



**STUDY INTO THE ESTABLISHMENT OF AN AROMA AND
FRAGRANCE FINE CHEMICALS VALUE CHAIN IN SOUTH AFRICA
(TENDER NUMBER T79/07/03)**

**FINAL REPORT
(Submission date: 15 September 2004)**

**Part Two/Four
Report: Aroma Chemicals Derived from Effluent from the Paper and Pulp
Industry**

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PART 2 – AROMA CHEMICALS DERIVED FROM EFFLUENT FROM THE PAPER AND PULP INDUSTRY

This Report has been divided into four separate Parts. Each Part is self-contained and self-explanatory.

Part One-
Executive Summary

Part Two-
Report: Aroma Chemicals Derived from Effluent from the Paper and Pulp Industry

Part Three-
Report: Aroma Chemicals Derived from Petrochemical Feedstocks

Part Four -
Report: Aroma Chemicals Derived from Essential Oils

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1. OVERVIEW of the AROMA CHEMICAL INDUSTRY

1.1 The South African Chemical Industry

South Africa has the largest economy on the African continent, accounting for 25% of Africa's GDP. The South African chemical industry is driven by the relatively large South African home market, accounting in many instances for the bulk of sub-Saharan African consumption. The South African chemical industry is of substantial economic significance to the country, contributing around 6% to GDP and approximately 25% of its manufacturing sales. It employs approximately 100,000 people. In 2001, the industry had an output of R 62 billion, exports accounting for R 29 billion, approximately 50% of domestic production.^{1, 2} The chemical and related industry is import-oriented, with export levels approximately half of import levels. In chemicals alone, 57% of the trade deficit pertained to downstream fine chemicals.

The industry, the largest of its kind in Africa, is highly complex and widely diversified, ranging from high volume-low value commodity or bulk chemicals through to high value-low volume, complex and highly specialized products. However, whilst the upstream sector is concentrated and well developed, the downstream sector, although diverse, remains underdeveloped. Chemical operations in South Africa focus predominantly on basic upstream chemical manufacturing with major production of liquid fuels, olefins, organic solvents and industrial mineral derivatives and downstream formulation and polymer conversion. There are a few major, integrated companies (companies employing more than 150 people) involved mostly in primary and intermediate manufacturing, with small (companies employing less than 50 people) and medium-size (companies employing between 50 and 150 people) enterprises found mainly in downstream formulation and conversion processes.

South Africa has historically had a bias towards upstream commodity chemicals production, as a result of its internal need to guarantee a supply of liquid fuels during period of economic sanctions. The industry focus was on the implementation of technology, rather than the development of technology. The commodity chemical sector is therefore well established, whilst the downstream industry remains comparatively underdeveloped, with relatively low levels of scientific and technological skills available.

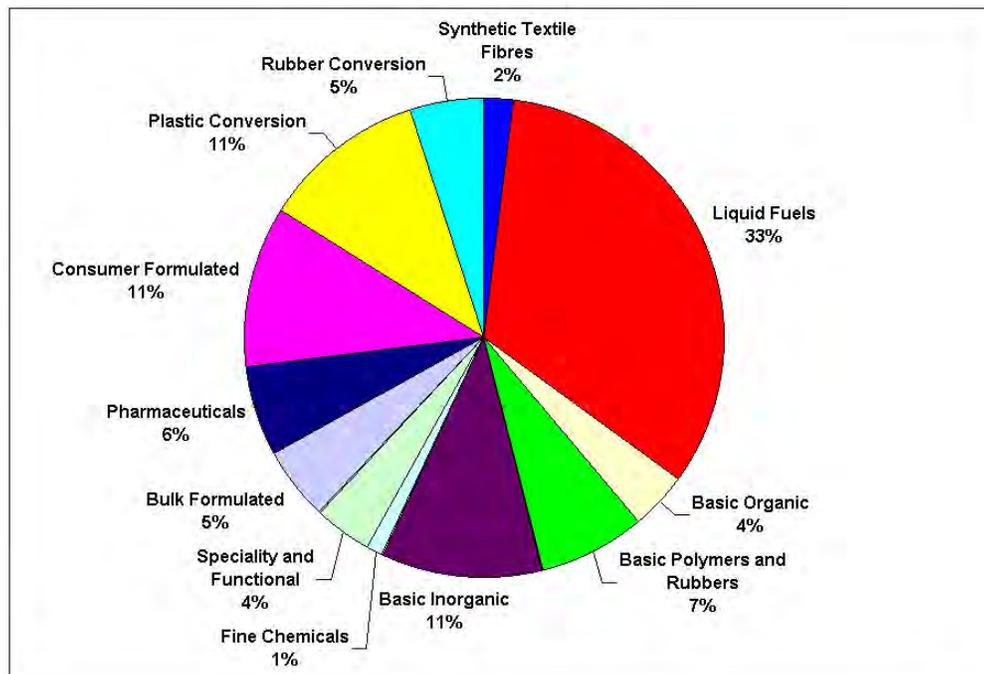
Figure 1 outlines the breakdown of the South African Chemical Industry according to the Department of Trade and Industry. The diagram shows that the Fine Chemicals, Speciality and Functional Chemicals currently only comprise 5% of the chemical sector.

¹ Seminar at the Helsinki School of Economics April 10, 2002: The New South Africa: Opportunities for Trade, Investment and Partnership

² South African Department of Trade and Industry Web-site: Overview of the South African Chemical Industry

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FIGURE 1: The Structure of the South African Chemical Industry. ³



The South African chemicals industry is in the midst of turmoil, and is undergoing a massive transformation process, these changes affecting mainly the downstream chemical sector. The restructuring process of large South African chemical companies due to global economic forces has resulted in a reduction in innovation from within the private sector. Research and development undertaken by large South African companies, with the exception of SASOL and some innovative small firms has shown a significant, measurable decline in the past four years. In many cases this results in many technologies being developed overseas. This trend is supported by the recent offshore listings of several large technology-intensive South African companies followed by the tendency for these companies to source research outside South Africa.

This process is resulting in a serious depletion of strategic skills in South Africa. Research and Development expenditure has been declining in the last 5 years, with South Africa undertaking only approximately 0.5% of global research. The percentage of the South African gross national product spent on research and development has declined from 1,1% in 1990 to its current level of around 0,7%. This is compared to the average OECD country, where expenditure is 2,15% of GDP; with at least 30% of Research and Development spending in large integrated developed economies made by the government. Currently,

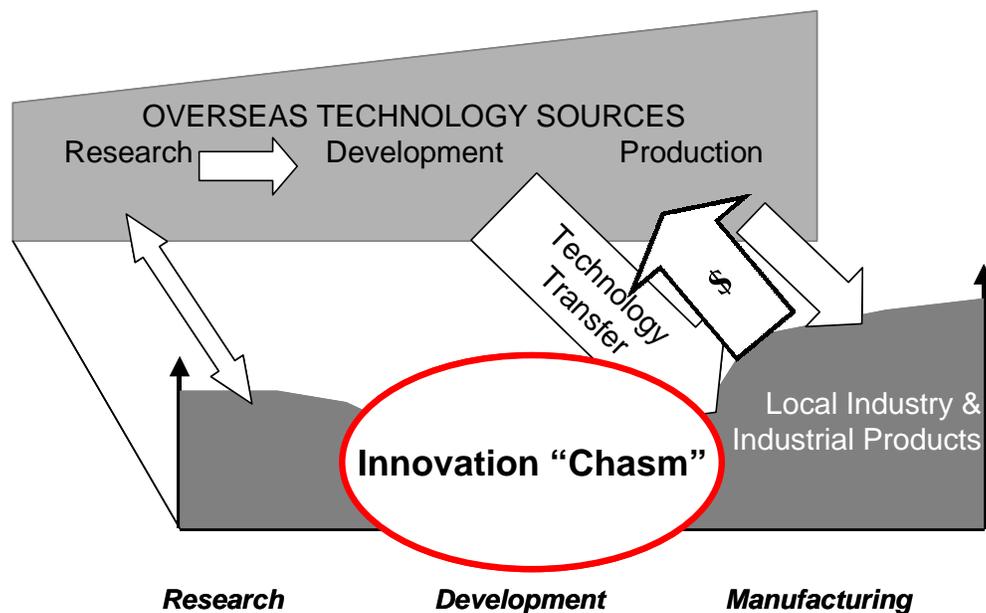
³ South African Department of Trade and Industry Web-site

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there is less than one researcher for every thousand members of the workforce, as compared with five in Australia and ten in Japan.⁴

Globally, the sector is knowledge-intensive and technology-intensive. However, South Africa does not conform to these trends, as evidenced by the indicators for value added per employee and wages, being substantially below international best practice. South Africa is a net importer of technology, and is generally recognized as being successful as a technology adapter and extender. The implementation rather than the development of technology has been a focus of South African industries and economic growth based on local innovation is low. A key feature of the South African terrain is therefore that, whereas South Africa both exports and imports technology, it rarely takes its own technologies through the complete development cycle. There is evidence of good technologies that are lost or not commercialized due to a lack of innovation resources. This phenomenon has led to the so-called “Innovation Chasm”. This is an innovation gap that exists between the knowledge generators and the market and has never been addressed strategically. This feature is depicted in a diagram below.⁵

FIGURE 2: South Africa – “The Innovation Chasm”



⁴ UNDP Report: 2001 Technology and Development

⁵ A National Perspective: Contribution of Research and Innovation to the SA Economy. Adi Paterson (Department of Science and Technology)

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High population growth constantly exceeds the growth in employment demands. This is compounded by the consistent loss of jobs in the formal sector, as the country's economy moves away from labour-intensive to capital-intensive operations. The labour market is characterized by an oversupply of unskilled workers and a shortage of skilled ones. Furthermore, in South Africa, the distortion of under development and/or disinvestment in the majority of South Africans has resulted in the skewed skills profiles from a racial perspective and in terms of the 'soft' and 'hard' qualifications. An overwhelmingly white, male and aging scientific population is not being replaced by younger groupings more representative of the country's demographics.

A study for the Chemical Industries Sector Education and Training Authority, Chieta, has found that while black people are predominantly located in the lower-skill occupational categories, 83% of African employees reported receiving no training relevant to work in the previous year, compared with 46% of white employees.⁶ A HSRC⁷ study for the Chieta on the skills needs in the chemical sector in South Africa has indicated that more than two thirds of all the workers in the Chemical Industries Sector are black, but that many top-level decision makers (financial, managing, and related senior management positions) and technically qualified posts (chemical, production, and process engineers etc.) are predominately filled by white males. The average age of workers at all occupational levels, except for that of operators, seems to be increasing, which makes the training of replacements an urgent matter.

The fact that employers in the Chemical Industries Sector experience difficulty in recruiting new staff at the managerial, professional and technician level, especially affirmative action candidates, can be ascribed to the low output of graduates in the natural sciences. This is indicated by the fact that South Africa produces about 10 times fewer scientists and engineers compared to typical first-world countries. Figures from the Department of Science and Technology state that only 3.9% of approximately 490,000 learners who wrote Matric exams in 2000 passed mathematics on the higher grade, and 4.7% passed science on the higher grade. The continual plea for access to expatriate skills and capacity by the industry is backed up by statistics that show there are insufficient locally based professionals to meet the demands of the sector in the short term.

South African ageing and shrinking human resources in science and technology are not being adequately developed and renewed and the number of A-rated scientists is declining annually. In 1998, 45% of all scientific publications were by authors over the age of 50. This is further compounded by the emigration of senior and junior scientists to further their careers

⁶ Chieta Report: "A Demographic Profile of the Workforce in the Chemical Industries Sector and Sub-sectors" May 2002

⁷ HSRC Chieta Report "Skills Needs by the Chemical Industries Sector in South Africa" December 2003

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in countries with a more competitive research environment. Innovations, patents and technology transfer are not sufficiently rewarded as core tasks of academics and researchers at academic institutions.⁸ This focus is reflected in the relatively low number of patents per South African scientist. Start-ups are derived at a low level of 2 per 100 patents in South Africa, vs the international norm of 10 to 15 start-ups for every 100 patents.⁹

Over the last 5 years, the chemical sector has nevertheless increased employment by 2.1% per annum and achieved an annual average value-added growth rate of some 5.1%.¹⁰ South Africa's performance in mathematics and science seems to be reaching a turning point and inequalities are gradually being eliminated. Although there has been some progress in developing black managers in the science and technology system there are still far too few black researchers. The percentage of university graduates (of all population groups) in the natural sciences has returned to the 1985 level.

The future prospects of the chemical industry will depend on an appropriate skills development and retention strategy. The South African government has adopted a proactive approach to many of the fundamental issues affecting the country. One of these is the investment in, and management of, human capital development in order to strengthen the transformation of its science and technology capacity. The chemical sector can therefore be seen as a critical industry from which to advance South Africa's social economic development objectives.

Stimulating the growth of a globally competitive and sustainable aroma and fine chemicals value chain can be seen as a means of developing the Fine Chemical, Speciality and Functional Chemicals sub-sectors and addressing the strategic imperatives discussed above that confront the growth of chemical industry as a whole. The findings enumerated in this report would suggest that by South Africa supporting an investment in an Aroma and Fine Chemicals cluster based on the portfolio of products indicated, the downstream sector would benefit positively and would help to bridge the innovation gap identified in the national research and development strategy for South Africa.

⁸ Draft Emerging Biotechnology Roadmap: Department of Science and Technology: November 2003

⁹ National Biotechnology Audit: September 2003

¹⁰ Chemicals SA 2003: South Africa's Petrochemical Industry – Globalisation, Restructuring, and Government Policies

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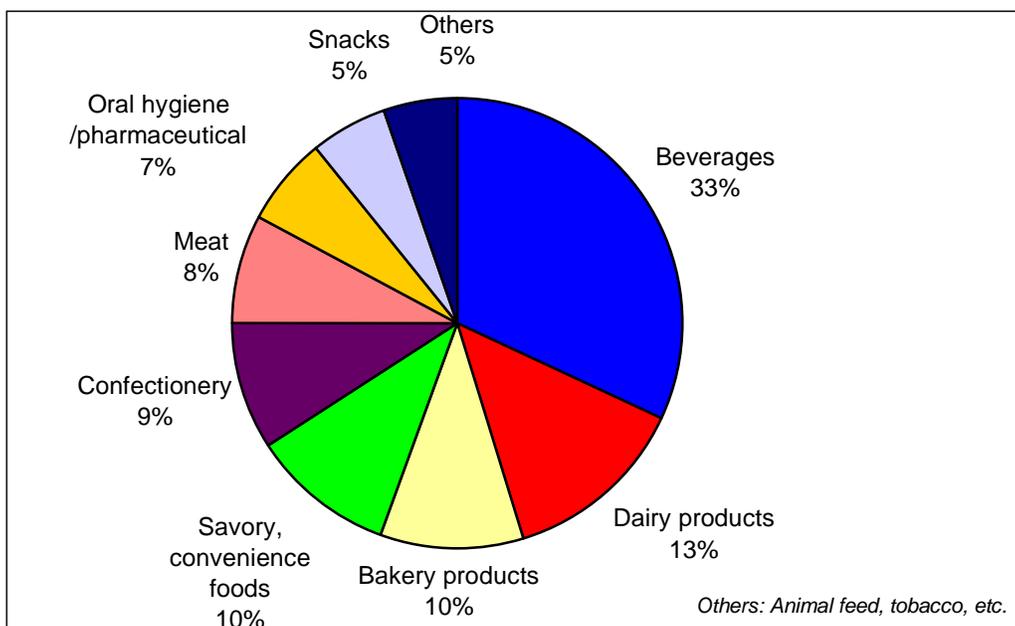
1.2 Overview of the International Flavour and Fragrance Industry

This section of the report provides an outline of the Flavour and Fragrance industry in a global context. It also serves to describe the position held by aroma chemicals and essential oils in this market.

Flavour and fragrance formulations are widely used globally for enhancing, among others, foods, beverages, detergents and pharmaceutical products. Compounded flavour and fragrances are thus complex blends designed to impart either an attractive taste and aroma to processed foods and beverages, or a pleasing scent to consumer products such as perfumes, toiletries, household cleaners etc. The formulations may contain aroma chemicals as well as essential oils and natural extracts. The formulation will also contain solvents, diluents and carriers.

Figures 3 and 4 outline the breakdown of the use of flavour and fragrance compositions in the end-markets.¹¹

FIGURE 3: Flavours End-Use Market



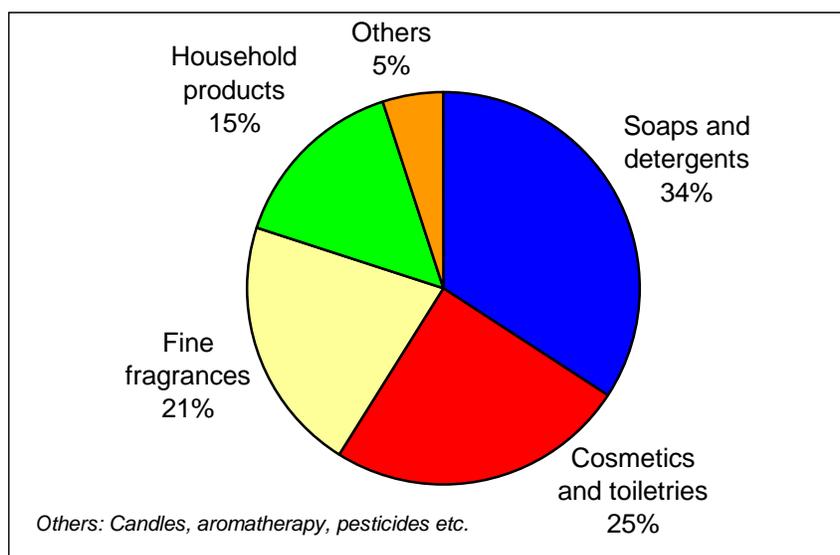
It is interesting to note that the major use in the flavour market is in beverages. In the fragrance end-use market, over 50% is used in two applications i.e. soaps/detergents and cosmetics/toiletries. These end-use markets are characteristically first-world markets. This

¹¹ Chemical and Engineering News: July 14, 2003

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is supported by the global consumption usages for flavour and fragrances, which show that the USA accounts for 31% of the market, with Western Europe representing about 29% of the world market and Japan 12%.¹² The rest of the market lies in developing countries with high growth rates and potential, as use of the consumer products in these particular major end-use markets increase. The South African market in 1999 was worth a total of \$ 107.3 million. Flavours were the largest application of \$ 56.7 million.¹³

FIGURE 4: Fragrances End-Use Market



In 2002, the worldwide flavour and fragrance business, including sales of compounded flavour and fragrance products, aroma chemicals as well as essential oils and natural extracts, was valued at an estimated \$ 15.1 billion.¹⁴ The industry is segmented broadly into three areas:

1. Isolation of synthetic and natural aroma chemicals or essential oils/natural products.
(Aroma Chemicals are single, chemically defined substances which act on the senses of smell and taste; and essential oils are naturally occurring, volatile products obtained from various parts of plants.)
2. Compounding of these products into formulations tailored to meet specific customer requirements
3. The sale and use of these formulations in the production of personal care and pharmaceutical active ingredients, food and beverage markets etc.

¹² Chemical and Engineering News: July 14, 2003

¹³ IAL Consultants: 2000 Data; C&EN July 2003; IAL Data 2001

¹⁴ Leffingwell and Associates

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This flavour and fragrance value chain is represented in Figure 5. This report uses the term “Flavour and Fragrance industry” to encompass this full value chain.

FIGURE 5: Flavour and Fragrance Industry Value Chain

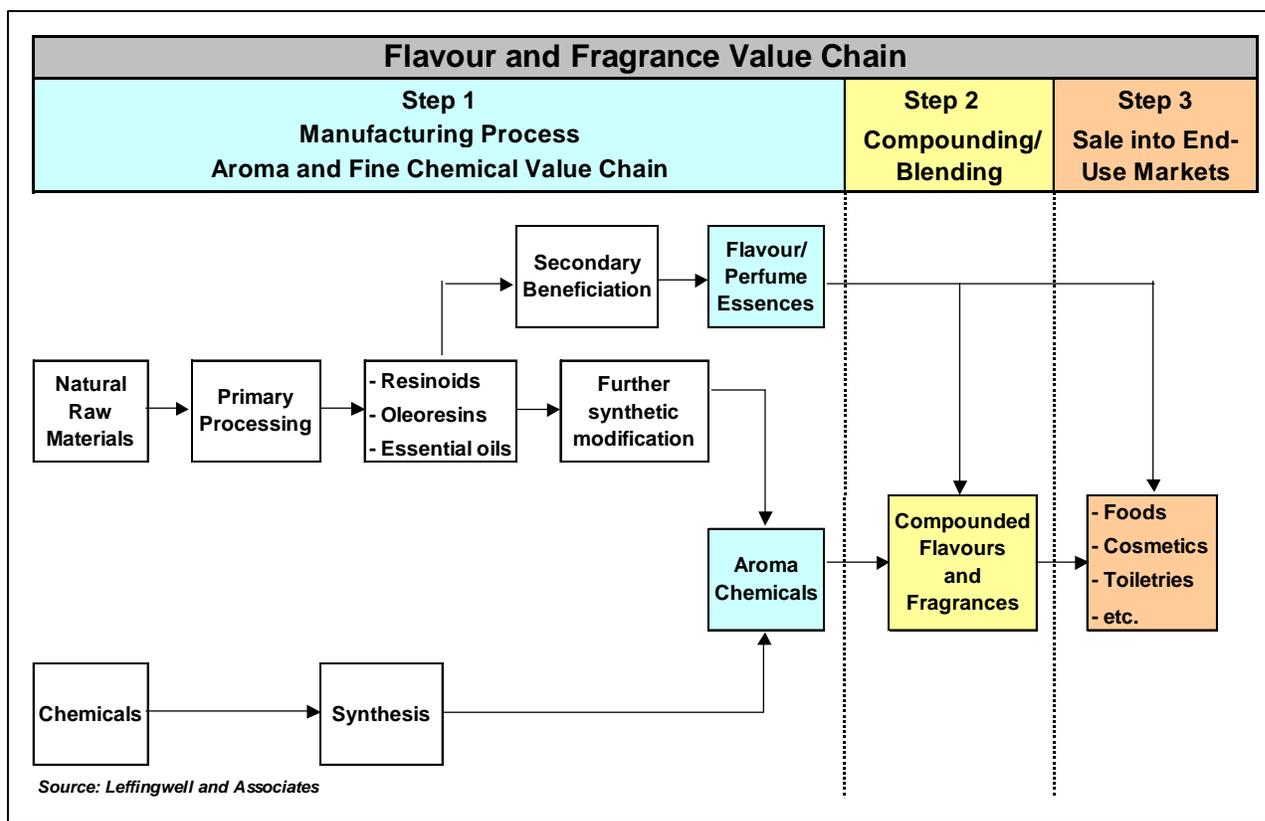


Table 1 illustrates the contribution of the various components of this value chain.¹⁵ It is worth noting that over 75 % of the industry’s value lies in the composition of the flavours and fragrances.

