioration should meet the following criteria:

Remain effective for the storing time in question;

Cost a reasonable amount in relation to losses incurred from chip deterioration;

Be compatible with the pulping process;

Not be too toxic to personnel and animals or cause pollution.

A large number of chemicals have been evaluated for effectiveness in controlling microbiological degradation of wood chips. Chemicals like chlorinated phenols, and in particular mercuric biocides, reduce wood losses but are unattractive because of pollution and toxic hazards.

Some of the more promising chemical treatments are:

Selective killing of the most harmful staining and decaying fungi has been reported to be achieved with nickel sulphate treatment. American investigations, however, have shown that nickel sulphate had little effect (Springer et al. 1971, Eslyn 1973). The cost of chemicals for the treatment has been estimated at about 25-30 cents per dry ton of chips (Bergman 1972a).

Sodium N-methyldithiocarbamate treatment has been effective in maintaining quality of chips stored for 6 months in pile simulators (Springer et al. 1973a, 1975b). In a pine chip pile, however, the treatment reduced wood substance losses after 2 months' storage, but had little effect after 6 months (Springer et al. 1974). The preservative concentrations were 0.2 - 0.25 percent with a chemical pickup between 0.8 - 1.5 kg/ton of ovendry wood giving a cost of chemicals of about $ 1. Adding other preservative chemicals like sodium 2.4-dinitrophenol to sodium N-methyldithiocarbamate has been an effective and more long-lasting treatment for preserving wood chips (Springer et al. 1973b, 1975a, b). This treatment may be both technically and economically feasible, but further evaluations are necessary.

Borax (2.9 kg/ovendry ton of wood) has rather effectively reduced chip weight loss by laboratory assessment and in simulated piles (Hulme and Hatton 1976a, b), but some irregular results are obtained in practice (Hulme and Shields 1973).

The optimum pH of the wood-destroying fungi is between 5 and 6, and either increasing the pH with alkalis or decreasing the pH with acids is possible. Cooking chemicals like kraft green liquor (sodium sulphide and sodium carbonate mixture), white liquor, and sodium hydroxide have been applied. Laboratory tests and results from chip pile simulators with application of green liquor are relatively promising (Springer et al. 1969, 1971, Feist et al. 1974). An experiment by Springer et al. (1974) on pretreatment of loblolly pine chips with green liquor gave an average wood loss of 2.7 percent due to treatment, but negligible losses occurred during the first 2 months of storage (Springer et al. 1974). Some loss occurred, however, after 6 months' storage. The treatment had no beneficial effect on overall yield or strength of kraft pulps, but untreated control chips were also little affected by storage. Sulphide-containing chemicals may possibly give an undesireable odor of hydrogen sulphide, but this experiment did not result in the release of quantities constituting a pollution hazard.

The advantages of applying chemicals that reduce deterioration, pulping makeup chemicals, screen rejects, and that shorten cooking time are discussed by Hulme and Hatton (1976a).

Application of preservative chemicals may be carried out by immersing the chips in the treating solution and using a rake or screw conveyor to remove the chips. A simpler method is to spray the chips through a nozzle inserted between the feeder and blower of a pneumatic conveying system. It may be advantageous to treat the chips in an equalizing bin between the chipper and the feeder to reduce the cloud of preservative droplets at the discharge end.

At a wood value of $ 40 a dry ton of chips, a wood loss of 4 percent balances a treatment cost of $ 1.60 per ton. When chip storage is undertaken as insurance against temporary supply shortages, or long-time storage is otherwise necessary, much higher treatment costs can be afforded.

Chemical preservation of wood chips during storage seems at present to be applied to a very limited extent.

Biological protection of chips by means of antagonistic microorganisms relatively harmless to wood needs more research before such methods can be put into practice.

VI. 4.9 Pulping Experiences with Stored Chips

The major pulping methods in terms of pulp production are sulphate pulping, mechanical pulping, sulphite pulping, and semi-chemical pulping.

Refiner mechanical pulping - with or without chemical pretreatment - and particularly thermomechanical pulping of wood chips is drawing considerable attention, mainly due to higher yields and less pollution than chemical pulping. Few reports cover storage of chips for mechanical pulping, but a general recommendation is to process the chips with a minimum of delay, particularly to avoid losses in brightness.

Basic research on biological prepulping or pulping with application of microorganisms has given interesting results (Eriksson 1974, Ander and Eriksson 1975a, b), but have not yet resulted in practical application. However, several mills produce alcohol or protein from mill residue by biological processes.

VI. 4.9.1 The Sulphite Process

The processing of stored chips does not differ much from that of log-stored wood. A long storage time at high temperature may, however, cause lignin condensation, which will lead to longer cooking time and also cause some reduction in yield. Heavily deteriorated wood chips will usually also give a somewhat reduced yield. The real pulp loss owing to storing is a product of loss in wood density and loss of pulp yield. However, the pulp yield based on digester input is generally not significantly changed, as is exemplified in Table 3. These data are extracted from three different storage experiments with spruce (Dillner 1972).

Table 3. Pulp yields and pulp properties from green and stored spruce.

Data of sulfite paper pulps from green and stored spruce

	Storage time months	Unbleached pulp, Roe no 5 Yield, % of wood	Resin,[1] %	Brightness, % SCAN	Bleached pulp Yield, % of wood	Resin,[1] %	Brightness, % SCAN
A Laboratory pulps (10)							
Green wood	0	52.2	1.30	64	49.1	1.30	92.5
Chip stored wood	1	52.3	0.86	55	48.6	0.63	93.5
-"-	4	51.8	0.82	50	49.3	0.47	92.5
-"-	13	52.6	0.73	48	48.1	0.48	93.5
Log stored wood	12	51.9	1.00	62	49.2	0.55	93.0
-"-	24	52.4	0.67	61	49.2	0.50	92.5
B Mill pulps (Billeruds Bruk 1971)							
Green wood	0-1		1.45	65		1.39	87.4
Chip stored wood	2-3		1.04	57		0.96	86.1
Log stored wood	ca 12		1.09	63.5		0.97	84.0

[1] Ethanol extractives in part A
DCM - - -"- B

An important change is, however, the rapid decrease in brightness of unbleached pulp, Fig. 97 (Croon and Frisk 1972). This decrease is too large to be accepted for unbleached pulp, but the pulp does not cause any difficulty in bleaching.

The most important change is the rapid decrease of the resin content, both in unbleached and especially in bleached pulps. This is a result of both the resin decrease in the wood and of chemical changes in the remaining resin, making it partly dissoluble in the cooking and bleaching processes. The change of resin content in bleached sulphite viscose pulp during storage is seen in Fig. 98 (Dillner 1972).

Besides the quantitative reduction of resin content of pulp during wood storage, there is a qualitative effect. Because of the oxidation of fatty acids there will be less tendency to chlorination of the resin. This is an important factor both for the quality of viscose pulp and in paper production. In viscose pulp chlorinated resin will give harmful particles, and in paper mills the very sticky chlorine-rich resin will to a large extent be responsible for pitch problems (Dillner 1972).

Some results of sulphite and high-yield neutral sulphite pulping experiments of hardwoods are shown in Table 4 (Dillner 1972). The decrease in pulp brightness is quite drastically reduced with increasing time of chip storage, but no problems in bleaching the pulp were observed. There were even quite considerable savings in the requirement for bleaching chemicals.

