NON-WOOD FOREST PRODUCTS

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Food and Agriculture Organization of the United Nations

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PREFACE

This global study was undertaken by the Natural Resources Institute (NRI)*, the scientific arm of the United Kingdom's Overseas Development Administration (ODA). Funding for the study and for the publication of the report was met by ODA's Forestry Research Programme.

The information and analyses presented in this report are based on the authors' research and first-hand knowledge of gum naval stores production in a number of producing countries.

A complementary study carried out by NRI, which provided some inputs for the present one and which was financed by the ODA Forestry Research Programme with support from FAO, has involved an assessment of the prospects for development of new gum naval stores industries in Central and Southern Africa. Single copies of the Africa report are available from the FAO Regional Office for Africa (PO Box 1628, Accra, Ghana).

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ABBREVIATIONS

ASTM	American Society for Testing and Materials
c & f	cost and freight
EC	European Community
IMDG	International Maritime Dangerous Goods
ISO	International Organization for Standardization
US$	United States dollar

In tables:
na indicates not available
ns indicates not specified
\- indicates nil

SUMMARY

Information is provided on the technical and economic aspects of crude resin production from pine trees and on the subsequent production of gum turpentine and gum rosin (known commercially as gum naval stores). Recent trends in world production and markets are also reviewed. The publication is aimed at prospective new producers of gum naval stores, and organizations and individuals appraising projects involving their production. It is particularly intended for those in developing countries.

Total world production of rosin is approximately 1.2 million tonnes annually, of which almost 720 000 tonnes, 60% of the total, is estimated to be gum rosin derived from tapping living pine trees. World production of turpentine is about 330 000 tonnes from all sources, of which 100 000 tonnes is estimated to be gum turpentine. The number of countries producing gum naval stores is large but the People's Republic of China dominates production and world trade; of the other producers, Indonesia, Portugal and Brazil are the most important in terms of world trade. Present (early 1995) prices for gum rosin are at the highest levels for some years, due largely to recent events in the People's Republic of China. The prospects of entry into the international market by new suppliers will depend mainly on future trends in Chinese production and consumption.

Rosin has a wide range of applications including adhesive, paper size and printing ink manufacture. Turpentine is used either as a solvent for paints and varnishes, or as a raw material for fractionation and value-added derivative manufacture. Most prospective new producers will have opportunities for domestic or regional sales of rosin and turpentine.

While most pines are capable of yielding resin on tapping, it is only economic to do so if the quantity obtained is sufficient and its quality is acceptable. Both these factors are determined primarily by the species of *Pinus* which is tapped, so information is provided on the suitability of different species for gum naval stores production. Tapping can be carried out either on natural stands or plantations. Methods of tapping which do not adversely affect the quality of the trunkwood are described and these enable plantation pines to be felled and utilized in the normal manner when tapping is stopped. The cleaning and distillation operations involved in processing the crude resin are described, and quality criteria, specifications and packaging options for rosin and turpentine are provided.

An indication of the costs involved in the production and processing of pine resin is given. These are based on 1000 tonnes of resin being produced from 400 000 trees which each yield an average of 2.5 kg of resin. The comparative advantages and disadvantages of domestic, regional and export markets for a new producer are discussed.

INTRODUCTION

'Naval stores' is the inclusive term used to denote the products obtained from the oleoresin or resin* of pine trees (genus *Pinus*). The term originates from the days when wooden sailing ships, including naval ships, were waterproofed using pitch and tar and other resinous products from pine trees. Although the connection with ships is now remote, the term is still commonly used by those in the trade and elsewhere. There are three distinct sources of naval stores:

- **Gum naval stores** are obtained by the tapping of living pine trees. Collection of the 'gum' or resin is a labour-intensive operation (similar to rubber tapping). Distillation of the resin, which can be undertaken in fairly simple equipment, produces gum rosin and gum turpentine in varying ratios, usually between 4:1 and 6:1.

- **Sulphate naval stores** are by-products recovered during the conversion of pine wood chips to pulp by the sulphate (kraft) pulping process. Sulphate turpentine is condensed from the cooking vapours. Crude tall oil, obtained from the alkaline liquors, is fractionated into various products including tall oil rosin and tall oil fatty acids.

- **Wood naval stores** are obtained from resin-saturated pine stumps long after the tree has been felled. The stumps are solvent extracted using capital intensive technology to give wood turpentine, wood rosin, dipentene and natural pine oil.

Pinus is one of the most widely distributed genera of trees in the northern hemisphere, extending from the polar region to the tropics; one species, *P. merkusii*, occurs naturally south of the Equator. The genus is also one of the most widely planted exotics because of its large-scale use for timber and pulp, and large areas of *Pinus* are found outside its natural range in South America, Africa and Australasia. Standing resources of pine trees exist, therefore, in many parts of the world.

The two major products of the naval stores industry are rosin (a brittle, transparent, glossy, faintly aromatic solid) and turpentine (a clear liquid with a pungent odour and bitter taste). Annual world production of gum rosin and gum turpentine is approximately 700 000 tonnes (valued at around US$420 million at first half 1994 prices) and 100 000 tonnes (valued at US$50 million), respectively. For many years rosin and turpentine were used in an unprocessed form in the soap, paper, paint and varnish industries. Today, most rosin is modified and used in a wide range of products including paper size, adhesives, printing inks, rubber compounds and surface coatings. The composition of turpentine can vary considerably according to the species of pine exploited, and this greatly influences its value and end use. Turpentine, like rosin, is a very versatile material and nowadays is used mainly as a feedstock by the world's chemical industries. The alpha- and beta-pinene constituents of turpentine, in particular, are the starting materials for the synthesis of a wide

* The terms 'oleoresin' and 'resin' may be used interchangeably, and for convenience the term 'resin', which must not be confused with rosin, is used in this report. Standard terminology relating to naval stores is given in the American Society for Testing and Materials (ASTM) standard D 804-92.

range of fragrances, flavours, vitamins and polyterpene resins, and form the basis of a substantial and growing chemical industry. However, the simpler, more traditional products in which rosin and turpentine can be used, such as soap, paper size and paints and varnishes, can still be of value to the domestic economy of developing countries, and it is not necessary to think only in terms of the wider international markets when planning naval stores production. Consumer demand in developing countries is expected to grow with increasing industrialization and urbanization and there are, therefore, opportunities for countries with suitable pine resources to replace imported naval stores products with those produced locally.

The aim of this publication is to provide basic information to enable prospective new producers of gum turpentine and gum rosin to make considered judgements on whether or not to proceed with investment. Information on the production of wood and sulphate naval stores, and on further processing of gum rosin and gum turpentine, is not included. The publication is intended particularly for prospective producers and government bodies, financial institutions or donor agencies in developing countries concerned with the appraisal of projects involving gum naval stores production. It is hoped, also, that it will assist existing producers, traders and consumers of gum turpentine and rosin by increasing their awareness of production methods and product characteristics in other parts of the world, and their knowledge of market demands, trends and preferences.

The text is presented in five chapters. Following this introduction, Chapter 1 summarizes major aspects of production, trade and markets for gum naval stores. The chief pine species used in different parts of the world are listed, and the levels of production and trends in all the major producing countries are indicated. Chapter 2 reviews the tapping methods used to recover resin from the tree, and in Chapter 3 the technology required to process the resin into rosin and turpentine is described. In Chapter 4, the financial and economic aspects of the resin tapping and processing operations are analysed. In the final chapter, the technical and economic aspects which must be considered when planning a gum naval stores industry are summarised. The appendices contain references and suggested further reading, quality criteria, specifications and test methods for rosin and turpentine, a discussion of genetic factors influencing resin composition and yields and the importance of correct species and provenance selection when assessing pine trees for tapping, packaging requirements for turpentine and rosin, a list of importers and traders of naval stores, and statistical tables.

CHAPTER 1

PRODUCTION, TRADE AND MARKETS

DESCRIPTION, USES AND PRINCIPAL SOURCES

Resin

Crude resin obtained by tapping living pine trees is a thick, sticky, but usually, still fluid material. It is opaque (due to the presence of occluded moisture), milky-grey in colour, and inevitably contains a certain amount of forest debris (pine needles, insects, etc.) when it is collected from the trees.

Most *Pinus* species 'bleed' when the stem wood (xylem) is cut or otherwise injured, but probably only a few dozen of approximately 100 species which exist has ever been tapped commercially as a source of resin for rosin and turpentine production; in the others, poor yields and/or quality of the resin make exploitation uneconomic. The principal species which are presently tapped, and the countries in which this takes place, are listed in Table 1.

Table 1

Commercially tapped sources of pine resin: species and country of production

Species[a]	Producing country[b]
Pinus elliottii Engelm.	Brazil, Argentina, South Africa, (USA, Kenya)
P. massoniana D. Don	People's Republic of China
P. kesiya Royale ex Gordon	People's Republic of China
P. pinaster Aiton	Portugal
P. merkusii Jungh. & Vriese	Indonesia, (Viet Nam)
P. roxburghii Sarg.	India, (Pakistan)
P. oocarpa Schiede	Mexico, Honduras
P. caribaea Morelet	Venezuela, (South Africa, Kenya)
P. sylvestris L.	Russia
P. halepensis Miller	Greece
P. radiata D. Don	(Kenya)

Notes: *a* In some case only the major species tapped in a particular country is indicated. In the People's Republic of China, *P. massoniana* is the main species utilized and although the contribution of species such as *P. kesiya* is small by Chinese standards, it is significant compared to the scale of production in other countries. Relatively small but increasing areas of *P. elliottii* and other exotic pines are tapped in China in addition to *P. massoniana* and other native species. In Mexico, *P. oocarpa* often occurs in mixed stands so that other species are likely to be tapped.

b The list of countries is not intended to be exhaustive. Parentheses indicate a minor producer.

Until very recently, the crude resin was never considered to be a product for international trade. Although it might often be transported some distance by road or rail to the factory where it was processed, processing still took place within the producing country. However, the acute shortage experienced by some traditional producers in recent years has led to the importation of resin for the first time; India and Portugal are both known to have imported crude resin. Although losing the benefits of added value, new producers therefore have the option of tapping trees and exporting crude resin to nearby countries without needing to process it themselves.

Rosin

Rosin is the major product obtained from pine resin. It remains behind as the involatile residue after distillation of the turpentine and is a brittle, transparent, glassy solid. It is insoluble in water but soluble in many organic solvents. It is graded and sold on the basis of colour, the palest shades of yellow-brown being the better quality. Quality criteria and specifications are described in Appendix 2. Several other physico-chemical characteristics influence the quality and these are largely dependent on the species of pine from which the rosin is obtained, i.e., they are determined more by genetic than environmental and processing factors. These aspects are discussed in more detail in Appendix 3.

Most rosin is used in a chemically modified form rather than in the raw state in which it is obtained. It consists primarily of a mixture of abietic- and pimaric-type acids with smaller amounts of neutral compounds. This intrinsic acidity, coupled with other chemical properties, enables it to be converted to a large number of downstream derivatives which are used in a wide range of applications. The derivatives include salts, esters and maleic anhydride adducts, and hydrogenated, disproportionated and polymerized rosins. Their most important uses are in the manufacture of adhesives, paper sizing agents, printing inks, solders and fluxes, various surface coatings, insulating materials for the electronics industry, synthetic rubber, chewing gums and soaps and detergents.

Although it is more economical to manufacture derivatives if large quantities of rosin are involved, small producers often manufacture simple derivatives for sale in the domestic market as a substitute for imported products. For example, fortified rosin sizes can be made based on the reaction of rosin with maleic anhydride. However, for the purposes of this report, no further reference is made to the technical aspects of additional processing or to the products themselves.

Turpentine

Turpentine is a clear, flammable liquid, with a pungent odour and bitter taste. It is immiscible with water and has a boiling point above 150^{o}C. Quality criteria and specifications are indicated in Appendix 2. Turpentine is a mixture of organic compounds, mainly terpenes, and its composition can vary considerably (more so than rosin) according to the species of pine from which it was derived. This greatly influences its value and end use and is discussed in greater detail in Appendix 3.

For some applications turpentine is used in whole form, usually as a solvent for paints and varnishes or as a cleaning agent. However, like rosin it is a very versatile material chemically, and nowadays, it is used mostly after further processing. It usually undergoes fractional distillation to isolate the desirable chemicals (mainly alpha-pinene and beta-pinene) which are then transformed into value-added derivatives. This further processing is only economic if it is carried out on a very large scale, and it is not something to be considered by a new producer of gum naval stores. Occasionally, the turpentine is rich enough in alpha-pinene, for example, to be used in whole form. The derivatives are widely used in fragrance, flavour, vitamin and polyterpene resin manufacture, and form the basis of a substantial and growing chemical industry. The biggest single turpentine derivative, synthetic pine oil, is used in disinfectants, cleaning agents and other products with a 'pine' odour. Many derivatives, including isobornyl acetate, camphor, linalool, citral, citronellol, citronellal and menthol are used either on their own or in the elaboration of other fragrance and flavour compounds. A few of the minor constituents of turpentine, such as anethole, are employed for fragrance or flavour use without the need for chemical modification. Downstream derivatives are not discussed further in this report.

WORLD PRODUCTION, TRADE AND OUTLOOK

Many of the uses to which rosin can be put are subject to intense competition from synthetic, petroleum-based resins, and between gum rosin and tall oil rosin. Tall oil rosin, which used to suffer from odour problems associated with its method of production and a tendency to crystallize, was considered to be inferior to gum rosin for many applications. Today, most of these problems have been overcome and tall oil rosin competes more effectively with gum rosin. Technical developments which have led to more effective formulations for many rosin-based products have meant that less rosin is needed to achieve a particular result. In the paper industry, for example, the development of more effective fortified rosin sizes and emulsions, and changes in the paper-making process itself, have led to a marked decrease in the amount of rosin consumed per tonne of paper produced. The increasing demand for paper, however, means that the use of rosin by the paper industry is still substantial.

Any detailed analysis of the naval stores industry which attempts to follow production, trade and markets beyond the primary rosin and turpentine stage, and between the different sources of naval stores, is complex and difficult and beyond the scope of this report. In any case, a prospective new producer of gum naval stores will first need to assess local pine resources, and their capacity to meet domestic or regional markets for rosin and turpentine (rather than their derivatives), and such additional detail is unnecessary.

Production and trade

Total annual production of rosin is about 1.2 million tonnes world-wide. Of this, it is estimated that almost 720 000 tonnes, or 60%, is gum rosin; most of the remainder, about 35%, is tall oil rosin and the rest is wood rosin. World production of turpentine is approximately 330 000 tonnes from all sources; almost 100 000 tonnes (30%) is estimated to be gum turpentine, and the bulk of the remainder is sulphate turpentine.

The naval stores industry is complex and ever-changing. In the early part of the century, gum naval stores production was the dominant, and in most cases, the only, means of producing rosin and turpentine. Wood naval stores production, involving the uprooting and extraction of old pine stumps, developed in those countries with large areas of raw materials, such as the United States and the former Soviet Union; production in the United States peaked during the 1950s and has since declined to a low level. The recovery of tall oil rosin and sulphate turpentine as by-products of chemical pulping of pine chips also began during the 1950s.

As labour in the more industrialized countries has become more expensive and less willing to undertake the task of tapping, gum naval stores production has declined and the centre of its production has shifted. The United States and many former producing countries of Europe are either no longer producers, or are now only able to sustain production at very low levels. Production has also declined in countries such as India and Mexico; in India, a shortage of trees for tapping has added to the other problems. During the 1980s, Brazil emerged as a significant producer of gum naval stores, but here too, the cost of labour is now being felt. Also, government financial incentives which encouraged new planting in Brazil have been reduced, so as existing areas of plantation come to the end of their tapping life fewer suitable trees are available to replace them.