¹⁵ Chemical and Engineering News Estimates May 2002/Leffingwell and Associates

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Table 1: Value of the Flavour and Fragrance Industry 2002¹⁶

| | % of the Value Chain | \$ Billion |
|-------------------------------------|----------------------|-------------|
| Aroma Chemicals | 12% | 1.8 |
| Essential Oils and Natural Extracts | 12% | 1.8 |
| Flavour Compositions | 41% | 6.2 |
| Fragrance Compositions | 35% | 5.3 |
| TOTAL | 100% | 15.1 |

Production of aroma chemicals is estimated to be worth \$ 1.812 billion. In 2000, the SRI Chemical Economic Handbook report estimated the market for aroma chemicals to be \$ 1.766 billion.¹⁷ This estimate was based on supply and demand estimates by the major geographic regions.

A recent survey by the market research company, Freedonia Group¹⁸, forecasts growth in global demand for flavours and fragrances of 5.4% per annum, with the industry reaching \$ 18.4 billion in 2004. Market growth will primarily be due to strong growth in the developing regions of Latin America and Asia (excluding Japan). Countries such as China, Brazil, India, Mexico, Vietnam and Chile particularly are experiencing dramatic growth in their food-processing and consumer-product industries. It is predicted that the growth in developed markets will in contrast be slow. The developed countries market growth is characterised by trends, which favour less flavour and fragrance-intensive consumer goods, consolidation in end-user industries, strong pressure on price reductions, and market maturity. It is also anticipated that the growth in the essential oil and natural extract market will exceed that in the synthetic aroma chemical market.

Large international Flavour and Fragrance houses specialise in the compounding of flavour and fragrance products. A number of these houses also produce selected aroma chemicals for captive use. In addition, some also manufacture personal care active ingredients from captive and purchased aroma chemicals. Generally, success in the formulation and compounding business is dependant on the ability to offer a basket of products, and an ability to respond quickly to ever-changing trends in consumer preference. Most major participants in the Flavour and Fragrance industry operate internationally and maintain a presence in virtually all markets of the globe. The major motivation for this is that the leading Flavour and Fragrance houses are following key end users such as food processors and

¹⁶ SRI Chemical Economic Handbook Report: Aroma Chemicals and the Flavour and Fragrance Industry August 2001

¹⁷ SRI Chemical Economic Handbook Report: Aroma Chemicals and the Flavour and Fragrance Industry August 2001

¹⁸ Freedonia Group News Release 2003

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detergent producers to these regions. China, Brazil, and Mexico have as a result seen a strong growth in production.

Over recent years there has been a large amount of rationalisation and consolidation within the industry and this process is likely to continue. It has been estimated that there are over 1,000 companies active in this industry worldwide, but 12 international flavour and fragrance companies hold over 65% market share. One major reason for this is that of the cost of owning an adequate infrastructure, which includes the cost of toxicological testing, research and development, quality control, and efficient manufacturing and marketing, is so high that only the largest of companies can afford it. The costs associated with these activities also explain the reason for the high value associated with this segment of the market.

Table 2 outlines the top 12 companies in 2002.¹⁹ It is noticeable that the top 6 participants have sales over \$ 800 million. The next tier has sales in the region of \$ 200 to 400 million. Below this level, the industry is highly fragmented with a host of much smaller players. A recent report from SRI International³ comments that there is a “virtual absence of medium-sized participants” with sales in the region of \$ 75 to \$ 100 million.

Table 2: Estimated Sales Volume Flavour and Fragrance Companies 2002

| Company | Country | \$ million | Market Share |
|-------------------------------|-------------|---------------|--------------|
| Givaudan | Switzerland | 1,933 | 12.8% |
| IFF | USA | 1,809 | 12.0% |
| Firminech | Switzerland | 1,373 | 9.1% |
| Symrise | Germany | 1,300 | 8.6% |
| Quest International | UK | 1,153 | 7.6% |
| Takasago | Japan | 850 | 5.6% |
| Sensient Technologies | USA | 423 | 2.8% |
| T.Hasagawa | Japan | 381 | 2.5% |
| Mane SA | France | 270 | 1.8% |
| Danisco | Denmark | 263 | 1.75 |
| Degussa Flavours | Germany | 234 | 1.5% |
| Robertet | France | 218 | 1.4% |
| TOTAL TOP 12 COMPANIES | | 10,206 | 68% |
| Others | | 4,894 | 32% |
| TOTAL | | 15,100 | 100% |

¹⁹ Leffingwell and Associates

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There are a number of reasons for this consolidation. A major reason has been the pressure on prices. As outlined above, the major market is USA followed by Europe and Japan. In the USA the advent and power of the supermarket chains has placed pressure on consumer product manufacturers to drop costs in order to be given “shelf space”. This has led to consolidation amongst consumer product manufacturers. These manufacturers in turn have pressurized the Flavour and Fragrance houses (which once commanded huge margins) to reduce prices. The Flavour and Fragrance industry is thus reacting to the concentration of its customer base. In addition, end-users have found it too costly to deal with too many Flavour and Fragrance houses, and accordingly only deal with the largest few. If the Flavour and Fragrance house is not strong in all markets it cannot keep the custom of a larger customer such as a Unilever or Procter and Gamble. Thus growth in turnover by the Flavour and Fragrance houses has come primarily from acquisitions with the company profiting from economies of scale.

A further reason for the consolidation has arisen from major chemical companies wanting to stick to core business of high volume manufacturing. As a result, many of them have sold their Flavour and Fragrance divisions to previous competitors. Recent examples are Bayer, which used to own Haarmann and Reimer, which was merged with Dragoco forming Symrise in 2002. In 2000, Roche spun off Givaudan. The only chemical company still with a Flavour and Fragrance house is ICI with Quest International.

The smaller and medium sized companies active in the Flavour and Fragrance industry have survived by concentrating on their specialist knowledge within a niche market and offering services and products that the industry giants don't offer. An example of this is Treatt plc, based in the United Kingdom. This company acts as a one-stop shop for the Flavour and Fragrance industry in Europe, but not in the US. Fine chemical companies are increasingly forging partnerships with Flavour and Fragrance customers through joint projects and special services, and are becoming indispensable partners of the Flavour and Fragrance industry. Rhodia is an example of this trend, producing natural vanillin under license from Givaudan who could not justify operating the process on its requirements alone. Fine chemical companies can develop new compounds at a smaller scale or offer process improvements to customers losing patent protection. The proposed portfolio of the petrochemical suite of products was designed to position AECI in this segment of the market.

1.2.1 Aroma Chemicals

Aroma Chemicals can be manufactured *via* a number of different routes:

1. **True synthetic chemicals:** This includes chemicals produced by synthesis from both natural aromatic compounds and from synthetic feedstocks e.g. petrochemicals.

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- 2. True Isolates:** Single aroma chemicals, which are extracted from natural materials and subjected only to further processes of purification. These include the following: anethole, camphor, citral, eugenol, and menthol.
- 3. Chemically modified derivatives:** Made by converting isolated products into a different chemical by subjecting them to various chemical processes. This includes the crude sulphonated turpentine derived aroma chemicals such as citral, geraniol and linalool. Crude sulphonated turpentine is a by-product of the Kraft paper pulping process. It also includes vanillin produced from lignin, also a by-product of the paper pulping process.

Aroma chemicals can be classified according to their chemical structure. The main groups and their share of the aroma chemical market are detailed in Table 3.²⁰ There are about 2,800 aroma chemicals approved for use in flavour and fragrance formulations worldwide. However, only a few hundred are produced in volumes over 50 tons for the merchant market. It is considered that synthetic aroma chemicals constitute 70 – 75% (by value and volume) of the raw materials used in the flavour and fragrance formulations. The aroma chemicals under consideration in this study fall into the categories of either benzenoids or terpenoids.

Table 3: World Consumption of Aroma Chemicals

| | Percentage by Value | Percentage by Quantity |
|------------------------|----------------------------|-------------------------------|
| Benzenoids | 34 | 48 |
| Terpenes/Terpenoids | 37 | 34 |
| Musk chemicals | 13 | 7 |
| Other aroma chemicals. | 16 | 11 |
| | 100 | 100 |

The majority of aroma chemical manufacturing is by batch processing, often in multi-purpose plants. This is due to the fact that few aroma chemicals are consumed in large enough volumes to justify dedicated equipment. Manufacturers need to shift production from one product to another as the market demand changes. Some aroma chemicals do have a demand in other purposes, however, the application as a flavour and fragrance ingredient usually is the most profitable for these products.

²⁰ SRI Chemical Economic Handbook Report: Aroma Chemicals and the Flavour and Fragrance Industry August 2001

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Aroma chemicals are generally produced by three different types of companies:

- Flavour and Fragrance Houses:

These companies produce the chemicals for their own use in compounds and blends and often also sell them on the merchant market.

- Large Diversified Chemical Companies:

These companies manufacture aroma chemicals as a minor component of their overall chemical business by upgrading small amounts of their large-scale chemical production to flavour and fragrance specifications. Product is sold to formulators or flavour and fragrance houses; the chemical companies do not themselves sell the products into the end consumer markets.

- Medium and small chemical producers:

These are companies involved in the synthesis of aroma and other fine chemicals using specialised technical knowledge. (AECI as a producer of a portfolio of fine chemical aroma products would have belonged in this category)

The aroma chemical industry has consistently earned returns in excess of the chemical industry standard. As it is so closely tied to the health, personal care, and food and beverage markets, it is robust, insensitive to commodity cycles, and relatively recession resistant. Success in the production of aroma chemicals is generally characterised by:

- Consistent product quality
- An approved organoleptic quality
- Long-term customer relationships
- Technology driven cost leadership
- An ability to research, develop and commercialise aroma chemicals
- A robust raw material/feedstock position

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1.2.2 Essential Oils

Essential oils are naturally occurring volatile products obtained from various parts of plants. Essential oils are usually extracted from the plant material by steam distillation, expression, or solvent extraction. Essential oils are distinguished from the fatty vegetable oils, such as canola and sunflower by the fact that they evaporate or volatilise in contact with the air and they usually possess a strong aroma (the name comes from "essence"). The amount of oil extractable ranges from an infinitesimal quantity to as much as 1-2% of the dry weight of the plant material distilled.

The methods of extraction differ considerably. The sources may be fresh or dried fruit, leaf, bark, root or seed. A typical essential oil is a complex mixture of chemical compounds, each of which possesses its own, individual set of properties. The odour of the oil can be due mainly to one single chemical constituent, or to a mixture of several odoriferous chemical bodies. The chemical constitution of the bodies may not always be known.

The major producers of essential oils are Brazil, China, U.S., Egypt, India, Mexico, Guatemala and Indonesia. All of them, with the exception of U.S., are developing countries with very low labour costs. The major consumers are the U.S. (40%), Western Europe (30%) and Japan (7%).

Although the essential oils industry is primarily an agricultural industry, the oils make up an important component of the flavour and fragrance supply chain, alongside synthetic aroma chemicals. Sales of essential oil and other natural extracts were equal in value to those of aroma chemicals in 2002 (estimated US\$1.8 billion each). Essential oils are sold into several different markets (foods and beverages, aroma and fragrances in foods, nutraceutical applications, medicinal applications, cosmetics and personal hygiene products). Most naturally derived aroma chemicals have their synthetic counterpart; however there has always been a niche for the natural products. Furthermore, over the last 50 years, the demand for essential oil products from plants has gradually increased because of a number of factors. Demand for flavouring, perfumery, and aromatherapy materials has risen because of the steep rise in the world population and a desire for greater variety in their food by the people of the industrialized countries. The increased concern for the environment and for the safety of food and the general difficulty in manufacturing synthetic alternatives has also contributed to the continued growth in demand for plant based essential oil products. According to the United Nations Trade Statistics, trade in essential oils and related products are growing at roughly 10% per annum whereas the overall flavour and fragrance market is growing at between 4% and 5% per annum.

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The world trade in essential oils may be divided into two components, often referred to as the major and minor oils. With regards to the major oils, these are those oils that are traded in large quantities (but often lower prices). There are approximately 160 essential oils traded globally. The top 10 oils make up some 80% of the world trade in essential oils. The remaining 150 minor essential oils are of higher value but are traded in quantities ranging from a few kilograms per annum to a few hundred tons per annum.

Although it is possible to isolate aroma chemicals from essential oils this is only done in respect of the major oils, where the economies of scale allow for the natural isolate to compete with the synthetic counterpart. The competition in the major essential oils is stiff with the low cost producers of Asia and South America dominating (particularly Brazil and China). On the other hand, the minor essential oils are traded and used more or less “as is”. Their attraction is in their complex chemical structure and consequent organoleptic properties they possess. The minor oils are more difficult to produce as they are not produced in “plantations” and neither can they be highly mechanised.

South Africa has a long involvement in the essential oil industry with regards to the production of major essential oils like eucalyptus and citrus oils, supplying some 5% and 2% of the world market. These industries are under pressure from the low cost producers and the strengthening of the Rand. With regards to the higher value minor essential oils (e.g. geranium, chamomile and lavender), South Africa has a fledgling essential oils industry that was pioneered by the CSIR. It is this latter industry that holds potential for growth. Internationally, essential oils form a major component of the flavour and fragrance industry and therefore the development of this industry in South Africa would be complementary to South African Aroma Fine Chemical industry.

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1.3 The South African Flavour and Fragrance Industry

The market for flavours and fragrances in South Africa and Sub-Saharan Africa in 1999 and projected for 2004 is shown in Table 5 below.

Table 5: Market for Flavours and Fragrance in South and Sub-Saharan Africa: 1999 – 2004²¹

| End-use (\$ millions) | South Africa | | Sub-Saharan Africa | |
|-----------------------------|--------------|--------------|--------------------|--------------|
| | 1999 | 2004 | 1999 | 2004 |
| FLAVOURS | | | | |
| Beverages | 18.1 | 21.0 | 22.4 | 30.8 |
| Dairy | 9.3 | 10.9 | 8.0 | 10.6 |
| Snacks/Savoury/Convenience | 7.0 | 9.2 | 6.8 | 9.7 |
| Bakery | 6.4 | 6.7 | 5.6 | 6.2 |
| Confectionary | 5.2 | 5.6 | 6.2 | 6.9 |
| Meat | 5.1 | 6.4 | 3.5 | 4.7 |
| Oral Hygiene/Pharmaceutical | 3.0 | 4.6 | 3.0 | 3.9 |
| Others* | 2.6 | 3.1 | 4.0 | 4.9 |
| TOTAL | 56.7 | 67.5 | 59.5 | 77.8 |
| Growth Rate | | 3.6% | | 5.5% |
| FRAGRANCE | | | | |
| Soaps / Detergents | 24.6 | 27.7 | 28.6 | 36.5 |
| Cosmetics/ Toiletries | 12.0 | 14.7 | 13.0 | 17.2 |
| Household cleaners | 8.3 | 9.2 | 5.9 | 7.4 |
| Fine Fragrances | 2.5 | 2.7 | 1.1 | 1.3 |
| Others# | 3.2 | 3.4 | 3.7 | 4.1 |
| TOTAL | 50.6 | 57.8 | 52.3 | 66.5 |
| Growth Rate | | 2.7% | | 4.9% |
| GRAND TOTAL | 107.3 | 125.3 | 111.8 | 144.3 |

* Including Pet Food and Tobacco

#* Includes: Candles, aromatherapy, insecticides etc.

In South Africa, the current emergence of the black middle class is having a positive impact on the consumption levels of flavour and fragrance containing compounds.

²¹ An Overview of the Global Flavours and Fragrances Market: IAL Consultants 2000

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The largest flavours sector in Africa is beverages followed by the dairy section. Higher flavour loads tend to be used in the beverage sectors in the African markets compared to more developed markets. For example, in Western Europe, fruit-flavoured soft drinks typically contain 12% fruit juice, reducing the need for added flavour. In the majority of countries in Africa, no fruit juice is used at all. Although South Africa in general has a food culture similar to the rest of Africa its food processing sector is however more sophisticated than in the rest of Sub-Saharan Africa.

Within the fragrance sector, the largest use is in soaps and detergents. Within this sector, washing soap is predominant in the less affluent regions, where the use of washing machines is at nominal levels. Many cosmetics and toiletries multinationals have located production facilities in South Africa as a production base for the Sub-Saharan region.

The South African total market in 2004 was therefore predicted to be \$ 125.3 million. At an exchange rate of R 7/US\$ this is equivalent to R 877 million. This figure for the value of the South African Flavour and Fragrance market in 2004 has been confirmed by industry sources. The regional South and Sub-Saharan African market in 2004 was expected to be in the order of \$ 279 million or R1,887 million. Growth in the region is anticipated to continue to be strong, the flavours market growing at 4%.

Any increase in aroma chemical and essential oil production in South Africa would increase the potential of participating more in the regional Flavour and Fragrance market.

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2 VANILLIN

2.1 Background

The development of a competitive, world-scale vanillin business was a cornerstone of AECI's growth strategy in Aroma Chemicals. Vanillin can be produced both synthetically as well as from lignin, the main component in the spent sulphite liquors from sulphite pulp mills. Lignin vanillin, being extracted from a renewable resource, is perceived in the market as a natural product, in contrast to the synthetic, but nature-identical, guaiacol vanillin.

2.2 Lignin Vanillin

AECI investigated this process based on lignin received from Sappi Saiccor. This investigation was however abandoned for a number of reasons:

- The large volumes of sodium-based waste liquors which could not be disposed of or economically recycled.
- The product spectrum obtained was compromised by other by-products arising from Sappi Saiccor's exclusive use of hardwood pulping, which produced a significantly lower yield of vanillin compared to softwood-based liquors.
- There are a number of major spatial and transport constraints associated with the Sappi Saiccor plant.

In March 1999 subsequent to the termination of the AECI study, Sappi Saaicor entered into a 50: 50 joint venture, LignoTech SA, with Borregaard to produce lignin by-products in South Africa in response to Sappi's environmental problems. Lignin based products are used as dispersing agents in concrete, textile dyes, pesticides, ceramics and as binding agents in briquetting, animal feed and dust suppression. LignoTech SA announced recently that it plans to expand its capacity through the introduction of a new production line. The increased capacity will partly compensate reduced global capacities at other lignosulphonate plants.

Sappi Saaicor uses both the calcium and magnesium sulphite pulping process, and pulping is mostly based on hardwoods, which give poor vanillin yields. It is therefore unlikely that a vanillin plant would be added to this joint venture as Borregaard will have to dispose of the sodium lignate effluent liquor which cannot be returned to the sulphite mill, in some other potentially more costly way e.g. discharged to the sea or dried to a lignin by-product. The lignin by-products market is however experiencing little growth.

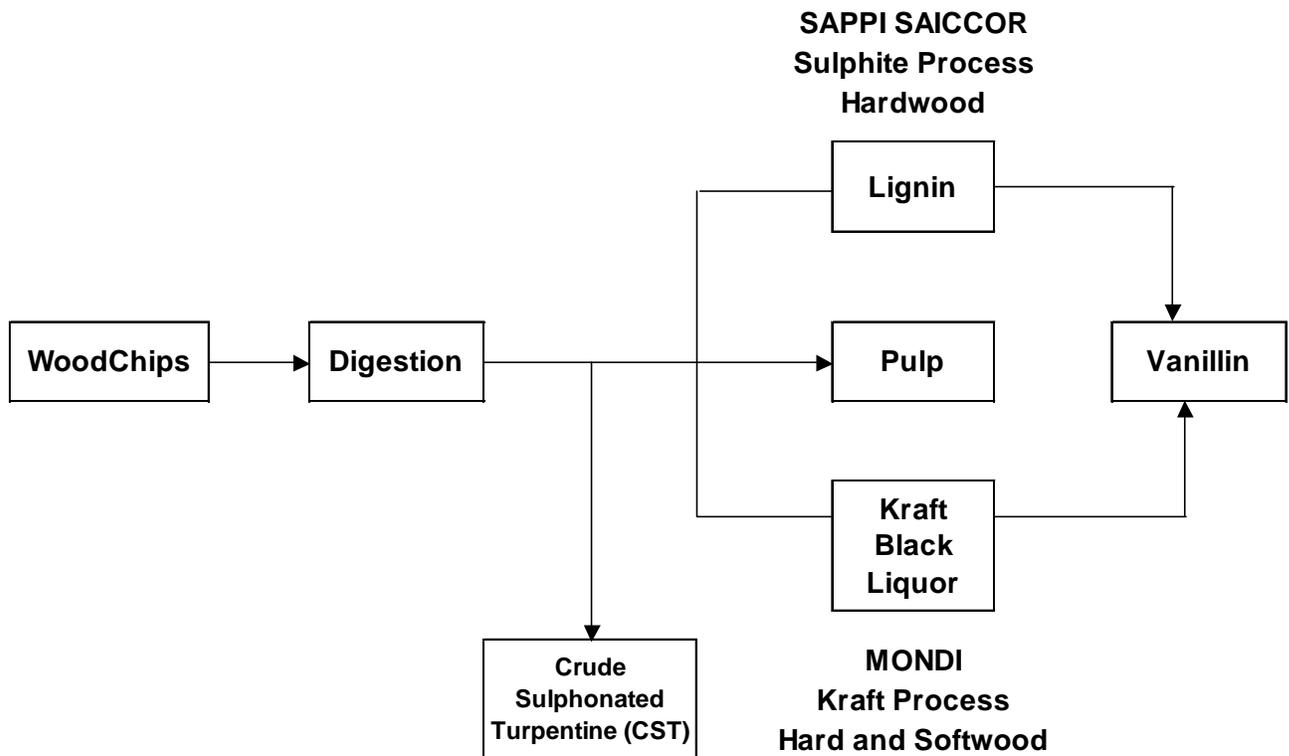
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2.3 Kraft Black Liquor Vanillin

During 1996, AECI was introduced to a new technology whereby vanillin could be produced from Kraft-based liquors. This process is similar to the traditional lignin vanillin technology, except that it incorporates novel modifications to permit the use of Kraft-based liquors, as well as the recovery and recycle of the sodium-based waste liquors produced. It was believed that the Kraft lignin technology incorporating recycling of spent liquors to the pulp mill's chemical recovery plant would be highly competitive and environmentally sound. At the time, large amounts of Kraft black liquor were available from Mondi Kraft's operation at Richard's Bay and firm support for such a project and for the future supply of feedstock from Mondi Kraft was obtained. AECI secured an exclusive technology license for the Kraft-based process.