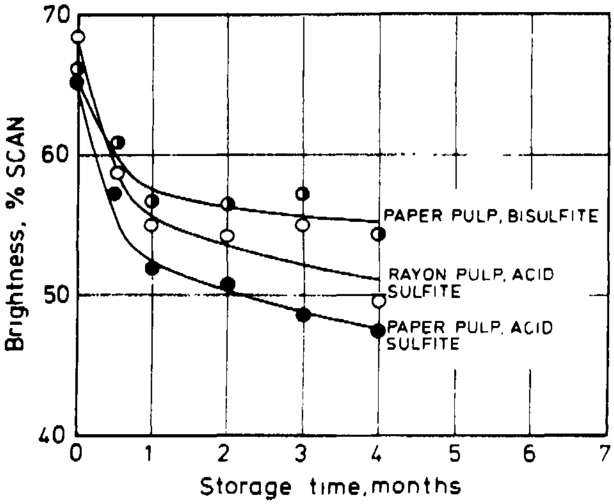


Fig. 97. Decrease in brightness as a consequence of storage time.

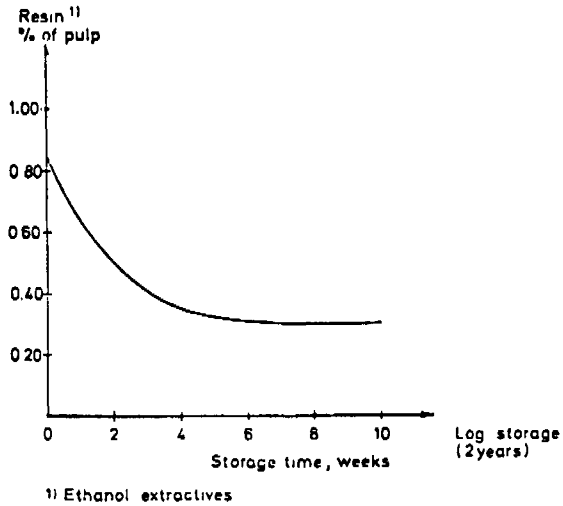


Fig. 98. Outside chip storage of spruce. Influence of storage time on the resin content of bleached sulphite viscose pulps.

Investigations of the strength properties of sulphite pulps are not very conclusive, but the general conclusion seems to be that the pulps are not much affected under reasonable storage conditions.

Table 4. A comparison of laboratory sulphite pulps from green and stored birch.

	Storage time months	Unbleached pulp			Bleached pulp		
		Yield, % of wood	Resin,[1] %	Brightness, % SCAN	Yield, % of wood	Resin,[1] %	Brightness, % SCAN
A Sulfite viscose pulp							
Green wood	0	43 5	4 30	56	39 5	2 70	93 0
Chip stored wood	1	45 0	2 65	34	38 3	0 40	96 6
-"-	1 5	45 0	2 55	40	38.9	0 10	96 8
Log stored wood	12-24	45 0	1 90	40	39 1	0 20	96 5
B NSSC pulp, 83% yield							
Green wood	0		0 50	53			
Chip stored wood	1		0 15	44			
-"-	1 5		0.10	39			

[1] Ethanol extractives in part A
DCM -"- -"- B

A couple of Scandinavian sulphite pulp mills have recently installed chip silos for artificial resin maturation. Warm air is introduced into the silo; and temperature, moisture, and oxygen content are controlled. The retention time of the chips in the silo is normally 2 - 4 days. Preliminary results seem quite promising. Such a chip treatment will probably lead to less need for roundwood or chip storage.

VI. 4.9.2 The Sulphate Process

According to North American and Scandinavian investigations (Bergman and Nilsson 1966, 1967, 1968, Hatton and Hunt 1972), the kraft pulp yield based on oven-dry wood weight fed into the digester is essentially unchanged after two to three months of outside chip storage. Further storage, say up to about six to nine months, has for spruce usually given a slightly reduced yield while yields of pines and hardwoods have usually shown small changes (± 1 percent). A slight increase in pulp yield is not unexpected. This can be ascribed among other factors to loss of resin, which is mostly dissolved during pulping.

Mixed tropical hardwood chips stored for 2-4 months at Papua New Guinea, gave NSSC and kraft pulps that deviated relatively little in terms of yields and quality from pulps of unstored chips. An exception was chips in wet zones near the surfaces of the piles (Phillips and Logan 1973).

Prolonged chip storage - 24 months - reduced a pulp yield by roughly 2 - 5 percent units. However, large variations occurred within the chip pile; screened yields as low as 37.7 percent for spruce and 30.1 percent for pine were recorded. Corresponding values for unstored chips were 47.7 and 43.6 percent, respectively (Hatton and Hunt 1972). Red alder chips stored 6 months in chip pile simulators have had overall pulp yield losses of about 12 percent, and substantial decreases in burst and tear strength (Springer et al. 1975a).

Laboratory experiments show that sterilized chips stored at elevated temperatures may be severely degraded by the action of heat and moisture. After 3 months of storage at 65°C, pulp yields can have been reduced by more than 20 percent, accompanied by a reduction in pulp quality (Feist et al. 1973, 1974). However, temporary storage of fresh, unsterilized hardwood chips at temperatures near 60°C is in another experiment (Hulme and Hatton 1976b) shown to have improved overall screened digester yields by conditioning the chips and making them easier to pulp.

In the kraft process, chip storing has an unfavourable effect on the yield of such valuable by-products as turpentine and pine oil (tall oil) (Hajny 1966). The turpentine content of pine chips stored in South Carolina was reduced to about 25 percent after two months' storage (Springer et al. 1974).

In a Swedish investigation, the tall oil yield decreased rapidly, as illustrated in Fig. 99 (Dillner 1972). Considerable reductions in tall oil yield are also reported by Springer et al. (1974, 1975b).

The decrease in pine oil yield is a result not only of the disappearance of resin in the wood, but also of the chemical changes in the remaining resin, which becomes more water-soluble after oxidation and cannot be separated from the black liquor after kraft cooking.

The resin content of the kraft pulps, however, does not necessarily decrease when stored chips are used as raw material. In birch pulp a slight decrease in resin is observed, but in pine there is a contrary change (Dillner 1972).

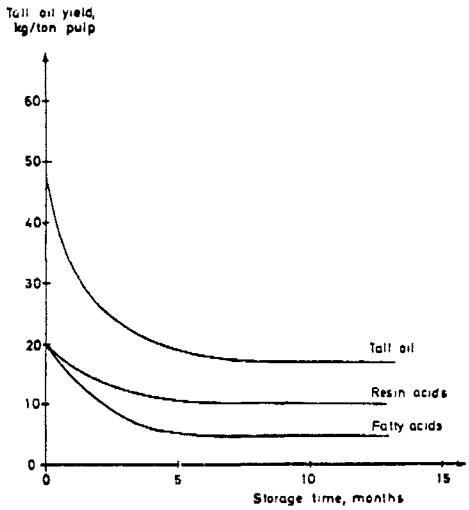


Fig. 99.

Outside chip storage of pine. Influence of storage time on the tall oil yield from kraft cooking.

The strength properties of kraft pulp usually decrease somewhat with increasing storage time of the chips. In Sweden a decrease in the tear strength of about 10 percent has been found when the chips were stored for several months at a temperature of 24 - 30°C. Other strength properties decreased only 5 - 7 percent (Bergman and Nilsson 1966). A storage period of 24 months in northern America has given great pulp strength variation within the pile. The reductions in burst and tear strength were up to 10 - 15 percent for spruce and 25 percent for pine (Hatton and Hunt 1972). In the southern United States mean strength reductions of 5 percent a month are reported (Hajny 1966).

Thus it seems safe to conclude that in kraft pulping, outside chip storage gives no advantages in pulp yield or quality. On the contrary the reductions in yield and quality have to be balanced against advantages in handling and transport.