The focus of production for world gum naval stores today is Southeast Asia. The People's Republic of China has been the world's dominant producer for many years, but a dramatic increase in production, signalled by the installation of an improved and expanded processing capacity in the early 1980s, has seen Indonesia become the second biggest producer of gum rosin and turpentine in the world. Chinese production accounts for 430 000 tonnes (about 60%) of the total annual production of gum rosin and Indonesia accounts for a further 69 000 tonnes (almost 10%). While Chinese production is unlikely to increase further, Indonesia has an ample (and growing) number of trees available for tapping and the potential to increase production significantly in the years to come.

The People's Republic of China and Indonesia also dominate world trade in gum rosin and turpentine. Trade statistics for the major exporting and importing countries are given in Appendix 6. Chinese exports of gum rosin were approximately 277 000 tonnes in 1993 (70% of world trade) and Indonesian exports were about 46 000 tonnes. Russia and Brazil produce more gum rosin than Portugal but most of it is used to meet domestic needs. Portugal is the third biggest exporter and exports most of its output (about 26 000 tonnes in 1992, although some of this was produced from imported crude resin). A much smaller proportion of the turpentine produced in the People's Republicof China is exported (about 5500 tonnes); both Indonesia (7500 tonnes) and Portugal (6000 tonnes) export more.

The future supply of gum rosin and turpentine to the world market depends mainly on production trends in the People's Republic of China, Indonesia and Portugal (in that order), and to a lesser extent, Brazil. It also depends on consumption trends in China which are difficult to predict; increasing Chinese industrialization and domestic consumption of naval stores may eventually result in a decreasing surplus available for export. The desire to earn foreign exchange, and the potential for some provinces to expand production as others decline (see below), may enable exports to be maintained at about their present level. Any decrease in exports could be partly or wholly made up by increased supplies from Indonesia.

The availability of gum rosin (and turpentine) decreased sharply in late 1994 as the effects of severe floods in the People's Republic of China during June to September became known. Many of the major production areas were affected and this led to a significant reduction in China's ability to collect and process crude resin and export it to world markets. Some trade estimates have suggested that supplies for 1994/95 may be reduced by as much as 30-40%. This damaging drop in production has been compounded by a rapid and competitive expansion in the number of licensed exporters within the country, and by a radical change in the export licensing system. Severe droughts in the production areas of Indonesia and Brazil also led to reduced production in 1994, and as a result of the ensuing disruption and disorganization, world prices rose sharply between late 1994 and early 1995.

Prices

Estimates for gum rosin price levels from 1991-94, and for the first quarter of 1995, are shown in Table 2. They show the large price rises between those dates and the difference in the price of rosin from different origins, but they are not exact transaction prices.

Table 2
Gum rosin[a]: landed prices, 1991-95[b]
(US$/tonne)

	1991	1992	1993	1994	1995
Portuguese	800	765	795	835	900
Chinese	675	675	650	575	750-775
Indonesian	570	620	575	560	650-670
Brazilian	680	680	600	590	775-850

Source: London dealers
Notes: *a* WW grade
b Average annual prices except 1994 (July) and 1995 (January)

It is likely that prices will fall back from the high levels of early 1995 to about US$700/tonne by the end of 1995. However, some uncertainty exists because the extent of lost production in the People's Republic of China, and the ability for production to recover during 1995/96 is not known. At the early 1995 price levels, Portugal and Brazil could both expand tapping but further falls in rosin prices would make this extra output doubtful. Indonesia will continue to expand production.

It is not useful to give a similar price series for gum turpentine, which is traded at high prices in drums or much lower prices in 20 000 litre ISO tanks. The scale and extent of international trade is more limited than for gum rosin, but a price level of US$450-550/tonne delivered was typical from 1993 to mid-1994. Levels of US$600-650/tonne c&f India or Europe would be more representative of early 1995 price levels.

Major markets

Virtually all the non-producing countries in the world (and some of the producers) import rosin and turpentine, or their derivatives or synthetic competitors. Examples of the scale of imports can be seen in some of the trade statistics in Appendix 6. The biggest markets for imported gum rosin are Japan, Western European countries, particularly Germany, the Netherlands and France, the Republic of Korea, the United States and India. Globally, the European Community (EC) is the biggest importer and consumer, and the People's Republic of China is its biggest supplier by far. France and Spain are the biggest importers of gum turpentine in the EC; they fractionate it and manufacture downstream derivatives for domestic consumption and re-export. Japan and India are other large importers of turpentine; supplies of rosin and turpentine to India supplement indigenous production. The very large requirements for both rosin and turpentine in countries such as the United States and the former Soviet Union are met primarily through domestic supplies of tall oil rosin and sulphate turpentine.

Elsewhere, although demand may be relatively low it is still significant. Demand is sometimes met by domestic production. In Kenya, the paper industry uses about 1000 tonnes of rosin per year, most of which is supplied from local sources. In other countries it is necessary to import most or all of the requirements. Thailand, for example, produces a few hundred tonnes of rosin but imports several thousand tonnes a year.

Trading structures and procedures

In some of the major producing countries, the structure of the industry, and the channels of distribution of gum naval stores into the international market, has changed in recent years. In Portugal, individual producers have formed producer groups through which trade is conducted. This relatively small number of groups has generally simplified the negotiation of imports from Portugal and given some measure of consistency in the level of prices. Conversely, there has been a move away from the more centralized system of trading in the People's Republic of China to one in which different provinces have the freedom to enter into contracts with international buyers. Even within one province there may be several groups competing for sales.

Most of the production in smaller producing countries is for domestic consumption. The processors sell directly to end users such as paper mills, paint or chemical companies. However, there are some basic procedures and practices which should be noted by prospective new producers or others considering the sale of exports. Most purchases are made on the basis of agreed specifications. As indicated in Appendix 2, these specifications will vary according to the origin of the rosin or turpentine. New producers will therefore need to reassure potential buyers of the quality of the material being offered by providing samples beforehand and, perhaps, a trial shipment. International trade is normally conducted through agents or dealers, rather than by direct negotiation between producer and end user. Agents usually act on behalf of a specific producer. Dealers buy and sell on their own account, their main contacts being other dealers, producers and end users. They are very well informed about markets and trends, prices, product uses and end user requirements; this knowledge may be difficult for producers to acquire, particularly small ones.

A new producer of gum naval stores may wish to sell directly to the final user to avoid paying commission to intermediaries. When selling the products domestically, this may be the only option. However, in the international market, various middlemen have a valuable role and end users will usually prefer to conduct their transactions using agents and dealers. Commercial practices vary between companies and countries, and details of terms and conditions for buying and selling are a matter of negotiation between the two parties. Established suppliers are normally paid by cash against documents, but buyers would prefer to make payment after receipt of the merchandise from new producers.

Brief reference is made to packaging options for rosin and turpentine in Chapter 3 and they are described in more detail in Appendix 4. Buyers of material transported by ocean freight prefer to minimize transport and handling costs by importing a minimum shipment size of one container load (approximately 20 tonnes gross weight).

Trade in crude resin

In any analysis of world production and trade in gum naval stores, the volume of trade taking place in crude resin needs to be estimated. Until recently, this did not need to be considered as all resin was processed at origin and rosin and turpentine were the primary products of trade. However, trade in crude resin has developed over the past five years as the capacity for tapping has fallen in some of the traditional producing countries, notably Portugal and India. These countries have excess processing capacity (usually fully depreciated) which can be brought back into production if an economic, external source of crude resin is found. The absence of capital costs therefore enables the processors of imported resin to sell the outputs (gum rosin and turpentine) at a price which only need cover raw material and processing costs, freight, drums and profit. The sale of crude resin also allows producing countries with a surplus to earn extra revenue without investing in additional capacity for processing.

The main suppliers of crude resin in 1993 were Brazil (exporting about 12 000-13 000 tonnes), Indonesia (2000-3000 tonnes) and the People's Republic of China (3000-4000 tonnes). Total exports in 1993, based on trade estimates, were therefore 17 000-20 000 tonnes. Present levels are likely to be much reduced in the short term as a result of the destructive floods in China in 1994 and the impact of severe summer droughts in Indonesia (Java) and Brazil. At the moment, Brazil is probably exporting less than 10 000 tonnes of crude resin, and the People's Republic of China and Indonesia may not be exporting any. The buyers of crude resin in 1993 were Portugal (which imported 8000-10 000 tonnes of Brazilian resin) and India (which bought 3000-4000 tonnes from Brazil, and most of Chinese and Indonesian resin exports, to give a total of 8000-11 000 tonnes).

There is little likelihood that tapping will be expanded in either Portugal or India, and if the present reduced trade in crude resin becomes permanent, Portugal will have less rosin to sell, and India will need to import more Chinese and Indonesian rosin and turpentine in order to meet domestic requirements.

It is suggested elsewhere (Chapter 4) that once domestic market demand has been satisfied, the export of crude resin could be more profitable for new, small producers than the export of small volumes of gum rosin and turpentine. However, this would depend on a continuing demand for external supplies of resin from Portuguese and Indian processors.

One unfortunate consequence of the use of crude resin which is not indigenous to the country in which it is processed is that the compositional characteristics of the rosin and turpentine may no longer indicate the source of the processed products. In the past, the different species of pine used by the major producers of internationally traded gum rosin and turpentine have conferred on the products intrinsic chemical properties which denote their origin. End users have also become accustomed to the predictable, consistent properties of products delivered from traditional suppliers; the greater the trade in crude resin, the less certain these properties become.

In the next sections, production and trade in the major producing countries and regions is described.

People's Republic of China

Vast areas of native pines growing in the south of the country form the basis of the Chinese gum naval stores industry. The principal species used is *P. massoniana* (mostly natural stands), with smaller contributions from *P. yunnanensis*, *P. latteri*, *P. tabulaeformis* and *P. kesiya*. A small proportion of the resin raw material is obtained from plantations of *P. massoniana* and a further small, but increasing, amount from plantations of exotic *P. elliottii*. *P. elliottii* was introduced primarily as a timber species but it has been found to give significantly higher yields of resin than the native pines when tapped. The main production areas are Guangxi, Guangdong, Fujian, Jiangxi, Yunnan and Hunan provinces; Guangxi and Guangdong are currently the most important. However, these two provinces are among those which are undergoing dramatic socio-economic changes, including the drift of the rural population to more attractive and remunerative employment in the cities. This may eventually lead to a decrease in gum naval stores production in these traditionally important areas. On the other hand, Yunnan has a considerably greater standing pine resource than any of the other provinces plus the benefit of a large pool of low-cost labour, so it will probably assume greater importance as a supply source.

In spite of the very recent fall in production due to the floods in 1994, total annual production of crude resin in recent years has exceeded 500 000 tonnes, giving around 400 000 tonnes of gum rosin after processing. Resin processing covers all scales of operation from the very small, involving only a few hundred tonnes of resin, to the very large; one factory in Wuzhou, eastern Guangxi, is claimed to be the largest in the world, with a rosin output capacity of 40 000 tonnes/year. A recent Chinese source (Shen Zhaobang, 1994) indicates that in 1993, 430 000 tonnes of rosin were produced, of which approximately 60% (277 000 tonnes) was exported. Of the rosin which remains for domestic consumption, about 44% is used for the manufacture of soap (1990 data) and about 35% for paper. Increasing amounts of rosin and turpentine (30 000 tonnes and 20 000 tonnes, respectively) are converted to downstream derivatives within the country.

Indonesia and other countries of Southeast Asia

Although Indonesia has produced rosin and turpentine for many years, it was not until comparatively recently that it emerged as a major force in world trade. Virtually all crude resin production is based on extensive areas of *P. merkusii* plantations on Java. These are managed by Perum Perhutani, the Forest State Corporation, who are also responsible for the tapping and processing operations (although some of the factories fall within the private sector). A very small quantity of resin is produced intermittently in Sumatra. In the early 1980s, modern processing methods were introduced to replace the older, direct-fired distillation units. Production subsequently rose from 16 000 tonnes of crude resin (9000 tonnes of rosin) in 1981 to 70 000 tonnes of resin (49 000 tonnes of rosin and 8000 tonnes of turpentine) in 1991; by 1993, it had risen to over 100 000 tonnes of resin (69 000 tonnes of rosin and 12 000 tonnes of turpentine). Slightly lower production levels are forecast for 1994 because of a severe drought which affected resin yields.

Although most of the rosin and turpentine produced in Indonesia is exported, an increasing proportion of both is being consumed domestically. Perum Perhutani statistics for 1993 show that approximately 46 000 tonnes of rosin (two thirds of total production) and 7500 tonnes of turpentine were exported. Figures from the official Indonesian trade statistics are significantly lower. Production of downstream derivatives is likely to attract increasing attention in the years to come.

In 1991, production in Indonesia came from about 100 000 ha of pine. The actual area of planted pine in Java is about four times this figure and still expanding. There are also large areas of pine plantations on Sumatra, Sulawesi and Kalimantan and these, too, are increasing in size to meet the demand for wood pulp. The potential for increased resin production is therefore very large (assuming that labour continues to be available) and in future years Indonesia will undoubtedly consolidate and improve its position as the second biggest producer of gum naval stores after the People's Republic of China.

Production elsewhere in Southeast Asia is very low. Viet Nam produced approximately 2500 tonnes of resin from *P. merkusii* in each of the five years from 1986 to 1990, and as the country is now open to foreign investment this figure may rise in the future. There is some production in Thailand and Laos from *P. merkusii*, and some from *P. kesiya* in Myanmar (Burma), but it is very low (less than 500 tonnes/year) and does not enter international trade.

Portugal and elsewhere in Europe

The warm summer temperatures which are conducive to high resin flow, and the large areas of natural pine which exist, made Portugal and some Mediterranean countries major producers of gum naval stores at one time. Some production also took place in central and eastern Europe. However, increasing labour costs and a growing unwillingness amongst workers to undertake tapping has led to a decline in production, sometimes to the point where it has ceased altogether.

P. pinaster occurs quite widely in central and western areas of northern Portugal and, with the exception of recent purchases of crude resin from Brazil, is the sole source of

Portuguese gum naval stores. In the ten years 1978 to 1987, crude resin production averaged 110 000 tonnes/year and yielded 84 000 tonnes of rosin and 19 000 tonnes of turpentine. By 1992, production had declined to approximately 30 000 tonnes of resin (equivalent to 22 000 tonnes of rosin), although a slight increase is predicted for the 1994/95 crop year. Most of Portugal's rosin output is still exported, although an increasing amount is being used internally; much of its turpentine is fractionated or consumed domestically.

France no longer produces gum rosin or turpentine and production in Spain has fallen to a very low level. Production in central and eastern European countries such as Poland, Bulgaria, and the former Yugoslavia and Czechoslovakia has also declined. Greece produced about 6000 tonnes of resin from *P. halepensis* in 1993, but the trend for production is downwards. Production of resin is now reported to have ceased in Turkey, although in the late 1980s it produced about 3000 tonnes/year from *P. brutia*.

Russia

P. sylvestris covers vast areas of Russia and other parts of the former Soviet Union and forms the basis of a substantial naval stores industry. The main areas for gum naval stores production are in Irkutsk and Yekaterinbourg (the former Sverdlovsk region), the central parts of the Krasnoyarsk region, and the central and northern regions of the European part of Russia. Siberia and the Urals account for about 50% of crude resin production; the remainder comes from European Russia. The colder regions of Siberia are not conducive to high resin yields and productivity, in general, is believed to be low. Russian sources have stated that production of resin has fallen in recent years from a high of 115 000 tonnes to around 90 000 tonnes in 1992; this total is believed to include very minor amounts of larch and fir oleoresin. If plans to tap trees in the Crimea go ahead, production may be stabilized at this level as resin yields in this area are expected to be higher.