Figure 6 depicts a flow chart for the production of vanillin from lignin *via* the sulphite and Kraft based pulping processes.

FIGURE 6: Vanillin Production from lignin via Sulphite and Kraft Black Liquor Pulping Process



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In 1999, work on this project was also terminated due to the process giving a very low yield of vanillin. The reason being that a high yield of a by-product, acetovanillone, was formed. In the key oxidation step, the yield of vanillin was 1.9 g/l, with an additional 1.2 g/l acetovanillone being produced. The benchmark final vanillin concentration was 4.2g/l vanillin, the ITT Rayonier plant having achieved 8 to 8.5 g/l.²² The result of this underperformance was that the amount of liquor to be processed for a 1,500 ton vanillin plant would be larger by a factor of 2.4. The benchmark capital cost was R 245 million. Assuming that the capital cost grows with the scale of operation raised to an exponent of 0.65, and that 80% of the capital is related to the front-end processing, the capital cost would increase by 54% compared to the benchmark figure. These factors served to make the project uneconomic. Furthermore, the Kraft Black Liquor feedstock was very inconsistent.

A number of attempts were made to improve the yield without success. The conclusion was therefore reached that an alternative source of lignin should be identified and investigated in South Africa with a view to obtaining a higher yield of vanillin and an associated reduction in the commercial capital cost.²³ This was not however investigated by AECI, as the alternative cresol route to vanillin *via* pHB was given priority.

Subsequent to the termination of this study, discussions with Mondi have confirmed that it has moved away from softwood to almost exclusively hardwood pulping. Mondi is currently undergoing a process of restructuring. Mondi South Africa and MCI Resources have agreed in principle to the creation of a new black empowerment partnership in Mondi's newsprint business, MNB. MNB is a significant southern hemisphere producer of newsprint at Mondi's Merebank mill close to Durban. MNB will include the relevant waste paper preparation, mechanical pulp and newsprint production equipment at the Merebank mill, as well as significant plantations in KwaZulu-Natal, which supply timber to the mill as raw material. The Merebank mill uses a mechanical pulping process and therefore does not produce any Kraft Black Liquor.

Following this newsprint empowerment transaction Mondi South Africa's wholly owned graphic paper interests would all be in the uncoated wood-free sector. As a result, Mondi will be focussing its business on hardwood pulping. Pine trees take up to 18 years to mature, whereas wattle/eucalyptus trees only take around 6 – 8 years. The rotation period for hardwood is therefore much shorter. Over a period of time therefore, Mondi will therefore be converting its forests from pine to wattle and eucalyptus as the trees are felled. As a result of this strategy, the Kraft mill at Richard's Bay no longer produces any crude sulphonated turpentine.

²² AECI Ltd Report: Dr Oldrich Mikus Technology Evaluation of Vanillin from Mondi Richard's Bay Kraft Black Liquor. ; January 1999

²³ Vanillin Project Status Note: P Statham to B Shroff (Katzen Int) 30 November 1999

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2.4 Environmental Issues

In the event that a suitable source of lignin is found and/or the technology is improved such that the benchmark yield is obtained, a substantial quantity of waste Kraft black liquor for recycling will still be formed. The Chemical Economic Handbook states that typically, one ton of sulphite liquor produces only 4.5 kg of vanillin, the remaining liquor having to be returned to the mill.²⁴ In the AECI project, it was estimated that the front-end plant for making 1,500 tons vanillin would have to process approximately 5,000 tons per day of Kraft Black Liquor. In terms of magnitude of operation, it would match the size of a typical medium capacity sugar mill. Hence, the production of vanillin *via* lignin will not remove the need to dispose of the Kraft Black Liquor. After removal of the vanillin, a substantial stream of sodium-enriched black liquor, due to the low yield of vanillin ex Kraft Black Liquor, is returned to the mill. In addition, this stream is returned at ambient temperature, compared to 80°C at which it is transferred to the vanillin plant. The spent sodium lignite liquor is returned to the Kraft mill's chemical recovery circuit for energy utilisation and the recycling of useful chemicals (sodium value).

This technology therefore will not solve any environmental problems in the paper and pulp industry. The aromas industry is researching the possibility of producing vanillin by modern chemical and biotechnologies as an alternative.

2.5 Conclusion

The development of a vanillin business based on production from lignin produced as a by-product in the paper and pulp industry is currently not viable. The viability of the technology would depend on a higher yielding feedstock being identified. Trends within the paper and pulp industry in South Africa however, indicate that it is unlikely that a sustainable source of this feedstock will be identified. However, in the event this feedstock is identified, the technology would not offer a means of reducing any environmental problems in the paper and pulp industry as a substantial stream of black liquor must still be returned to the mill.

²⁴ Chemical Economic Handbook, SRI International: Report 2001

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3 AROMA CHEMICALS FROM TURPENTINE

3.1 Turpentine

Turpentine is the volatile oil obtained from pine trees by three manufacturing processes, namely gum turpentine, sulphate turpentine, and wood turpentine. Turpentine obtained by distillation from the oleoresin collected *via* the tapping of living trees of the genus *Pinus* (whether natural stands or plantations) is known as gum turpentine. This distinguishes it from turpentine recovered as a by-product from chemical pulping of pines and which is referred to as sulphate turpentine. Wood turpentine is obtained from aged pine stumps. This latter production is no longer of any commercial significance.

Turpentine purchased by the chemical industry as a source of isolates for conversion to pine oil and fragrance and flavour compounds is assessed on the basis of its composition. Crude sulphate turpentine is a complex mixture of C₁₀ monoterpene hydrocarbons composed mostly of alpha pinene (60 – 65%), beta pinene (25 – 35%) and other monocyclic terpenes such as limonene and including a small amount of anethole. Beta pinene is the more versatile chemically, although alpha pinene is usually more abundant.

The composition of turpentine varies considerably according to the species of pine from which it is harvested and this greatly influences its value and end use. A total pinene content of 90 % or greater would be regarded as good, becoming excellent as the beta-pinene contribution increases above 30-40 %. Portuguese, American and Brazilian turpentines are all high in pinenes. Anything much less than 70-80 % pinene would be of limited value for derivative manufacture, at least if the turpentine were offered for sale on the international market.²⁵ The presence of certain compounds in the turpentine lowers its value; the most common of these is 3-carene, which may comprise 50% or more of Indian turpentine. This product finds little use other than as a solvent.

It has been estimated that total world production of turpentine is around 335,000 tons, of which around 100,000 tons is believed to be gum turpentine, most of the remainder being sulphate turpentine. From these 335,000 tons approximately 100,000 tons are used as starting material for the production of aroma chemicals. The USA and the People ' s Republic of China are the world ' s largest producers and consumers of turpentine. The Southeast region of the USA is the largest crude sulphonated turpentine producing area of the world. Most American requirements are met by domestic sulphate turpentine production but gum turpentine is also imported for fractionation and conversion into derivatives. Chinese requirements are met by internal production of gum turpentine.

²⁵ National Resources Institute (1995): Gum Naval Stores Turpentine and rosin from pine resin in non-wood forest products 2; Published by Food and Agricultural Organisation of the United Nations, Rome Chapter 8

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The biggest single turpentine derivative is synthetic pine oil, which is used in disinfectants, cleaning agents and other products with a "pine" odour. There are also some specialized uses, for example in the pharmaceutical industry. Most turpentine nowadays, however, is used as a source of chemical isolates, which are then converted into a wide range of products. The alpha and beta pinene constituents of turpentine are the starting materials for the synthesis of a wide range of fragrances, flavours, vitamins and polyterpene products and form the basis of a substantial and growing chemical industry. Derivatives such as isobornyl acetate, camphor, citral, linalool, citronellal, menthol and many others are used either in their own right or for the elaboration of other fragrance and flavour compounds. Many of the odours and flavours in use today, which are associated with naturally occurring oils, may well be derived from turpentine.

Turpentine is traded in much higher volumes than other essential oils and is often imported direct from source by the end-user or fractionator. Prices are subject to negotiation although they are very dependent on the quality and composition of the turpentine: the greater the proportion of beta-pinene compared to alpha-pinene, the higher its value.

The price of turpentine is linked to the pulp and paper market. When the industry is weak, production of crude sulphonated turpentine suffers. From 1997 through 1999, the paper and pulp industry performed poorly, leading to a shortage of crude sulphonated turpentine. In 1998, prices had peaked at US\$ 1.75/gallon. In 2001, prices were in the order of US\$ 0.5/gallon. As demand fell off and inventories rose, the price collapsed to US\$ 0.5/gallon in 2000. Prices have stayed in this region, even though the production of turpentine in the US has decreased. Globally, the overall market for turpentine has declined. Other markets include commodity products such as polyterpene resins and dipentene.

The market for crude sulphonated turpentine in 2003 was oversupplied and demand low. In addition, a new source of competition is gum turpentine, supplied from China. This type of turpentine does not contain sulphur, which makes synthesis easier since sulphurous compounds do not need to be removed.

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3.2 Aroma Chemicals

The sulphate turpentine method produces turpentine and tall oil as by-products of the sulphate pulping of pine, commonly known as the Kraft pulping process. In this process, wood chips (chiefly pine) are cooked in an alkaline liquor to produce pulp. During the cook the turpentine contained in the oleoresin of the pine chips is volatilised and then condensed. The condensate contains crude sulphate turpentine, which has a dark colour and foul odour from the constituent sulphur compounds. During further synthesis, the sulphur compounds are removed from the crude sulphonated turpentine. The Kraft pulping of pine trees produces roughly 450 lbs of chemical by-products and 5 tons of cellulose pulp from 10 tons of wood chips.²⁶

Components of the crude sulphonated turpentine, such as alpha and beta pinene are distilled and used to produce a variety of flavour and fragrance materials as shown in figure 7 below. While terpenoids are components of essential oils and oleoresins of plants, most terpenoids consumed in the Flavour and Fragrance industry are however produced *via* synthetic methods.

The cost of pinenes ex crude sulphonated turpentine significantly affects the price of the terpenoid aroma chemicals. For example, geraniol, which is typically stable, declined when the price of crude sulphonated turpentine fell in 1999 and 2000. Price volatility and supply uncertainty limit the competitiveness natural terpenoids, as users often switch between natural and synthetic materials, depending on the relative cost and availability of the compounds. For example, when heavy rains in the main growing regions of Litsea Cubeba substantially escalated the price of natural citral and its lemongrass oil feedstock in the late 1990's, some users of citral switched to synthetic alternatives. Natural types are however sometimes preferred for higher value applications such as fine fragrance. For example, natural geraniol produced from fractionating palmarosa oil is preferred in these applications whereas the synthetic version is favoured in soaps and detergents.

A short review of some of the more important aroma chemicals produced from turpentine or alpha/beta-pinene will be given below^{27, 28} A more detailed diagram of the products, their uses and relationships with each other is attached as Appendix 1.

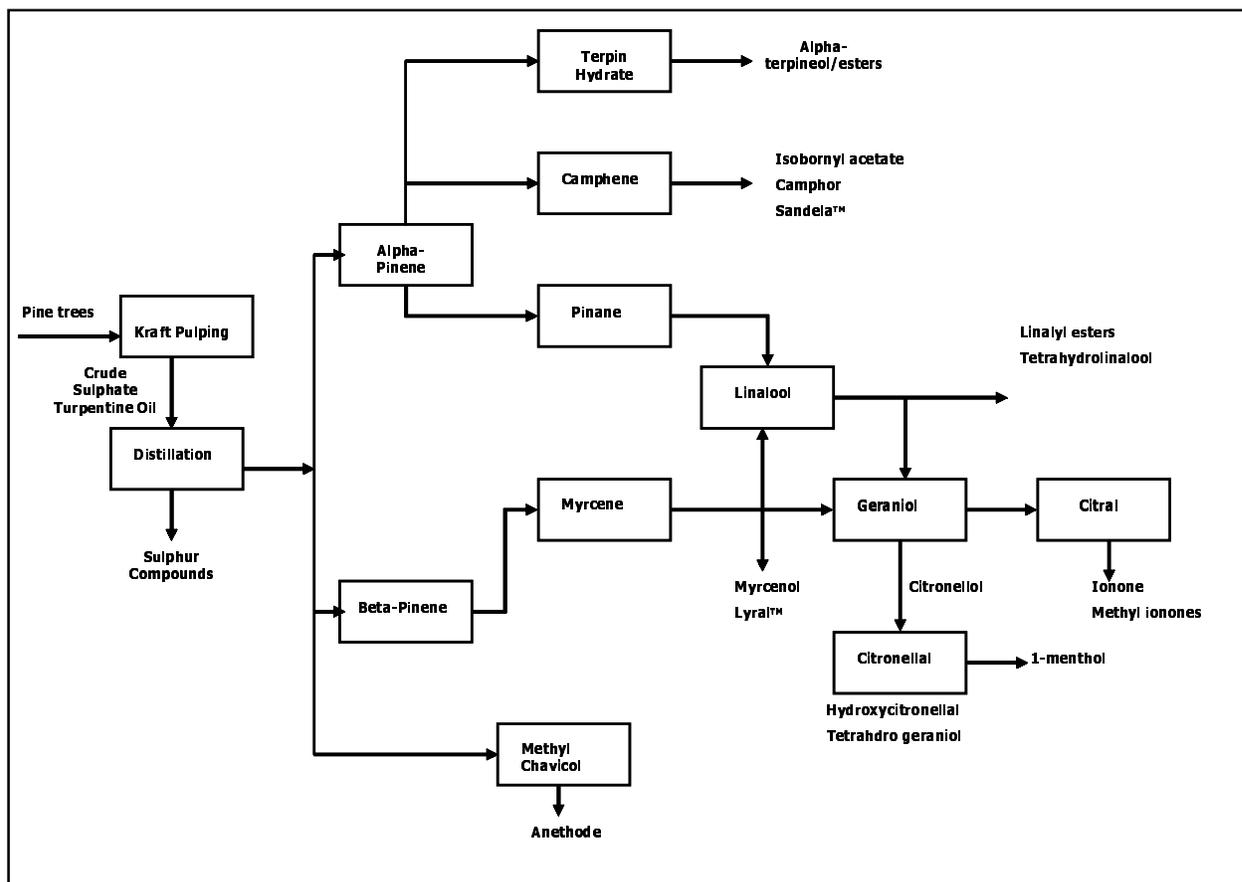
²⁶ Arizona Chemical: Converting papermaking and citrus by-products to performance chemicals; Kerry Thompson

²⁷ Boelens Aroma Chemical Information Service (BACIS), The Netherlands, 1997

²⁸ Perfumer and Flavourist: 1978 Vol 3., No. 1, Page 45; John M. Derfer SCM Corporation

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FIGURE 7: Conversion of Turpentine Oil to Aroma Chemicals



1. Anethole

Anethole is a benzenoid aroma chemical. It is widely used in fragrances, but most importantly in alcoholic beverages for its anise flavour. Anethole is one of the highest-value benzenoid aroma chemicals produced in large volumes. Anethole and methyl chavicol occur in the “bottoms” from fractionation of sulphate turpentine and can be isolated by efficient fractionation. Anethole can be prepared from anisole, or by the chemical transformation of methyl chavicol contained in turpentine. Isomerisation of the double bond in methyl chavicol with potassium hydroxide yields a mixture of cis and trans anethole with the trans isomer predominating (13:87). Methyl chavicol itself has a strong root beer odour. Synthetic anethole is extensively used in toothpaste flavours.

2. Borneol/isoborneol and their acetates

The primary use of these products is in soap and detergent perfumes for their woody, camphoreaceous, pine odour and their relatively low cost. The turpentine is first distilled to obtain the alpha pinene fraction, which is isomerised with a titanium oxide

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catalyst to camphene. The camphene is further purified by distillation under vacuum and is then esterified with either formic or acetic acid to obtain a methyl or ethyl ester of isoborneate. The ester after purification is saponified with sodium hydroxide solution to produce isoborneol. The major use of isobornyl acetate is as an intermediate in the production of camphor.

3. Camphene/Camphor

Camphene is produced *via* the isomerisation of alpha pinene over acid catalysis in the absence of water. Camphor is used in the production of celluloid and in the pharmaceutical industry. Isoborneol is dehydrogenated under the effect of a catalyst. The camphor is purified by sublimation.

4. Citral

Citral has lemon characteristics and is used in fragrances and flavours. Whilst a significant amount of citral is highly purified for use in the flavour and fragrance industries, the biggest use is as an intermediate in the manufacture of vitamins A, E, carotenoids, and certain other pharmaceuticals. Natural citral is sourced by extraction from litsea citrata oil, litsea cubeba oil and lemongrass oil, or by derivation from pinene *via* myrcene and the subsequent oxidation of geraniol/nerol. Natural citral is often seen as a comparative product to synthetic citral in flavour and fragrance applications. Synthetic routes are also available through acetylene/acetone or isobutylene route. Citral is a mixture of geraniol and nerol, which are cis/trans isomers.

5. Citronellol and its esters

These are very important fragrance intermediates for soap and detergents and also when a rosy, fresh floral tone is required. Natural citronellol is obtained from geranium oil, known as rhodinol. This has only minimal production. Most commercial product is produced synthetically *via* selective hydrogenation of geraniol/nerol. Citronellol is the dihydro analogue of geraniol/nerol.

6. Citronellal

Citronellal has a fresh, green citrus character, and is used in flavour and fragrances. Citronellal is prepared *via* extraction of citronella or Eucalyptus citriodora oil. More than 80% of the worldwide production, is however *via* the dehydrogenation or oxidation of citronellol (*via* geraniol). Another use of citronellal is in the production of menthol, hydroxycitronellal, and methoxycitronellal.

7. Geraniol/nerol and their esters

Geraniol and its esters have a mild sweet floral or rose character and very important fragrance and flavour ingredients. Geraniol/nerol are cis/trans isomers. They can be prepared by isolation from citronella oil or as is mostly the case, by various synthetic routes. Geraniol is produced from myrcene. Hydrochloric acid is added to myrcene

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in the presence of a copper chloride catalyst to form geranyl/neryl chloride, which in turn are reacted with sodium acetate to form the corresponding acetates. Geranyl/neryl acetates are subsequently hydrolysed and fractionally distilled to the yield pure geraniol/nerol. In recent years, geraniol has also become available as a product of linalool isomerisation of using ortho-vanadate catalysts. The subsequent mixture is further purified by distillation. This route *via* linalool starts from alpha-pinene as opposed to the myrcene route, which starts from beta-pinene.

8. Hydroxycitronellal

This is a classic perfume ingredient used in soap, detergents, and cosmetics as well as for flavours. It has a fresh, floral, lily-of-the-valley odour. Synthetic routes are predominant and start from citronellal by hydration of the bisulphite adduct.

9. Ionones and methyl ionones

The ionones are classic perfume ingredients, having a warm, balsamic, violet odour. They are prepared by a variety of synthetic methods, including from dehydrolinalool. Reaction of citral with acetone under basic conditions produces pseudoionone, which cyclises under the influence of acid to produce alpha and beta ionone. One isomer or the other can be made to predominate by proper selection of the cyclising acid. Alpha ionone is used in fragrances and flavours, but the large-scale use is for beta ionone as an important intermediate for the synthesis of Vitamin A and carotenoids. Hexahydropseudo-ionone is a common starting material for vitamin E production. Methyl ionones are widely used fragrance ingredients with a warm, balsamic, violet odour. They are prepared predominantly by the base catalysed condensation of citral and methyl ethyl ketone (as opposed to acetone). The preparation of the important fragrance alpha methyl ionone can be obtained in excellent yield from the reaction of dehydrolinalool and the enol ether of methyl ethyl ketone and methanol.

10. Linalool and esters

Linalool and its esters are very important perfume ingredients with a lavender or bergamot odour. They are also important intermediates for the synthesis of Vitamins A, E and carotenoids. Natural linalool is extracted from rosewood oil. Commercial linalool is produced in large quantities *via* a variety of synthetic methods. Alpha pinene is converted by catalytic hydrogenation to cis-pinane, which is oxygenated with a peroxide to cis-pinanol. This pinanol subsequently is pyrolysed at high temperature to linalool. Linalyl acetate is prepared by the esterification of linalool with acetic anhydride.