VI. 4.10 Economic Considerations

Every mill operation is unique, and minimizing the cost of raw material per unit of the finished product requires a separate and more or less continuous analysis for each mill.

Wood storage is just one of the many links in the handling and transport chain from the forest to the end product - but an important one. A clear understanding about factors that cause changes in the quantity and quality of the wood raw material is needed. The industry must recognize and try to determine the losses caused by deterioration during handling and storage.

An indication of the economic consequences of poor chip quality is given in Table 5 (Croon and Frisk 1972).

Table 5. Estimated economic consequences of poor chip quality in comparison with "perfect" chips.

		dollars/ton	loss of tonnage %
Poor handling performance:	screenings, transporting low digester filling	0 - 0.2	0 - 1 0 - 3
Poor processability (plugging of strainers etc):	batch kamyr		0 - 3 2 - 10
Discarding of fines		0 - 1	
Low yield due to:	uncooked chips - screenings overcooked chips	0.4 - 4 0 - 3	0 - 10
Poor strength properties of pulp:	market pulp pulp for own use	0 - 1 0 - 3	
Poor cleanliness:	increased production costs complaints and downgradings	0 - 0.4 0 - 1	0 - 3
		0.4 - 12.6	2 - 27

When pulp yield loss due to storage is estimated, this must be based both on pulp yield of the stored wood as well as reduction of the wood weight during storage, since it is possible to experience large losses in either without large losses in the other. Other factors that must be evaluated include changes in processing capacity, changes in product quality and yield of by-products.

Chip handling at the mill-yard is usually space-saving, labour-saving and cheaper compared to handling of roundwood.

Some chip handling costs are given by Croon and Frisk (1972):

The total chip handling costs from the receiving bin to the digester room at five different mills in Sweden gave a mean of $ 0.70 per ton of dry chips (see Table 6). Comparable figures for roundwood storage amounted to $ 1.50, which means that direct chip handling costs were about half that of roundwood. Since then, more effective methods for log handling and storing are also developed, e.g. log booms storing the logs in a circle or in two semi-circular rows.

The installation cost for a complete outside chip storage system at a 600-ton-per-day mill is $ 600 000 - 900 000. Of this, a cost of $ 35 000 is estimated for the chip pile base, excluding the base itself. Concrete 6 in thick, complete with mesh, costs $ 13.00 per sq. m. Asphalt on 4 in of macadam over a 6-in gravel base, costs $ 7.00 per sq. m. A good pneumatic transport system to, on and from the pile costs $ 250 000 - 400 000 and reclaiming devices of reliable construction cost about $ 40 000.

Table 6. Cost of chip handling at five Swedish mills, cents per ton of dry wood.

Mill	Costs before depreciation						Depreciation and interests	Total
	Wages	Tractor rent	Material	Maintenance	El.power	Total		
A	9.5	12.0	0.7	5.6	5.6	33.4	55	88
B	19.0	10.0	6.0	6.5	1.5	43.0	23	66
C	9.0	1.0	3.0	7.0	9.0	29.0	27	56
D	13.3	2.2	6.7	4.4	15.5	42.1	49	91
E	3.9	0.4	1.9	5.5	1.8	13.5	36	50
								70 ± 20

Insurance for outside chip storage is estimated to be one-third that of roundwood storage.

A fair-sized sulphite mill, storing wood for seasoning of resin, may, on introduction of chip storage, lower its inventory to less than half. This means that perhaps $ 5 million can be released for other investments. Furthermore, interest costs are cut by about 50 percent.

The reduced transport and handling costs must be weighed against the possible increased loss in pulp yield and quality. For kraft pulp mills the losses of turpentine and pine oil must also be considered.

VII. SOME TERMS USED IN WOOD CHIPS TRADE

Bone Dry Unit

The bone dry unit (BDU) is a transaction unit for the transport of chips by ship. One BDU is 2 400 lbs. of dry wood (dried to 0 percent moisture at 103^{o}C for 24 hours).

A BDU is not concerned with the original green weight nor the volume of chips required to make the 2 400 lbs. dry weight. Species with high specific gravity will normally require less volume than lighter species. The BDU derives from an earlier common method of purchasing sawmill waste and is said to be equivalent to one cord of stacked douglas fir sawmill slabs.

Bone Dry Ton

One bone dry ton (BDT) is one ton of dry wood (dried to 0 percent moisture at 103^{o}C for 24 hours). It must be made clear whether it means metric ton, short ton, or long ton.

1 metric ton	= 1.1023 short ton	= 0.9842 long ton	= 1000 kg
1 short ton	= 0.8929 long ton	= 0.9072 metric ton	= 2000 lbs.
1 long ton	= 1.0160 metric ton	= 1.12 short ton	= 2240 lbs.

Moisture Content

There are two ways of stating moisture content, depending on whether it is calculated on a dry weight or a green weight basis:

$$1)\quad M = \frac{\text{Wet weight - Dry weight}}{\text{Dry weight}} \cdot 100$$

$$2)\quad M = \frac{\text{Wet weight - Dry weight}}{\text{Green weight}} \cdot 100$$

When moisture content is discussed, it should be made clear on which basis it has been calculated. Normally, the pulp and paper industry calculates it on a green weight basis, whereas the wood-working industry uses dry weight.

Basic Density

Basic density is the oven dry weight divided by the green volume, often expressed as kg/cu m.

Compaction

$$C = \frac{\text{BDU} \cdot 200 \cdot 100}{\text{available cubic feet}}$$

100 percent compaction means 1 BDU per 200 cubic feet space.

Relative Solid Volume

The relative solid volume of chips (or logs) is the solid volume of the chips divided by its loose wood volume. The relative solid volume can also be expressed in percent, sometimes called the compaction rate.

Fluffing Factor

The "fluffing factor" $f = \frac{\text{total volume occupied}}{\text{volume of solid wood}}$

f = 2.5 - 2.8 for uncompacted "fluffy" chips and 2.1 - 2.3 for well-loaded chips. The relative solid volume = 1/f.

Stowage Factor

The stowage factor can be defined by the following formula:

$$Sf = 22.4 \cdot (V/V_w) \cdot (100 - M)/d$$

where, Sf is the stowage factor in cubic feet per long ton

V is the total volume occupied by the chips

V_w is the volume of the solid wood

M is the moisture content as percent of the green weight

d is basic density in lb./cubic foot (dry weight/green volume)

A simpler explanation is that the stowage factor is the total hold capacity in cubic feet occupied by a stowage of one long ton of a cargo (e.g. chips).

VIII. LIST OF REFERENCES BY CHAPTERS

II. The Demand and Supply of Raw Materials from the Forest

FAO 1975a. Yearbook of forest products. Review 1962-1973. Rome. 371 p.

FAO 1975b. An assessment of pulp and paper production and demand trends, 1975-79. FO: PAP/75/Inf. 5/Rev. 1.

Glesinger, E. 1949. The coming age of wood. Simon and Schuster, Inc. New York. 279 p.

Keays, J.L. 1975. Projection of world demand and supply for wood fiber to the year 2000. Tappi 58 (11): 90-5.

Keays, J.L. and Hatton, J.V. 1975. The implication of full-forest utilization on worldwide supplies of wood by year 2000. Pulp & Paper International 17 (6): 49-52.

Persson, R. 1974. World forest resources. Review of the world's forest resources in the early 1970:s. Stockholm. Rapp. Inst. Skogstaksering, Skogshögsk. 17: 265 p.

Persson, R. 1975. Forest resources of Africa. An approach to international forest resource appraisals. Part I: Country descriptions. Stockholm. Rapp. Inst. Skogstaksering, Skogshögsk. 18: 294 p.