Most of the rosin and turpentine produced in Russia is used domestically, but small amounts have been offered on the international market in recent years.

North America

For many years, the United States has experienced problems in recruiting labour for the arduous task of tapping trees at a wage which makes the collection and processing of resin economically viable. This has led to a steady decline in gum naval stores production, and from a wide supply base in the southeast where *P. elliottii* (slash pine) is grown for pulpwood, tapping is now confined to the state of Georgia. Extant production is probably only a few thousand tonnes; exports of gum rosin averaged about 1200 tonnes/year for the five years 1989-93 and were less than 1000 tonnes in 1993. Naval stores production remains a major industry in the USA (and a dominant force in the world), but it is based largely on sulphate turpentine and tall oil rosin recovered during chemical pulping (sulphate naval stores) and, to a much lesser extent, on wood naval stores.

There are probably more native *Pinus* species in Mexico than in any other country in the world. Although many of the species are unsuitable for tapping, a large naval stores industry has developed using those which are. Although mixed stands of pines are often tapped, the major species is *P. oocarpa*. Tapping is concentrated in the states of Michoacán, Jalisco and Mexico. However, as in the United States, there has been a downward trend in resin production, and output has fallen from about 60 000 tonnes/year in the early 1980s to about 30 000 tonnes/year in the early 1990s. Gum rosin and turpentine production was around 22 000 tonnes and 4000 tonnes, respectively, in 1991; most was consumed domestically.

Central and South America and the Caribbean

Several countries in Central America have tapped pines for resin at some time but Honduras remains the major producer. Most of the resin is obtained from *P. oocarpa* although a small quantity comes from *P. caribaea* var. *hondurensis*. Production of crude resin in Honduras peaked in the early 1980s, but has since declined. In recent years it appears to have stabilized at about 6000-8000 tonnes/year (equivalent to approximately 4500-6000 tonnes of rosin). Most of the rosin is exported, mainly to Europe, where Germany is the largest importer.

Brazil is the biggest producer of gum naval stores in South America. Considerable areas (approximately 1.5 million ha) are planted with pine of different species; the tropical *P. caribaea* and *P. oocarpa* are grown in the north and the more temperate *P. elliottii* and *P. taeda* (a poor resin yielder) are grown in the south. Large-scale tapping began in the late 1970s and production of crude resin increased steadily to around 65 000 tonnes in the late 1980s. The resin has been obtained almost entirely from *P. elliottii* and production has taken place mainly in São Paulo state; there is some additional production in Paraná, Santa Catarina, Rio Grande do Sul and Rio de Janeiro. Production fell somewhat in 1991 and 1992 but is currently believed to be around 60 000-65 000 tonnes (equivalent to 42 000-45 000 tonnes of rosin and 7000-8000 tonnes of turpentine). Most of the processed products are consumed domestically, but significant quantities are exported (13 500 tonnes of gum rosin and 3000 tonnes of turpentine in 1993). Replanting is not keeping pace with the loss of *P. elliottii* trees as they come to the end of their tapping life and it is likely that *P. caribaea* will be increasingly targeted as a source of resin in the future.

Argentina and Venezuela are the only other two countries producing gum naval stores in South America. In Argentina, plantations of *P. elliottii* are tapped in the north-eastern provinces of Misiones, Corrientes and Entre Rios. Crude resin production is estimated at approximately 30 000 tonnes (1993) from which 21 000 tonnes of rosin and 4000 tonnes of turpentine are obtained. Substantial amounts of both products are converted into value-added derivatives for domestic consumption and export. Venezuela is believed to produce around 7000 tonnes of crude resin from *P. caribaea*.

There are some very large plantations of *P. radiata* in Chile (about 1.5 million ha). Experimental tapping has taken place and although the quality of the turpentine from *P. radiata* is probably superior to that from any other species, yields of resin are not high enough to encourage commercial production.

In the Caribbean, small quantities of resin have been produced in Cuba from three native pines (*P. caribaea* var. *caribaea*, *P. tropicalis* and *P. cubensis*) but output has averaged less than 700 tonnes/year for the five years from 1989 to 1993.

Africa

Although large areas of pines have been planted for timber or pulp for some time, Africa has only become a producer of gum naval stores relatively recently. Tapping of *P. elliottii* in the Chimanimani area of the Eastern Highlands of Zimbabwe began in 1976. Production of crude resin has never exceeded about 1000 tonnes/year, however, and as the pine resource comes under increasing pressure for use as timber, output is expected to fall and perhaps cease altogether. Small amounts of rosin have been exported intermittently to South Africa but most is consumed domestically by the paper industry.

Kenya and South Africa both began production in about 1986. A diverse source of raw materials is used in Kenya; *P. elliottii* growing in the Machakos area of southern Kenya provides most of the resin, *P. caribaea* var. *hondurensis* is tapped in the southern coastal region of Kwale, and *P. radiata* is tapped at higher elevations near Nakuru. The total resin production of about 1000 tonnes/year is showing a small upward trend. All the rosin is converted to a modified form and sold to local paper mills for use as a sizing agent.

South African tapping operations are centred on the extensive *P. elliottii* and *P. caribaea* var. *caribaea* plantings in the Lake St Lucia area of northern Natal. Production of resin is more than 2000 tonnes/year, which is the highest of the three African countries. Most of the resulting rosin and turpentine is consumed domestically. The rosin is used mainly for paper size and in the manufacture of adhesives; some is exported.

Several other African countries have the potential for gum naval stores production by using the extensive areas of under-exploited pines which exist. There are signs that in some cases this potential is being realized in practical terms. Malawi, for example, has more than 50 000 ha of mature pines in the north of the country and although most of them are *P. patula*, a species with little or no prospect as a commercial source of resin, there are probably enough *P. elliottii* to make commercial tapping a viable proposition; it is unlikely, however, to become a large producer of naval stores in international terms. It is understood (late 1994) that commercial production will begin in Malawi in 1995. In Uganda, commercial tapping of *P. caribaea* began on a small scale in late 1994. Several other countries, including Tanzania and Zambia, have substantial areas of pines, but their suitability and capacity to support gum naval stores production has not yet been proved.

Indian sub-continent

India has been producing naval stores for a long time. Areas of natural and, more recently, plantation *P. roxburghii* (chir pine) have been used in the northern states of Jammu and Kashmir, Uttar Pradesh and Himachal Pradesh. *P. wallichiana* grows at higher elevations along the same Himalayan belt but as it gives lower yields of resin than *P. roxburghii*, little, if any, is tapped commercially. Crude resin production peaked at about 75 000 tonnes in 1975/76 and has since fallen steadily. Production in 1990/91 was less than 25 000 tonnes, although it is now believed to have recovered and stabilized at about 25 000-30 000 tonnes (equivalent to approximately 18 000-21 000 tonnes of rosin). The main reason for the decline has been the loss of trees for tapping, either because many of them have reached the end of their productive lives and there are no new areas of pine with which to replace them, or because the damage done to trees by the use of inefficient, incorrectly applied methods of tapping has led to Forest Department bans on tapping.

The loss of substantial indigenous production of crude resin, and the demands of Indian industry for naval stores products, have meant that India is now a net importer of both rosin and turpentine. The shortfall in local production has been further compensated by the importation of about 10 000 tonnes/year of crude resin. The greatest single use of turpentine in India is for the production of synthetic camphor.

P. roxburghii is also tapped in Pakistan, Nepal and Bhutan. The quantity of resin produced by the three countries combined does not exceed a few thousand tonnes and is probably much less. All the output from Nepal and Bhutan goes to India.

In Sri Lanka, about 30 000 ha of *P. caribaea* (mainly var. *hondurensis*) have been planted on degraded land, on which the species has flourished. These plantations have great potential as sources of gum naval stores, but although some small-scale tapping has taken place, there is no large-scale collection and processing of resin at present.

ESTIMATES OF WORLD PRODUCTION AND EXPORTS

Estimates for production of crude resin, gum rosin and gum turpentine, and exports of gum rosin and gum turpentine are presented in Table 3. The estimates are based on published data which are believed to be reliable, and on trade sources. In cases where figures differ widely the authors have used their judgement to provide an estimate.

Table 3
Estimated world production and exports of crude resin, gum rosin and gum turpentine
(tonnes)

		Production			Exports	
		Crude resin	Rosin	Turpentine	Rosin	Turpentine
Total		976 000	717 000	99 400	384 000	25 000
of which:						
China, People's Rep. of	[a] 1993	570 000	430 000	50 000	277 000	5 500
Indonesia	1993	100 000	69 000	12 000	46 000	7 500
Russia	1992	90 000	65 000	9 000	1 000	500
Brazil	1993	65 000	45 000	8 000	13 000	3 000
Portugal	1992	30 000	[b] 22 000	[b] 5 000	26 000	6 000
India	1994	30 000	[b] 21 000	[b] 4 000	~	~
Argentina	1993	30 000	21 000	4 000	[c] 10 000	2 000
Mexico	1991	30 000	22 000	4 000	5 000	?
Honduras	1992	8 000	6 000	1 000	5 000	500
Venezuela	1993	7 000	5 000	800	~	~
Greece	1993	6 000	4 000	600	~	~
South Africa	1993	2 000	1 500	200	~	~
Viet Nam	1990	2 000	1 500	200	1 000	~
Others		6 000	4 000	600	~	~

Source: Based on various literature and trade estimates
Notes: *a* Production and exports expected to be sharply reduced for 1994/95
b Does not include that produced from imported crude resin
c Mainly downstream derivatives
~ Indicates small amounts

CHAPTER 2

RAW MATERIALS AND INPUTS

RAW MATERIAL REQUIREMENTS

The fundamental requirement is an adequate number of suitable, mature pine trees available for exploitation over the lifetime of a processing plant. Both natural forests and plantations may be used, although the high tree density and easier terrain which enables the tapper to visit a greater number of trees per day, makes resin collection cheaper and easier to manage in plantations. If the annual yield of resin is 3 kg/tree, at least 330 000 mature pine trees would be necessary to provide resin feedstock to a small processing plant with an annual throughput of 1000 tonnes.

Many countries have substantial resources of pine trees of one or more species, either as natural forests of indigenous species or as plantations of introduced exotics. Although all pines are capable of yielding resin, both the obtainable yield and the intrinsic quality of the rosin and turpentine can vary considerably according to the species. The way in which these genetic factors can influence resin characteristics at the species, provenance and individual tree level are discussed in more detail in Appendix 3. Species selection is therefore crucial to the marketability of the products and the profitability of the overall operation. The principal pine species tapped in various parts of the world have already been noted in Chapter 1. It should be appreciated, however, that those which are tapped are invariably chosen from the standing resource already existing within the country either as natural stands or plantations. Pines are usually planted for timber or pulp rather than resin, and whether the species originally selected for wood or fibre quality are also suitable for resin production is a matter of chance. *P. patula*, for example, which is one of the most widely planted pines in Africa, produces a very poor quality resin in low yields and cannot be tapped economically.

As well as being dependent on the species of pine tapped, the quantity of resin that may be obtained from a particular group of trees depends on a number of other factors. The most important of these include ambient temperature (and altitude insofar as it affects temperature), rainfall, diameter and crown size of the tree, method of tapping and length of tapping season.

High temperatures are conducive to good resin flow, while prolonged periods of high rainfall are not, and the extent of seasonal changes in climate will largely determine the period during the year when it is profitable to tap the trees. In temperate countries such as Portugal, tapping takes place for eight to nine months of the year. The time between the end of one tapping season and the beginning of the next is used for cleaning or replacing tools and accessories and installing or raising gutter systems and cups on the trees. In more tropical countries, where there are no prolonged cold periods, tapping may proceed all year round, although seasonal heavy rains may interrupt it.

In general, the greater the diameter of the tree tapped and the bigger the proportion of live crown, the greater the resin yields. Selection of groups of trees for tapping will therefore be made on the basis of utilizing the oldest or largest trees available of the preferred species. Plantation pines are usually at least 15-20 years old before tapping commences; some countries have regulations which limit tapping to those trees with diameters greater than about 20-25 cm. Comprehensive data are available, from many sources, relating diameter and crown size to expected resin yields However, although such data may serve to illustrate the general dependence of yields on tree size, they apply only to a particular species; they might also be misleading if used directly to estimate yields outside the country from which they were derived. Furthermore, as resin yields are known to be genetically determined, considerable provenance and tree-to-tree variations may exist. As a guide, suitable species grown under favourable conditions can yield 3-4 kg/tree annually. Minimum acceptable yields are around 2 kg/tree; it is unlikely that yields much below 2 kg could support a viable resin tapping operation.

Tapping trials to assess yields should therefore complement any feasibility study which examines the prospects for establishing a gum naval stores industry. At the same time, samples of the resin obtained should be analysed to determine quality. Regardless of the quantity produced, if the quality of the rosin and turpentine derived from the resin is so poor that the products are unacceptable to the market, the trees will not be worth tapping. Quality assessment criteria for gum rosin and gum turpentine are described in Appendix 2. In general, as far as international markets are concerned, the products from Portugal and the People's Republic of China will set the standards against which gum naval stores from new sources will be judged.

RESIN TAPPING OPERATION

Resin is obtained from the tree in a manner analogous to rubber tapping except that the exudate is more viscous and slow-running than rubber latex. Tapping generally involves the following basic steps:

- preparation of the face of the tree
- installation of the resin collection system
- wounding of the tree to induce resin flow
- application of a chemical formulation to stimulate and maintain resin flow
- collection of the resin, re-wounding of the tree, and application of the stimulant at suitable intervals.

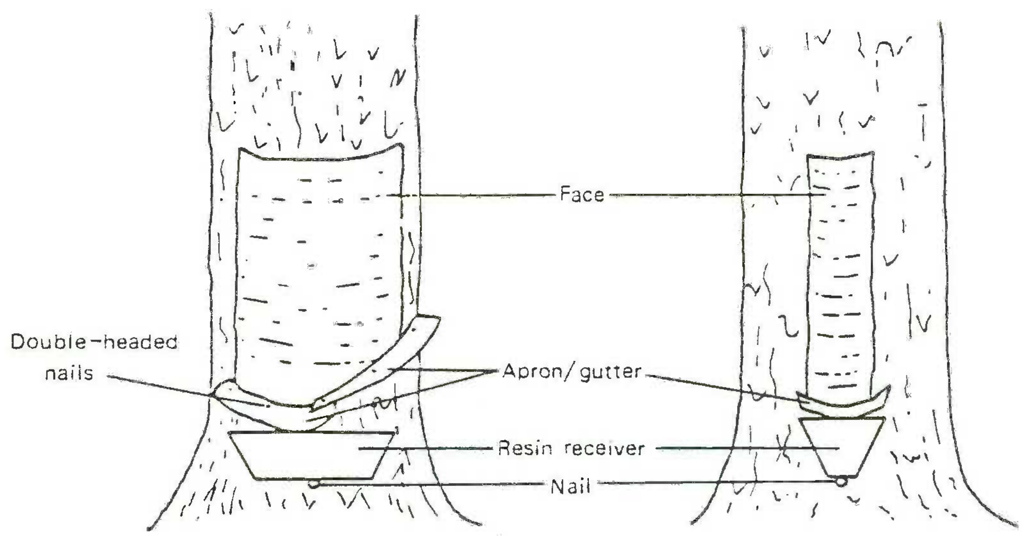
In some countries, traditional methods of tapping are used which do not entail application of a chemical stimulant and which are generally less efficient.