11. Alpha terpineol and esters

The lowest boiling and largest fraction from turpentine fractionation is alpha pinene. One use of alpha pinene is in the production of pine oil, which has a refreshing piney odour and finds high volume usage in cleaners, odourisers, and sanitisers. Synthetic

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pine oil is actually a mixture of terpene alcohols, chiefly alpha terpineol, along with smaller amount of other mono- and bicyclic terpene alcohols. Pine oil contains 50 – 80% terpineol. Globally 80 – 85% of the pine oil produced is made by hydration of alpha pinene with aqueous mineral acid at room temperature to terpin hydrate and subsequent dehydration of this hydrate with phosphoric acid and simultaneous steam distillation of alpha-terpineol. The remainder comes chiefly from sulphate turpentine fractionation. Perfume grade alpha terpineol is a delicate floral, lilac-type odour, and is one of the most widely used of all perfume chemicals because of its low cost and stability. It also finds use in the flavour industry. Alpha terpinyl acetate has a herbaceous bergamot-lavender odour and considerable quantities of it are used in low cost fragrances for household products.

12. Tetrahydrogeraniol and esters

These esters are used as fragrance chemicals, and find a wide use in perfuming soap and household products. They are prepared from geraniol or citronellol (or their esters) by hydrogenation.

13. Myrcene

The greatest use of myrcene is as an intermediate in the commercial production of terpene alcohols: geraniol/nerol, and linalool, which serve as intermediates for the production of large-volume aroma and flavour chemicals. It is also used in large quantities in the manufacture of specialty aroma compounds (myrcenol and its derivatives). The only important commercial source of myrcene is the pyrolysis of beta pinene at 550-600°C. Typical crude pyrolysate contains 75 to 77% myrcene, 9% limonene, approximately 2% PSI-limonene, and minor cracking products. Fractional distillation is used to produce high purity myrcene, with precautions taken to prevent polymerisation. A polymerisation inhibitor such as butylhydroxytoluene is normally added to crude or high purity myrcene, respectively, during shipment or extended storage. On prolonged heating at moderate temperatures, myrcene readily dimerises.

14. Myrcenol

Myrcenol is manufactured from myrcene by hydration of its sulphur dioxide-adduct with sulphuric acid and removing of the sulphur dioxide under reduced pressure.

15. Dihydromyrcenol

Dihydromyrcenol, a perfumery compound that has a citrus floral fragrance, can also be made from alpha pinene. Alpha pinene is hydrogenated to cis-pinane (see Linalool), by pyrolysing it to 3,7-dimethyl-1,6 octadiene, react this production with formic acid to a mixture of dihydromyrcenol and its formate and saponify the product. This product is however not commercially of great significance.

16. Menthol

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Menthol has been produced from turpentine by a variety of methods. One of these started with the optically active beta pinene, and involved its conversion to citronellal, cyclisation to isopulegol, which is hydrogenation to menthol. Takasago has commercialised a process *via* myrcene.

17. Myrcenol/Lylal

Condensation of myrcenol, produced indirectly from beta pinene, with acrolein yields lylal, another specialised perfumery material with an odour not unlike that of hydroxycitronellal.

Alpha pinene can also be converted to beta pinene. The beta pinene isomer is more versatile than the alpha isomer, and has a higher commercial value. The isomerisation is accomplished over a noble metal catalyst with high selectivity. The production of synthetic beta pinene from alpha pinene effectively allows all of the world's turpentine to be useful as a chemical raw material.

Turpentine comprised of alpha and beta pinene is therefore a valuable source of starting materials for a wide variety of useful flavour compounds, or as components for the manufacture of synthetic essential oils. Synthetic essential oils can replace or extend the use of some natural oils, which are subject to wide variations in quality, price and availability. Some such synthesised oils include spearmint, peppermint, lemon, bergamot, and nutmeg. All of these contain substantial quantities of terpenes and their derivatives.

Unlike petroleum, turpentine is a renewable resource. The chemical versatility of this product therefore makes all turpentine of commercial interest to the chemical processing industry.

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3.3 Industry and Market Analysis

3.3.1 Market Demand

In 2000 the worldwide demand for terpenoid aroma chemicals was estimated at 55,000 tons with a value of \$ 630 million. The world consumption broken down by region is illustrated below.²⁹

TABLE 6: World Consumption of Terpenoids by Major Region - 2000

| Region | Consumption Million Dollars | Percentage |
|----------------|--------------------------------|------------|
| United States | 242 | 38 |
| Western Europe | 213 | 34 |
| Japan | 70 | 11 |
| China | 60 | 10 |
| Other | 45 | 7 |
| TOTAL | 630 | 10 |

Worldwide demand in 2000 for cyclic and acyclic terpenes and terpenoids is outlined below.

The demand for acyclic terpenes (geraniol, citronellol, linalool, tetrahydrogeraniol and their esters; citronellal, citral and hydroxydihydrocitronellal; ionones and methylionones) was estimated at 25,000 tons. Another 40,000 tons of acyclic terpenes are produced as chemical intermediates for vitamin A, E and K, carotenoid production, and for the manufacture of two vitamin A derived pharmaceuticals, retinoic acid and etretinate.

The sources of these terpenes are various essential oils, alpha and beta pinene in turpentine oil, and synthetic manufacture. Only about 10% of the aroma chemical requirements come from essential oil extraction. The worldwide market for anethole, which is not a terpenoid aroma chemical but which can be synthesised from turpentine oil, in 2000 was estimated to be in the order of 4,000 tons per annum.

²⁹ Chemical Economic Handbook: SRI International 2001

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TABLE 6: Market Demand for Terpene and Terpenoid Aroma Chemicals: 2000

| Product | Demand (tons)# |
|--------------------------------------|----------------|
| Menthol (natural and synthetic) | 12,000 |
| Linalool and esters* | 6,500 |
| Geraniol/nerol and esters* | 4,000 |
| Ionones/methyl ionones* | 3,500 |
| Citronellol and Esters* | 3,500 |
| Citral* | 2,600 |
| Borneol/Isoborneol and esters* | 2,500 |
| Benzyl Alcohol (synthetic) | 1,400 |
| Hydroxycitronellal* | 1,000 |
| Alpha terpineol and esters* | 750 |
| Acetylated Cedarwood Terpenes | 650 |
| I-Carvone | 500 |
| Citronellal* | 500 |
| Lyral* | 500 |
| Other | 7,000 |
| TOTAL TERPENES AND TERPENOIDS | 55,400 |

For flavour and fragrance use only

* Derived from crude sulphonated turpentine

3.3.2 Production

Major producers of terpenes from alpha and beta pinene are tabled below.

TABLE 8: Producers of Terpenes from alpha and beta pinene

| Company | Plants | Production Route |
|---|--|--------------------------------|
| Millennium Speciality Chemicals | Brunswick, Georgia, USA | Via linalool from alpha pinene |
| IFF | Jacksonville, Florida, USA Widnes, United Kingdom | Geraniol from beta pinene |
| Pinova (Previously Hercules Inc. Resin Division) | Brunswick, Georgia, USA | Geraniol from beta pinene |
| DRT/Tecnal | Anacortes, Washington, USA Castets; Vielle Saint Giron; Lesperon; France. | |

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Millennium

Millennium is one of the world's leading producers of chemicals derived from crude sulphonated turpentine, and is the world's largest purchaser and distiller of crude sulphonated turpentine in the world. Its primary turpentine based products are intermediate fragrance chemicals, such as linalool and geraniol, which are used in fragrance compounds and which also provide a starting point for the production of a number of other fragrance ingredients. It operates manufacturing facilities for its fragrance chemicals in Jacksonville, Florida and Brunswick, Georgia. The Jacksonville site has facilities for the fractionation of turpentine into alpha and beta pinene, sophisticated equipment to further upgrade fragrance chemical products, as well as manufacturing facilities for synthetic pine oil, anethole, and a number of other fragrance and flavour chemicals.

The Brunswick site produces linalool and geraniol, from the alpha pinene component of crude sulphonated turpentine utilising a proprietary and unique technology based on the more prevalent isomer of turpentine, a significant advantage compared to the technologies used by other terpene-based competitors. The company believes this technology gives it a significant advantage in raw material availability. Its technology also has significant environmental advantages. Linalool and geraniol produced at Brunswick are generally further processed at the Jacksonville site to produce fragrance chemicals such as citral, citronellol and pseudoionone. Capacity for linalool was expanded in 1999 and the anethole plant was debottlenecked, Millennium Specialty Chemicals operates the world's largest dihyromyrcenol facility at Brunswick with a rated annual capacity of over 5 million pounds.

Millennium purchases crude sulphonated turpentine from approximately 50 pulp mills in North America, as well as quantities of both crude sulphonated turpentine and gum turpentine or its derivatives from Asia, Europe and South America. Due to the nature of the crude sulphonated turpentine market, with tightness in supply often experienced together with corresponding price increases, Millennium prefers to enter into long-term supply agreements with the pulp mills to secure its raw material crude sulphonated turpentine supplies. Crude sulphonated turpentine in general does not generate significant revenue and profit for the mills; therefore Millennium tends to work closely with these mills and provides them with incentives to produce more crude sulphonated turpentine.

Millennium converts 10,000 tons of technical linalool intermediate from alpha pinene for conversion to downstream grades of aroma terpenes – linalool, geraniol, citronellol, hydroxycitranellal, citral and pseudoionone. These production estimates do not include additional requirements for alpha pinene for terpineols, terpinyl esters and pine oils in non-flavour and fragrance applications.

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Over 80% of Millennium's terpene chemical sales in 2000 were to the fragrance chemicals market, with additional sales to the pine oil cleaner and disinfectant market. Approximately 60% of the 2000 fragrance chemical sales were to more than 50 different export countries.

IFF International

IFF converts 8,000 tons geraniol intermediates from beta pinene as a feedstock for aroma terpene production including ionones. These production estimates do not include additional requirements for alpha pinene for terpineols, terpinyl esters and pine oils in non-flavour and fragrance applications. In 2000, IFF purchased Bush Boake Allen, which was a subsidiary of International Paper. Bush Boake Allen had an annual capacity of 6,900 tons terpene and petrochemical based aroma chemicals. International Paper specialises in forest products such as paper, paperboard, packaging and other wood products and has a Kraft paper and paperboard complex. In the US, the Jacksonville, Florida facility processes 9 million to 10 million gallons of turpentine.

Beta pinene is further processed to produce a range of aroma chemicals, including geraniol, citral, citronellol and ionones. The Jacksonville facility also supplies intermediates to Widnes for further processing. IFF obtains roughly 22 % of its crude turpentine from its former parent, International Paper. It also uses procurement services provided by Arizona Chemical, a subsidiary of International Paper, for other external purchases of turpentine.³⁰

In 2000, IFF completed a significant expansion of geraniol at its Jacksonville, Florida facility, started in 1997. IFF invested about \$ 10 million to modernise the plant, which now produces all of the company's geraniol, increasing its capacity by 250% to 8,000 tons per annum. The company still produces the same amount of geraniol annually, but it is now produced all at one site. The work included an upgrade of the pyrolysis unit, installation of a new boiler, and the addition of a new distillation column to enable the plant to continuously distill upgraded terpene aroma chemicals. In the wake of the Asian crisis, IFF tabled plans in 1997 to construct a \$ 10 million world-scale aromas chemicals plant outside Madras, India. The goal was to tap into that country's growing consumption of aroma chemicals and give IFF ready access to export it chemicals, into India.

Pinova

Pinova is the new name for the operating division within Hercules Incorporated that was previously known as the Rosin and Terpene Specialties Division. This business was formerly part of the Resins Division, portions of which were divested by Hercules

³⁰ Chemical Marketing Reporter: November 27, 2000

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in 2001. Pinova is the world's only manufacturer of refined wood rosin and natural wood terpenes from pine stumpwood. It is the world's leader in hydrogenated rosin products. Pinova's products are used as performance-enhancing ingredients in a wide variety of applications in diverse industries. Principal applications include: tackifying resins for specialty adhesives, resins for compounding chewing gum base, weighting/clouding agent for citrus beverages, aroma chemicals for compounding flavours and fragrances, active ingredients in household and industrial cleaning products, and flotation reagents in mining.

Pinova produces geraniol intermediates from beta pinene and is a large buyer of crude sulphate turpentine and gum turpentine. The majority of Pinova's operations are at the major facility in Brunswick, Georgia, USA. Some Pinova products are produced at Hercules plants in Hattiesburg, Mississippi, and Savannah, Georgia.

DRT

DRT (Les Derives Resiniques et Terpeniques) is the largest independent European fractionator of crude sulphate turpentine from the paper industry and natural gum turpentine with sales of over \$150 million. In 1998, DRT purchased Tecnal Corporation, a basic fractionator of crude sulphate turpentine, from Enso Oy of Finland. Through this acquisition, DRT moved Tecnal (based in the USA) towards value-added aroma chemical production, thereby complementing its aroma chemical production in France. Tecnal is the only crude sulphated turpentine distiller on the US western coast. This capacity has boosted DRT's ability to transform 100,000 tons of pulp chemicals per year into pine oil, terpenes and aroma chemicals.

DRT has three production sites. One produces terpene alcohols and terpene hydrocarbons; another facility manufactures terpene alcohols and hydrocarbons, tall oil fatty acids, polyterpene resins, tall oil rosins and rosin esters; and the third makes numerous aroma chemicals, such as dihydromyrcenol, geranyl acetate, myrcene, terpineol, terpinyl acetate as well as pine oil.

Synthetic Producers

Terpene synthetic producers include F. Hoffman la Roche, using acetylene/acetone process; BASF using the isobutylene process; Kuraray using the isoprene process. In 2000,³¹ capacities for these three companies were estimated at over 30,000 tons per annum of equivalent linalool and citral intermediates.

In 2002, BASF announced its intentions to build a new production plant for the fine chemical intermediate citral with an annual capacity of 40,000 metric tons. The plant is scheduled to come on stream in 2004. The world-scale plant will replace the

³¹ Chemical Economic Handbook; SRI International 2001

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existing citral plant, which had a capacity of 10,000 metric tons per year. The capacity expansion will make citral the production platform for Vitamin A and Vitamin E, carotenoids and an expanded range of aroma chemicals. The citral synthesis is integrated backwards to the steam cracker at the Ludwigshafen site of BASF. The current production process was developed by BASF. BASF stated that the plant and the subsequent production stages for vitamin and aroma chemical production will use numerous, innovative processes and catalyst systems developed by researchers in recent years. BASF intends to use citral increasingly in the future as a raw material for a series of aroma chemicals used by the fragrance and flavour industry in the manufacture of perfume oils and flavourings.

Roche supplies the Flavour and Fragrance house, Givaudan with its internal requirements for linalool from Roche for its internal needs, and for sale into the merchant market. It is likely that this agreement was negotiated when Givaudan became independent from Roche.

It is estimated that the available installed capacity exceeds total demand worldwide.

3.3.3 Prices

TABLE 9: USA List Prices for Synthetic Terpenoid Aroma Chemicals

| Terpenes/Terpenoids | Year-end 1992 (USD/kg) | Year-end 1996 (USD/kg) | Year-end 2000 (USD/kg) |
|---------------------|---------------------------|---------------------------|---------------------------|
| Citral | 19.73 | 23.70 | 16.50 |
| Citronellal | 7.01 | 9.92 | 15.18 |
| Citronellol | | | 16.50 |
| Geraniol | 8.38 | 8.73 | 10.45 |
| Geranyl Acetate | 10.36 | 25.51 | 17.60 |
| Hydroxycitronellal | 18.19 | 18.74 | 11.50 |
| Alpha-Ionone | | 23.59 | 35.10 |
| Beta-Ionone | 32.08 | 58.42 | 33.44 |
| Alpha-Methyl Ionone | | | 34.10 |
| Linalool | 12.13 | 12.13 | 14.63 |
| Linalyl Acetate | 13.78 | 13.78 | 12.87 |
| Methyl Ionones | 36.38 | 34.17 | 34.10 |
| Alpha-Terpineol | 4.41 | 3.97 | 3.90 |
| Terpinyl Acetate | 3.97 | 5.73 | 7.37 |

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Major long-term contracts are however typically fixed below these prices.

Linalool and geraniol are normally very stable products that follow broad economic trends, but pricing has softened recently primarily because of weakening prices for its main feedstock, crude sulphate turpentine. Pricing for geraniol was under severe pressure in 2000, particularly in light of the bottoming out of the crude sulphonated turpentine feedstock prices, and capacity expansions by Millennium and Bush Boake Allen. These companies control about 90% of the world's market for synthetic geraniol/nerol. In addition, DRT entered the market in Europe, bringing another several hundred tons into the market. The strength of the US dollar had an impact on pricing, with the dollar trading at \$1.17 to the Euro in early 1999, but in 2000 trading at less than 97cents. The French based company DRT had an advantage operating in a soft currency environment, but this advantage was largely offset by higher raw material prices. DRT's efforts were not anticipated to have much impact on markets outside of Europe.

Pricing for linalool, a highly used, low-cost material in perfumery, has remained fairly constant since 1986. Recently however, the product has experienced some current downward movement stemming from low crude sulphonated turpentine prices. In addition, IFF's aroma chemicals division recently moved into the linalool market as BASF began producing large volumes of citral, formerly a major product for BBA. Global supply and demand remain reasonably in balance, and linalool producers are cautiously optimistic that the industry has weathered the worst of the downturn. On the positive side, there have been no new entrants into the linalool market or major capacity expansions, unlike the market for geraniol, which is being further squeezed by recent increases by Millennium and IFF, as well as the entry of French-based DRT. Market prices for crude sulphonated turpentine derivatives like linalool and geraniol have now adjusted to the low level.

The prices from pine oil come under pressure when the paper industry reduces output of crude sulphonated turpentine. With low crude sulphonated turpentine supplies, fractionators tend to switch to higher-value added products such as the aroma chemicals. Pine oil prices therefore also increase. Other applications for alpha pinene have greater value than pine oils. Most fractionators therefore convert to these bigger profit making products and use leftover stocks for pine oil.

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3.4 South African Market for Turpentine Aroma Chemicals

South African international Flavour and Fragrance houses, the consumer goods companies, tobacco houses, and a number of traders active in importing flavour and fragrance chemicals were interviewed with respect to their purchases of terpene aroma chemicals. The import statistics for the previous two years were also obtained.

3.4.1 Import Statistics

Import statistics for 2002 and 2003 were obtained. The trade statistics are however difficult to analyse. There is a loss of identity within a number of the categories, as the statistics are not disaggregated. For example, the category with the largest import value, \$ 2.2 million, includes terpene peroxides used in the rubber industry as well as the terpene esters used in the flavour and fragrance industry. Some general comments can however be made. South Africa imports in the region of \$1 – 1.1 million of synthetic pine oils, as well as \$0.8 – 0.9 million of the terpeneols. Another large terpene product import is camphor, \$0.3 – 0.5 million. The acyclic terpene alcohols i.e. linalool are imported at a value of roughly \$ 0.15 million.

TABLE 10: South African Trade Statistics

| US \$ | IMPORTS | | EXPORTS | |
|---|-----------|-----------|---------|---------|
| | 2002 | 2003 | 2002 | 2003 |
| Pine Oil | 1,146,754 | 1,093,242 | 15,545 | 62,537 |
| Terpeneols | 88,381 | 104,609 | 823 | 6 |
| Camphor | 331,860 | 594,516 | 26,821 | 27,418 |
| Acyclic Terpene Alcohols | 156,701 | 150,491 | 211 | 15 |
| Gum, wood or sulphate turpentine | 47,970 | 2,717 | 372,800 | 228,859 |
| Ethers | 240,537 | 20,868 | 34,344 | 30,498 |
| Polycarboxylic acids, peroxides, anhydrides, halides and derivatives. | 233,753 | 347,130 | | |
| Monocarboxylic acids, peroxides, anhydrides, halides and derivatives. | 2,255,135 | 2,168,621 | | |

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3.4.2 Aroma Chemicals

Of the companies interviewed, only Symrise and Quest add value locally by blending and compounding. All the others import ready mixed compounds, the components of which they were reluctant to divulge. The two aroma chemicals used in the greatest volumes are menthol and anethole, which are used in toothpastes. Three Flavour and Fragrance houses, Firminech, Symrise and Quest, and a local Flavour House Cranbrook Flavours, provided their usages of some of their individual terpene aroma chemicals purchased, however these are in trivial quantities.

Symrise has a global buying strategy, although the local office sources the bulk of its aroma chemicals from its mother company in Germany. The company has a raw ingredient list of over 1,000 products, but the company is very small in South Africa and most ingredients are purchased only in kilogram or even gram volumes. Symrise will buy locally where appropriate.

Firmenich imports all of its raw materials from its parent company in France and only a limited amount of compounding is done locally. IFF supplies fragrances to the local market and markets about 350 tons of fragrance in South Africa. These fragrances are all compounded in Europe and the blends are brought in as finished product. The parent company uses its global contacts to source worldwide at the best prices. Hence even the local company can get favourable prices, even for very small volumes. IFF would purchase locally if the quality and price were acceptable.

Proctor & Gamble only imports finished products. Unilever now consists of three companies. The food division consists of Unilever, Best Foods, and Robertsons is known as UBR. Lever Ponds, the personal care arm, makes laundry soap, personal products, deodorants and skincare products at the Durban factory and the Boksburg factory makes washing powder and liquid detergents. Levers is the chemical arm. Lever Ponds makes brands such as Omo, Sunlight, Domestos and Dove. All fragrances are imported as compounds which are mixed by the international flavour and fragrance houses. Unilever's Paris team purchases globally.

Quest International imports a number of terpene aroma chemicals. Some compounding is performed locally. These products are sourced from all over the world and the company is always looking for new supplies.