Segerström, G. 1971. Observations on the flow pattern of forest products trade. FAO/SWE/TF 53: 52-61.

Seip, H.-K. 1972. FAO/NORAD Symposium on production, handling and transport of wood chips. Keynote speech. FAO/NOR/TF 83: 5-8.

Stone, R.N. and Saeman, J.F. 1976. Future world demands and cost of supply of timber products. XVI IUFRO World Congress, Proc. Division V: 11-23.

Thune-Larsen, E. and Luhr, F. 1972. A comparison between utilizing wood from industrial countries (Scandinavia) and plantation forests (eucalyptus). FAO/NOR/TF 83: 80-93.

Young, H.E. 1974. Complete-tree concept: 1964-1974. Forest Prod. J. 24: 13-6.

III. International Trade in Wood Chips

Anonymous. 1972. Impressive start to Tamar woodchip project. Appita 26: 88-9.

Forestry Commission. 1976. Woodchip Symposium Papers. 47th ANZAAS Congress, Tasmania.

Lembke, C.A. 1974. New era for PNG forest industries. Repr. Australian Forest Industries Journal 40 (7): 19 p.

Marstrand, T. 1972. Cheap chips by ships to the Japs. Norsk Skogind. 26: 271-2.

Ministry of Agriculture and Forestry. 1973. "Basic plan regarding forest resource" and "long range prospect regarding demand and supply of important forest products". Japan. 56 p.

Nordin, A.L. bin and Ismail, H. bin. 1970. Utilization of rubber wood and waste from primary wood-based industries for chips. The Malayan Forester XXXIII (4): 334-41.

Ruderman, F.K. 1976. Production, prices, employment, and trade in northwest forest industries. 1st quarter 1976. Pacific Northwest Forest and Range Experiment Station. Portland, Oregon. 52 p.

Seip, H.-K. 1972. FAO/NORAD Symposium on production, handling and transport of wood chips. Keynote speech. FAO/NOR/TF 83: 5-8.

Warner, D.W. 1975. Current and future trends in North American marine transportation. In: Transport and handling in the pulp and paper industry. Volume 1. Proc. first PPI International Symposium. Miller Freeman Publications, Inc., San Francisco. 336 p.

White, V.S. 1972. Japan's search for more fiber has impact around the world. World Wood. 13 (11): 42-6.

Yoshida, M. 1972. The wood chip industry in Japan and the present status and prospects of the wood chips trade. FAO/NOR/TF 83: 308-13.

IV. Conversion to Chips

Arola, R.A., Sturos, J.A. and Mattson, J.A. 1976. Research in the quality improvement of whole-tree chips. Tappi 59 (7): 66-70.

Auchter, R.J. 1976. Prospectus for research and development proposals. Tappi 59 (7): 6-8.

Binns, W.O. 1975. Whole tree utilization - consequences for soil and environment - experience and opinion in Britain. Konferens SK 2, Elmia 75, Jönköping, Sweden. 18-25.

Boyle, J.R. 1976. A system for evaluating potential impacts of whole-tree harvesting on site quality. Tappi 59 (7): 79-81.

Boyle, J.R., Phillips, J.J. and Ek, A.R. 1973. "Whole tree" harvesting: nutrient budget evaluation. J. For. 71 (12): 760-2.

Christensen, E. 1976. Advancing the state-of-the-art in screening bark-free and non-bark-free chips. Tappi 59 (5): 93-5.

Croon, I. and Frisk, E. 1972. Handling of logs and chips at pulp mills. FAO/NOR/TF 83: 227-32.

Deal, E.L. 1976. Whole tree harvesting by chipping methods in North America. ECE/FAO/ILO Symposium on the harvesting of a larger part of the forest biomass. TIM/EFC/WP. 1/SEM. 3/R. 5. 13 p.

Erickson, J.R. 1972a. Field chipping: problems and solutions. FAO/NOR/TF 83: 128-38.

Erickson, J.R. 1972b. The status of methods for debarking wood chips. Tappi 55: 1216-20.

Erickson, J.R. 1976. Sorting whole-tree and branch chips for industrial use. ECE/FAO/ILO Symposium on the harvesting of a larger part of the forest biomass. TIM/EFC/WP. 1/SEM. 3/R. 4. 8 p.

FAO. 1959. Catalogue of portable wood chippers. Forestry Equipment Notes. Rome. 27 p.

FAO/ECE/LOG/98. 1962. Portable and semiportable wood chipping machines. Part I. Uses of chipping machines and wood chips.

FAO/ECE/LOG/161. 1965. Portable and semi-portable wood chipping machines. Part II. Information on chipping and the yield and cost of chipping.

FERIC. 1975. Progress report on work program.

FO - FAO/ECE/LOG/162. 1966. Symposium on mechanical barking of timber.

Gislerud, O. 1974. Whole tree utilization. II. Biomass and biomass properties of trees from thinnings of spruce, pine, birch, and alder. NISK, Skogtekn. avd. Rapport 6/74. 59 p.

Gislerud, O. and Tveite, B. 1973. Whole tree utilization. I. A literature study on raw material quantities and raw material properties of spruce, pine and birch with particular weight on smallsized trees. NISK. 74 p.

Grantham, J.B. 1974. Status of timber utilization on the Pacific Coast. USDA Forest Service, General Technical Report PNW-29. 42 p.

Grantham, J.B., Estep, E.M., Pierovich, J.M., Tarkow, H. and Adams, T.C. 1974. Energy and raw material potentials of wood residue in the Pacific Coast States - a summary of a preliminary feasibility investigation. USDA Forest Service, General Technical Report PNW-18. 37 p.

Hakkila, P. 1969. Weight and composition of the branches of large Scots pine and Norway spruce trees. Comm. inst. for. fenn. 67.6. 37 p.

Hakkila, P. 1971. Coniferous branches as a raw material source. Comm. inst. for. fenn. 75.1. 60 p.

Hakkila, P., Kalaja, H. and Mäkelä, M. 1975. Full-tree utilization as a solution to the problem of small-sized trees. Folia Forestalia 240. 78 p.

Harrison, R.T. 1975. Slash-equipment and methods for treatment and utilization. USDA Forest Service. ED & T Report 7120-7. 47 p.

Hartler, N. 1972. Chips for industrial use. FAO/NOR/TF 83.

Hartler, N. 1975. Rapport om flisrening i Nordamerika 1975. Projekt Helträdsutnyttjande. Stockholm. 29 p.

Jorgensen, J.R., Wells, C.G. and Metz, L.J. 1975. The nutrient cycle: key to continuous forest production. J. For. 73 (7): 400-3.

Keays, J.L. 1971a. Complete-tree utilization. An analysis of the literature. Part I: Unmerchantable top of bole. Canadian Forestry Service. Forest Products Laboratory. Information report VP-X-69. 98 p.

Keays, J.L. 1971b. Complete-tree utilization. An anlysis of the literature. Part II: Foliage. Canadian Forestry Service. Forest Products Laboratory. Information report VP-X-70. 94 p.

Keays, J.L. 1971c. Complete-tree utilization. An analysis of the literature. Part III: Branches. Canadian Forestry Service. Forest Products Laboratory. Information report VP-X-71. 67 p.

Keays, J.L. 1971d. Complete-tree utilization. An analysis of the literature. Part IV: Crown and slash. Canadian Forestry Service. Forest Products Laboratory. Information report VP-X-77. 79 p.

Keays, J.L. 1971e. Complete-tree utilization. An analysis of the literature. Part V: Stump, roots and stump-root system. Canadian Forestry Service. Forest Products Laboratory. Information report VP-X-79. 62 p.