The precise manner in which the above steps are carried out in the various producer countries has developed in different ways over the course of many years. Nevertheless, it is generally recognized that tapping should be carried out carefully and in such a way as to avoid permanent damage to the tree. Older methods in which cuts were made deep into the wood have mostly been replaced by more modern practices involving removal of bark alone. Some producing countries have spent much time and effort developing and refining procedures and investigating the use of different materials and accessories such as cups and gutters. Others still adhere to traditional methods and materials. In Indonesia, trees are tapped by the frequent removal of slivers of wood from the stem without the application of stimulant (although steps are being taken to introduce alternative methods which do not involve the removal of so much wood). In India, although tapping is still carried out which entails removal of wood from the tree in the form of 'blazes', the 'rill' method, in which an acid-based stimulant is applied to small channels cut in the xylem in a 'herring bone' fashion, is advocated. The method of tapping usually followed in the People's Republic of China is unusual because it involves moving down the tree during the course of the season rather than starting at the base and moving up; although the benefits of using stimulants to enhance resin yields have been demonstrated, the practice has not been widely adopted.

The particular style of tapping employed may also be influenced by the extent to which the trees are used for purposes other than naval stores production. If tapping is conducted on plantation pines, for which the principal interest is the final sale of the logs for sawtimber or pulpwood, the common practice is to tap fairly intensively, using a wide face, for four years (perhaps extending to six or eight years) prior to felling. If there are no pressing demands for felling, or if there is a large enough number of trees available to allow the use of a narrow face and still maintain the required production overall, tapping may be carried out for up to 20 years or more on the same group of trees.

Systems of tapping developed in the United States and Portugal are now described. Both entail the removal of bark and the application of sulphuric acid as a stimulant, but whereas the former uses a wide face for intensive tapping, the latter uses a narrow face with a simpler system of guttering. The two methods are illustrated in Figure 1.

Figure 1
Systems of resin tapping using a wide and narrow face



Either method, adapted to meet local circumstances where necessary, could be adopted by intending new producers. Both systems are well documented and the intention here is only to give an outline of the methods and materials used, highlighting the differences between the two systems, rather than to offer a complete guide to tapping with detailed descriptions of tools and accessories.

Variations of the US system have been used in many parts of the world including Brazil, other countries in Central and South America, and Zimbabwe. Countries using the Portuguese narrow face method include Mediterranean producers, South Africa and Kenya. Alternative tapping procedures which may be used in other countries are not described here either because their use is limited to a particular country, or because they are generally considered to be less efficient.

System of tapping using a wide face

In order to facilitate installation of the collection system on trees which are to be worked for the first time, the rough outer bark is first removed from the area at the base of the tree where it is to be fixed. This rough shaving is usually extended for part of the way up the tree to make the subsequent tapping easier. Although a two-piece apron and gutter system made of galvanized iron is illustrated in Figure 1, this has been dispensed with in Brazil and a specially designed plastic bag is used instead; this fits across the width of the face and is held flush to the tree by wire which goes round it. This system is simpler, cheaper and quicker to install than the cup and gutter system, and does not risk contaminating the resin with dissolved iron (which may result from the corrosive action of the acid stimulant on the galvanized iron gutter if its application is over-zealous). The risk of leaving the nails used to fix the apron/gutter system in the tree after tapping has finished, and of damaging saw blades if the trees are destined for sawtimber, is also removed. However, it is rather more difficult to remove the resin from the bags without wastage than from the rigid system, and the bags have a shorter life. The apron/gutter system can be nailed in position using five double-headed nails which are easy to remove and facilitate later removal of the guttering. Immediately below the guttering, a cup made of galvanized iron, aluminium or durable plastic is fixed; it is supported on a large nail and held in place by the bottom edge of the apron. In Zimbabwe, galvanized iron gutters and a small spout are used to direct the resin into glass jars.

A horizontal strip of bark 2-2.5 cm high is removed across the width of the tree, just above the gutter, to cause the resin to flow and the chemical stimulant, usually acid-based, is applied along the top edge of the exposed tissue ('streak'). The combination of bark removal and acid treatment makes it unnecessary to cut into the wood to open the resin ducts, which was characteristic of older methods of tapping. Wounding to the tree is therefore only superficial and loss in growth during tapping is minimal. The acid also maintains resin flow for a longer period of time and the tapper, instead of having to return to the face within two to four days, as is the case when traditional methods of tapping are used, need not repeat the task until some weeks later, at which time the bark is removed above and adjacent to the first streak. In this manner, a two-week tapping interval using a streak height of 2 cm would necessitate about 16 visits to the tree in the course of an eight month tapping season, and would result in a vertical face about 32 cm high, down which the resin would flow to the cup. A shorter tapping interval, say 10 days, would use a streak height proportionately less than 2 cm.

The first type of stimulant to be used commercially was a 50% solution of sulphuric acid, applied as a fine spray from a plastic bottle. Later developments led to the production of a specially formulated sulphuric acid paste. This is applied as a thin bead from a plastic bottle and is now quite widely used, although the precise formulation varies somewhat according to the availability of local materials.* As well as being less wasteful and less hazardous to the person using it, the paste has the advantage of requiring slightly less frequent applications than the spray. The greater penetration of the paste requires the removal of a bigger strip of bark than normal; so in spite of fewer visits to the tree, the total height of the face worked is about the same as for the spray. Whichever type of stimulant is used, its strength, frequency of application, and the height of bark removed should be optimized so that at each removal of bark there is some live xylem tissue showing. This is indicated by the paler colour of the wood above the line which shows the extent of penetration of the acid from the previous streak; the wood below the line is darker and redder in colour. More recent research has shown that inclusion in the formulation of 2-chloroethylphosphonic acid (e.g. Ethrel™), a chemical used to enhance yields of latex in rubber tapping, also has beneficial effects on resin production. However, further research is needed to demonstrate the long-term benefits and it is not thought to be used commercially in tapping pine trees at present.

During the course of its flow some resin solidifies on the face of the tree before reaching the receiver. The extent to which this happens depends on the species of pine being tapped. The solid may be scraped off periodically during the season, or it may be left to the end and collected and processed separately from the bulk of the resin as it will yield a slightly lower grade of rosin.

At about six monthly intervals, or at the end of the season, the cup and gutter system is removed and re-installed where the last removal of bark was made; a second season's tapping can then be carried out. This is repeated for a third, fourth and, perhaps, fifth season (3-4 years in total), when the height finally attained is likely to be too great for a person to reach and it becomes uneconomic to proceed any higher. Depending on the intended use for the trees, it may be possible to initiate a second face for tapping on the opposite side of the trunk.

System of tapping using a narrow face

Procedures using a narrow face are also based on the removal of bark with acid treatment. However, the use of a narrower face, usually 10 cm wide, brings with it several advantages, the most important being the simpler system of guttering that can be used. A small, flat, arc-shaped piece of galvanized iron is inserted edgewise into the shaved part of the tree with a special tool; it requires no nails to hold it in place. A clay or plastic pot is supported under it by a single nail or wooden splint; in appropriate circumstances, a bamboo cup or coconut shell can be used as the resin receiver. The height of bark removed at each visit to the tree is similar to that for a wide face, about 2-2.5 cm; the tapping schedule (using spray or paste-based stimulant) is also similar. After working on one vertical face for four years,

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* In addition to the sulphuric acid solution itself, a typical paste contains small amounts of a lubricant-cum-surfactant (to reduce drying out and prevent sticking of the paste to the sides of the container), an acid-stable emulsifier (to prevent separation of the oil and aqueous phases), a pyrogenic silica (to act as a thickener) and a carrier such as finely graded pecan shell or rice bran flour (to impart adhesive qualities to the paste and provide texture). The concentration of the acid used to make the paste may be between 40% and 60% (w/w) depending on the tapping method used and the climatic conditions under which the paste is applied. *Note*: appropriate safety precautions should be taken when preparing, handling and using strongly acidic materials and their formulations.

another may be started about 10 cm to one side of the first. In this way, four or five faces, each lasting for four years, may be worked on large trees. If the trees are large enough, two or more faces may be worked simultaneously; however, although they will be higher, resin yields for two faces are not twice that for a single face.

Tapping remains essentially a manual operation whatever system is used, and although attempts have been made, notably in the United States, to introduce mechanization for some of the tasks, particularly those which are physically demanding such as the initial shaving of the tree and the removal of bark, they have met with little success. The tools and accessories required for tapping are relatively few and simple and include the following:

- bark shaving tool
- cup or other form of receiver
- guttering
- nail(s) (to support cup and/or to fix guttering)
- hammer
- bark hack
- file or whetting stone (for sharpening bark hack)
- sulphuric acid-based stimulant (liquid or paste)
- bottle (plastic, for application of acid)
- bucket (into which resin from cup is emptied)
- funnel (for transfer of resin from bucket to drum)
- drum or barrel
- protective clothing and accessories (for tapper, including visor or goggles, acid-proof gloves, plastic apron or other garment, and rubber boots).

LABOUR AND ORGANIZATION

Labour requirements and organization during the tapping season vary from producer to producer. Methods of tapping which involve the removal of bark and application of a chemical stimulant usually mean that the tapper only needs to visit the tree every 7-14 days; the interval may be even longer under favourable conditions and using acid paste. Methods which involve the removal of wood without applying stimulant require more frequent visits, every one to three days, and are therefore more demanding in terms of labour. Resin is emptied from the receiver every second, third or fourth visit depending on the system of tapping used and the size of the receiver. It is emptied into buckets and the full buckets are emptied into drums or barrels strategically located amongst the trees. When full, the drums are transported directly to the processing plant or to a central storage depot.

Productivity is dependent on the system of tapping used and the efficiency of the tapper; it is also influenced by tree density and the terrain over which the tapper has to move when going from tree to tree. Between 200 and 800 faces may be attended in one day, so in a two-week cycle of 10 working days, 2000-8000 trees (or less if more than one face is being worked per tree) can be tapped by one person. Although a different individual usually collects the accumulated resin from the trees, there may also be a division of labour amongst the tappers themselves. For example, one person in a team may be responsible for applying the stimulant and/or replacing the cup on the tree (which is either covered or removed during streaking to avoid pieces of bark falling into it) while the others carry out the streaking.

In addition to the tappers, small teams of people are required during the establishment and maintenance phases: to shave the trees and install the cups and gutters prior to tapping new groups of trees (establishment), and to remove the cups and gutters and repeat the process at the end of one season in preparation for the next (maintenance).

Several systems of remuneration exist. The hourly wage system, which requires constant supervision, increases production costs and gives the labourers no incentive to work efficiently. A system in which contractors or pieceworkers undertake the tapping has the advantage of relieving management of some of the problems associated with having a large labour force under its direct control, and payment on the basis of the quantity of resin produced encourages higher levels of production. Some supervision or checking is still required to ensure that tapping is being carried out correctly, and a system of bonuses or penalties may be adopted to reward productivity and penalize poor workmanship. In some countries a plot-holder is allocated a specific number of trees, perhaps 5000; he can then employ extra tapping labour at his own expense if he needs it, or involve other members of his family.

CHAPTER 3

PROCESSING AND PLANT DESCRIPTION

INTRODUCTION

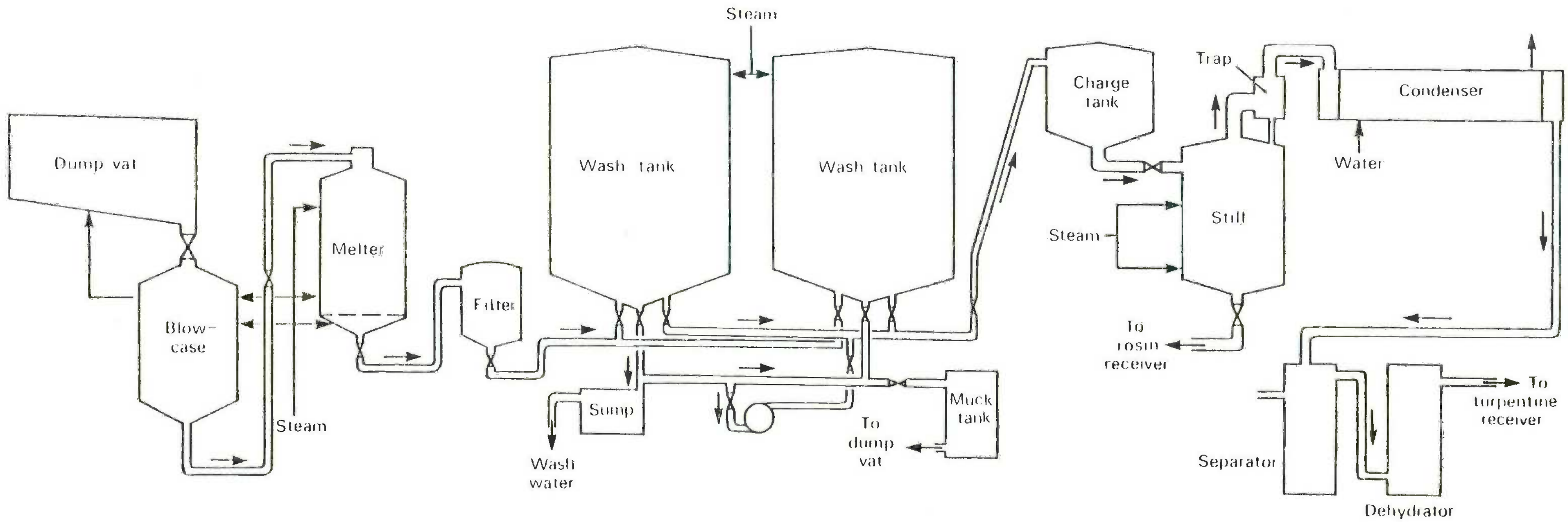
The separation of resin into its component parts, rosin and turpentine, involves two basic operations: cleaning and distillation. Cleaning is necessary to remove all extraneous material from the resin, both solid and soluble. This includes forest debris such as bark, pine needles and insects, which may have fallen into the cup during its period on the tree, and which require removal by filtration. Water-soluble impurities carried into the cup by rain water are removed by washing the filtered resin with water. The approximate composition of crude resin, as it is received at the plant for processing, is 70% rosin, 15% turpentine and 15% debris and water. Small amounts of iron produced by the corrosive action of excess sulphuric acid on galvanized iron guttering and cups may also contaminate the resin. As the presence of iron would lead to a darker, lower-grade rosin, it is removed by adding oxalic acid prior to filtration. Iron contamination has become less of a problem as the use of acid paste rather than spray has become more widely adopted. The use of cups made of plastic or other non-ferrous material eliminates the risk of iron contamination from this source.

The cleaned resin is then ready to be distilled, or, to be precise, steam-distilled; the older type of direct-fired still has given way, almost universally, to a still in which steam is used both to heat the resin and to facilitate the distillation by co-distilling with the turpentine vapours. Designs of equipment, and the procedures followed, vary somewhat between producing countries. The Olustee process, developed and used in the United States and adopted elsewhere, is described first. The methodology is well documented, and since the differences between this and any other system of processing are likely to be matters of detail rather than principle, a description of the process serves as a useful guide to any prospective processor of crude resin. The final design of plant can be tailored to suit local preferences and requirements in terms of scale. A description is then given of Portuguese methods which are based on the same principles as the Olustee process, but which differ in the layout of equipment and the relative capacity of some of the units. Processing methods used in other producing countries are not described. To a greater or lesser degree they all follow the same basic principles, namely, filtration of the hot, diluted resin, usually including a washing stage, and steam-distillation.

OLUSTEE PROCESS FOR THE PRODUCTION OF TURPENTINE AND ROSIN

The scheme of processing is illustrated in Figure 2. Barrels of resin arriving at the plant are immediately weighed and upturned over an iron grill covering a large concrete or mild steel dump vat. The barrels are placed over steam outlets to remove the last of the adhering semi-solid resin. 'Scrape', the solidified resin which is taken off the face of the tree at the end of the season and which yields a poorer quality rosin, is emptied into a separate compartment for separate processing.