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TABLE 11: Terpene Aroma Chemical Usage in South Africa

| Aroma Chemical (kgs) | Firmenich | Cranbrook Flavours | Quest | Symrise Last 9 months |
|----------------------|-----------|--------------------|-------|-----------------------|
| Alpha -Terpineol | | | 120 | |
| Alpha Terpinene | | | | 97 grams |
| Anethole | | 15 | 600 | 3 |
| Beta Pinene | | | | 1.4 |
| Citral | | 20 | 600 | |
| Citronellol | 3 | 6 | 80 | 11 |
| Geraniol | 10 grams | 5 | 200 | 4.5 |
| Geranyl Butyrate | | | | 165 grams |
| Linalool | | 2 | 200 | 1,600 |
| Linalyl Acetate | 24 grams | | | |
| Nerol | | | 20 | |
| Methyl Ionone | 5 | | 10 | |
| Menthol | 1,500 | | 1,200 | 7,827 |
| Myrcene | | | 6 | 5 |

3.4.3 Pine Oils and Terpeneols

Users of pine oils and terpeneols were also interviewed. **Eniline Pharmaceuticals** is a contract packer for Reckitt & Benckiser. Approximately 20 tons per month of pine oil is imported from IFF, Jacksonville USA, at a cost of about R 8/kg. Hence the total purchase of pine oil is around R 1.9 million per annum. The pine oil is used in Dettol a medicinal product, which is registered with the Medicine's Control Council and therefore has very strict quality specifications. **Johnson & Johnson** buys a blend of pine oils through IFF for use in the production of Savlon. IFF formulates according to Johnson and Johnson's in-house specification (which is confidential). Consumption is around 20 tons per annum. **Adcock** uses about 23 tons of pine oil per annum. The pine oil is also pharmaceutical grade and is all imported through an agent. The price is confidential but was reported to be much more than R 8/kg. It is therefore likely to be a higher-grade terpeneol product.

Sara Lee is an international company, which produces household cleaning products. The company uses a fatty acid derivative of pine oil imported from New Zealand. No other aroma chemicals are used but some formulated fragrances are bought from the local fragrance houses. The parent company does any creative compounding required for Sara Lee and supplies the formulations directly.

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Appendix 2 outlines some of the uses of synthetic pine oil, terpineol and terpineol acetate.

3.4.3.1 Camphor Market

Camphor is used in South Africa in snuff products as well as in hand creams. Dingler Tobacco Products uses approximately 24 tons per annum of camphor in its snuff, which goes by the brand name of Taxi. The camphor is imported from China and sold by Crest Chemicals. Van Erkoms Tobacco in Potgietersrus produces the Singletons brand of snuff but has not used any camphor in this product for two years. **Adcock Ingram** use in the region of 10 – 20 tons per annum of a pharmaceutical grade product.

3.4.4 Conclusion

The South African market for terpene aroma chemicals is therefore extremely small.

Due to the limited local market, there is unlikely to be substantial import substitution from a South African Terpene Aroma Chemicals business. Any business created will therefore have to export the majority of its products. Thus, in order to create an aroma chemicals business based on such limited quantities of feedstock, the production facility must be configured in order to optimise the number of products that can be produced for the minimal capital investment. At the same time, the production of synthetic pine oil or any aroma chemicals with a local demand should be maximised whilst not compromising the plant's overall profitability. This approach will maximise the investment return.

3.5 Feedstock Analysis

3.5.1 Crude Sulphonated Turpentine

Crude sulphonated turpentine is a by-product of cellulose/paper pulp obtained from pinewood using the Kraft sulphate wood pulping process. The source of crude sulphonated turpentine within South Africa is therefore limited to those paper and pulp plants which use the Kraft process on softwood i.e. pine. A recent report from the Paper Manufacturers Association of South Africa published a table of the capacities and products from the South African pulp mills.

From this table it can be seen that the only potential sources of crude sulphonated turpentine are the Mondi Richard's Bay mill and the Sappi Ngodwana mill. Mondi is however increasingly switching to hardwood. Discussions with Mondi indicated that it no longer produces crude sulphonated turpentine. Sappi Ngodwana is the only South

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African mill producing any crude sulphonated turpentine in significant quantities. This mill currently produces roughly 30 tons per month. The Sappi Tugela and Sappi Usutu (Swaziland) mills produce minor amounts of crude sulphonated turpentine, in the region of 10 tons per month each, however these quantities are variable. The maximum amount of crude sulphonated turpentine available from the Sappi plants therefore appears to be in the range of 360 – 600 tons annually.

TABLE 12: South African pulp mill capacities 2001

| Company | Mill | Products | 2001 Capacity (1000 t/a) |
|---------|-------------------|--|--------------------------|
| Mondi | Richards Bay Mill | Hardwood and softwood Kraft pulp | 576 |
| | Piet Retief Mill | Hardwood and softwood neutral sulphite semi-chemical pulp | 55 |
| | Felixton Mill | Unbleached bagasse pulp | 50 |
| | Merebank Mill | Thermomechanical pulp Groundwood pulp | 171 55 |
| Sappi | Ngodwana Mill | Hardwood and softwood Kraft pulp Groundwood pulp | 410 100 |
| | Tugela Mill | Unbleached softwood pulp Hardwood neutral sulphite semi-chemical pulp | 230 120 |
| | Stanger Mill | Bleached bagasse pulp | 60 |
| | Enstra Mill | Bleached hardwood pulp | 90 |
| | Saiccor Mill | Dissolving pulp | 600 |
| | | Total | 2,517 |

The specification of Tugela Turpentine is shown below. This specification may change with species and other processing parameters, but gives an indication of the alpha and beta pinene content of South African turpentine.

TABLE 13: Specification of Tugela Turpentine

| Constituent | Percentage |
|--|------------|
| Alpha Pinene | 51.3% |
| Beta Pinene | 24.7% |
| Beta Phellandrene | 17.6% |
| Myrcene, camphene, limonene, and alpha terpineol | 6.4% |

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| | |
|--------------|-------------|
| TOTAL | 100% |
|--------------|-------------|

Sappi is however currently reviewing its South African pulping processes. There is a strong possibility that within the next few years the Ngodwana mill may change one of its digesters to Eucalyptus (hardwood). The reason for this change would be driven by Sappi's strategy in terms of maximising its profitability by optimising the types of paper produced as well as the amount of short-fibre pulp sold internationally. Currently there is a large global demand for short-fibre pulp, on which the profitability is high. Short fibre requires Eucalyptus.

Should this change occur, it would obviously have a dramatic impact on the quantity of crude sulphonated turpentine available, as only one digester will remain on softwood. This change is not a certainty, and before any decision is taken a full feasibility study including an environmental analysis would have to be performed. However, in the long-term, the possibility of a decrease in the availability of crude sulphonated turpentine must be considered. The other two Sappi mills producing crude sulphonated turpentine i.e. Tugela and Usutu, will not change from softwood. These plants however produce crude sulphonated turpentine in much smaller quantities than Ngodwana.

The sustainable volume from the Ngodwana mill should therefore be decreased by 50%. Feedstock from the Tugela and Usutu mills varies between 0 – 240 tons annually. Sappi Ngodwana could in addition range between 180 – 360 tons annually, depending on whether 1 or 2 digesters remain on softwood. Discounting one of the Ngodwana mills therefore, leaves the sustainable amount of feedstock anywhere between 180 and 420 tons crude sulphonated turpentine annually, with a corresponding amount of alpha and pinene of only 137- 319 tons per annum.. The feedstock supply in South Africa can be summarised as follows:

TABLE 18: Crude Sulphonated Turpentine Feedstock Supply in South Africa

| | Tons |
|---|------------------|
| Sappi Ngodwana | 180 |
| Sappi Usutu | 0 – 120 |
| Sappi Tugela | 0 – 120 |
| Total Potential Crude Sulphonated Turpentine | 180 – 420 |

As the product is extremely environmentally unfriendly Sappi disposes of the product as quickly as possible. This entails putting it immediately into tankers and selling it. There is currently only one customer who purchases the entire amount, including the small volumes from Usutu and Tugela. This customer is a South African trader,

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based in London. The crude sulphonated turpentine is all shipped off-shore to this customer who pays a price linked to the crude sulphonated turpentine index, which ranges from R 800 – 1400/ton depending on exchange rates. The price is paid to Sappi in Rands/ton, although internationally crude sulphonated turpentine is traded in litres. Sappi performs some minor chemical analyses, mostly related to the water content, but the customer does other additional tests, and on the basis of these results determines the price.

In principle, Sappi is prepared to sell to a local South African customer, provided that this customer is committed prepared for an immediate off-take as Sappi obviously cannot afford to have the product unsold.

3.5.2 Gum Turpentine: Alternative feedstock for Terpene Aroma Chemicals

Gum turpentine, a potential alternative South African source of feedstock, for the production of terpene aroma chemicals has been identified. Whilst at first it appeared that this would provide substantial quantities of feedstock for the production of these aroma chemicals, it unfortunately transpires that the long-term sustainability of this product is also under threat.

3.5.2.1 Case study of South African Gum Turpentine Production

In KwaZulu Natal, at Dukuduku in the St Lucia region, a small operation taps pine trees to produce oleoresin. The tapping operation is run by Associated Resins, a division of a company called Associated Motor Carriers. Associated Motor Carriers' core business is in the transportation of the timber once the trees have been felled. This company took over management of these resin-tapping operations in 2002 when the company, PineChem, originally operating it ran into financial difficulty. Reference to the takeover of this operation is mentioned by Mr Ronnie Kasrils (Minister of Department of Water Affairs and Forestry in 2002) in his budget speech in 2002. (See Appendix 3)

At the peak of its operation, 550 tons per month of crude resin was produced. Industrial Oleochemical Products, based in Durban, distils gum turpentine from this resin and performs further processing of the solid material, known as rosin, left behind after distillation. The rosin is converted into further downstream products including products for the adhesive market and paper sizing. Industrial Oleochemical Products markets the gum turpentine through Protea Chemicals for R 9.00/kg for quantities over 540 kg. (See attached specification).

Typically, crude resin comprises 70 – 75% rosin, 15 – 20% turpentine and 10% foreign matter (pine needles, bark, insects etc.) and rainwater. Hence, approximately 400 tons per month of crude rosin and 110 tons per month gum turpentine could be

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produced from the crude gum resin. This translates into 1,320 tons per annum of gum turpentine, of which most was exported, the market locally being limited.

The Dukuduku forest plantation where the pine trees are tapped has however been declared part of the Greater St. Lucia Wetland Park. As a result, after the trees have been tapped, they are being felled and replaced by indigenous trees. The resin tapping operation will therefore cease completely. The amount of oleoresin processed by Industrial Oleochemical Products is currently in the order of 100 tons per month. The resin tapping operation at its peak employed 575 - 600 people. Currently only 80 tappers are employed and shortly, even these jobs will be lost.

Industrial Oleochemical Products has therefore also had to decrease its amount of gum rosin derivatives produced, whereas if larger quantities were available the company would have no problem selling it. The company has previously investigated the potential for making pine oil from the gum turpentine for the mining industry, but found that it was not economic to do so. This conclusion is consistent with reports that fractionators struggle to sustain profits producing pine oil as crude sulphate turpentine prices increase. To remedy this, crude sulphonated turpentine up-graders such as Arizona Chemical Group and Pinova, are increasingly moving to the production of higher value-added products such as the aroma chemicals.³²

Had the Dukuduku tapping operation continued, approximately 1,320 tons of gum turpentine would have been available for further processing into Terpene aroma chemicals. The alpha/beta pinene content of this feedstock is higher than that from the Sappi crude sulphonated turpentine. In addition, this source of turpentine does not contain sulphur, making synthesis of the aroma chemicals easier since the sulphurous compounds do not need to be removed. Associated Carriers had plans to expand its operation, in the process creating another 350 jobs (Appendix 3). This would have potentially given rise to an additional 4,000 tons gum resin, equivalent to 800 tons gum turpentine.

Whilst it is difficult to quantify this lost opportunity cost exactly, an approximation can be made using the price of linalool, one of the higher value aroma chemicals that can be produced from crude sulphonated turpentine³³ and assuming the same process yields used in the evaluation in section 3.10 below.

On this basis, table 14 below outlines the potential aroma chemical business based on the two types of feedstocks.

32 Chemical Marketing Reporter: Vo. 249, Issue 17, 1996

33 Current Linalool price of \$ 9.50/kg: C. Teubes (Pty) Ltd

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TABLE 14: Potential Feedstock Availability and Opportunity Value

| | Feedstock (tpa) | Pinene Content (%) | Pinene Content (tpa) | Potential Turnover (\$ millions) |
|---|------------------------|---------------------------|-----------------------------|---|
| Gum Turpentine (at peak operation) | 1,320 | 94% | 1,240 | 5.9 |
| Gum Turpentine (proposed expanded capacity) | 800 | 94% | 755 | 3.6 |
| Sappi crude sulphonated turpentine | 180 – 420 | 76% | 137 – 319 | 0.7 – 1.5 |
| TOTAL | 2,300 – 2,520 | | 2,132 – 2,314 | 10.2 – 11.0 |

The Food and Agricultural Organisation estimates that the yield of resin per tree can realistically be expected to be in the order of 3 kg.³⁴ In order to replace the lost opportunity at Dukuduku and produce the same capacity of resin i.e. 10,600 tons per annum, a forest of approximately 3.5 million trees will be required.

In addition to the lost added value, which could have been created *via* conversion of gum turpentine to aroma chemicals, the gum rosin also produced from the resin was converted into further downstream products including products for the adhesive market and paper sizing. The company currently performing this operation has therefore had to decrease its amount of gum rosin derivatives produced. South Africa must now import these products, which were originally produced locally.

The decision to remove the Dukuduku forest plantation has therefore had the following consequences:

- Loss of 600 existing jobs and a loss of 350 potential further jobs in an impoverished area.
- Loss of opportunity for the production of further added value aroma chemicals. Realisation of this opportunity would have:
 - Created a business worth approximately \$ 9.5 million.
 - Created further jobs in this downstream industry.

³⁴ Food and Agricultural Organisation: Chapter 8 - Turpentine from Pine Resin

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- Decreased South Africa's trade balance due to the decrease in products currently imported.
- Generated foreign exchange.
- Decrease in a South African company's profitability.
- Increased imports of rosin derivatives with a corresponding decrease in South Africa's trade balance.

3.5.2.2 *Alternative Sources of Gum turpentine*

Associated Resin has begun the process of investigating other sources of oleoresin. Whilst 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 acceptable. These factors depend on the species of *Pinus* tapped. The species found in South Africa, *P. Elliottii* and *P. Caribaea* are suitable for tapping. *P. Caribaea* produces a crystalline resin, although not of as high a yield as the *P. Elliottii* variety. Furthermore warm summer temperatures in particular are conducive to high resin flow and pine plantations at higher altitudes, above 900 m, and those in the lowveld are not particularly high yielding. Currently, Associated Resin has contracted a company to perform the pine tapping operation on its behalf in Swaziland (250,000 trees), using Sappi Usutu plantations. Due to the cold winter temperature, tapping can only be performed for 5 – 6 months of the year and the long-term viability of this operation is under question.

Other areas have been investigated, such as in Kokstad, however these did not yield a high enough yield to be economically viable. In many other areas, the plantations have been over felled resulting in the trees not yielding enough resin. Trees yield only between 1.8 – 4.2 kg resin per annum. Other factors such as drought and fire have seriously affected the plantations in the KwaZulu Natal region, and therefore ultimately the yield of the resin available.

Not much research has been done in South Africa as to the factors influencing the yield of resin from pine plantations. A comprehensive survey as to the extent of *Elliottii* plantations in South Africa has also not been performed. In addition, it is known that different tapping methods can influence the yield greatly, and this has not been studied further.

(a) **Sappi**

Sappi would first want to have proof that tapping of the pine trees did not affect the quality of the wood in any way such that it would have an impact on the downstream pulping operations. A bigger problem however is that the plantations of *Elliotti* trees at the coastal regions in South Africa in general are being replaced by hardwood trees such as Eucalyptus for reasons identified

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earlier. Sappi have in addition noted that the resin yields of the pine trees are decreasing, and as a result its tall oil operations are also reducing.

The plantations are mostly owned by the Department of Water Affairs and Forestry. The Department of Water Affairs and Forestry are currently in the process of selling many of its plantations to small black economic empowerment consortiums, which are replanting the pine trees with hardwood. The question would therefore have to be raised with the Department of Water Affairs and Forestry firstly as to whether or not any suitable plantations in the KwaZulu Natal region exist that could be tapped, and secondly whether they would be prepared to consider the option of not felling the trees and replanting, but keeping the trees solely for the purpose of creating a resin tapping operation.

(b) Mondi

Mondi is in the process of converting its softwood forestry plantations to hardwood for reasons already identified. The softwood trees were mostly *Pinus Patula* trees, and not *Elliotti*. *P. patula*, although widely planted as an exotic species in Africa and elsewhere, does not give good yields of resin and the quality of the turpentine and rosin is extremely poor. As a consequence it is not tapped anywhere in the world. The *Elliotti* trees that Mondi used to own are now part of the St. Lucia conservation area and form part of the resin-tapping operation already referred to. The case study based on this operation has been outlined above.

(c) Other options

A pine tapping operation exists in Zimbabwe. This may be an option to pursue in terms of sourcing additional gum turpentine, but would not use South African raw materials. The only South African *Elliotti* forestry plantations that will be in existence for any long period of time are those that belong to the saw-milling operations. These companies will continue to require softwood and will therefore not replace the trees with hardwood after felling. The Komati Land Forestry Company based in Nelspruit may be an option. The Department of Water Affairs and Forestry has a substantial number of big *Elliotti* trees in large plantations. Global Forestry Products, part of the Bonheur Consortium, operate a saw-milling operation near Sabie using pine trees. This is a Safcol forest recently privatised and known as the Department of Water Affairs and Forestry. This may an option, but it is likely that the resin yields will be too low to make a resin tapping operation viable.

(d) Conclusion

There are some potential *P. Elliottii* forest plantations in South Africa.

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1) Saw mill plantations

These plantations are inland and the yields may be too low to make the operation viable. It is known that coastal regions in South Africa are better suited to tapping. Inland tapping operations do however exist internationally e.g. in Zimbabwe, so the trees would need to be tested to first determine the yield. In addition, the impact of resin tapping on the quality of the wood may be a concern to a saw-milling operation, but this would need to be investigated and may be the subject of negotiation. A resin tapping process may be possible, which does not affect the quality of the tree such that it impacts on the saw-milling operation.

2) The Department of Water Affairs and Forestry plantations

These plantations are being converted into hardwood as they form part of the South African pulping value chain and this is the trend within the industry. The Department of Water Affairs and Forestry would have to be consulted as to whether it could possibly consider earmarking any plantations specifically for the purpose of tapping. This would most likely be an economic consideration, driven by the potential for any additional job creation and better long-term profitability of the plantation as part of a bigger terpene aroma chemicals business.

Whilst at first sight it would appear that South Africa has large pine plantations relatively “untapped”, this does not appear to be the case. Potentially however, if more is known about the factors influencing yield and the influence of different tapping methods, perhaps the pine forests in non-coastal areas could be used. Should a source of suitable *P. Elliottii* trees be identified, the potential for job creation as well as increasing the size of this business could be substantial.

The long-term availability of gum turpentine, an alternative feedstock for the production of terpene aroma chemicals, does not however appear to be sustainable at this point. At this point however, this alternative source of feedstock cannot be considered in evaluating the potential for the creation of an aromas business based on turpentine.

3.5.2.3 Job Creation Potential for Resin Tapping Operation^{35, 36}

The tapping of pine trees to produce resin, and thereby gum turpentine and rosin to which further value can be added, is a particularly labour intensive operation,

³⁵ Food and Agricultural Organisation: Non-wood Forest Products Turpentine from Pine Resin Chapter 8

³⁶ Food and Agricultural Organisation: Gum Naval Stores – Turpentine and Rosin from Pine Resin

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constituting between 50 – 80% of the production costs. As labour in the more industrialised countries has become more expensive and less willing to perform the arduous task of tapping, resin production has declined and the centre of its production has shifted to Southeast Asia. First-world countries have problems in recruiting labour at a wage that makes the collection and processing of the gum resin economically viable. The United States and many former-producing countries of Europe are either no longer producers, or are only able to sustain production as very low levels. China has been a dominant producer for many years. Indonesia has become the world's second largest producer with a dramatic increase in production since the 1980's. While Chinese production is unlikely to increase further, Indonesia has ample and growing number of trees available for tapping and the potential to increase production significantly. Brazil has also moved from being a net importer to a net exporter. The state of development of the gum resin industry tends to be inversely related to the level of economic development in the country at the time: the higher the GNP, the smaller the industry.³⁷

Two types of turpentine – gum and sulphate – are the only forms produced in any significant commercial quantities today. Turpentine, rosin and derivatives of these are known collectively as gum naval stores and the turpentine and rosin known as gum turpentine and gum rosin respectively. No resin itself enters the export market; it is all processed in the country of production. Most naval stores production is also consumed in the country of origin, and only around one-third of all rosin produced enters world trade.

Most rosin is modified and is used in a wide range of applications including adhesives, paper size, rubber compounds, surface coatings, and printing ink manufacture. Turpentine, is used mainly as a raw material for fractionation and value-added derivative manufacture. However, simpler, more traditional products in which rosin and turpentine can be used; such as soap, paper size and as a solvent for paints or varnishes can still be of value to the domestic economy of developing countries where tapping occurs. Producers therefore generally seek to satisfy domestic or regional markets products first before looking for export opportunities.

There are two major and distinct operations involved in the production of gum rosin and gum turpentine: the tapping of the 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 seen as unlikely to be economic as a separate operation. Operations in most producing countries combine tapping with processing the crude resin into rosin and turpentine. Further processing demands a

³⁷ Greenlagh, P. (1982): The Production, Marketing and Utilisation of Naval Stores. Tropical Products Institute (now Natural Resources Institute) report

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high volume of output to take advantage of economies of scale. In South Africa, the local paper industry has a demand for the production of rosin size.

The fundamental requirement is an adequate number of suitable, mature pine trees. Natural forests and plantations may be used, although the high tree density and easier terrain in plantations enables the tapper to visit a greater number of trees per day. Although all 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. These factors depend on the species of *Pinus* tapped.