Kreutzer, K. 1975. The effect of economizing on nutrient economy in central European forests. Konferens SK 2, Elmia 75, Jönköping, Sweden.

Kreutzer, K. 1976. Effect on growth in the next rotation (regeneration). ECE/FAO/ILO Symposium on the harvesting of a larger part of the forest biomass. TIM/EFC/WP. 1/SEM. 3/R. 15. 12 p.

Lapointe, J.A. 1973. Chip quality improvement program. The design and operation of disc chippers. Domtar Research Centre. Senneville, Quebec. 30 p.

Mattson, J.A. 1975. Debarking chips from whole trees in the Lake States. USDA For. Serv. Res. Pap. NC-115. 9 p.

McKenzie, W.M. 1970. Choosing your chipper. Chipping for pulp production. Div. For. Prod. Repr. CSIRO, Aust. No. 834. 21-31.

Mälkönen, E. 1975. Whole tree utilization - consequences for soil and environment. Experiences from Finnish research and practice. Konferens SK 2, Elmia 75, Jönköping, Sweden. 26-30.

Mälkönen, E. 1976. The effect of fuller biomass harvesting on soil fertility. ECE/FAO/ILO Symposium on the harvesting of a larger part of the forest biomass. TIM/EFC/WP. 1/SEM. 3/R. 6. 9 p.

Nykvist, N. 1974. Växtnäringsförluster vid helträdsutnyttjande. En samanställning av undersökningar i gran- och tallbestånd. Rapp. Inst. Skogsteknik, Skogshögsk. 76. 74-93.

Palenius, I. 1976. The state of whole-tree utilization in Scandinavia. Tappi 59 (7): 72-4.

Papworth, R.L. and Erickson, J.R. 1966. Power requirements for producing wood chips. Forest Prod. J. 16 (10): 31-6.

Parker, F. 1975. Recognized disk chipper design and chip production differences - millyard chippers compared to mobile field chippers. 1975 TAPPI Alkaline Pulping Conference. 81-3.

Plummer, G.M. 1976. Uses and potential productivity of whole-tree chippers. Tappi 59 (7): 64-5.

PPRIC. 1975. The separation and segregation of bark from chips. Logging research progress report. No. 46: 1-4.

Ranhagen, G. 1973. Influence of chip quality on pulp quality. Good chips for good paper pulp and how to achieve it. Aktiebolaget Karlstads Mekaniska Werkstad. 13 p.

Ranhagen, G. 1974. Influence of chipper geometry on chip quality and resulting pulp. Paper Trade J. 158 (4): 20-3.

Ribe, J.H. 1973. Puckerbrush weight tables. Agr. Exp. Sta., Univ. of Maine. Misc. Rep. 162. 92 p.

Snow, R.W. 1976. Chip washing. TAPPI Annual Meeting. Preprint. 27-8.

Tamm, C.O. 1975. Losses of plant nutrients and other adverse effects of full tree logging. Konferens SK 2, Elmia, Jönköping, Sweden. 5 p.

Thommesen, O. 1972. Evaluation of investments and returns by employing different chip production systems. FAO/NOR/TF 83: 322-34.

USDA. 1972. Report of close timber utilization committee. Forest Service. 73 p.

USDA. 1975. Stretching the Nation's timber. Forest Service. Current Information Report No. 15. 14 p.

Weiner, J. and Pollock, V. 1972. Barkers and barking of pulpwood. The Institute of Paper Chemistry. Bibliographic Series, Number 190, supplement II. 56 p.

Young, H.E. 1975. Utilization of forest residues - a segment of the complete tree concept. Complete Tree Institute, Univ. of Maine. 6 p.

Young, H.E. 1976. A summary and analysis of weight table studies. XVI IUFRO World Congress, Working Party on the Mensuration of the Forest Biomass, S 4.01. 30 p.

Young, H.E. and Carpenter, P.M. 1967. Weight, nutrient element and productivity studies of seedlings and saplings of eight tree species in natural ecosystems. Agr. Exp. Sta., Univ. of Maine. Tech. Bull. 28. 39 p.

Young, H.E. and Guinn, V.P. 1966. Chemical elements in complete mature trees of seven species in Maine. Tappi 49 (5): 190-7.

V. Transport Systems

Appert, E. 1972. Organization of national markets of by-products of wood. FAO/NOR/TF 83: 139-44.

Bjerkreim-Hansen, T. 1972. Definitions of technical and economic terms. FAO/NOR/TF 83: 30-47.

Croon, I. and Frisk, E. 1972. Handling of logs and chips at pulp mills. FAO/NOR/TF 83: 227-32.

Evensen, T.B. 1972. Long-distance transport of logs, wood chips and pulp. FAO/NOR/TF 83: 168-77.

Evensen, T.B. 1975. Rationalizing the shipment of wood. Unasylva 27 (108): 15-9.

Haas, L.E. and Kalish, J.E. 1975. Transport and handling in the pulp and paper industry. Volume 1. Proc. first PPI International Symposium. Miller Freeman Publications, Inc., San Francisco. 336 p.

Hanaya, M. 1975. Ocean transport of woodchips - specialized ship design and handling facilities. In: Transport and handling in the pulp and paper industry. Volume 1. Proc. first PPI International Symposium. Miller Freeman Publications, Inc., San Francisco. 336 p.

Haug, B. 1972. Pipelines for wood chips. FAO/NOR/TF 83: 156-65.

Ishii, M. 1972. Design and technical features of specialized wood chip carriers. FAO/NOR/TF 83: 178-208.

Lembke, C.A. 1974. New era for PNG forest industries. Repr. Australian Forest Industries Journal 40 (7): 19 p.

Lindahl, H. 1971. Logistics. FAO/SWE/TF 53: 73-81.

Lindgren, F. 1972. Internal transport of wood chips. FAO/NOR/TF 83: 209-20.

Lund, H. 1972. Chip transport. FAO/Billerud.

Rydholm, S. 1972. Transport of wood chips at mill. FAO/Billerud.

Sanvictores, B.F. 1975. Moving away from log exports. Unasylva 27 (108): 10-4.

Segerström, G. 1971. Observations on the flow pattern of the forest products trade. FAO/SWE/TF 53: 52-61.

Segerström, G. 1972. Fibre logistics. FAO/NOR/TF 83: 120-7.

Sundberg, U. 1972. Opening-up forests through efficient planning of logging and road network. FAO/NOR/TF 83: 114-9.

Wibstad, K. 1972. Transport by rail. FAO/NOR/TF 83: 145-9.

VI. Wood Chips as Raw Material for the Chip-using Industries

Alestalo, A. 1973. On the possibilities of the utilization of needles and bark. IUFRO, Division 4, Subject Group 1, Working Group on Forest Biomass, Paper No. 6. 12 p.

Auchter, R.J. and Horn, R.A. 1973. Economics of kraft pulping of unbarked wood. Paper Trade J. 157 (26): 38-9.

Ander, P. and Eriksson, K.-E. 1975a. Influence of carbohydrates on lignin degradation by the white-rot fungus *Sporotrichum pulverulentum*. Svensk PappTidn. 78: 643-52.

Ander, P. and Eriksson, K.-E. 1975b. Mekanisk massa från forrötad flis - en inledande undersökning. Svensk PappTidn. 78: 641-2.

Appert, E. 1972. Organization of national market of by-products of wood. FAO/NOR/TF 83: 139-44.

Back, E.L. and Lundqvist, K.E. 1975. Egenskaper hos skivor av bark. Svensk PappTidn. 78: 199-205.

Barton, G.M. 1975. Foliage. Part II. Foliage chemicals, their properties and uses. Canadian Forestry Service, Western Forest Products Laboratory. 41 p.