Figure 2
Scheme of resin processing in the United States of America



Source: Based on McConnell (1963)

In order to facilitate the flow from one unit to another, the resin has to be diluted with turpentine and heated. As well as making the resin more fluid, dilution lowers its specific gravity, so that in the later washing stage it will form a two-phase system with water more readily. The resin is transferred first from the dump vat to a blow-case, and then from the blow-case to a melter, by the use of steam pressure. Filter aid (diatomaceous earth, 0.5-0.6 kg/tonne of resin) and oxalic acid (0.6-1.2 kg/tonne) are added at either of the two units. Turpentine (from a previous distillation) is added to bring the turpentine content of the resin to between 30% and 40%; the precise amount added depends on whether good quality resin or 'scrape' is being processed. The temperature inside the melter is raised to 85-100°C by steam, the exact temperature again being dependent on the quality of the resin. Steam pressure is then used to force the hot resin first through a metal screen at the bottom of the melter to remove the larger sized solid matter, and then through a filter to remove all remaining solids. The filter is of the horizontal or vertical plate type and consists of about 12 plates backed with filter paper or cloth; filtration is assisted by the filter aid added previously. The resin passes directly from the filter to the bottom of a wash tank containing hot water. Each tank holds 1500-2000 litres of water which is sufficient for washing up to 20 000 litres of resin (about seven charges from the melter). After washing, the mixture is allowed to settle for at least 4 hours and preferably overnight. The bottom aqueous layer is then run off to waste, an intermediate layer of unbroken emulsion ('muck') is run off to be returned to the low grade dump vat for reprocessing, and the top layer, which consists of washed resin, is drained and pumped to a charge tank in preparation for distillation.*

The still is filled with resin from the charge tank. The temperature is then raised by means of steam coils to about 110°C at which point live steam is gradually introduced through sparger valves. As the temperature continues to rise, distillation proceeds and the sparger steam inflow is increased until, at the end of the distillation, the temperature has reached 160-170°C. The rate of increase in temperature, and therefore the time taken for the distillation, is dependent on the steam pressure used; the higher the pressure within the range 8.8-10.5 kg/cm^2 (125-150 psi), the faster the distillation. For still capacities of about 4-5 tonnes, distillation times vary between 90 and 150 minutes. If the steam pressure is too low, it will be more difficult to remove the last of the turpentine (particularly if there are appreciable amounts of high-boiling components) and there will be an inordinately long residence time for the hot rosin in the still; both these factors have an adverse effect on the quality of the rosin. The turpentine and steam vapours pass through an entrainment trap to remove any entrained resin and then condense in a water-cooled condenser. Completion of distillation is indicated by a minimal level of turpentine in the distillate (which, by experience, is found to correspond to a particular temperature). A small proportion of the turpentine coming over at the beginning and end of the distillation may be collected separately as slightly lower-quality turpentine, and used for diluting the next batch of resin at the melter. Otherwise, there is no fractionation.

The water-turpentine distillate is led immediately to a separating tank; the upper turpentine layer overflows and passes first down to the base of the dehydrator and then upwards through a bed of rock salt to remove all traces of water. The dry turpentine is

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* Simple batch, rather than continuous or vacuum distillation, is most commonly used and is described here, although the other methods offer some advantages in terms of product quality and steam consumption if there is sufficient throughput of resin to justify their use.

then fed to holding tanks for subsequent storage in bulk or in galvanized steel drums. The hot rosin from the body of the still is discharged from the bottom into suitable containers which are set aside for the rosin to cool and solidify.

Yields of rosin and turpentine obtained by US producers were about 700 kg and 160 litres (140 kg), respectively, from one tonne of resin. 'Scrape' yields less turpentine than normal resin. Specifications for both products are given in Appendix 2. The general appearance of the rosin should be hard, clear and bright, pale yellow-brown in colour, and with no visible sign of foreign matter or turbidity due to the presence of moisture. Packaging options for turpentine and rosin are described below, but more detailed packaging and labelling requirements are given in Appendix 4.

The materials used for the construction of the plant are important. The dump vat is concrete or mild steel and the blow-case is mild steel. In order to avoid corrosion by the acidic material, any area where hot resin is handled should be stainless steel; the melter, filter (where it comes into contact with the resin), charge tank, still and all pipework are all therefore made of stainless steel. The wash tank may be aluminium or stainless steel. The condenser, separator and dehydrator are also usually of stainless steel.

In the United States, melter capacity varied between 2.5 and 5 tonnes of resin when there were a number of independent processors. There were usually two or more wash tanks, each capable of holding up to 22 tonnes of resin and each providing material for four distillations. Operation of two stills, or double shifts, allowed up to 10 000 tonnes of resin to be processed in a year.

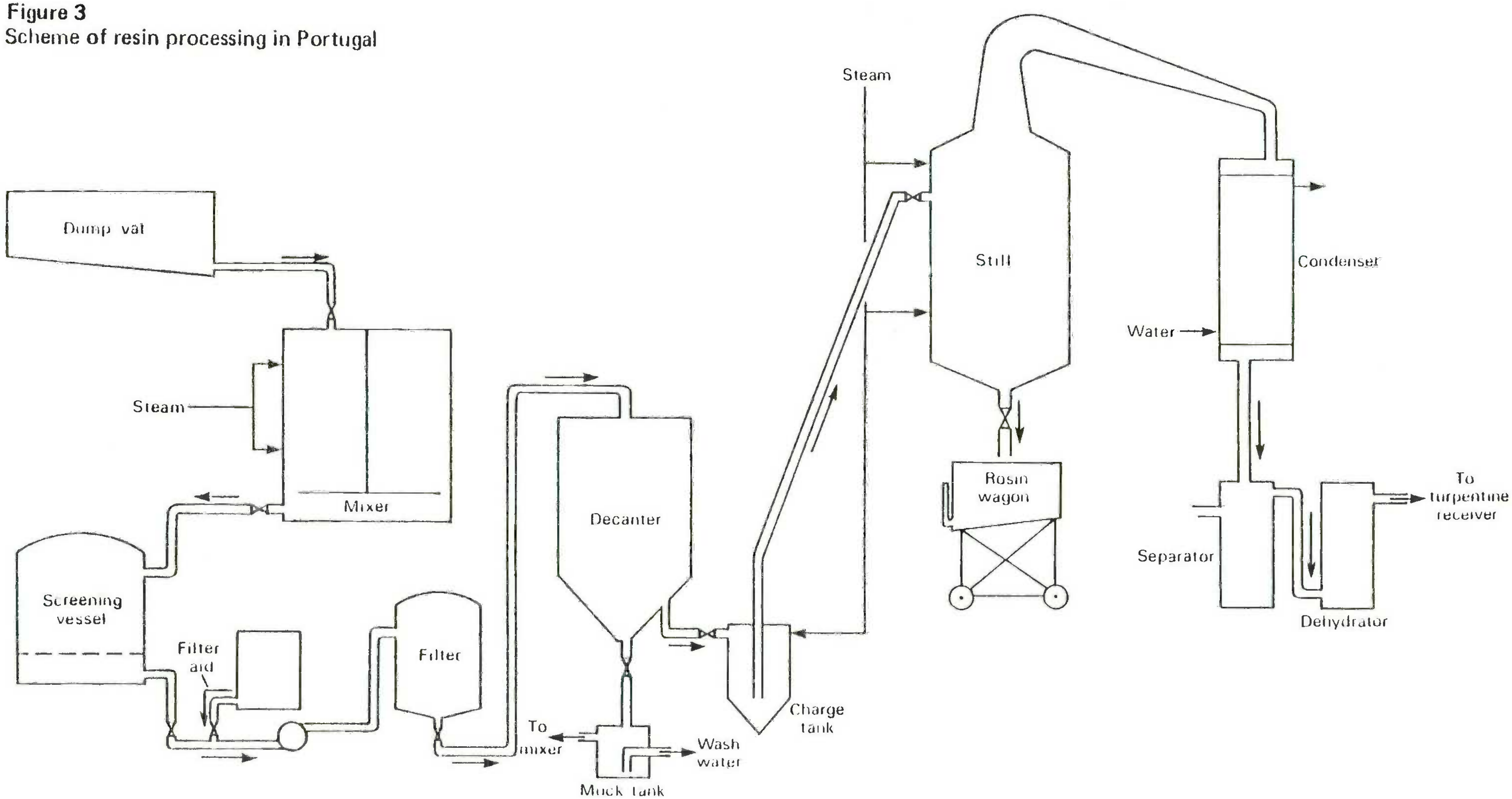
PRODUCTION OF TURPENTINE AND ROSIN IN PORTUGAL

The scheme of processing followed in Portugal is based on the same principles which led to the development of the Olustee process in the United States but some of the units which make up the plant differ in design and capacity. The process lay-out is illustrated diagrammatically in Figure 3.

Metal drums containing resin are unloaded at the dump vat. To facilitate the emptying of the drums (which is the most labour-intensive part of the whole process), a rectangular section (measuring about 25 cm x 15 cm) is cut out of the side before use. The section is then replaced but can easily be removed subsequently as required. On receipt, the drums are rolled on their sides to the vat opening and the resin is forced out with large spatulas. Resin from the dump vat is fed directly into a mixer (the equivalent of the melter in the previous scheme) with no intermediate transfer to and from a blow-case. The mixer, rather than being just a containing vessel like the melter, incorporates a stirrer so that the contents, including the added turpentine and oxalic acid (if used), can be thoroughly mixed as well as heated.

Another significant difference is the addition of washing water in the form of live steam (up to 10%) at this stage rather than in liquid form at a later stage. The hot mixture is next passed through a metal screen to take out the larger solid impurities; this occurs in a separate vessel rather than at the bottom of the melter as in the Olustee process.

Figure 3
Scheme of resin processing in Portugal



Source: Based on Gama (1982)

A slurry of diatomacaeous earth is added from another vessel and the screened mixture then passes immediately through a fine filter as before. The hot, filtered mixture passes to one of several decanters in which the aqueous portion is allowed to settle out, usually overnight; one charge from the mixer is sufficient to fill one decanter (unlike the Olustee system where one wash tank takes four to seven charges from the melter).

Both batch and continuous distillations are carried out in Portugal and although batch stills are predominant, the larger throughput which is possible with continuous distillation means that a significant proportion of Portuguese production is obtained in this way. Batch stills in Portugal are relatively small, with a capacity of 0.5 or 1 tonne, and distillation times are short, about 20-30 minutes. On completion of the distillation, the rosin is often drained from the still into a wagon; this can then be pushed between two lines of steel drums spaced out on a concrete floor, and rosin can be discharged into them by lowering an overflow arm. Alternatively, paper sacks may be filled.

Stainless steel is again the main construction material. Mixer and decanter capacities are each about 5-7 tonnes, and there are usually at least four decanters to provide a constant supply of material for distillation. Nominal plant capacities range from a few thousand tonnes up to about 10 000 tonnes/year.

SCALE OF OPERATIONS AND LABOUR REQUIREMENTS

The target production is determined by the availability of crude resin, the throughput which can be sustained, and the size of the market for the products. In some cases, the resin supply may be limited by the number of suitable trees available for tapping. The annual production capacity required to meet the target is largely dictated by the still size, the number of stills, and the shifts worked. The smallest sized plant might have a single still with a capacity of one tonne and be capable of performing three distillations per day (single shift). The number of working days available each year will be governed by the length of the tapping season, but assuming a 260-day year, an annual throughput of around 800 tonnes of resin could be achieved.

The factors to be considered when choosing between the different processing systems include relative plant costs, availability and cost of technical expertise, the costs of maintenance and spare parts, steam and water requirements, and the relative advantages or disadvantages of using larger or smaller batch sizes. Estimates of plant costs are discussed in Chapter 4. Data necessary to make an accurate comparison of steam and water requirements for the different types of plant are not available. The use of larger stills means fewer distillations are needed to process a given amount of resin. However, a small still allows for greater flexibility if interruptions in steam, water or raw material supplies are anticipated. As the stills designed for distillation of pine resin are not suitable for distilling harvested plant material to produce essential oils, this is not an option for using spare capacity should it occur. In any case, the risk of cross-contamination and taints would be too high.

The labour requirements are comparatively small for a plant capable of handling up to 1000 tonnes/year of resin. Only four or five skilled workers and a greater number of general labourers are needed; one person is normally responsible for operating the still, two or three others assist and operate the other pieces of equipment, and one is in charge of the boiler. The emptying of the barrels or drums of crude resin is the most labour-intensive and time-consuming part of the whole processing operation and at least six labourers are required for unloading, loading and similar work. A storeman, and office and transport staff, are also required. The total labour requirements for a larger plant do not increase proportionately as the same number of workers are needed to operate the specialized pieces of equipment. More general labourers will be required, though, to handle the greater quantities of resin and its products.

CHAPTER 4

FINANCIAL AND ECONOMIC ASPECTS OF RESIN TAPPING AND PROCESSING

The aim of this section is to provide economic and financial guidelines for the production and processing of pine resin. Although the production of crude resin, and its processing into rosin and turpentine, are distinct operations, the cost levels of resin tapping will directly affect the economic and financial competitiveness of resin processing.

It is impossible to compete in world markets if crude resin costs are markedly higher than those of the largest three exporters, the People's Republic of China, Indonesia and Brazil. The international trade in crude resin has expanded over the last five years, particularly from Brazil to Portugal and India, but it still represents a very small percentage of the total volume of rosin and turpentine traded.

It must be emphasized that costs will be site specific and there could be substantial differences according to local circumstances. This is particularly true of the tapping operation, and a detailed feasibility study, which would be necessary before making any investment decision, would need to look closely at the pine resource and the likely productivity. It has already been noted that intrinsic resin yields are influenced by species and local climatic conditions, but output is also greatly influenced by the productivity of the workforce and the effectiveness of the management, and this may vary considerably from one country to another (or even within-country).

RESIN TAPPING OPERATIONS

Tapping is a labour-intensive operation and labour costs will therefore greatly influence production costs and, hence, profitability. The tapping operation itself can be carried out by contractors or pieceworkers who are paid according to the amount of clean resin they produce. The advantages of this system of payment have been discussed in a previous section. A much smaller, permanent work force is required to supervise and manage the tapping operation, arrange for purchase, storage and transport of crude resin, and maintain stores and accounts. However, it is essential for management to undertake periodic checks to ensure that correct tapping procedures are being followed.

The major capital cost when establishing a tapping operation is the purchase of gutters and cups, a range of tools, and items of protective clothing and footwear for the tappers. The gutters and cups may be manufactured specifically for the purpose, or they may be made using suitable secondhand materials. Other major items of expenditure include pre-production and start-up costs, transport within the forest and to the processing plant, and licence fees payable to the owner of the trees for tapping rights.

Although it is impossible to provide accurate costs of a tapping operation, Table 4 gives details of the estimated pre-production, start-up, fixed investment, working capital and annual production costs for an African country at 1995 prices.