As well as being dependant 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 of the tree, method of tapping and length of the tapping season.

South Africa has pines of the species *P. Elliottii*, which is theoretically suitable for tapping. Recent research in South Africa and Brazil has demonstrated that some *Pinus* species which have been developed for improved wood production also give enhanced resin yields. Crosses of *P. Elliottii* and *P. caribaea*, one of the most promising hybrids, may therefore be the choice of tapping in the future.³⁸

Resin is obtained from the tree similar to rubber tapping, except that the exudate is more viscous and slow running than rubber latex. The manner in which tapping occurs in the different producer countries has developed in different ways over a course of many years. However, it is generally agreed that tapping methods should avoid permanent damage to the tree. The particular style may also be influenced by the extent to which the trees are to be used for other purposes other than tapping i.e. whether the trees are for saw timber or pulpwood. Productivity depends on the system of tapping and the efficiency of the tapper. In a two-week cycle of 10 working days, 2,000 – 8,000 trees can be tapped by one person.

In most countries, contractors or piece workers who are paid according to the amount of clean resin they produce carry out the tapping operation. A smaller, permanent work force is required to supervise and manage the tapping operation, arrange for purchase, storage and transport of the crude resin, and maintain stores and accounts. Management must also undertake periodic checks to ensure that correct tapping procedures are carried out. The capital expenditure for tapping operations is very small, consisting mainly of gutters and cups, a range of tools, and items of protective clothing and footwear for the tappers.

³⁸ Food and Agricultural Organisation: Chapter 8 Turpentine from Pine Resin

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Once it arrives at the factory, the resin is steam distilled. The resin must first be cleaned before it goes into the still. As an approximate guide, mean annual yields of resin should not be much less than 2 kg per tree if tapping is to be economically viable; around 3 kg per tree is probably a realistic expectation. This translates to an operation producing 1,000 tons of resin per year requiring 0,3 – 0,5 million trees. Distillation of this quantity of resin will produce approximately 650 – 700 tons of rosin and 150 tons of turpentine. Using the production figures for Associated Carriers who employed 600 people to produce 3,600 tons resin, this would imply a forest of 1,2 million trees, and imply that 1 person is employed for every 2,000 trees.

The future production of oleoresin globally depends on the availability of cheap labour and the availability of suitable coniferous forests. Rising labour costs and decreased supplies of gum naval stores from traditional sources means that there are opportunities for countries with standing resources of pine trees. It is an industry based on renewable resources. The production of resin and from it turpentine and rosin brings many social and economic benefits as the tapping operations are labour intensive. A large number of unskilled and unemployed rural labour can be utilised in resin tapping operations. Integration of pine tapping with the pine plantation programmes could also reduce the afforestation and maintenance costs. Local industries can also derive some benefit from the tapping operations in terms of higher value added products such as paper size, and flavour and fragrance products.

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3.6 Attractive Options

The products in the terpene aroma chemical portfolio were subjected to a screening process designed to identify the most attractive products in the portfolio (Appendix 4 and 5). The products were categorised accordingly into “Bets” categories - Good, Conservative, High Risk and No Bets. The results are displayed as Appendix 6.

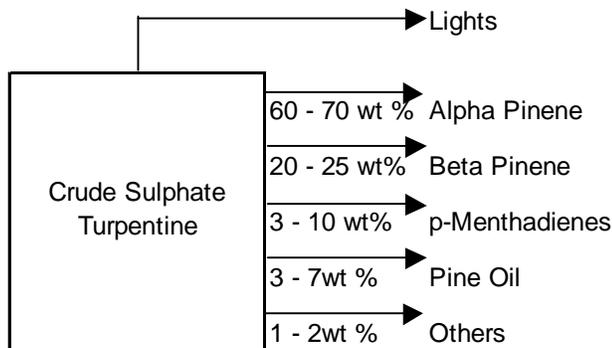
The products linalool, geraniol, citral and terpineol are all categorised as “good bets”. Pine oil is a “conservative bet”. Of these products, terpineol and pine oil are the least favoured. This is due to the fact that these products have the lowest margins and create the least value. Their market size internationally is also much smaller than the other terpene aroma chemicals. However, a local market for both products exists, and this factor should be considered in the selection of the final product portfolio. These products will therefore constitute the portfolio considered in the evaluation as to the viability of the creation of this business.

3.7 Intellectual Property

In nature, the two most abundant natural sources of terpenes are turpentine and other essential oils. Since about the late 1950's, synthetic methods have been developed for manufacturing most of the industrially important terpenes, and these synthetics have taken over a large share of the market. The synthetic methods for producing the terpene aroma chemicals are therefore well known and the patents have expired.

Industrially, turpentine is separated into its constituents by high efficiency vacuum fractionation as indicated below.

FIGURE 8: Separation of crude sulphonated turpentine



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For most purposes alpha and beta pinene are desulphurised before further processing. Desulphurisation techniques involve fractionation, absorption, hypochlorite treatment, treatment with metals, or a combination of technique. A number of patents exist for these techniques.^{39, 40, 41 42}

The chemical use of alpha and beta pinene is intertwined. An equilibrium between the two with retention of optical activity can be obtained over a supported palladium catalyst and lies heavily in favour of the alpha isomer (alpha: beta = 95:5)^{43, 44} Beta pinene undergoes many of the same reactions as alpha pinene, for example hydration to pine oil, hydrogenation to pinane etc. Beta pinene often reacts under milder conditions being the higher energy isomer, and sometimes gives different product ratios and yields.

3.7.1 Routes from Alpha Pinene

Geraniol, nerol and linalool can be produced from alpha pinene. Alpha pinene is selectively hydrogenated to pinane (97% selectivity) in the presence of partially poisoned nickel catalyst⁴⁵. Beta pinene or a mixture of the two can also be used. Cis pinane is then oxidised to pinane hydroperoxide, followed by the reduction of the hydroperoxide to produce 2-pinanol and the pyrolysis of 2-pinanol to linalool.⁴⁶ Linalool is isomerised to geraniol/nerol by use of a vanadium catalyst.^{47, 48} Geraniol/nerol are geometrical isomers, which can be separated by high efficiency fractionation into high purity individual isomers. By far the largest volumes of the synthetic products are sold and used as the isomeric mixture. The mixture is commonly known as geraniol (being the predominant isomer at 60%). Manufacturer's specifications will give the isomer ratio by gas chromatography.

Geraniol/nerol can be converted to citronellol by hydrogenation over a copper chromite catalyst.⁴⁹ In the absence of hydrogen and under reduced pressures, citronellal can be obtained by rearrangement.⁵⁰

³⁹ Can. Patent 973,206 (Aug 14, 1975) to Anglo Paper Products

⁴⁰ U.S patent 3,359,342 (Dec 19 1967) to The Glidden Company

⁴¹ US patent 3,420,910 (Jan 7 1969) to SCM Corp.

⁴² US Patent 3,660 512 (1972) to Glidden Company: Process for removing sulphate from Crude Sulphate Turpentine or distilled fraction thereof.

⁴³ US Patent 3,278,623 (Oct 11, 1966) to Glidden Company.

⁴⁴ Isomerisation of Pure Hydrocarbons ACS Monograph No. 88, American Chemical Society, 1942.

⁴⁵ US Patent 4,018,842 (April 19, 1977), to SCM Gildco

⁴⁶ Tetrahedron, 18, 37 (1962)

⁴⁷ US Patent 3,925,485 (Dec 9, 1975) to Rhone Poulenc; US Patent 4,006,193 (Feb 1 1977) to Kuraray Co. Ltd.

⁴⁸ US Patent 4,254,291 (Mar 3 1981) to SCM Corp

⁴⁹ US Patent 3,346,650 (Pct 10, 1967) to The Glidden Company.

⁵⁰ USSR Patent 118,498 (Mar 10 1959)

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Geraniol/nerol is converted to citral by oxidation with activated nickel oxide as the oxidant. The active oxide is produced by reaction of nickel salts with aqueous sodium hypochlorite.⁵¹

The most common route to produce terpineol is *via* terpin hydrate produced from alpha and beta pinene by reaction in dilute sulphuric acid.⁵² The advantage of the two-step method of first manufacturing terpin hydrate and then converting it into terpineol, lies in the fact that terpin hydrate is easily purified, thus making the purification of the terpineol more efficient. Terpineol can however be produced directly from alpha and beta pinene *via* the acid catalysed hydration of pinene followed by distillation.⁵³ The elimination of water from terpin hydrate with hot dilute acid gives terpineol.^{54, 55, 56} The synthesis of terpinyl acetate proceeds by reacting terpineol with acetic anhydride in the presence of an acid catalyst.^{57, 58}

3.7.2 Routes from Beta Pinene

One of the chief uses for beta pinene has been as a starting material for the production of geraniol, nerol and linalool. The first step in this process is the thermal rearrangement of beta pinene to myrcene at 500 – 600°C,⁵⁹ which is then hydrochlorinated in the presence of a cuprous chloride catalyst to obtain a mixture of geranyl, neryl and linalyl chloride. These chlorides are converted to the alcohols *via* their acetate esters.⁶⁰ Saponification of the acetates then produces the geraniol/nerol alcohols, which can be separated by efficient fractionation.

⁵¹ US Patent 4,005,031 (Oct 25 1977) to Hoffman La Roche

⁵² Organic Chemistry: pg 316, (1956); Longmans, Green & Co., New York

⁵³ USA Patent 2,060,597 (Nov 10 1936) Terpineol from Pinene

⁵⁴ Manufacturing Chemist, pg 350 – 352 (1955)

⁵⁵ Manufacturing Chemist pg 22, 52, 153 (1951)

⁵⁶ Chemica Stosowana, 2A, page 171, (1966)

⁵⁷ Bollettino Chimico Farmaceutico, Vol 101, 519 – 526, (1962) French

⁵⁸ Compt. Rend. 246, 2793 – 2795 (1958))

⁵⁹ US Patent 2,420,131 (May 6 1947)

⁶⁰ US Patent 3,031,442 (April 24, 1962) to Glidden Corp.

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3.8 Environmental Issues

The sulphide components of crude sulphate turpentine can be burnt or collected as a mixed source of mercaptans. The most common means of solving the environmental problem associated with these sulphides is *via* treatment of the crude turpentine with sodium hypochlorite solution prior to distillation.^{5,8}

3.9 Technical Options

In 1987 AECI conducted research into the manufacture of terpineol, dipentene, terpinolene, and terpinyl acetate from crude sulphonated turpentine.⁶¹ At the time of the investigation, approximately 2,000 tons Kraft Black Liquor was available from the Kraft pulping process in the paper industry. The conclusion was that terpineol, terpinyl acetate, and other terpenoids from crude sulphonated turpentine could be produced successfully in the laboratory. A crude process flowsheet and economic evaluation were presented in the report. The process investigated was *via* the distilled alpha/beta pinene. This was reacted to form terpin hydrate, and subsequently terpineol and terpinyl acetate.

In the early 1990's, AECI investigated the production of linalool and geraniol *via* the hydrogenation of the pinene isomers to form pinane, which was then oxidised to form pinane hydroperoxide. The hydroperoxide is subsequently reduced to produce a mixture of the pinalols, which on pyrolysis yields linalool. Linalool is isomerised to geraniol/nerol. This work was done at laboratory scale, up to 1 litre.

Hence, although some research and development work has been done on the terpene aroma chemicals under consideration, this was at a very preliminary level (laboratory) scale, and a technology package would have to be developed before the process could be commercialised.

⁶¹ AERD 1304/C: DGP De Vincentiis and MJ Mitchell. AECI Research and Development Department

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3.10 Feasibility of the Production of Terpene Aroma Chemicals

3.10.1 Affordable Capital

An evaluation model to assess the viability of the production of terpene aroma chemicals from the quantity of crude sulphonated turpentine available in South Africa has been created. The model makes some assumptions regarding yields and recovery, but in so far as is possible takes into account known processes.

The basic objective of this model is to determine the affordable capital for the business. Comparison with an order of magnitude capital estimate will give an indication as to the viability of the project. At this stage of technology definition, it is not possible to give any more than an order of magnitude estimate of the capital required.

The products selected for inclusion in the analysis have been based upon the results of the screening exercise above in section 3.6. This selection also takes into account those products for which some technical work has been performed in South Africa, for which a local market exists, and those with the potential for the highest value addition. The selection of the products also considers the possibility of creating a basket of products whilst at the same time attempting to minimise the amount of process steps needed, thereby reducing capital expenditure.

The value chain selected is illustrated diagrammatically in Appendix 7. Current prices for these products have been illustrated in the diagram.⁶² Based on this value chain two business cases can be identified.

1) Export Market

The production of linalool being maximised. Geraniol/nerol sells for the same price after one additional process step. Linalool also has a much higher selling price/kg than the pine oil and terpineol value chain.

2) Local Market

Production of pine oil, terpineol and terpineol acetate sufficient to satisfy the local market according to import statistics. Remaining crude sulphonated turpentine is converted into linalool.

Both of these business cases have a number of sub-cases depending on the amount of crude sulphonated turpentine available as feedstock. The sustainable level of crude sulphonated turpentine has been determined to be 180 – 420 tons per annum.

⁶² Personal communication C. Teubes (Pty) Ltd

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TABLE 15: Crude Sulphonated Turpentine Value Chain – Determination of Maximum Contribution Margin

| Feedstock Availability (tons) | Export Market | | Local Market | |
|---|---------------|-----|--------------|------|
| | 420 | 180 | 420 | 180 |
| Turnover (R millions) | 7.1 | 3.1 | 5.8 | 1.4 |
| Crude sulphonated turpentine Variable Cost | 3.8 | 1.6 | 3.8 | 1.6 |
| Margin after Crude sulphonated turpentine Variable Cost | 47% | 47% | 31% | -18% |

Clearly, the business will not survive if dependent on the local market only, particularly if the feedstock availability drops to only 180 tons. A terpene aroma chemical business based on the amount of crude sulphonated turpentine available in South Africa, **must** export as much linalool or other higher value added products as possible. The amount of linalool theoretically possible is in the range of only 46 - 153 tons.

3.10.2 Single Year Costing Model

The affordable capital can be determined based on a single year costing analysis. The single year costing essentially uses a year's trading accounts for the business that will result from the proposed investment, once it is at full output. The evaluation is done in constant money, with prices and costs on a consistent basis. Trading cash flow must fund sustenance capital expenditure and working capital increases, pay tax, reward the capital and working capital invested in the business. For a given set of assumptions about the fiscal environment, product construction duration, production phase up and project life, there is a fixed relationship between required reward, as a percentage of capital cost (including working capital) and the project IRR.

The single year costing method can therefore be used to estimate quickly the expected IRR if an estimate of capital is available, or conversely to estimate the affordable capital cost given a target IRR. A 20% return on investment was used in this determination, relating to a conservative real IRR in the order of 8%.

The results of this analysis are depicted below for the business case where exports of higher value added product such as linalool is maximised. Contribution margins of 35 – 45% were assumed. Insufficient process chemistry is available for a more accurate determination of the actual gross margins for the business.

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Table 16: Affordable Capital for the Terpene Aroma Facility (Rands Millions)

| Gross Margin | Feedstock Availability (Tons) | |
|--------------|-------------------------------|-----|
| | 420 | 180 |
| 35% | 7.5 | 3.2 |
| 45% | 9.7 | 4.2 |

The affordable capital is thus in the range of R 3.2 – 9.7 million. This capital assumes that the turnover of the business is maximised. Hence, as much of the higher-value products such as linalool, geraniol, citral etc. must be produced. The plant will however be capable of producing other products for which a local market exists, such as pine oil, terpineol, terpeniol acetate, although coupled with a loss in value.

3.10.3 Capital Cost

The capital costs estimate for a 420 tpa crude sulphonated turpentine plants was performed. At this stage of technology definition, it is not possible to give any more than an order of magnitude estimate of the capital required. It should be emphasised that this estimate is based on the level of information available. There is very little technical data to define and size process equipment properly. The capital cost estimate is hence an order of magnitude costing. A more accurate costing would depend on more detailed process chemistry information being available. The capital estimate has therefore been based on the consultant's interpretation of the chemistry outlined in the literature and patents.

The estimate nevertheless provides a ballpark Inner Battery Limits plus Outer Battery Limits cost. No infrastructure has been costed. The capital estimates were based on the cost of the individual main plant items, to which an installation factor was applied in order to arrive at a total installed cost. Engineering and contingency costs were allowed for. Based on discussions with the CSIR, the capital estimate allows for only one oxidation reactor, such the CSIR's SAFOX™ reactor, and one Continuous Stirred Tank Reactor with reactor stills. It has been assumed that there is no requirement for crystallisation type process equipment. Based on the assumptions outlined above, the capital estimate is therefore in the order of R 11.57 million for a 420 tons plant. A summary of the capital estimate is provided below in Table 17.

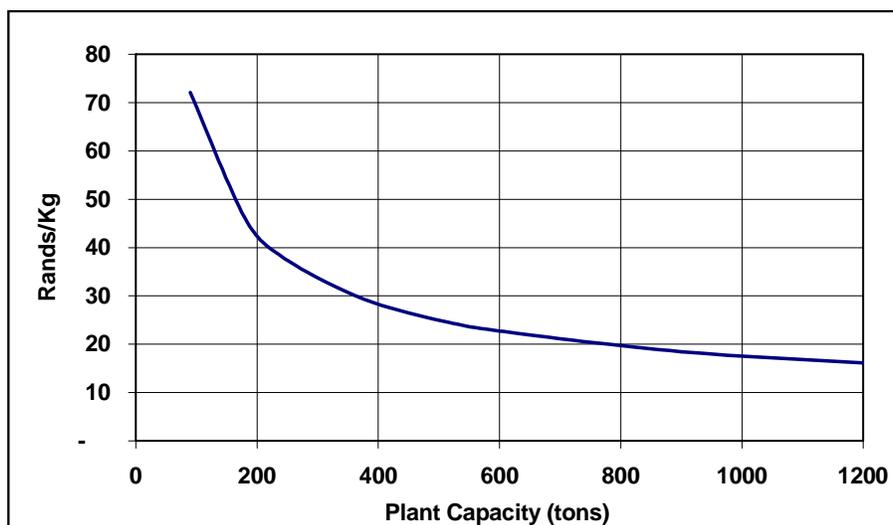
PART 2 – AROMA CHEMICALS DERIVED FROM EFFLUENT FROM THE PAPER AND PULP INDUSTRY

TABLE 17: Capital Estimate for 420 ton Crude Sulphonated Turpentine plant

| R millions | 420 Tons |
|---|------------------|
| Reactors | 3.46 |
| Distillation | 1.17 |
| Heat Exchangers | 0.25 |
| Miscellaneous (Pumps, filters, tanks, air compression etc.) | 2.11 |
| TOTAL EQUIPMENT | 6.99 |
| Ancillary | 1.40 |
| Contingency | 0.87 |
| TOTAL ERECTED PLANT | 9.26 |
| Engineering | 2.31 |
| TOTAL INSTALLED PLANT | 11.57 |
| Affordable Capital (TABLE 11) | 7.5 – 9.7 |

Figure 9 shows the economy of scale for the terpene aroma chemical plant. The economy of scale of a production plant indicates how the capital investment per unit of production relates to the plant capacity and shows at what capacity the effectiveness of capital invested would reach a minimum. The chart shows that the capital cost per unit capacity plateaus to round about R 20/kg pAA at about 800 tpa. No substantial further capital cost benefit will be derived for a plant exceeding this capacity. Conversely, any plant built that has a smaller capacity will not benefit from the economy of scale and might not yield investment economics.

FIGURE 9: Economy of Scale – Terpene Aroma Chemical Plant



PART 2 – AROMA CHEMICALS DERIVED FROM EFFLUENT FROM THE PAPER AND PULP INDUSTRY

3.10.4 Conclusion

At 420 tons per annum, the affordable capital of R 7.5 – 9.7 million must be compared to the estimate of R 11.6 million. However, there is no guarantee that the annual supply of crude sulphonated turpentine at this level is sustainable. If the quantity of feedstock in South Africa is not maintained at the 420 tons per annum level, a business will not be able to afford the capital investment required. Given the fact that the feedstock supply at this point in time can only be guaranteed at the 180 tpa level, the risk in making this investment is considered too high.

However, should Sappi decide to keep both digesters committed to softwood, a minimum amount of 360 tons crude sulphonated turpentine feedstock would be guaranteed annually. An investment in a plant to process 420 tpa crude sulphonated turpentine then becomes potentially viable. However, more detailed process chemistry, requiring some technical development work will be required in order to generate to allow a more accurate techno-economic model upon which an investment decision can be made.

PART 2 – AROMA CHEMICALS DERIVED FROM EFFLUENT FROM THE PAPER AND PULP INDUSTRY

3.11 Socio-Economic Assessment

3.11.1 Potential Direct Jobs Created

The amount of crude sulphonated turpentine available in South Africa for conversion into terpene aroma chemicals has been determined to be in the range of 180 – 420 tons per annum. Based on this, together with the assumption that sales of the higher value products such as linalool are maximised, the business was defined as having a potential turnover of R 3.1 – 7.1 million. This business is therefore very small in the international context and is more suited to a SME-type business. Due to the small size of the business, a manning structure for the proposed plant has not been developed. A factor approach to the assessment of the potential for job creation was therefore used.

The South African Computable General Equilibrium model has data on the different labour intensities for various sectors of the South African economy. The model lists the consolidated chemical sectoral labour/output coefficient in 2000 as 1.99 workers per million Rands of expanded output.^{63, 64} The Computable General Equilibrium table is attached as Appendix 8.

The calculation of direct jobs created is based on the maximum business size, as the smaller business will probably not have sufficient critical mass to be economic as a stand-alone business. The potential number of direct jobs created would therefore be in the order of 14.