Bergman, Ö. 1972a. Deterioration and protection of wood chips in outside chip storage. FAO/NOR/TF 83: 267-87.

Bergman, Ö. 1972b. Wood substance losses in some chip storage experiments. IUFRO. Wood in storage. Stockholm. Rapp. Inst. Virkeslära, Skogshögsk. 83.

Bergman, Ö. 1974. Thermal degradation and spontaneous ignition in outdoor chip storage. Stockholm. Rapp. Inst. Virkeslära, Skogshögsk. 91. 18 p.

Bergman, Ö. and Nilsson, T. 1966. On outside storage of pine chips at Lövholmen's Paper Mill. Stockholm. Rapp. Inst. Virkeslära, Skogshögsk. 53. 40 p.

Bergman, Ö. and Nilsson, T. 1967. On outside storage of aspen chips at Hörnefors' Sulphate Mill. Stockholm. Rapp. Inst. Virkeslära, Skogshögsk. 55. 60 p.

Bergman, Ö. and Nilsson, T. 1968. On outside storage of birch chips at Mörrum's Sulphate Mill. Stockholm. Rapp. Inst. Virkeslära, Skogshögsk. 60. 56 p.

Bois, P.J., Flick, R.A. and Gilmer, W.D. 1962. A study of outside storage of hardwood pulp chips in the Southeast. Tappi 45 (8): 609-18.

Brown, C.L. 1976. Forests as energy sources in the year 2000: what man can imagine, man can do. J. For. 74 (1): 7-12.

Chase, A.J., Hyland, F. and Young, H.E. 1971. Puckerbrush pulping studies. Agr. Exp. Sta., Univ. of Maine. Tech. Bull. 49. 64 p.

Chase, A.J., Hyland, F. and Young, H.E. 1973. The commercial use of puckerbrush pulp. Agr. Exp. Sta., Univ. of Maine. Tech. Bull. 65. 54 p.

Chen, T.-Y., Paulitsch, M. and Soto, G. 1972. On the suitability of the biological surface mass from spruce thinnings as raw material for particle board. Holz Roh- u. Werkstoff 30: 15-8.

Croon, I. and Frisk, E. 1972. Outside chip storage (OCS). FAO/NOR/TF 83: 253-66.

Dadswell, H.E. 1972. The anatomy of eucalypt woods. CSIRO Aust. Div. Applied Chem. Technol. Pap. No. 66.

Dillner, B. 1972. Outside stored chips as raw material for pulping. FAO/NOR/TF 83: 288-301.

Djerf, A.C. and Volkman, D.A. 1969. Experiences with water spray wood storage. Tappi 52: 1861-4.

Dutrow, G.F. 1971. Economic implications of silage sycamore. USDA For. Serv. Res. Pap. SO-66. 9 p.

Edberg, U., Engström, L. and Hartler, N. 1971. Så sållas sågverksflis. Sågverken/Trävaruindustrien 7: 451-3.

Einspahr. D.W. 1976. The influence of short-rotation forestry on pulp and paper quality. XVI IUFRO World Congress, Proc. Division V: 145-57.

Eriksson, K.-E. 1974. Mikroorganismer och enzymer som redskap i en ny utveckling inom skogsindustrien. Norsk Skogind. 28: 125-31.

Eskilsson, E. and Hartler, N. 1973. Whole tree pulping. Part 2. Sulphate cooking. Svensk PappTidn. 76: 63-70.

Eskilsson, S. 1974. Whole tree pulping. Part 3. Pulp properties. Svensk PappTidn. 77: 165-74.

Eslyn, W.E. 1973. Evaluating chemicals for controlling biodeterioration of stored wood chips. Forest Prod. J. 23 (11): 21-5.

Eslyn, W.E. and Laundrie, J.F. 1973. How anaerobic storage affects quality of Douglas-fir pulpwood chips. Tappi 56 (7): 129-31.

Eslyn, W.E. and Laundrie, J.F. 1975. Effect of anaerobic storage upon quality of aspen pulpwood chips. Tappi 58 (6): 109-10.

FAO. 1973. Guide for planning pulp and paper enterprises. FAO Forestry and Forest Products Studies No. 18. 379 p.

Farkas, J. and Farkasova, V. 1975a. Influence of bark on pulping and properties of beech kraft pulp. Papir a Cellul. 30 (7-8): V 40-4.

Farkas, J. and Farkasova, V. 1975b. Beech bark in kraft pulping. Papir a Cellul. 30 (7-8): V 21-4.

Feist, W.C., Springer, E.L. and Hajny, G.J. 1971. Encasing wood chip piles in plastic membranes to control chip deterioration. Tappi 54: 1140-2.

Feist, W.C., Hajny, G.J. and Springer, E.L. 1973. Effect of storing green wood chips at elevated temperatures. Tappi 56 (8): 91-5.

Feist, W.C., Springer, E.L. and Hajny, G.J. 1974. Storing wood chips at elevated temperatures - effect of alkali pretreatment. Tappi 57 (8): 112-4.

Galloway, D. 1976. Hardboard spent liquor product edges wood toward multi-billon food market. Forest Industries 103 (3): 62-3.

Gislerud, O. 1974. Whole tree utilization. V. Storing of whole tree chips. NISK, Skogtekn. avd. Rapport 5/74. 29 p.

Gislerud, O. 1976. Storage of whole-tree chips. NISK, Skogtekn. avd.

Günther, B., Götze, H., Luthardt, H. and Schulze-Dewitz, G. 1972. Eigenschaften und Verwertung des Astholzes von Kiefer (*Pinus silvestris* L.) und Rotbuche (*Fagus silvatica* L.). 3. Mitt. Holztechnologie 13 (2): 80-7.

Götze, H. Günther, B., Luthardt, H. and Schulze-Dewitz, G. 1972. Eigenschaften und Verwertung des Astholzes von Kiefer (*Pinus silvestris* L.) und Rotbuche (*Fagus silvatica* L.). 2. Mitt. Holztechnologie 13 (1): 20-8.

Hajny, G.J. 1966. Outside storage of pulpwood chips. A review and bibliography. Tappi 49 (10): 97A-105A.

Hakkila, P. 1971. Coniferous branches as a raw material source. Comm. inst. for. fenn. 75.1. 60 p.

Hakkila, P. 1972a. Industrial utilization of waste wood. FAO/NOR/TF 83: 233-8.

Hakkila, P. 1972b. Mechanized harvesting of stumps and roots. Comm. inst. for. fenn. 77.1. 71 p.

Hakkila, P. 1974. Harvesting of stump and root wood. Metsäteho Report 332. 19 p.

Hakkila, P. 1975a. Bark percentage, basic density, and amount of acetone extractives in stump and root wood. Folia Forestalia 224. 14 p.

Hakkila, P. 1975b. Whole-tree utilization in the USA by the end of 1973 - and possibilities for its application in Finland. Rapp. Inst. Skogsteknik, Skogshögsk. 82. 57 p.

Hannus, K. and Pensar, G. 1970. Ekstraktivämnen i barr. Institute of Wood Chemistry and Cellulose Technology, Åbo Akademi. 40 p.

Hannus, K. and Pensar, G. 1973. Silvichemicals in technical foliage. I. Water steam distilled oil from pine material. Paperi Puu 55: 509-16.

Harries, E.D., Levy, C.R. and Phillips, F.H. 1973. Outside storage of tropical hardwood chips. I. Establishment and control of pilot scale chip piles. Appita 26: 273-7.

Hartler, N. 1972. Chips for industrial use. FAO/NOR/TF 83.

Hartler, N. and Stade, Y. 1975. Krav på cellulosaflis och sätt att uppfylla dem. Sågverken 8: 585-91.