Table 4

Resin tapping operations: estimated pre-production, fixed investment, working capital and annual production costs for an African country

	Sub-total (US$)	Total costs (US$)
Pre-production and start-up costs		
Manpower recruitment and training; initial management and administrative expenses; materials for training	25 000	
Contingencies (10%)	2 500	27 500
Fixed investment costs		
Site preparation, civil works and loading bay	5 000	
Buildings: staff housing and office	65 000	
Production equipment: bark shavers, gutters, cups, tapping tools, acid applicators, buckets, funnels, drums, acid-proof aprons, rubber boots	80 000	
Auxiliary equipment: vehicles, workshop and office equipment	70 000	
Contingencies (10%)	22 000	242 000
Working capital costs		
3 months' working capital for raw materials, labour and staff costs, exploitation fees, vehicle licences and insurance		96 000
TOTAL fixed and working capital costs		365 500
Annual production costs		
Manpower: wages and salaries to permanent labour force	20 000	
Raw materials:		
Licence fees for use of trees	30 000	
Contractors' payments (based on 200 trees with double face to be tapped per working day)	80 000	
Production materials:		
Nails	9 000	
Sulphuric acid paste	15 000	
Transport: fuel, licences and insurance	35 000	
Equipment: maintenance and replacement	10 000	
General stores	15 000	
Contingencies (10%, all items except manpower/raw materials)	8 400	222 400
Annual charge for fixed and working capital (20%)		73 100
TOTAL annual cost of resin		295 500

All the costs are based on 1000 tonnes of crude resin being produced from 400 000 trees, each yielding an average of 2.5 kg of resin per year from two faces. As stated above, labour productivity and annual resin yields per tree will be critical in determining the profitability of the tapping operation.

It should be noted that in order for the data to reflect the true annual costs of production, fixed and working capital costs are charged at 20%/year; this is lower than is usual in many African countries.

Table 4 shows a total annual cost of crude resin at the production site of US$295/tonne. World prices for crude resin in the period 1991-94 (for traded material) averaged US$270-320/tonne (c&f) but prices may fall back slightly between 1996 and 2000. Allowances for ocean freight, internal transport costs, and *ad valorem* import duties, will enable a new resin producer in Africa, for instance, to be competitive in domestic and regional markets and to make a profit on capital employed, even if crude resin is produced at levels slightly above this range. Profitability is likely to be low, however, if imports are permitted and duty levels are only 20% or lower.

RESIN PROCESSING OPERATIONS

The overall capital costs of a resin processing plant cover machinery and equipment, freight of all imported items, and installation and start-up. Pre-production costs such as manpower recruitment and training and all initial management and administrative expenses also have to be included. It is assumed that the training element will be provided by a foreign technical expert. Additional provision must be made for land costs and civil works, buildings, utilities, auxiliary equipment and spares.

An approximation of pre-production, fixed investment, working capital and annual production costs for an African country is given in Table 5 (based on 1995 prices). Costs relate to single-shift working throughout the year and are based on 1000 tonnes of crude resin as raw material (costed in Table 4) producing an estimated 700 tonnes of rosin and 110 tonnes of turpentine. Operation of the factory on a two-shift basis processing 2000 tonnes of resin annually, would reduce unit fixed and working capital costs per tonne of rosin produced. The annual charge for fixed costs would fall by US$60 000, but annual production costs would rise. Table 5 shows a total annual cost for processing 1000 tonnes of crude resin of about US$668 000.

Using the figures for total annual costs shown for the African model in Tables 4 and 5, and assuming that 700 tonnes of rosin and 110 tonnes of turpentine are recovered from 1000 tonnes of crude resin, it is possible to calculate the annual production cost per tonne of rosin. In those parts of Africa where petroleum-based 'mineral turpentine' or white spirit is available cheaply, gum turpentine may not be highly valued, and it may be uneconomic to ship small consignments to export markets because of the cost of drums and ocean freight. Therefore, in calculating a break-even price for rosin, turpentine is given a nominal value of US$350/tonne. The total value for 110 tonnes of turpentine is thus US$38 500, and deducting this from the total annual production costs of US$668 400 gives a residual cost of US$629 900; this is equivalent to a break-even price for the rosin of US$900/tonne.

Table 5

Resin processing operations: estimated pre-production, fixed investment, working capital and annual production costs for an African country

	Sub-total (US$)	Total costs (US$)
Pre-production and start-up costs		
Technical expertise	20 000	
Manpower recruitment; training and administration; materials for trial runs	25 000	
Contingencies (10%)	4 500	49 500
Fixed investment costs		
Site preparation and civil works	10 000	
Buildings:		
Factory	60 000	
Workshop and staff housing	80 000	
Contingencies (10%)	15 000	
Plant and equipment:		
Boiler (imported)	74 000	
All other production equipment (made locally)	240 000	
Manager's 4WD vehicle; workshop and office equipment; clothing and tools	60 000	
Contingencies (5%)	18 700	557 700
TOTAL fixed costs		**607 200**
Annual production costs		
Manpower: wages and salaries to permanent labour force	84 000	
Raw materials: 1000 tonnes of resin at US$295/tonne	295 000	
Production materials: filters, filter aid and oxalic acid	20 000	
Transport: truck hire; fuel, licences and insurance for own vehicles	36 000	
Equipment: maintenance and replacement	10 000	
Packaging: 4-ply paper sacks with HDPE lining, 20 kg net	7 000	
General overheads: office, telephone, fax, etc.	30 000	
Contingencies (including a provision for working capital to cover two months' supply of resin)	65 000	547 000
Annual charge for fixed costs (20%)		121 400
TOTAL annual costs		**668 400**

It should be noted that the gum naval stores industries established during the last 20 years will be operating with older, lower-cost equipment which will have fully or partially depreciated. As a result, they should be able to produce both crude resin and processed rosin at prices 20-30% lower than those shown in Tables 4 and 5 which are based on capital equipment purchase and start-up costs at 1995 prices.

COMPARATIVE ADVANTAGES AND DISADVANTAGES OF DOMESTIC, REGIONAL AND EXPORT MARKETS FOR A NEW PRODUCER

It is recognized that the break-even price for rosin of US$900/tonne is high compared with the price of Chinese or Indonesian imported rosin, although it should be possible to reduce costs by improvements in productivity, particularly in the tapping operation. However, if the quality of his product is acceptable, an African (or any other) producer would have an advantage over the end user of imported rosin, in terms of meeting domestic or regional demand, because he would not incur the following additional costs. First, internal transport costs from port to factory for imported material would probably be around US$40-60/ tonne. Even if exports are made to regional countries by rail and truck, the advantage will be retained of not having to bear the cost of ocean freight (approximately US$70-90/tonne) incurred by Chinese, Indonesian and other competitors.

Secondly, any customs duties or tariffs levied on imports will add to the landed cost; a duty of 20% will add a further US$100-120/tonne. It is also possible that a neighbouring country buying gum naval stores will have a reduced (or preferential) rate of duty, allowing the regional exporter to pay only 50% of the full *ad valorem* tariff.

Thirdly, relatively small users often experience difficulty in opening 30-day letters of credit or providing sight drafts; several months' working capital may be tied up in the import of 50-200 tonnes of rosin in a single shipment, and interest charges may add a further US$50-100/tonne to their costs.

These additional costs amount to US$190-280/tonne for imported rosin and would raise the cost to the end user from about US$600 (c&f) to US$790-880/tonne. At the early 1995 rosin price of US$750-800 rather than US$600, the African producer could sell competitively in the domestic market for between US$900 (his break-even price) and US$1100/tonne. However, as these price levels are unlikely to be sustained over the next three to five years, a new producer should aim to produce rosin at US$750-800/tonne or preferably less.

Once the domestic demand is satisfied, the new producer will face a dilemma. He will be obliged to become a competitive exporter to find new markets but will only have marginal tonnage to sell. He may have a surplus of crude resin, but will have to contend with low prices and with buyers' minimum volume requirements which are hard to meet. His factory may be able to sell all its rosin and rosin products but may also need to dispose of 50-150 tonnes of turpentine in drums. Turpentine in such small quantities, and possibly not of the best quality, may be difficult to sell on international markets. However, it is also difficult to expand output from 1000 tonnes of product sold in domestic markets, to 3000-

4000 tonnes split between export and domestic markets. The greatest barrier is the extra cost incurred from local transport by road or rail, port handling charges and ocean freight; although this was an advantage when import substitution began, it has now become a major barrier to profitable exporting, even if markets can be found for small tonnages. The cost of new drums will add a further US$20-25/tonne to export costs.

These charges mean that the ex-factory prices of rosin and turpentine for a new producer must be US$130-175/tonne (internal transport + ocean freight + packaging) below the market price for established producers if it is to be landed in importing countries at parity. For many small producers, the swing from a freight advantage of US$110-150/tonne (internal transport + ocean freight) on domestic sales to a freight disadvantage of US$130-175/tonne on export sales, is too great. Agents and brokers are sometimes reluctant to handle very small consignments of uncertain and untested material, and the time and effort which may be required to overcome such difficulties often provides a further disincentive to the new or small producer.

The best solution to this problem is to first expand the processing capacity for rosin and turpentine in line with domestic or regional demand. Assuming there are sufficient trees to support increased production of resin, crude resin exports, or increased output of processed products (by working multiple shifts) which will be more marketable than very small quantities, can be considered at a later date.

New producers of crude resin, rosin and turpentine should anticipate these problems of balancing resin supply, local demand, capacity and export sales, if they are to operate profitably. It should not be presumed that the price levels of late 1994/early 1995 of US$750-800/tonne for rosin will continue for two or three more years.

CHAPTER 5

CONCLUSIONS AND ADVICE TO A NEW PRODUCER

There are two major and distinct operations involved in producing gum rosin and gum turpentine: the tapping of pine trees to produce resin, and the recovery from resin of rosin and turpentine using the relatively simple technique of steam distillation. Production of crude resin alone is unlikely to be economic as a separate operation. A resin price of about US$300/tonne close to the tapping operations in the forest will rise to an export price of about US$500/tonne when the costs of drums, internal transport and ocean freight are added. This price could not compete with that for the crude resin currently available from Brazil, Indonesia and the People's Republic of China which normally sells at below US$300/tonne delivered to the importing country.

Operations in nearly all producing countries combine tapping with processing the crude resin into rosin and turpentine. There may be options for further processing but this usually demands a high volume of output to take advantage of economies of scale. However, if there is a local paper industry, the production of rosin size is a fairly simple process which is worth considering. Despite the existence of a substantial international market for rosin and turpentine, it is recommended that a developing country should base its operation initially on supplying, perhaps, the soap, paper and paint manufacturing industries of the domestic market. This would yield immediate benefits from import substitution and the saving of foreign exchange. Once the raw materials and the technology have been proven in the domestic market, it would be appropriate to expand into neighbouring regional markets and wider international ones.

A gum naval stores operation has several attractions for a developing country with suitable pine resources. It is an industry based on renewable natural resources. The tapping operations are labour intensive and can therefore offer employment and income-earning opportunities to people in rural areas. Although the processing operations have low labour requirements, the total investment cost is also relatively low. In addition to saving and earning foreign exchange from import substitution or exports, local industries should derive some benefit from the resin producer's expenditure on buildings and tapping equipment, as well as on the local fabrication of part of the resin processing plant.

As a guide, the minimum size of plant necessary for a viable processing operation would be one with sufficient capacity for a throughput of around 1000 tonnes of resin annually, working on a single-shift basis. There would be scope for increasing the quantity of resin processed by working multiple shifts, with only marginal additions to fixed capital (storage capacity) and working capital for financing stocks of resin, rosin and turpentine. It is estimated that for an operation of this size in one African country, the total investment costs for the tapping operation are likely to be about US$350 000; this includes all pre-production and start-up costs and three months' working capital. The investment cost of the processing operation is about US$600 000. These figures could vary substantially according to the site and the specific local circumstances; costs, in general, are likely to be about US$250 000-400 000 and US$500 000-700 000 for the tapping and processing operations, respectively.

The viability of any gum naval stores industry depends mainly on the number of pine trees available for tapping, resin yields and resin quality. The above estimates have been based on 400 000 trees each yielding 2.5 kg of resin annually. It is unlikely that yields much below 2 kg could sustain an economically viable tapping operation. In favourable circumstances, and depending on the tapping regime, 3-5 kg/year are possible. If a development is contemplated, detailed and reliable information must first be obtained on the identity, availability, age and distribution of the pine species, and on the climatic conditions at the forest sites. All stages of the development process should be undertaken in consultation with the Forest Department or owner of the trees as they will need to be assured that tapping will not injure the trees. In some instances, the preliminary data may indicate that tapping would be unprofitable. If the preliminary survey suggests that the availability of the raw material is satisfactory, limited tapping trials combined with a laboratory evaluation of resin samples should be undertaken. If these results are also satisfactory, more extensive tapping trials, together with a detailed feasibility study, should be carried out.

Any feasibility study must examine carefully the costs of capital (with an adequate allowance for working capital costs and profits) and the annual charge for this, along with annual production costs, so that potential investors can compare their break-even selling price for rosin with the cost of imported rosin. The key elements or questions for any feasibility study are listed below.

- **Marketing** The local demand for rosin and turpentine, the competition from imports whether from regional producers or international suppliers, the potential for market growth over the next three to five years, and the level of prices from these competitors need to be assessed.

- **Quality** An estimate will be needed of how locally produced rosin and turpentine will compare with internationally traded material.

- **Raw materials** The availability of the pine resource and its potential productivity should be determined, taking full account of the felling and replanting policy in the case of plantation pines, and of the possible changes which might occur in end use which would affect their availability for tapping. The ability to bring new trees 'on stream' as worked ones reach the end of their tapping life is crucial to the sustainability of a gum naval stores operation. The intrinsic productivity of the trees, and the efficiency of the work force involved in tapping, need to be sufficient to provide crude resin at an economically attractive price.

- **Processing** If an existing producer is willing to consider purchases of crude resin, the advantages and disadvantages of initially setting up a tapping operation only, need to be evaluated. The location of a processing plant (availabilty of energy, water and labour supplies, transport costs, and the relative merits of siting the plant close to either the tapping areas, the end users, or the ports of exit for international markets) also requires consideration.

- **Labour** The availability and cost of labour, particularly in the forest areas, and methods of organization and payment, need to be determined. Adequate incentives will be required to retain an efficient work force who can collect resin at a low unit price.

- **Financial and economic appraisal** An assessment of the financial and economic returns will depend primarily on establishing a correct value for the cost of fixed and working capital to the investor(s) planning the project. A realistic annual charge for capital must be included in the calculations to allow an accurate estimate of the full costs of tapping operations and resin processing. The key factors will not be factory and office overheads, marketing costs, depreciation or interest on loans, but the price of crude resin and the project's ability to sell gum rosin, against competing imports, at a price above the operation's break-even production cost level. A cash flow analysis based on discounted costs and revenues over the life of the project should use two or three different prices for crude resin and three different prices for sales of rosin and turpentine. A proper sensitivity analysis will show that crude resin costs and prices and the sales price of rosin will largely determine whether a gum naval stores project is economically viable or not.

APPENDIX 1
REFERENCES AND FURTHER READING

Pinus species

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Additional note

Naval Stores Review is published bi-monthly and contains trade news, information and technical papers on all aspects of the pine chemicals industry. It also includes papers from the annual International Naval Stores Conference organized by the Pulp Chemicals Association. The present annual cost of subscription (late 1994) is US$80 (six issues and the *International Yearbook*). The address for subscriptions is: Naval Stores Review, Kriedt Enterprises Ltd, 129 S. Cortez Street, New Orleans, LA 70119, USA.

The address of the Pulp Chemicals Association is: PO Box 105113, Atlanta, GA 30348, USA.

APPENDIX 2

QUALITY CRITERIA, SPECIFICATIONS AND TEST METHODS

Rosin

Although several other criteria determine rosin quality and acceptability for different applications, colour and softening point are usually sufficient indicators of quality to satisfy purchasers of rosin from traditional and proven sources. Rosin is graded on the basis of colour, the palest being the most desirable and designated WW* ('water-white'). This grade and the slightly lower grade WG ('window-glass') are the most commonly traded rosins. A superior grade, X, is sometimes offered. Darker grades are N, M, K, I, H and lower. Rosin is a glass, rather than a crystalline solid, and the point at which is softens when heated is referred to as the softening point (rather than melting point). A softening point in the range 70-80°C is usual, the higher end of the range representing the better quality.