This number of direct jobs can be compared to the number calculated using a table published recently by Chemicals SA.⁶⁵ This table contained capital: labour ratios for the chemical industry. The 2002 ratio (in constant 1995 money) was R 540,000 of capital per job created. Using this factor together with maximum affordable capital of R 9.7 million, the total number of direct jobs created is 9.

⁶³ Policies to create Growth and Employment in South Africa: Jeffrey D Lewis, The World Bank Southern African Department, July 2001

⁶⁴ South African CGE Model

⁶⁵ Chemicals SA 2003: South Africa's Petrochemical Industry – Globalisation, Restructuring, and Government Policies.

PART 2 – AROMA CHEMICALS DERIVED FROM EFFLUENT FROM THE PAPER AND PULP INDUSTRY

3.12 Conclusion

The assessment of the terpene aroma chemical size has concluded that the size of this business in the international context will be very small, with a maximum potential turnover in the region of R 7 million. This size of business is therefore suited to a SME-type business. An order of magnitude capital estimate of R 11.6 million has been determined for a 420 tpa crude sulphonated turpentine plant based on export of the plant's full output. This can be compared with the estimated affordable capital in the range of R 7.5 – 9.7 million.

There is however no guarantee that the annual supply of crude sulphonated turpentine at this level is sustainable. The feedstock supply at this point in time can only be guaranteed at the 180 tpa level i.e. one Sappi digester.

The assessment of a terpene aroma chemical business based crude sulphonated turpentine feedstock available from the paper and pulp industry in South Africa has thus concluded that if a minimum supply of 360 – 420 tons crude sulphonated turpentine annually can be guaranteed, an investment case is potentially feasible. If a lesser amount of crude sulphonated turpentine is available annually, from 180 to 360 tons, there may be a potentially viable case for using existing facilities. However, due to the early stage of definition of the processes involved in the production of the terpene aroma chemicals, before a final investment decision can be made, a more accurate techno-economic model would have to be developed.

PART 2 – AROMA CHEMICALS DERIVED FROM EFFLUENT FROM THE PAPER AND PULP INDUSTRY

3.13 Recommendations

Strategic Intervention: To motivate a detailed feasibility study to establish a viable SME terpene aroma chemicals manufacturing business based on processing a guaranteed minimum supply of crude sulphonated turpentine and a defined technology.

Specific strategic recommendations

1. Hold discussions with potential crude sulphonated turpentine suppliers to ascertain the potential of a guaranteed supply of crude sulphonated turpentine.
2. Initiate technology development to generate more detailed process chemistry and establish process performance and technical data in order to develop a more accurate techno-economic model.

PART 2 – AROMA CHEMICALS DERIVED FROM EFFLUENT FROM THE PAPER AND PULP INDUSTRY

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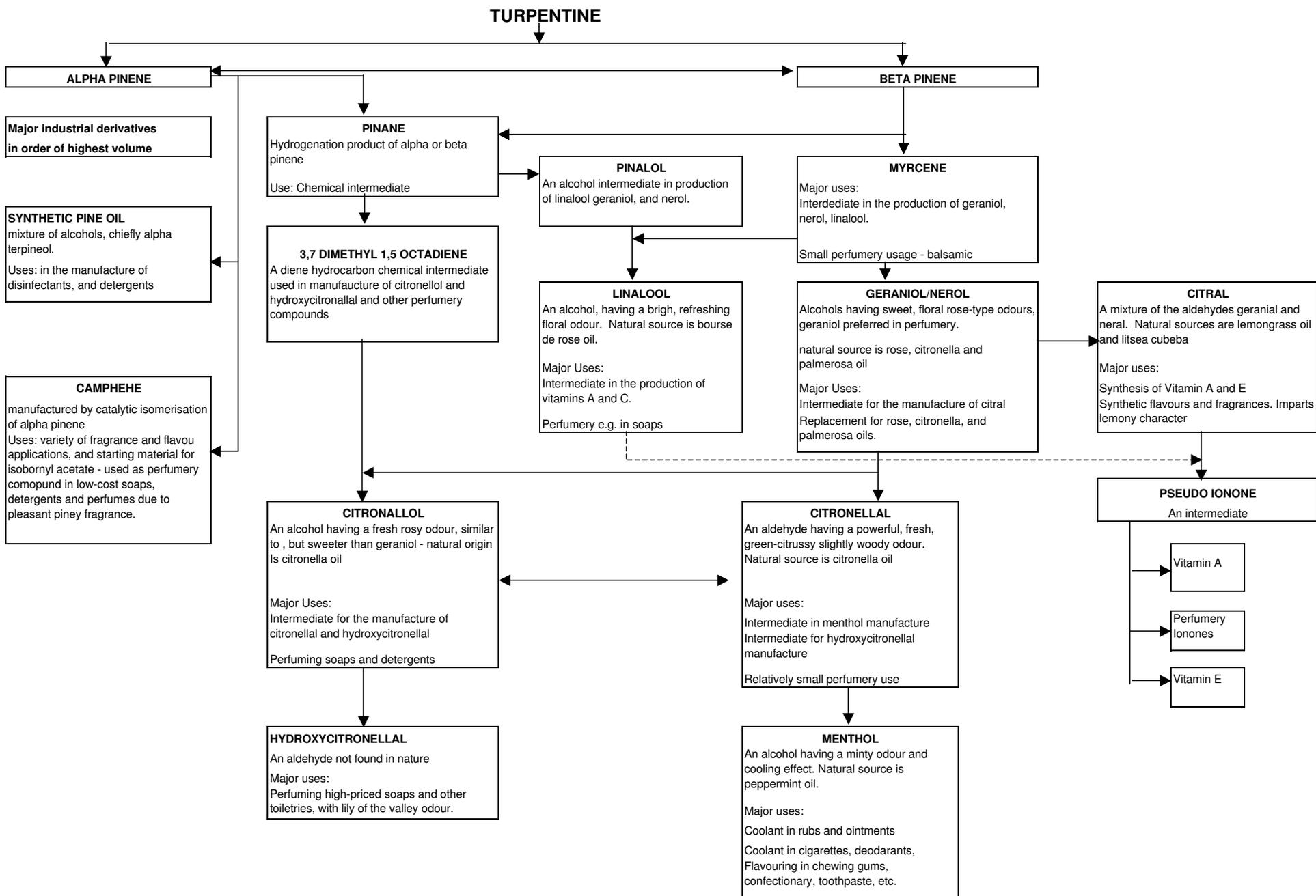
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APPENDIX 1 Turpentine Aroma Chemicals



APPENDIX 2

USES OF TERPIN HYDRATE, TERPINEOL, TERPINYL ACETATE, DIPENTENE, AND TERPINOLENE

TERPIN HYDRATE

Fixing Essential Oils

Improving the durability of paper, cardboard and cartons.

Pharmaceuticals due to its disinfectant qualities

Expectorant

TERPINEOL/PINE OIL

Denaturing fats for soap manufacture

Perfumes

Solvent for resins, gums, waxes, and oils

Powerful germicide

Frothing agent for reclaiming low-grade copper, lead and zinc bearing ores

Wetting agent in the manufacture of a variety of textiles and synthetic fibres

Disinfectant in cleaning and scouring soaps.

Ingredient in many liquid soaps, preservatives, insecticides, deodorants, polishes, sweeping oils.

TERPINYL ACETATE

Perfumes

Flavouring agent in foods

Scenting of soaps

Modifier in perfume compounds of the lavender and Eau de Cologne type.

Substitute for oils of lavender, spike-lavender and even bergamot orange, used in the soap manufacturing industry

DIPENTENE

Solvent for oleoresinous products, rosin, ester gum, alkyd resins and waxes

Scenting of cosmetics and soaps, as well as flavouring of pharmaceuticals

Rubber compounding and reclaiming of rubber

Dispersing agent for oils, resins, resin-oil combinations, pigments and driers

Paints, enamels, lacquers and varnishes

Substitute for turpentine and petroleum solvents in floor waxes and furniture polishes

Manufacture of synthetic resins and polyterpenes

TERPINOLENE

Scenting of all kinds of technical preparations

Low cost perfumes for household products, e.g. air fresheners, cleaners, disinfectants and polishes, as well as in industrial deodorants

APPENDIX 3

In a budget vote address in May 2002, by the Minister of Water Affairs and Forestry, Mr Ronnie Kasrils, stated the following:

This Government knows that job creation is one of the greatest challenges we face, that we are going to be measured by our achievements in this field. And there are encouraging developments in the forest sector. A small KwaZulu-Natal company, which collected the sap from pine trees, which is processed to make speciality chemicals ran into financial trouble. When my Director of Commercial Forestry, Winston Smit learnt of this, he encouraged another company to get into the business. The firm, Associated Carriers recently wrote to us to say:

“At the time Pinechem ceased to trade, 250 people were employed in the industry and were harvesting an average of 110 000 kgs of resin each month. We now employ 575 people and harvest 550 000 kgs per month. We are continuing to expand and hope to have a resin-processing factory by January next year. This plant will create another 28 positions. We feel you should be aware that your input into this industry has directly created 315 jobs with a potential for a further 350.”



Industrial Oleochemical Products

Product Data Sheet

Gum turpentine

CASR No: 90080-7
EINECS: 232688-5



pine forest [pinus elliottii]

Typical physical properties:

| | |
|------------------------------|------------|
| Specific gravity, [25/25°C]: | 0.9 |
| Viscosity, 25°C, [mPa.s]: | 2 |
| Flash point, [°C]: | 32 |
| Colour, [Gardner scale]: | 0 |

| | |
|-------------------------|----------|
| HEALTH | 2 |
| FLAMMABILITY | 3 |
| REACTIVITY | 0 |
| NFPA ratings (H) | |

| | |
|------------------------|-----------|
| Document ref: PDS A.1- | 64 |
| Revision: | 01 |
| Date: | July 2000 |

Industrial Oleochemical Products
323 Chamberlain Road, Jacobs,
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Fax: +27-31-461-3743
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Website: www.oleo.co.za



Specifications:

British Pharmacopoeia, 1998:

Appearance:
Colour:
Moisture, [%]:
Refractive index, 20°C:
Weight per mL:
Residue on evaporation, [%]:
Solubility in 90% ethanol, 20°C:
Solubility in 96% ethanol, 20°C:

clear & bright
colourless
visibly free
1.467-1.477
0.855-0.868
0.5 max.
1 : 7 *
1 : 3 **

* 1 part turpentine in 7 parts ethanol
** 1 part turpentine in 3 parts ethanol

Typical composition:

| | |
|-------------------------|------------|
| alpha-pinene, [%]: | 56 |
| beta-pinene, [%]: | 38 |
| camphene, [%]: | 1 |
| delta-3-carene, [%]: | 0.3 |
| myrcene, [%]: | 1 |
| limonene, [%]: | 1 |
| beta-phellandrene, [%]: | 3 |

APPENDIX 4
Selection of Attractive Options

Product Screening Questionnaire

For Evaluation of Single Products or Product Clusters as required.

The questionnaire is designed to assess two aspects, viz. Market Arena Attractiveness and South Africa's Internal Business Strengths. The Arena Attractiveness is a global issue and Business Strengths are specific and internal to the South African situation. Assess each product at the point at which South Africa would anticipate entering the market.

Market Arena Attractiveness

(A) Market Attractiveness

Size of the global product market :

- Petrochemical
- 100 Market is > \$ 150 million
75 Market is in the range \$ 100 - 150 million
50 Market is in the range \$ 50 - 100 million
25 Market is in the range \$ 10 - 50 million
0 Market is < \$ 10 million

Gross margin for the business (GM = Sales-VC-FC) :

- 100 Gross margin is > 40%. (high)
50 Gross margin is in the range 20 – 40%. (medium)
0 Gross margin is < 20%. (low)

Market growth of the product :

- 100 Growth is High
50 Growth is in the range Medium
0 Growth is Low

Number of potential customers for the product :

- 100 Number of customers is > 8.
50 Number of customers is in the range 4 – 8.
0 Number of customers is in the range 1 – 4.

Period from time to market before the product comes under threat (either product

lifecycle or major competitor e.g. Chinese):

- 100 No threat to product
75 Product only under threat in the long term > 10 years
50 Product under threat in the medium term 5 - 10 years
25 Product under threat in the short-term (0 - 5 years)
0 Product already under threat

The pricing trends for the product over the next 5 years :

- 100 The price is staying constant in real terms.
50 The price is declining in real terms by 0 - 2% p.a.
0 The price is declining in real terms by > 2% p.a.

Are there any barriers to entry e.g. high demand for capital, an inaccessible/difficult technology, a key raw material, and or a regulated market, potential for further differentiation of product.

APPENDIX 4 Selection of Attractive Options

- 100 3 or more of the above barriers to entry.
- 75 2 of the above barriers to entry.
- 50 1 barrier from the list above.
- 0 None of the above barriers exist.

SA's Internal Strengths

(B) Technological Synergy

- Technology Status:**
 - 100 Technology Fully Developed
 - 50 Technology Partially Completed
 - 0 No technology developed as yet
- Integration Benefit**
 - 100 Benefit from integration into Aromas Cluster
 - 0 No benefit from integration
- SA Skills readily available :**
 - 100 Personnel/resources experience base is common and readily available.
 - 50 Skills exist, but will need substantial upgrading.
 - 0 Personnel and resources expertise is not available.

(C) Marketing Synergies

- The marketing synergy with other customer groups and application areas :**
 - 100 Overlapping customer group and existing application area.
 - 0 No overlapping customer group
- South African market**
 - 100 South africa market exists
 - 0 No South African market

(D) Production Advantages

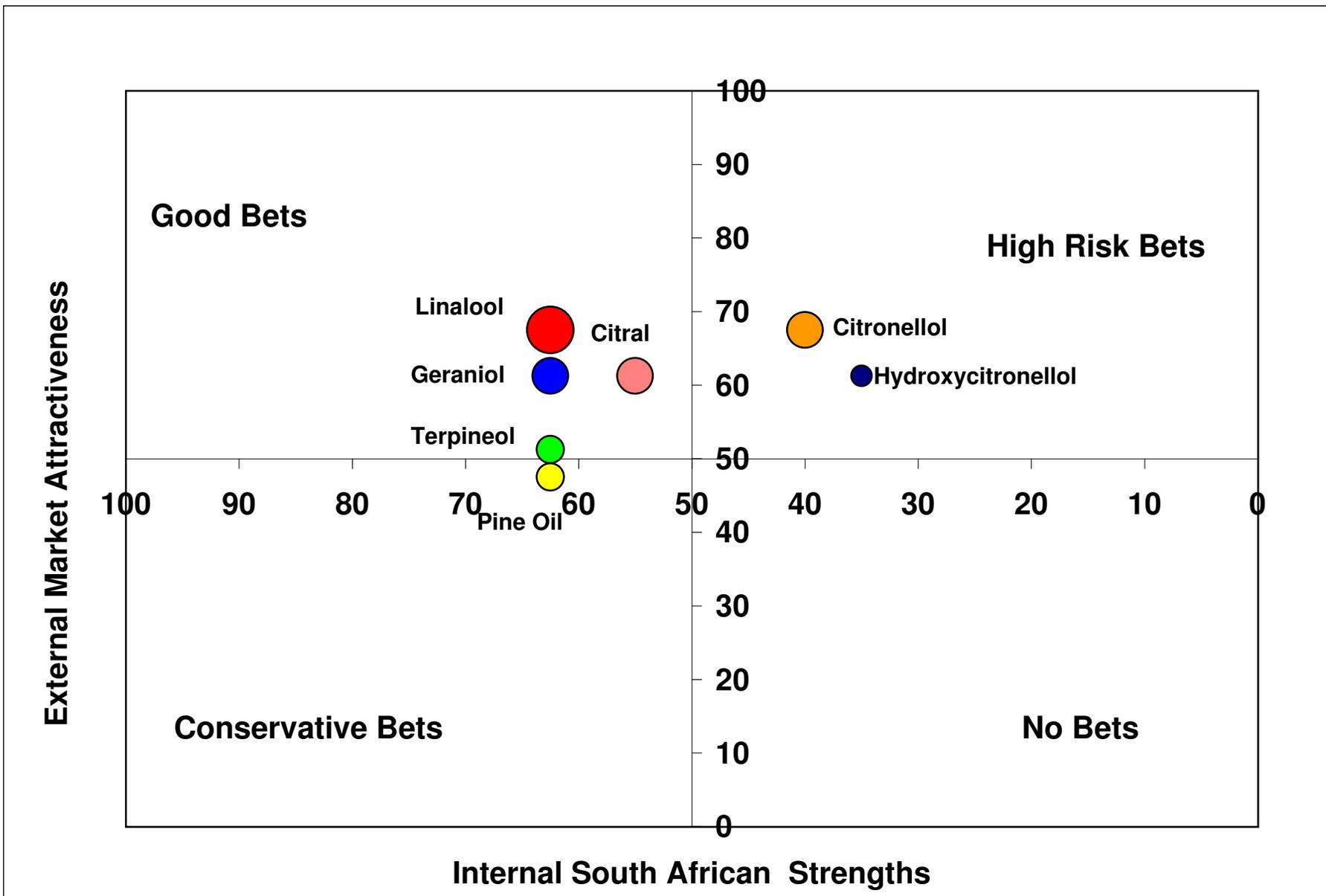
- Sustainable and specific SA cost of production advantage: e.g. local raw materials and utilities, an established or potential site, a regional advantage and/or access to globally competitive technology :**
 - 100 2 or more of the above sustainable competitive advantages.
 - 50 1 of the above sustainable competitive advantages.
 - 0 None of the above advantages.
- Production processes :**
 - 100 Process better than International Benchmark
 - 50 Process equal to International Benchmark
 - 0 No competitive advantage or advantage not quantified

APPENDIX 5
Selection of Attractive Options: Results

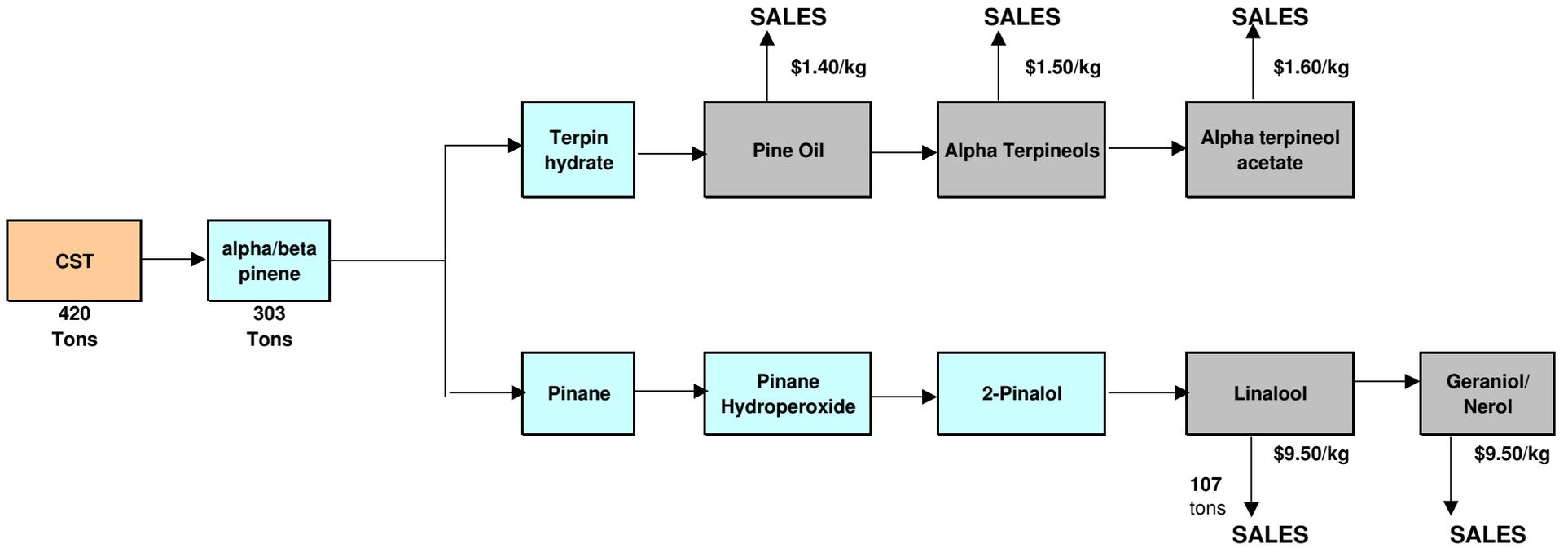
| Arena Attractiveness | Weight | Linalool | | Citral | | Geraniol | | Terpineol | | Pine Oil | | Citronellol | | Hydroxycitronellol | |
|--|------------|----------|----------------|--------|----------------|----------|----------------|-----------|----------------|----------|----------------|-------------|----------------|--------------------|----------------|
| | | Score | Weighted Score | Score | Weighted Score | Score | Weighted Score | Score | Weighted Score | Score | Weighted Score | Score | Weighted Score | Score | Weighted Score |
| (A) Market Attractiveness | 100 | | 68 | | 61 | | 61 | | 51 | | 48 | | 68 | | 61 |
| <input type="checkbox"/> Size of the global product market : | 25 | 50 | 13 | 25 | 6 | 25 | 6 | 25 | 6 | 25 | 25 | 50 | 13 | 25 | 6 |
| <input type="checkbox"/> Gross margin for the business : | 20 | 50 | 10 | 50 | 10 | 50 | 10 | 0 | 0 | 0 | 0 | 50 | 10 | 50 | 10 |
| <input type="checkbox"/> Market growth of the application area in which the product is used : | 10 | 50 | 5 | 50 | 5 | 50 | 5 | 50 | 5 | 25 | 3 | 50 | 5 | 50 | 5 |
| <input type="checkbox"/> Number of potential customers for the product : | 5 | 100 | 5 | 100 | 5 | 100 | 5 | 100 | 5 | 100 | 0 | 100 | 5 | 100 | 5 |
| <input type="checkbox"/> Period from time to market before the product comes under threat : | 10 | 100 | 10 | 100 | 10 | 100 | 10 | 100 | 10 | 100 | 10 | 100 | 10 | 100 | 10 |
| <input type="checkbox"/> The pricing trends for the product over the next 5 years : | 10 | 50 | 5 | 50 | 5 | 50 | 5 | 50 | 5 | 0 | 0 | 50 | 5 | 50 | 5 |
| <input type="checkbox"/> Barriers to entry defined by a high demand for capital, an inaccessible/difficult technology, a key raw material, and or a regulated market : | 20 | 100 | 20 | 100 | 20 | 100 | 20 | 100 | 20 | 50 | 10 | 100 | 20 | 100 | 20 |

| Business Strengths | Weight | Linalool | | Citral | | Geraniol | | Terpineol | | Pine Oil | | Citronellol | | Hydroxycitronellol | |
|---|------------|----------|----------------|--------|----------------|----------|----------------|-----------|----------------|----------|----------------|-------------|----------------|--------------------|----------------|
| | | Score | Weighted Score | Score | Weighted Score | Score | Weighted Score | Score | Weighted Score | Score | Weighted Score | Score | Weighted Score | Score | Weighted Score |
| (B) Technology Synergies | 20 | | 13 | | 5 | | 13 | | 13 | | 13 | | 0 | | 5 |
| Technology Status | 15 | 50 | 8 | 0 | 0 | 50 | 8 | 50 | 8 | 50 | 8 | 0 | 0 | 0 | 0 |
| Skills | 5 | 100 | 5 | 100 | 5 | 100 | 5 | 100 | 5 | 100 | 5 | 100 | 0 | 100 | 5 |
| (C) Marketing Synergies | 20 | | 20 | | 20 | | 20 | | 20 | | 20 | | 10 | | 0 |
| <input type="checkbox"/> The marketing synergy with existing customer groups and application areas : | 10 | 100 | 10 | 100 | 10 | 100 | 10 | 100 | 10 | 100 | 10 | 100 | 10 | 0 | 0 |
| <input type="checkbox"/> South African market exists | 10 | 100 | 10 | 100 | 10 | 100 | 10 | 100 | 10 | 100 | 10 | 0 | 0 | 0 | 0 |
| (D) Production Advantages | 60 | | 30 | | 30 | | 30 | | 30 | | 30 | | 30 | | 30 |
| <input type="checkbox"/> local competitively prices raw materials and utilities, established site, access to effluent disposal, and/or a regional advantage : | 30 | 100 | 30 | 100 | 30 | 100 | 30 | 100 | 30 | 100 | 30 | 100 | 30 | 100 | 30 |
| <input type="checkbox"/> Production Process Internationally Competitive | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| - Business Strengths | 100 | | 62.5 | | 55 | | 63 | | 63 | | 63 | | 40 | | 35 |