Hatton, J.V. 1970. Precise studies on the effect of outside chip storage on fiber yield: white spruce and lodgepole pine. Tappi 53: 627-38.

Hatton, J. 1975a. WFPL chip quality analytical procedure: Effect of test parameters on screening efficiency and analysis time. Pulp Pap. Can. 76 (7): 79-81.

Hatton, J. 1975b. WFPL chip quality analytical procedure: Effect of chipper, wood species and season on production of pin chips and fines. Pulp. Pap. Can. 76 (8): 64-70.

Hatton, J.V. 1976. Chip quality evaluations. Pulp Pap. Can. 77 (6): 61-8.

Hatton, J.V. and Hunt, K. 1972. Effect of prolonged outside chip storage on yield and quality of kraft pulps from *Picea glauca* and *Pinus contorta* chips. Tappi 55: 122-6.

Hatton, J.V. and Keays, J.L. 1973. Effect of chip geometry and moisture on yield and quality of kraft pulps from western hemlock and black spruce. Pulp Pap. Can. 74 (1): 79-87.

Helge, K. 1976. The use of whole tree chips in the production of fibre building board. The Norwegian Pulp and Paper Research Institute. 12 p.

Helge, K. and Rødland, G. 1976. Heltreutnyttelse - trefiberplater. The Norwegian Pulp and Paper Research Institute. 7 p.

Hemingway, R.W., Nelson, P.J. and Hillis, W.E. 1971. Rapid oxidation of the fats and resins in *Pinus radiata* chips for pitch control. Tappi 54: 95-8.

Horn, R.A. and Auchter, R.J. 1972. Kraft pulping of pulpwood chips containing bark. Paper Trade J. 156 (46): 55-9.

Hosia, M. and Kortelainen, V.-A. 1971. Investigations on utilizing softwood branches as pulp and hardboard raw material II. Paperi Puu 53: 721-7.

Hosia, M., Lindholm, C.-A., Toivanen, P. and Nevalainen, K. 1971. Investigations on utilizing softwood branches as pulp and hardboard raw material I. Paperi Puu 53: 49-66.

Howard, E.T. 1974. Needleboards - an exploratory study. Forest Prod. J. 24 (5): 50-1.

Hulme, M.A. and Shields, J.K. 1973. Treatments to reduce chip deterioration during storage. Tappi 56 (8): 88-95.

Hulme, M.A. and Hatton, J.V. 1976a. Increased kraft pulp fiber yields by chip treatment before outside storage: a laboratory assessment. Tappi 59 (1): 108-11.

Hulme, M.A. and Hatton, J.V. 1976b. Influence of high temperatures during chip pile storage on hardwood fiber yields. Tappi 59 (1): 154-5.

Ievins, I.K., Galvans, U.I., Daugavietis, M.O. and Kevins, J.J. 1973. Utilization of needles and leaves in the USSR. IUFRO, Division 4, Subject Group 1, Working Group on Forest Biomass, Paper No. 2. 7 p.

Ievins, I.K. 1975. Die Verwendung der Holzgrünmasse in der UdSSR. Konferens SK 1, Elmia 75, Jönköping, Sweden.

Jett, J.B. and Zobel, B.J. 1975. Wood and pulping properties of young hardwoods. Tappi 58 (1): 92-6.

Keays, J.L. 1971a. Complete-tree utilization. An analysis of the literature. Part I: Unmerchantable top of bole. Canadian Forestry Service. Forest Products Laboratory. Information report VP-X-69. 98 p.

Keays, J.L. 1971b. Complete-tree utilization. An analysis of the literature. Part II: Foliage. Canadian Forestry Service. Forest Products Laboratory. Information report VP-X-70. 94 p.

Keays, J.L. 1971c. Complete-tree utilization. An analysis of the literature. Part III: Branches. Canadian Forestry Service. Forest Products Laboratory. Information report VP-X-71. 67 p.

Keays, J.L. 1971d. Complete-tree utilization. An analysis of the literature. Part IV: Crown and slash. Canadian Forestry Service. Forest Products Laboratory. Information report VP-X-77. 79 p.

Keays, J.L. 1971e. Complete-tree utilization. An analysis of the literature. Part V: Stump, roots and stump-root system. Canadian Forestry Service. Forest Products Laboratory. Information report VP-X-79. 62 p.

Keays, J.L. 1974. Full-tree chips for kraft - yield, quality and economics. Pulp Pap. Can. 75 (9): 43-7.

Keays, J.L. 1975. Foliage. Part I. Practical utilization of foliage. Canadian Forestry Service. Western Forest Products Laboratory. 42 p.

Keays, J.L. and Hatton, J.V. 1971. Complete-tree utilization studies. II. Yield and quality of kraft pulp from the components of *Picea glauca*. Tappi 54: 1721-4.

Keays, J.L. and Hatton, J.V. 1975. The effect of bark on wood pulp yield and quality and on the economics of pulp production. Canadian Forestry Service. Western Forest Products Laboratory. Information report VP-X-126. 20 p.

King, K.F.S. 1975. It's time to make paper in the tropics. Unasylva 27 (109): 2-5.

Koch, P. 1976. New technique for harvesting southern pines with taproot attached can extend pulpwood resources significantly. XVI IUFRO World Congress, Project Group P 3.01. 20 p.

Koch, P. and Coughran, S.J. 1975. Development of a puller-buncher for harvesting southern pines with taproot attached. Forest Prod. J. 25 (4): 23-30.

Latvian Scientific Research Institute of Forestry Problems and Problem Laboratory for utilization of tree living elements, Leningrad Forest-Technical Academy. 1973. Ispolzovanie biologicheski aktivnykh veshchestv dereva (Utilization of biological active substances in trees). Riga 1973. 152 p.

Liiri, O., Kivistö, A. and Laine, L. 1972. Branches and whole trees as raw material for particle board. Paperi Puu 54: 593-609.

Lönnberg, B. 1975a. Short-rotation hardwood species as whole-tree raw material for pulp and paper. 1. General aspects. Paperi Puu 57: 443-7.

Lönnberg, B. 1975b. Short-rotation hardwood species as whole-tree raw material for pulp and paper. 2. Wood raw material. Paperi Puu 57: 507-16.

Lönnberg, B. 1976a. Short-rotation hardwood species as whole-tree raw material for pulp and paper. 3. Chemical pulping. Paperi Puu 58: 113-23.

Lönnberg, B. 1976b. Short-rotation hardwood species as whole-tree raw material for pulp and paper. 4. Effects of bark upon chemical pulping. Paperi Puu 58: 181-97.

Lönnberg, B. 1976c. Short-rotation hardwood species as whole-tree raw material for pulp and paper. 5. Bleached pulps; fine papers. Paperi Puu 58: 455-72.

Lönnberg, B., Palenius, I. and Saxena, V.B. 1975. Short-rotation hardwood as a raw material for absorbent pulp. Paperi Puu 57: 721-7.

Marton, R., Amidon, T., Brown, A., Granzow, S. and Koeppicus, R. 1975. Whole-tree utilization in pulping. ESPRA.

Ministry of Forestry and Forest Industry in the Latvian SSR, Latvian Scientific Research Institute of Forestry Problems. 1975. Compleksnaya mekhanizatsiya rubok ukhoda (Complex mechanization of stand treatment). Riga 1975. 191 p.

Moran, J.S. 1975. Kraft mill experience with whole tree chips. TAPPI Annual Meeting, New York. Manuscript. 10 p.

Nilsson, T. 1972. Microorganisms in chip piles. IUFRO. Wood in storage. Stockholm. Rapp. Inst. Virkeslära, Skogshögsk. 83.