Since rosin is an acidic material and the manufacturer of downstream derivatives depends on its acid functionality, a high acid number (and saponification number) is also an indication of good quality. The better quality rosins usually have an acid number in the range 160-170. Provided that the acid number is high, the detailed resin acid composition of rosin is usually of little consequence or interest to the end user. An exception is rosin derived from *P. merkusii* which, because of the presence of a rather rare resin acid, has an acid number which is higher than normal; it may reach 190 or more. The percentage of unsaponifiable matter indicates the amount of non-acidic material in the rosin, so the lower this value, the better; anything above about 10% unsaponifiable matter would be considered a poorer quality rosin.

There are no international standards for rosin, and although the American Society for Testing and Materials (ASTM) describes standard test methods, it stipulates no specifications to which rosin should conform. The appropriate controlling bodies of some producing countries do provide specifications but, inevitably, companies and traders involved in the rosin industry have their own 'in-house' specifications which will vary from company to company, and this makes it difficult to generalize and quote 'typical' analytical data.

Table 6, which was compiled from trade sources, presents some specifications for gum rosin of different origins and may be used as a guide for assessing the acceptability of rosin by those thinking of entering rosin production.

Data such as the contents of volatile oil, insoluble matter, ash and iron (which should all be low) may be specified by producers of rosin. Other, less well defined properties, such as the tendency of the rosin to crystallize (which is undesirable), also affect its value; Chinese and, to some extent, Indonesian rosin have this particular shortcoming.

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*The notation follows the USDA colour scale for rosin which is used universally in international trade.

Table 6
Some trade specifications for gum rosin

Origin	Colour	Softening point (°C)	Acid number	Saponification number	Unsaponifiable matter (%)
China, PR	WW	70-85	162-175		max 7.5
Portugal	WW	min 70	165-171	171-177	4.3-5.5
Brazil	X/WW	70-78	155-170	165-185	max 10
Indonesia	WW/WG	75-78	160-200	170-210	

For determination of these physical data, reference should be made to the definitions and methods of analysis given by the ASTM. The following test methods concerning rosin are described (*Annual Book of ASTM standards,* Section 6):

D 269-92	Insoluble matter in rosin
D 464-92	Saponification number of rosin
D 465-92	Acid number of rosin
D 509-70	Sampling and grading rosin
D 889-58	Volatile oil in rosin
D 1063-51	Ash in rosin
D 1064-58	Iron in rosin
D 1065-92	Unsaponifiable matter in rosin
D 3008-90	Resin acids in rosin by gas-liquid chromatography
E 28-92	Softening point by ring-and-ball apparatus

Turpentine

Specifications for 'gum spirit of turpentine' have been published by several national bodies including the American Society for Testing and Materials (ASTM D 13-92) and the Bureau of Indian Standards (IS 533:1973). These standards were devised largely for the quality assessment of turpentine intended for use as a solvent, i.e., in whole form rather than as a chemical feedstock in which the composition is of prime importance. They generally specify parameters such as relative density or specific gravity, refractive index, distillation and evaporation residues.

The International Organization for Standardization (ISO), which is a world-wide federation of national standards institutes, has issued a standard, the main requirements of which are shown in Table 7.

A draft ISO standard for 'Oil of turpentine, Portugal type, *Pinus pinaster*' (1994) includes physical data very similar to that in Table 7 but with the addition of a range for optical rotation (20°C) of -28° to -35°. Compositional ranges are also given for a number of constituents of the turpentine including alpha-pinene (72-85%) and beta-pinene (12-20%).

Table 7
Physical property requirements of the International Organization for Standardization specification for gum spirit of turpentine (ISO 412-1976)

Relative density (20/20°C)	Refractive index (20°C, D line)	Distillation (% v/v)	Evaporation residue (% m/m)	Residue after polymerization (% v/v)	Acid value	Flash point (°C)
0.862-0.872	1.465-1.478	max 1 below 150°C min 87 below 170°C	max 2.5	max 12	max 1	min 32

Turpentine purchased by the chemical industry as a source of isolates for subsequent conversion to pine oil, fragrance and flavour compounds, and other derivatives, is assessed on the basis of its detailed composition. The major demand is for turpentines containing a high total pinene content. *P. elliottii* turpentine contains around 60% of alpha-pinene and 30% of beta-pinene. *P. radiata* turpentine, noted earlier as being of exceptionally good quality, generally contains more than 95% of total pinene, of which over half is beta-pinene; it has virtually no high-boiling constituents. However, the relative proportions of other components may also influence an individual buyer's quality evaluations; 3-carene, which is found in significant proportions in the turpentine of some *Pinus* species (such as *P. roxburghii* and *P. sylvestris*) is of little value, and even if it is present in relatively small amounts it may be undesirable for certain applications. Depending on the variety, *P. caribaea* turpentine may contain up to 50% or more of beta-phellandrene. While such a composition does not diminish its value as a solvent for paints, it would not be attractive as a source of pinenes for derivative manufacture.

APPENDIX 3

GENETIC FACTORS INFLUENCING RESIN COMPOSITION AND YIELDS

Some of the factors which affect resin yields have been referred to earlier. Genetic factors play a major role in determining both yields and composition (quality) of the resin, and a provisional judgement on the suitability of a standing resource of pines for tapping can often be made simply by consideration of the species concerned. For example *P. patula*, which is widely planted in Africa, gives a very poor quality resin in low yields, and is not tapped commercially anywhere in the world. *P. caribaea* provides turpentine and rosin of acceptable, but not exceptional quality, but it is now being recognized as a particularly high-yielding species; in Africa and Brazil it has out-yielded *P. elliottii*, a species often used as the benchmark by which others are judged. *P. radiata*, on the other hand, produces probably the best quality turpentine in the world, but resin yields are poorer than *P. elliottii*, for example, and it is not widely tapped.

Table 8 gives an indication of the relative quality and quantities of resin which might be expected from some species of *Pinus*.

Table 8

Resin quality and yield characteristics of some *Pinus* species

Species	Quality	Quantity
P. elliottii	++	++
P. pinaster	++	+
P. massoniana	+	+
P. merkusii	+	+
P. caribaea	+	+++
P. radiata	+++	+
P. roxburghii	+	+
P. kesiya	+	+/-
P. oocarpa	+/-	+/-
P. sylvestris	+/-	+/-
P. patula	-	-

Note: Resin characteristics are rated on a scale from very good (+++) to poor (-)

The list is not intended to be exhaustive, and no attempt has been made to provide specific quantity values based on yield data reported in the scientific literature. Such data encompass a wide range of variables (age and size of trees, climate, tapping method, etc.) and it could be misleading to quote precise figures. Site-specific factors can affect the rating either favourably or adversely, so a relatively poor rating does not mean that the species cannot be used (*P. oocarpa* and *P. sylvestris* are tapped in Mexico/Central America and Russia, respectively). Conversely, a high rating does not ensure profitability if that particular species is tapped; if temperatures are low the resin will not flow, no matter how good a yielder the species may be intrinsically.

A relatively recent development is the interest shown by foresters in *Pinus* hybrids. By controlled crossing of appropriate species it is possible to combine the desirable features of one species with those of another at the expense of the less favourable attributes. Recent work in South Africa, following earlier research in Australia, has confirmed the potential for improved wood production of *P. elliottii* x *P. caribaea* hybrids over the parent species. Of equal importance to naval stores production, was the finding that the hybrid also gives enhanced resin yields. In the future, *Pinus* hybrids may become a valuable resource for combined wood and resin production, if they are found to be suitable.

In spite of the generalizations which can be made about the suitability of certain pine species for naval stores production, intrinsic variation in resin properties can also occur within a species according to the natural population from which the trees are derived, i.e., the provenance origin; *P. caribaea* shows some variability between and within each of the varieties (var. *caribaea*, var. *hondurensis* and var. *bahamensis*). As resin composition (measured in terms of the turpentine and rosin) is easily determined and is less influenced by environmental factors than yield, most of the available information on provenance variation relates to composition rather than yield. Compositional variation is most often seen in the turpentine and can sometimes be quite marked. The turpentine from one provenance might have a high (and therefore desirable) pinene content, whereas turpentine from a different provenance might be richer in 3-carene. Rosin composition is much more stable within a species than turpentine.

If natural stands of pines are being considered for tapping, it is essential to survey the different areas where it grows in order to determine the extent of any major variation in resin quality; tapping trials at different sites should also be carried out to assess productivity. If plantation pines are derived from different provenances, samples from each provenance should be tested to ensure that they are all suitable for exploitation. Although the variability of turpentine composition may appear to impose constraints on the utilization of a pine resource, in practice it does not, particularly for a small producer. The turpentine is likely to be used locally, in whole form, rather than as a source of chemical isolates for which composition is crucial. Variations in resin yields are far more important.

If individual trees are examined, pronounced differences in resin (turpentine) composition and yields become apparent even within the same provenance. Trees of comparable size growing close to each other (and therefore experiencing identical climatic and edaphic conditions) can yield vastly different amounts of resin. In order to evaluate the productivity of a particular site, tapping trials should be designed to take account of this variability by testing a sufficient number of trees. In spite of the disadvantages, these differences offer some long term scope for improvements in quality and productivity by élite germplasm selection. In a few cases, seed orchards have been established from which superior seed can be purchased (*P. elliottii* in the United States, for example).

APPENDIX 4

PACKAGING OF TURPENTINE AND ROSIN

Turpentine

International shipments of turpentine are usually made in container size (20-tonne) bulk tanks. In response to the world-wide concern for adequate safety measures to ensure the safe handling and transportation of materials that are actually or potentially dangerous substances, increasing attention is being paid by importing countries to the packaging and labelling of 'dangerous goods'. As turpentine is a flammable material it is classified under this heading.

Within the European Community, a 1979 Council Directive (79/831/EEC), which has now become mandatory, details 'laws, regulations and administrative provisions relating to the classification, packaging and labelling of dangerous substances'. The Directive requires every package to show the name and origin of the substance, the danger symbol (e.g. a flame in a red diamond indicating a flammable liquid) and standard phrases indicating special risks (e.g. 'flammable') and safety advice. The minimum size and placement of labels is also specified. When dangerous 'substances' are transported they become 'goods', and when conveyed from one country to another they are subject to international regulations according to the means of conveyance. When sending shipments by sea, the regulations of the International Maritime Dangerous Goods (IMDG) code have to be observed. As with dangerous substances, dangerous goods have to be marked with warning labels.

Turpentine is shipped under United Nations number 1299 which means that the container must meet certain requirements; this number falls within Class 3, Packing Group III, and has to be quoted in all shipping documents. A new producer contemplating the export and international shipment of turpentine should obtain more detailed information from national transportation authorities or prospective importers.

When it arrives in the country to which it is being shipped, the importer may divide the consignment into lacquer-lined steel drums for local sales. If the importer is willing to take the turpentine in drums, they should be new galvanized steel drums of about 200 litres (170-185 kg net) capacity. Internal lacquering of the drums is usually preferred, but care should be taken to avoid cracking the lacquer layer when handling because this has an adverse effect on the turpentine.

Rosin

Requirements for the labelling of rosin for transportation into, and within, the European Community are currently (late 1994) under discussion and may not be resolved for some time. Prospective exporters of rosin to the EC or elsewhere are therefore advised to seek up-to-date information from importers in the countries concerned.

Rosin may be packaged in a variety of forms. On discharge from the still, the molten rosin is often fed into new, galvanized steel drums of around 225-250 kg (net) capacity. The drums have domed tops so that after they have been set aside for the rosin to cool and solidify (with resulting contraction in volume), the tops can be hammered flat. Alternatively, flat-topped drums can be filled in two or three stages over several days to allow for the change in volume on cooling. International shipments of rosin are also usually made in container loads. In the larger producing countries in which there are large end-user consumers of rosin, transportation of molten rosin in specially designed tank-cars is feasible; this is unlikely, however, to be something which a new, smaller producer would contemplate.

End users are showing a growing preference for less robust forms of packaging to enable easier opening and handling, and in this case, silicone or polypropylene-lined multi-wall paper bags can be used. The sacks can be filled either with molten rosin directly from the still (which is then allowed to cool to form a solid block) or with flakes of solidified rosin. The flakes are formed by discharging hot rosin onto a moving belt; by the time it has reached the end of the line, the rosin has solidified into a thin sheet which can easily be broken up and transferred to bags. For ease of handling, 25 kg bags are a convenient size.

For relatively small naval stores operations, the quantities of rosin produced or the intended markets may not warrant investment in new drums or other forms of more expensive packaging, so simpler ways of handling and transporting the rosin can be used. The molten rosin from the still can be drained either into cardboard boxes supported by suitable frames, or into split drums. Solidified rosin from split drums can be broken into lumps and bagged. The disadvantage of this method is the formation of an appreciable quantity of powdered rosin which is prone to oxidation and discolouration, and which results in a poorer quality product.

APPENDIX 5

LIST OF IMPORTERS AND TRADERS OF NAVAL STORES

The following list gives the names and addresses of some of the companies which import or trade in naval stores. Such companies may be willing to consider purchases of export-quality, container-load shipments of rosin or turpentine from a new producer. Only companies in Europe, Japan and the United States are given. The list should not be regarded as exhaustive and inclusion in the list does not imply that FAO or NRI have any knowledge of the financial standing of the company.