APPENDIX 6
Selection of Attractive Options



APPENDIX 7
Potential South African Terpene Aroma Chemical Facility



APPENDIX 8

Direct and Indirect Labour Coefficients (Workers per R million output) 2000

| Sector | Direct Coefficient | Total Coefficient | Multiplier (Total/Direct) |
|---|--------------------|-------------------|---------------------------|
| Agriculture, forestry, and fishing | 18.42 | 23.63 | 1.28 |
| Mining and Quarrying | 7.71 | 12.26 | 1.59 |
| Food Processing | 2.00 | 14.22 | 7.13 |
| Textiles and apparel | 12.07 | 22.26 | 7.84 |
| Leather Goods and Footwear | 7.79 | 15.58 | 2.00 |
| Wood and Furniture | 8.52 | 17.11 | 2.01 |
| Paper and Printing | 3.30 | 10.22 | 3.10 |
| Petroleum products | 0.72 | 10.40 | 14.39 |
| Chemicals | 1.99 | 7.20 | 3.62 |
| Rubber, Glass, plastic | 2.49 | 9.29 | 3.73 |
| Basic Metals | 2.14 | 7.18 | 3.36 |
| Electricity and, gas and water | 2.87 | 11.56 | 2.49 |
| Construction | 8.84 | 6.48 | 2.26 |
| Machinery and Equipment | 4.64 | 17.40 | 1.97 |
| Trade | 6.85 | 10.97 | 1.60 |
| Tourism | 12.66 | 20.03 | 1.58 |
| Transport and Storage | 4.57 | 9.02 | 1.97 |
| Financial & business service | 4.28 | 7.71 | 1.80 |
| Medical and health service | 2.71 | 7.74 | 2.86 |
| Social and personal services | 47.55 | 51.46 | 1.08 |
| General gov. and Other products | 17.50 | 17.67 | 1.01 |
| Total | 7.42 | | |

ANNEXURES

TERMS OF REFERENCE

Aroma Fragrance Fine Chemicals formulations are used globally for imparting attractive taste and aroma to processed foods and beverages and adding pleasing scents to perfumes, toiletries and detergents. The worldwide industry generally earns returns in excess of the chemical industry average. The industry's close association with the health, personal care and food and beverage markets, means that its revenues are relatively stable, largely insensitive to commodity cycles and relatively recession-resistant.

The industry can be segmented, broadly, into three areas, namely: (i) natural and synthetic aroma and flavour fine chemicals production, (ii) compounding of these chemicals into formulations tailored to meet specific customer requirements, and (iii) use of the formulations in the production of personal care and pharmaceutical active ingredients.

Certain large international flavour and fragrance houses exist, which specialize in compounding flavour and fragrance chemicals, and which, for historical and strategic reasons, also produce selected aroma and flavour chemicals for captive use. In addition, some also manufacture personal care active ingredients from captive and purchased aroma chemicals.

Success in the formulation and compounding business is dependent on an ability to offer a basket of products, the creativity of flavourists and perfumers, branding and marketing skills, and an ability to respond quickly to ever-changing trends in consumer preference.

Commencing in the late 1980's, AECI Limited had identified certain aroma and flavour fine chemicals, which it believed could form part of a new fine chemicals business that the company wanted to develop. AECI carried out an intensive research and development programme, over a period of more than ten years, aimed at developing competitive manufacturing technologies for selected aroma and flavour fine chemicals.

During 1998, AECI decided to scale down its wide-ranging in-house research and development programme, and outsourced further work on aroma and flavour fine chemical technology development to the CSIR.

Together with the CSIR, AECI developed an AFFC portfolio with the original intention of becoming a leading global producer of selected products, supplying a basket of strategic aroma chemicals to specific flavour and fragrance houses for formulation and compounding. The AECI portfolio was constructed around the synthesis of petrochemical feedstocks.

During 2001, in line with a wide-ranging business transformation process, AECI took a strategic decision to exit from its fine chemicals development programme, and to offer the know-how and technology, which had been developed, to interested parties. AECI reached agreement with the CSIR during 2003, that AECI would transfer the rights to the

ANNEXURES

range of aroma and flavour fine chemical technologies to the CSIR, in exchange for sharing of the benefits which may arise from licensing or sale of any of the technologies.

The CSIR now owns the technologies in respect of the proposed portfolio of AFFC and the Fund for Research into Industrial Development, Growth and Equity (FRIDGE) proposed a study with the following broad objectives:

- To review the AECI proposed Aroma Fragrance Fine Chemicals portfolio for potential commercial development;
- To include a study on the potential use of effluent from the paper and pulp industry as a raw material for Aroma Fragrance Fine Chemicals products;
- To include a study on the potential synergy between developing synthetic Aroma Fragrance Fine Chemicals production facilities and developing South African natural sources of Aroma Fragrance Fine Chemicals.

The products proposed for commercialization by AECI were selected on the basis that they were large volume aroma and flavour chemicals, serve actively growing end-use markets, had low risk of substitution, and did not require lengthy and costly registration processes for product approval.

The technology developed by AECI, and now owned by CSIR, was aimed at producing the following portfolio:

| | |
|------------------------------|--|
| p-Hydroxybenzaldehyde (pHB) | precursor for PAA, RK, vanillin, ethyl vanillin and 3,4,5-TMB. precursor for pharmaceutical active ingredients |
| p-Anisaldehyde (pAA) | flavour and fragrance ingredient precursor for p-anisyl alcohol. precursor for sunscreen active ingredients precursor for pharmaceutical active ingredients |
| Raspberry ketone | flavour and fragrance ingredient |
| p-Anisyl alcohol | flavour and fragrance ingredient. precursor for pharmaceutical active ingredients |
| l-Menthyl acetate | flavour and fragrance ingredient |
| Vanillin | flavour and fragrance ingredient. precursor for pharmaceutical active ingredients |
| Ethyl vanillin | flavour and fragrance ingredient |
| 3,4,5-Trimethoxybenzaldehyde | precursor for pharmaceutical active ingredients |
| m-Cresol | feedstock for l-menthol, produced as a co-product of PHB production |
| Zingerone | flavour and fragrance ingredient |

ANNEXURES

The above listed products are strongly inter-related in terms of market areas and customers. This synergy offers an investor the opportunity to access markets and customers, which may find a basket of related products from one supplier attractive.

The stated objectives of the study are:

- The study should clearly indicate the following:
 - Labour requirements and number of jobs expected to be created
 - The attractiveness of local manufacture of synthetic aroma, fragrance and flavour chemicals with specific emphasis on the products already identified.
 - The potential and attractiveness of producing specific aroma, fragrance and flavour compounds from indigenous plant material.
- The study should also explore the potential to use effluent from the paper and pulp industry as a raw material for this product stream. In this regard the logistical and location considerations of a manufacturing facility, or facilities, need to be addressed.
- The study should investigate the following aspects of the project:
 - The feasibility of the manufacturing potential products from indigenous plant material and potential markets.
 - The feasibility of supplying potential regional and international markets with synthetic aroma, fragrance and flavour chemicals.
 - Identify potential technology constraints and costs, and research needs and costs.
 - Recommend government interventions that may be required to ensure success of investment projects.
- The study should also analysis present and future economic developments and their implications on the viability of the commercialization of these technologies in an internationally competitive manner. This will include reviewing the capacity, preferred location of a potential business, or businesses, as well as the relevant value chains, and the investment implications of such economic developments to local or international investors.
- The study should recommend the design of an appropriate suite of investment incentives, within the context of the incentives offered by the Government, to improve the attractiveness of an investment in the proposed product portfolio.

ANNEXURES

MILESTONE DECISIONS DURING THE STUDY

As the project progressed the following issues arose that required direction to be given by the Study's Counterpart Group:

- The original scope of the Study (per the Request for Tenders) did not include the study of the potential of the menthol technology package. Presumably this was because AECI had already disposed of the technology prior to referring these matters to FRIDGE. The technology currently resides with Mbuyu Biotech, a joint venture involving CSIR. There is a strong relationship between the product and technologies referenced for the Study and the menthol technology package. It was proposed that the Consultant take the menthol potential into account. This was agreed. (Milestone One)
- The original scope of the Study (per the Request for Tenders) as it related to Aroma Chemicals from the by-products of the paper and pulp industry, appeared to have been confined to the production of the chemicals listed (i.e. vanillin and perhaps ethyl-vanillin). This would be produced from Kraft Black Liquor (KBL). The Consultant proposed that Crude Sulphonate Turpentine (CST) derived from the paper and pulp industry should also be considered as a source for the production of Aroma Chemicals. This was agreed. (Milestone One)
- The original scope of the Study (per the Request for Tenders) did not include the study of the essential oils industry per se (except perhaps in so far as it related to indigenous flora). However, it was identified that essential oils would be the most likely route for the commercial exploitation of indigenous flora and accordingly the Consultant proposed that this important sector be the focus of the investigation into the potential of natural sources of Aroma Chemicals. This approach was agreed. (Milestone One)
- With regards to the Aroma Chemicals derived from petrochemical feed stocks, the Consultant was requested not to focus on specific sources of meta-para-cresol, neither to focus on specific industry partners (investors) but to keep the analysis generic. (Milestone Two).
- With regards to essential oils the Consultant was instructed not to focus too much attention on the agricultural issues surrounding essential oil production. This would be the focus of another study. The Consultant noted that it would not be practical to perform an economic feasibility on a particular essential oil or basket of essential oils as a large component of the feasibility would require consideration of the agricultural costs of production. It was agreed that the Consultant should focus on the broader strategic issues surrounding the development of the essential oils industry and its potential impact on an Aroma Chemicals value chain. (Milestone Three)

ANNEXURES

- With regards to Aroma Chemicals derived from the paper and pulp industry, the Consultant identified that the tapping of pine forest for gum turpentine could also be a source of material for the production of turpentine derived Aroma Chemicals. It was agreed that this was outside the scope of the current project, but that the Consultant should provide whatever information was readily available to it. (Milestone Four).

STAKEHOLDER LIST

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| IDC co-ordinator | Hloni Monyeki | 011-269-3597 |
| CPG Chairperson | Mary Tsatsi | 012 428-7959 / Cell 0824640530 |

| Item | Organisation | Contact name | Contact Details | Comments |
|--|----------------------------------|--------------------------------|-------------------------------|--|
| Petrochemical | | | | |
| 1 | CSIR: Biochemtek | Fanie Marais | 0116052310 | Several meetings |
| 2 | Consultant | Aubrey Parsons | 011 726-2376 Cell 083 300 431 | Initial meeting |
| 3 | AECI | Andre Engelbrecht | 011 806 8885 | |
| 4 | Merisol | Joe Makhoere/Ahmed Karachi | 016 960 3733 | Initial meeting |
| 6 | Chemincubator | Joe Kruger | 041- 503 6700 | Initial meeting |
| 7 | SASOL | Herman Berry | Tel: 011 344 0206 | Initial Meeting and research assistance |
| 8 | Mbuyu Biotech | Paul Abrahams | 011 605 2943 | Held meeting to discuss menthol project |
| Paper and Pulp | | | | |
| 9 | CSIR: Biochemtek | Fanie Marais | 0116052310 | Meetings: documentation and project discussions |
| 10 | CSIR: Biochemtek | Michael Barkhysen | 0116052310 | Initial meeting: vanillin |
| 11 | CSIR: Biochemtek | Shavindra Sukdeo | 011 605 2174 | Initial meeting: vanillin |
| 12 | Clive Teubes | Clive Teubes | 011 792-4451 | Initial meeting; emails |
| 13 | Mondi | Ciska Terblanche | 035 902 2111 | Contact made |
| 14 | Mondi | Tony Scheckle | 031 304 7837 | Meeting held |
| 15 | Sappi Lignotech | Craig Hogan ex AECI Project | 039 9736 008 | Contact made |
| 16 | Paul Statham | Ex AECI Vanillin Project | 011 709 8985 | Contact made |
| 17 | Sappi | Kobus Geldehuys | 013 734 611 | Contact made, amount of CST from Ngodwana |
| 18 | Sappi | Chris Davies | 011 360 0271 | Contact made, Technology Director Sappi |
| 19 | Associated Motor Carriers | Mike Hunter: Forest Operations | 035 580 7950/082 657 5558 | Telephonic discussions |
| 20 | Associated Motor Carriers | Arlenee | 035 787 7017 | Telephonic discussions |
| 21 | Industrial Oleochemical Products | Gillian Lee | 031 461 3740 | Telephonic discussions |
| Indigenous Flora and Essential Oils | | | | |
| 22 | CSIR: Biochemtek | Fanie Marais | 0116052310 | Several meetings |
| 23 | CSIR: Biochemtek | Marthinus Horak | 0128413295 | Currently off ill (Met with Vinesh Maharaj) |
| 24 | CSIR: Biochemtek | Shavindra Sukdeo | 011 605 2174 | Initial meeting |
| 25 | SAEOPA | Karen Swanepoel | 0827858700 Tel 013 753 3064 | Several telephone discussions and meeting in April |
| 26 | SAEOPA | Willie Alberts | 829636142 | Meeting in April |
| 27 | Biosys | Robin Learmonth | 012 841-4025 | Several meetings |
| 28 | ARC | Kobus Coetsee | 021 8085430 | Telephone interview (Now Ex-ARC) |
| 29 | Flavourcraft | Ryan Ponquett | 031 719 0618 | |
| 30 | Symrise | Johan Esterhuizen (Sales)/ Rud | 011 921 5911 | Telephone : Re Local Market |
| 31 | Sharon Bolel | Sharon Bolel | 011 487 1661 | Telephone interview |
| 32 | SAAFFI | Michael Gristwood | Tel/Fax: +27 11 447 2757 | Initial meeting |
| 33 | DEAT | | | Outside of scope |
| 34 | Teubes (Pty) Ltd | Clive Teubes | 011 792-4451 | Several discussions |

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IDC co-ordinator
CPG Chairperson

Hloni Monyeki
Mary Tsatsi

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| Item | Organisation | Contact name | Contact Details | Comments |
|------|--|-------------------------|-----------------------------|---|
| 35 | Cranbrook Flavours | Hennie Jooste | 011 392-6650 | Telephonic interview |
| 36 | Giyani Project - Limpopo Province | Vinesh Maharaj | 012 841-3295 | Initial Meeting/subsequent meetings |
| 37 | Chemin Godisa Incubator | Joe Kruger | 041- 503 6700 | Initial Meeting and several telephone calls |
| 38 | SAAFost | Aubrey Parsons | 011 726-2376 | Initial meeting |
| 39 | Firminech | Bruce Perkins | 011 653 0700 | Telephone call: Re Local Market |
| 40 | IFF | Robert Fletcher | 011-922-8800 | Telephone call: Re Local Market |
| 41 | Proctor and Gamble | Denzel Pillay | 011-700-5000 | Telephone call: Re Local Market |
| 42 | Lever Ponds | Robert Waugh | 031-571-9600 | Telephone call: Re Local Market |
| 43 | Quest International SA | Raj Rama | 011 613-6211 | Meeting re local market |
| 44 | Quest International SA | Tony Scott | 011 406 8700 | Telephone call: Re Local Market |
| 45 | Wesgro | Sector Research Section | 021 418 6464 | Information received |
| 46 | Grassroots Natural Products | Norman Collins | 023 232 0526 | Telephonic interview |
| 47 | Cape Organics Producers Association | Eddie Redelinghuys | 021 872 5962 | |
| 48 | George Oils | Pancho Ndabele | 011 881 8299 | Out of business |
| 49 | Ecocert | Ralph Peckover | 021 545 0409 | Telephonic interview |
| 50 | Producer | Kleinste Van Rensburg | | Visit |
| 51 | Ekuseni Essential oils- Production | Hennie Duplessis | 031-712 2656 | Visit |
| 52 | Ntala - Producer | Hanneke Hibbert | 013 753 3839 | Visit |
| 53 | Ekuseni Essential oils- Marketing | Jean duplessis | 082 461 7385 | Telephonic interview |
| 54 | Producer | Ian Macdonald | 832284535 | Telephonic interview |
| 55 | Producer | Jarrett Peck | 332129045 | Telephonic interview |
| 56 | Producer | Prof Earle Graven | 836330149 | Telephonic interview |
| 57 | Producer | Chris Rumble | 832287695 | Telephonic interview |
| 58 | Bio Africa | Steph | 082 534 4807 | Telephonic interview |
| 59 | Institute of Natural Resources | Myles Mander | 033 346 0796 | Telephonic interview |
| 60 | TRAFFIC (ES Africa) | David Newton | 011 486 1102 | Telephonic interview |
| 61 | Claman | Ronelle Roberts | 011 591 2640 | Telephonic interview |
| 62 | Cape Fynbos Essential oils | Salome van Eerden | 028 314 1614 | Telephonic interview |
| 63 | Natchem Aromatech | Jean Serra | 011 452 1760 | Telephonic interview |
| 64 | University of Potchefstroom | Prof Breedt | 018 482 1241 | Telephonic interview |
| 65 | University of Witwatersrand | Pro Alvaro Viljoen | 011 717 2169 | Telephonic interview/ Meeting |
| 66 | Afriplex | | 021 872 4976 | Telephonic interview |
| 67 | Cedara (KZN) | Dr Maria Defiguera | 033 355 9156 | Telephonic interview |
| 68 | Carst&Walker | Uru Maganol | 011 359-4800 | Telephonic interview |
| 69 | Highland Essential Oils | Flippie Pienaar | 051 943 0317 | Telephonic interview |
| 70 | Herbs A Plenty | Elmarie de Bryn | 021 874 1684 | Telephonic interview |
| 71 | National Dept of Agric | Thabo Ramashala | 012 3196079/2 / 072357 3845 | Initial Meeting |
| 72 | DWAF (Irrigation - Walter vd Westhuizer) | Gauteng | 012 392 1300 | Telephone contact |

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|------|---------------------------------------|-----------------|----------------------|----------------------|
| 73 | DWAF (Irrigation) | National | 012 336 8245/8066 | Telephone contact |
| 74 | DST | Dr Lusunzi | 012 317 4330 | Telephone contact |
| 75 | DST | Geof Mashambye | 012 317 4341 | meeting arranged |
| | | | | |
| | GENERAL | | | |
| 76 | Antioxidants and Aroma Fine Chemicals | Geoff Blewitt | 035 797 6001 | Discussion |
| 77 | IFEAT (head office UK) | Louise Kopor | Fax no 0944712500965 | email |
| 78 | Rooibos limited | | 274822155 | Info obtained |
| 79 | Proctor & Gamble | Denzel Pillay | 011 700 5000 | Telephonic interview |
| 80 | Lever Ponds | Robert Waugh | 031 571 9600 | Telephonic interview |
| 81 | Johnson& Johnson | Deedee Sampson | 043 709 3211 | Telephonic interview |
| 82 | Beacon | Tom Larkin | 031 460 7200 | Telephonic interview |
| 83 | BAT | Hanro Steenkamp | 021 888 3765 | Telephonic interview |
| 84 | Nestle | Elize - Buyer | 011 889 6579 | Telephonic interview |
| 85 | Adcock Ingram | Judy Dunner | 011 971 4559 | Telephonic interview |
| 86 | MLG Tobacco | Mr Chirag | 011 661 5777 | Telephonic interview |
| 87 | Sara Lee | Mr Horsley | 031 719 7111 | Telephonic interview |