Nordlinder, B.G. and Tufvesson, M.I. 1975. Helträdsutnyttjande för fiber- och spånskivor. Projekt Helträdsutnyttjande, Stockholm. 42 p.

Nyholm, P. 1976. Separate harvesting of fresh stumps and roots, handling of stumpwood at the mill. ECE/FAO/ILO Symposium on the harvesting of a larger part of the forest biomass. TIM/EFC/WP. 1/SEM. 3/R. 8. 9 p.

Nylinder, P. 1972. Measuring of wood chips. FAO/NOR/TF 83: 243-52.

Okstad, T. 1972. Methods of scaling wood chips. FAO/NOR/TF 83: 239-42.

Paulitsch, M. 1976. Verarbeitung von Astholz, Rinde und Nadeln/Blättern zu Spanplatten. XVI IUFRO World Congress, Congress Group V. 4. 8 p.

Peters, W. 1976. Herstellung von Spanplatten aus Ganzbaum - Waldhack-schnitzeln. FESYP. 6 p.

Phillips, F.H. and Logan, A.F. 1973. Outside storage of tropical hardwood chips. II. Pulping and papermaking potential of chips after storage. Appita 26: 355-60.

Preikschat, F.K., Preikschat, E. and Pope, D.F. 1974. Factors affecting automatic wood chip moisture measurement. Paper Trade J. 158 (30): 21-5.

Projekt Helträdsutnyttjande. 1976. Stubbdagen 1976-03-09. Stockholm. 104 p.

Ribe, J.H. 1974. A review of short rotation forestry. Agr. Exp. Sta., Univ. of Maine. Misc. Rep. 160. 52 p.

Rogers, I.H., Harris, A.G. and Rozon, L.R. 1971. The effect of outside chip storage on the extractives of white spruce and lodgepole pine. Pulp Pap. Can. 72 (6): 84-90.

Rose, D.W. 1976. The potential of short-rotation forest crops for production of fiber and energy. College of Forestry, University of Minnesota. 6 p.

Sellæg, M. and Gislerud, O. 1972. Green chips from thinnings for use in fibreboard production. Tidsskr. Skogbr. 80: 423-32.

Sellæg, M., Kucera, B. and Mengkrog, Ø. 1972. Chipping of birch for particle board production. Tidsskr. Skogbr. 80: 433-44.

Skjelmerud, H. 1972. Importance of residue utilization from a sawmill point of view - a Norwegian case study. FAO/NOR/TF 83: 335-52.

Smith, R. 1972. Colonization and degradation of outside stored softwood chips by fungi. IUFRO. Wood in storage. Stockholm. Rapp. Inst. Virkeslära, Skogshögsk. 83.

Springer, E.L., Eslyn, W., Zoch, L.L. and Hajny, G.J. 1969. Control of pulp chip deterioration with kraft green liguor. USDA For. Serv. Res. Pap. FPL 110. 4 p.

Springer, E.L., Haslerud, E.J., Fries, D.M., Clark, I.T., Hajny, G.J. and Zoch, L.L. jr. 1971. An evaluation of four chemicals for preserving wood chips stored outdoors. Tappi 54: 555-60.

Springer, E.L., Feist, W.C., Zoch, L.L. jr. and Hajny, G.J. 1973a. Evaluation of chemicals for preserving wood chips using pile simulators. Tappi 56 (6): 125-8.

Springer, E.L., Feist, W.C., Zoch, L.L. jr. and Hajny, G.J. 1973b. New and effective chemical treatment to preserve stored wood chips. Tappi 56 (6): 157.

Springer, E.L., Feist, W.C., Zoch, L.L. jr. and Hajny, G.J. 1974. Evaluation of two chemical treatments in outside chip piles. USDA For. Serv. Res. Pap. FPL 243. 15 p.

Springer, E.L., Schmidt, F.L., Feist, W.C. and Zoch, L.L. 1975a. Storage of red alder chips with and without bark - treated and untreated. USDA For. Serv. Res. Pap. FPL 261. 9 p.

Springer, E.L., Feist, W.C., Zoch, L.L. jr. and Hajny, G.J. 1975b. Evaluation of five treatments to prevent deterioration of wood chips during storage in pile simulators. Tappi 58 (3): 128-31.

Stade, Y. 1975. Helträdsutnyttjande vid massatillverkning 1975. Projekt Helträdsutnyttjande, Stockholm. 55 p.

Stewart, J.F. and Diaz, R.J. 1972. Use of spent stumpwood in linerboard production. Tappi 55 (8): 1212-5.

TAPPI. 1954. Sieve analysis of pulpwood chips. T 16 m - 54. Technical Association of the Pulp and Paper Industry. 2 p.

Thune-Larsen, E. and Luhr, F. 1972. A comparison between utilizing wood from industrial countries (Scandinavia) and plantation forests (eucalyptus). FAO/NOR/TF 83: 80-93.

Uusvaara, O. 1969. On density and weight of sawmill chips. Comm. inst. for. fenn. 67.3. 44 p.

Uusvaara, O. 1972. On the properties of sawmill chips. Comm. inst. for. fenn. 75.4. 55 p.

Uusvaara, O. 1974. Properties of sawdust utilized in industry. Comm. inst. for fenn. 83.1. 43 p.

Vakomies, P.J. 1972. Wood raw materials for pulp and paper in tropical countries. FAO/NOR/TF 83: 221-6.

Vethe, A. 1973. Sulfatkoking av ubarket virke. The Norwegian Pulp and Paper Research Institute. 13 p.

Virkola, N.-E. 1976a. Developments and trends in industrial utilization of fuller biomass branchwood, foliage and stumps in traditional wood industry. ECE/FAO/ILO Symposium on the harvesting of a larger part of the biomass. TIM/EFC/WP. 1/SEM. 3/R. 17. 16 p.

Virkola, N.-E. 1976b. Developments and trends in industrial utilization of fuller biomass branchwood, foliage and stumps in traditional wood industry. ECE/FAO/ILO Symposium on the harvesting of a larger part of the biomass. Manuscript. 9 p.

Warren. B.R. 1972. Assessment of quality and quantity of woodchip shipments. Appita 26: 209-10.

Wawer, A. 1975. Bark in hardwood chips - effect on mill operations. Pulp Pap. Can. 76 (7): 51-4.

Weiner, J., Roth, L., Cowling, E.B. and Hafley, W.F. 1974. Changes in the value and utility of pulpwood, sawlogs, and veneer bolts during harvesting, transport and storage. The Institute of Paper Chemistry. Bibliographic Series, Special Number 60. 629 p.

Wiedermann, A. 1972. Kraft pulping of several unbarked European hardwoods. Tappi 55: 1209-11.

Wilhelmsen, G. 1972. Factors influencing and determining the necessity of wood storage in Norway. IUFRO. Wood in storage. Stockholm. Rapp. Inst. Virkeslära, Skogshögsk. 83.

Wilhelmsen, L.A., Preikschat, E. and Stergion, D.L. 1976. Automatic wood chip moisture - bulk density meter. Tappi 59 (8): 56-9.

Wolf, E. 1976. Herstellung von Ganzbaumhackschnitzeln im Wald. FESYP. 5 p.

Zielinski, M. 1972. Fungal communities in piles of birch wood chips. IUFRO. Wood in storage. Stockholm. Rapp. Inst. Virkeslära, Skogshögsk. 83.

VII. Some Terms used in Wood Chips Trade

Bjerkreim-Hansen, T. 1972. Definition of technical and economic terms and figures used in the logs, wood chips and pulp trade. FAO/NOR/TF 83: 30-47.

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