EUROPE

France

Almimet SA
18 Rue de la Michodière
75002 Paris

Dérives Resiniques et Terpeniques
30 Rue Gambetta
40105 Dax

Germany

Gratenau & Hesselbacher Chemie KG
Klosterwall 2
20017 Hamburg

Hermann ter Hell & Co.
Kattrepelsbrücke 1
20095 Hamburg

Weissmeer-Baltische GmbH
Lange Mühren 9
2000 Hamburg

Willers, Engel GmbH & Co.
Grimm 8
20457 Hamburg

Italy

Chemverga SL
Via Romagnosi 20
00196 Rome

IEMPSA Delta
Via Boccaccio 3
29020 Trezzano on Naviglio
Milan

Netherlands

De Monchy International BV
PO Box 762
Meent 106
3000 AT Rotterdam

Integrated Chemicals BV
Kanaalstraat 276
PO Box 302
2160 AH Lisse

G.C. Rutteman & Co.
Exchange Building, Room 374
PO Box 30028
3001 DA Rotterdam

United Kingdom

Ferguson & Menzies Ltd
312 Broomloan Road
Glasgow G51 2JW

Langley Smith & Co. Ltd
36 Spital Square
London E1 6DY

A.V. Pound & Co. Ltd
83a High Street
Esher KT10 9PZ

White Sea and Baltic Co. Ltd
Arndale House
Otley Road
Headingley
Leeds LS6 2UU

Japan

Arakawa Chemical Industries Ltd
3-7 Hirano-machi 1-chome
Chuo-ku
Osaka 541

Harima Chemical Inc.
6-7 Dosho-machi 3-chome
Chuo-ku
Osaka 541

Sang Yo Boeki Ltd
Daiwa Bank Buildings 2-5-28
Kyu Taro-machi
Chuo-ku
Osaka 541

Toyo Chemical Co. Ltd
16-12 Ginza 6-chome
Chuo-ku
Tokyo 104

United States

PDM Inc.
3512-6 Silverside Road
Wilmington
DE 19810

Rausch Naval Stores Co. Inc.
PO Box 4085
New Orleans
LA 70178

Ter Chemicals Inc.
PO Drawer P
Pass Christian
MS 39571

STATISTICAL TABLES

Table 9
Rosin[a]: exports from the People's Republic of China, 1987-92
(tonnes)

	1987	1988	1989	1990	1991	1992
Total	193 000	193 000	182 975	174 000	205 000	261 000

Source: *Customs Statistical Yearbook*, 1992
Note: *a* Believed to be wholly or mainly gum rosin

Table 10
Rosin[a]: exports from Portugal, 1987-92
(tonnes)

	1987	1988	1989	1990	1991	1992
Total	84 456	59 068	54 258	57 107	47 050	26 069
of which to:						
France	13 107	8 059	10 448	9 091	7 655	5 068
Germany	22 156	15 454	15 687	20 518	18 493	9 535
Netherlands	9 590	8 338	4 302	4 213	3 368	1 994
Italy	9 122	7 005	7 657	8 894	6 882	2 804
UK	5 687	5 028	3 342	3 122	1 831	1 520
Belgium/Luxembourg	907	434	289	698	325	471
Spain	14 059	8 890	7 250	5 664	3 997	649
Switzerland	356	412	315	400	369	258
Austria	485	428	181	275	269	354
Japan	300	263	193	193	298	315
USA	3 016	2 471	2 311	1 985	1 592	1 389
Canada	408	169	476	180	403	111
Venezuela	1 224	100	106	140	140	140
South Africa	1 115	337	224	120	80	135
Morocco	830	302	547	402	641	679
Other countries	2 094	1 378	930	1 212	707	647

Source: *Eurostat*
Notes: *a* Defined as 'rosin obtained from fresh oleoresins' or 'gum rosin' [excludes other types of rosin and rosin derivatives]

Table 11
Rosin[a,b]: exports from Indonesia, 1987-92
(tonnes)

	1987	1988	1989	1990	1991	1992
Total	14 966	22 103	7 380	14 562	17 480	23 274
of which to:						
Germany	-	na	-	18	696	653
Netherlands	-	126	-	342	1 397	1 920
Italy	-	350	36	288	936	1 453
UK	-	126	54	36	108	40
Belgium/Luxembourg	-	na	-	-	-	346
Portugal	-	-	-	-	340	1 056
Spain	-	-	-	-	38	1 709
Greece	-	na	-	36	36	125
Turkey	-	-	-	18	36	594
India	5 645	5 294	1 310	5 937	3 290	1 795
Bangladesh	386	474	54	144	54	454
Pakistan	-	791	-	630	15	913
Sri Lanka	-	na	-	72	-	113
Japan	2 786	4 822	4 420	2 520	4 392	2 856
Taiwan, Prov. of China	3 417	5 660	702	1 574	1 088	2 451
Singapore	1 388	2 115	492	225	239	352
Korea, Rep. of	522	594	162	1 166	2 282	2 072
Thailand	750	499	101	1 085	742	595
Philippines	54	864	50	176	387	650
Australia	-	76	-	144	186	1 116
USA	-	16	-	95	614	1 015
Mexico	-	na	-	-	-	55
Colombia	-	na	-	-	-	335
Ecuador	-	na	-	-	-	72
Egypt	-	-	-	-	528	96
Other countries	18	296	0	56	76	438

Source: *Indonesia Foreign Trade Statistics*
Notes: *a* Defined as 'pine resin' but believed to be wholly or mainly gum rosin
b Additional, small quantities are classified under 'rosin'. Totals are: nil (1987), na (1988), 148 (1989), 607 (1990), 404 (1991), 104 (1992); in each case, most went to India.
na = Not available

Table 12

Rosin[a,b]: exports from Brazil, 1987-93

(tonnes)

	1987	1988	1989	1990	1991	1992	1993
Total	962	11 682	13 843	8 451	8 330	10 384	13 502
of which to:							
Germany	101	490	na	15	na	na	na
Netherlands	120	1 779	na	1 772	na	na	na
Italy	-	177	na	20	na	na	na
UK	40	925	na	235	na	na	na
Belgium	-	84	na	38	na	na	na
Portugal	-	415	na	-	na	na	na
Spain	-	60	na	79	na	na	na
Japan	-	36	na	779	na	na	na
Singapore	10	10	na	74	na	na	na
USA	477	4 531	na	3 938	na	na	na
Mexico	-	-	na	387	na	na	na
Uruguay	135	326	na	302	na	na	na
Chile	42	705	na	425	na	na	na
Ecuador	30	10	na	-	na	na	na
Venezuela	-	1 598	na	156	na	na	na
Peru	-	103	na	120	na	na	na
Argentina	-	-	na	25	na	na	na
South Africa	4	335	na	40	na	na	na
Other countries	3	98	na	46	na	na	na

Source: National trade statistics

Notes: *a* Defined as 'colofonias' [excludes rosin derivatives]

b Believed to be wholly or mainly gum rosin

na = Not available

Table 13
Rosin[a]: exports from the United States, 1989-93
(tonnes)

	1989	1990	1991	1992	1993
Total	1 808	1 087	1 274	1 109	820
of which to:					
Germany	91	122	35	-	19
Netherlands	30	-	5	-	4
Italy	5	22	17	17	-
UK	-	-	83	-	57
Belgium	-	-	101	-	-
Lebanon	-	-	-	-	95
Pakistan	-	-	-	15	71
Japan	480	428	477	51	258
Singapore	7	1	18	6	22
Thailand	23	11	11	-	-
Philippines	9	8	7	-	27
Canada	116	-	-	-	-
Mexico	78	191	38	706	69
El Salvador	60	15	11	27	-
Panama	5	54	28	32	-
Venezuela	2	80	232	49	35
Peru	10	2	49	32	15
Colombia	36	7	45	-	-
Argentina	-	-	-	-	95
Egypt	750	-	-	-	-
Kenya	-	-	-	139	-
South Africa	-	85	-	-	18
Other countries	106	61	117	35	35

Source: National trade statistics
Note: *a* Defined as 'gum rosin' [separate from wood rosin and tall oil rosin]

Table 14
Rosin[a]: imports into the European Community, 1987-92
(tonnes)

	1987	1988	1989	1990	1991	1992
Total	151 986	147 897	141 961	146 075	160 354	188 036
of which from:						
France	672	574	362	544	496	2 276
Germany	1 254	1 551	1 835	1 405	1 782	1 989
Netherlands	395	1 796	2 889	1 624	2 490	5 213
UK	69	58	215	593	1 276	2 068
Belgium/Luxembourg	472	407	401	465	1 677	3 243
Portugal	71 875	54 442	50 219	51 654	41 551	23 142
Spain	509	292	412	457	478	520
Yugoslavia, former	5 187	8 539	312	-	45	-
Greece	165	91	81	157	302	300
Soviet Union, former	23	347	2 894	977	952	303
Russia	ns	ns	ns	ns	ns	942
China, People's Rep. of	65 468	66 725	66 459	76 843	94 790	123 895
Indonesia	-	404	180	579	4 664	10 872
Hong Kong	329	1 879	161	304	234	1 389
USA	763	1 303	716	689	799	1 110
Mexico	1 221	835	585	142	197	73
Honduras	2 809	2 308	3 352	2 749	2 841	3 463
Brazil	101	3 045	5 941	2 063	2 708	5 009
Argentina	15	42	973	241	76	639
Venezuela	-	-	66	1 316	20	-
South Africa	-	-	-	-	-	81
Other countries	659	3 259	3 908	3 273	2 976	1 509
of which to:						
France	20 888	19 861	17 396	18 211	21 725	21 979
Germany	49 069	47 425	44 833	54 487	54 553	61 053
Netherlands	33 644	34 025	38 023	33 445	39 564	43 811
Italy	16 036	13 601	12 846	12 292	15 083	15 639
UK	15 546	18 386	14 033	13 335	11 323	12 658
Belgium/Luxembourg	2 087	1 970	2 228	3 121	3 038	5 758
Spain	14 037	10 519	11 158	8 999	8 607	13 994
Portugal	12	1 410	503	809	3 115	8 875
Greece	2	-	9	-	-	134
Denmark	329	310	356	184	794	1 029
Ireland	336	390	576	1 192	2 552	3 106

Source: *Eurostat*

Notes: *a* Defined as 'rosin obtained from fresh oleoresins' or 'gum rosin' [excludes other types of rosin and rosin derivatives]

ns = Not specified

Table 15
Rosin[a]: imports into Japan, 1987-93
(tonnes)

	1987	1988	1989	1990	1991	1992	1993
Total	71 011	82 416	78 911	60 844	74 442	68 927	75 303
of which from:							
China, People's Rep. of[b]	60 473	66 399	59 589	48 328	60 697	58 046	61 755
Taiwan, Prov. of China	-	230	-	-	-	522	630
Indonesia[b]	3 372	5 038	9 005	3 474	5 656	4 968	8 172
Hong Kong	118	200	1 022	535	1 150	1 531	212
Viet Nam[b]	-	-	-	-	300	815	821
New Zealand	1 885	1 375	1 491	1 374	1 163	845	1 003
Portugal[b]	248	298	263	158	333	333	263
USA	4 809	8 663	7 429	6 072	4 416	1 554	2 379
Brazil[b]	-	36	97	798	634	20	20
Other countries	106	177	15	105	93	293	48

Source: *Japan Exports and Imports*
Notes: *a* Defined as 'rosin' or 'rosin and resin acids' [excludes salts, ester gums and other derivatives]
b Believed to be wholly or mainly gum rosin

Table 16
Rosin[a]: imports into the United States, 1989-93
(tonnes)

	1989	1990	1991	1992	1993
Total	14 301	16 783	13 703	14 639	13 671
of which from:					
Portugal[b]	1 863	1 758	1 895	2 118	2 168
China, People's Rep. of[b]	3 281	5 818	5 508	7 028	3 112
Indonesia[b]	-	18	678	1 073	1 228
Hong Kong	220	127	1 081	560	347
Singapore	-	-	-	151	-
Canada	274	294	-	-	202
Mexico[b]	963	390	26	16	49
Honduras[b]	396	120	60	20	-
Brazil[b]	6 068	4 275	3 756	2 864	6 093
Argentina[b]	838	3 382	664	807	433
Venezuela[b]	44	452	-	-	-
Other countries	354	149	35	2	39

Source: National trade statistics
Notes: *a* Defined as 'gum rosin' [separate from wood rosin and tall oil rosin]
b Believed to be wholly or mainly gum rosin

Table 17
Turpentine[a]: exports from the People's Republic of China, 1987-92
(tonnes)

	1987	1988	1989	1990	1991	1992
Total	2 855	6 769	24 323	1 788	8 052	5 560

Source: *Customs Statistical Yearbook*, 1992
Note: *a* Believed to be wholly or mainly gum turpentine

Table 18
Turpentine[a]: exports from Portugal, 1987-92
(tonnes)

	1987	1988	1989	1990	1991	1992
Total	12 695	9 888	7 974	5 784	7 875	5 775
of which to:						
France	5 675	4 398	3 153	1 694	2 767	1 561
Germany	665	749	517	603	510	363
Netherlands	182	196	170	89	149	91
Italy	318	160	54	429	280	398
UK	417	352	222	60	102	64
Belgium/Luxembourg	344	250	185	159	275	299
Spain	4 583	3 480	3 614	2 658	3 721	2 968
Other countries	511	303	59	92	71	31

Source: *Eurostat*
Notes: *a* Defined as 'gum spirits of turpentine' [separate from spirits of wood and sulphate turpentine]

Table 19
Turpentine[a]: exports from Indonesia, 1987-92
(tonnes)

	1987	1988	1989	1990	1991	1992
Total	2 147	3 421	3 403	4 935	3 989	7 234
of which to:						
France	-	-	-	97	237	508
Germany	-	-	349	360	65	165
Netherlands	-	-	163	-	192	38
Italy	-	-	-	227	126	754
UK	-	-	50	312	42	164
Belgium/Luxembourg	-	-	-	394	20	123
Greece	-	-	-	-	95	366
India	1 587	1 619	2 030	2 470	2 559	4 121
Bangladesh	-	-	-	-	-	68
Japan	358	1 128	552	292	204	95
Taiwan, Prov. of China	95	269	96	82	152	68
Hong Kong	-	-	-	-	-	94
Singapore	-	34	-	-	59	-
Korea, Rep. of	27	14	-	-	14	-
Thailand	80	-	109	14	-	41
New Zealand	-	327	54	-	-	-
USA	-	-	-	631	39	209
Canada	-	-	-	57	152	379
Egypt	-	-	-	-	14	28
Other countries	0	30	0	0	19	13

Source: *Indonesia Foreign Trade Statistics*
Note: *a* Defined as 'gum turpentine'

Table 20

Turpentine[a]: imports into the European Community, 1987-92
(tonnes)

	1987	1988	1989	1990	1991	1992
Total	14 715	14 546	21 288	19 903	15 821	16 415
of which from:						
Portugal	12 965	11 042	9 350	6 415	8 062	5 977
Germany	127	311	1 063	2 135	825	992
Bulgaria	58	-	90	150	266	376
Yugoslavia, former	505	1 243	945	302	87	-
Soviet Union, former	589	879	415	103	717	120
Russia	ns	ns	ns	ns	ns	457
China, People's Rep. of	-	80	7 498	7 528	3 149	3 492
Indonesia	-	-	501	1 072	594	2 125
Brazil	28	233	513	771	1 155	1 684
Argentina	-	-	-	-	-	626
South Africa	-	-	109	339	247	127
Other countries	443	758	804	1 088	719	439
of which to:						
France	5 648	5 886	9 301	6 725	6 453	3 938
Germany	868	1 103	2 658	2 557	1 540	1 341
Netherlands	159	259	283	176	308	132
Italy	1 472	1 555	1 542	1 359	770	1 379
UK	490	468	411	463	339	306
Belgium/Luxembourg	441	375	357	650	379	481
Spain	5 305	4 869	5 452	7 260	4 936	6 373
Portugal	59	-	1 100	445	650	1 618
Greece	135	-	148	236	417	812
Denmark	95	15	10	16	21	22
Ireland	43	16	26	16	8	13

Source: *Eurostat*

Notes: *a* Defined as 'gum spirits of turpentine' [separate from spirits of wood and sulphate turpentine]

ns = Not specified

Table 21
Turpentine[a]: imports into Japan, 1987-93
(tonnes)

	1987	1988	1989	1990	1991	1992	1993
Total	7 995	12 266	14 894	6 580	7 629	8 240	6 533
of which from:							
China, People's Rep. of[b]	1 711	4 828	8 357	2 484	2 384	1 809	3 196
Indonesia[b]	302	1 521	770	176	272	136	567
Hong Kong	-	-	53	53	98	56	-
Viet Nam[b]	20	40	40	30	-	24	-
New Zealand	899	1 120	498	1 360	1 307	1 915	906
USA	4 418	3 979	4 551	2 001	3 039	3 537	1 274
Chile	645	775	625	476	528	762	571
Other countries	0	3	0	0	1	1	19

Source: *Japan Exports and Imports*
Notes: *a* Defined as 'gum, wood or sulphate turpentine oils'
b Believed to be wholly or mainly gum turpentine

Pinus is one of the most widely distributed genera of trees in the northern hemisphere. Its range extends from the polar region to the tropics and includes Central and North America, Europe and Asia. Pines are among the most widely planted exotics for timber and pulp purposes, and large areas of these trees are therefore found outside their natural range in South America, Africa and Australasia. Pine trees are important not only for wood, but also as a valuable source of non-wood forest products. They can be tapped for resin, which can then be distilled to produce gum turpentine and gum rosin.

Gum naval stores: turpentine and rosin from pine resin provides information on the technical and economic aspects of pine resin production including the tapping of trees and the distillation of the resin. It also reviews recent trends in world production and markets for gum turpentine and gum rosin. The book is intended for prospective producers of turpentine and rosin and for organizations and individuals appraising projects involving their production. It is particularly intended for readers in developing countries.

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