EUCALYPT DEBARKING:
an international overview with a
Southern African perspective

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June 2000
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EXECUTIVE SUMMARY

Considering the range of factors that influences it, debarking is probably the most critical activity in eucalypt harvesting. A significant amount of research and development was done nationally and internationally to investigate this issue.

The forest industry, through Forest Engineering Southern Africa, identified eucalypt debarking as an area requiring focus. The specific need is compounded by various issues: i.e., escalating labour cost, exchange rate, globalisation, high unemployment and the HIV/AIDS pandemic.

The factors influencing bark adhesion and debarking are discussed, and an overview of different technologies is given. This is based on national and international literature survey and communication with numerous operational persons.

In support of sustainable development the most appropriate technology for eucalypt debarking will be specific to a situation and requires consideration of the three core values: i.e., economic, social and environmental, that the forestry industry subscribes to. Grower management and harvesting contractor are jointly responsible for the objective evaluation of the contract situation and to base technology and equipment selection on a sound assessment of all the relevant criteria influencing the three core values.

This report is an attempt to objectively rectify inadequacies with past eucalypt debarking technology transfer in South Africa. It is not meant to negatively reflect on any company or individual, but rather to benefit the learning experience of the industry as a whole.
1. INTRODUCTION

1.1 Background

Internationally decision-makers are continuously faced with the question of appropriate technology (AT) for their forest operations. In South Africa economic, social and environmental forces are generally responsible for driving change in Forest Engineering.

AT is a spectrum of basic, intermediate, and highly mechanised technologies, evaluated and selected for a specific situation based on a range of criteria that support economic, social and environmental values (Grobbelaar, 2000). In real terms this means that depending on the economic, environmental and social values of a specific situation, the same technology can be appropriate, less appropriate or inappropriate.

The South African timber debarking situation for 1988 and 1997 is summarised in table 1. Between 1988 and 1997 the total annual cut (m$^3$) in South Africa increased by 25% (Brink, 1989 and 1998). During this period the manual debarking of hardwood increased from 42% to 51%, mainly as a result of a 68% reduction in hardwood sold with bark. Mechanical debarking of hardwood reduced from 0.7% to 0% in 1997.

Table 1. Timber debarking in South Africa between 1988 and 1997 (Brink, 1989 and 1998)

<table>
<thead>
<tr>
<th>Method of debarking</th>
<th>1988</th>
<th></th>
<th>1997</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SW</td>
<td>HW</td>
<td>Total</td>
<td>SW</td>
</tr>
<tr>
<td>None (%)</td>
<td>42.1</td>
<td>8.0</td>
<td>50.1</td>
<td>36.0</td>
</tr>
<tr>
<td>Manual (%)</td>
<td>0.5</td>
<td>42.3</td>
<td>42.8</td>
<td>10.0</td>
</tr>
<tr>
<td>Mechanised (%)</td>
<td>6.4</td>
<td>0.7</td>
<td>7.1</td>
<td>1.0</td>
</tr>
<tr>
<td>Total (%)</td>
<td>49.0</td>
<td>51.0</td>
<td>100.0</td>
<td>47.0</td>
</tr>
<tr>
<td>Volume ('000 m$^3$)</td>
<td>7,114</td>
<td>7,405</td>
<td>14,519</td>
<td>8,497</td>
</tr>
</tbody>
</table>

Considering the range of influencing factors, debarking is probably the most critical activity in eucalypt harvesting. A significant amount of research and development was done, nationally and internationally, to investigate this issue. Nationally these initiatives were hailed in with great fanfare by the forestry media, fading over a period of time without explanation. This lack of subsequent reporting on the successes or the failures of technologies or equipment has to date denied the broader industry to learn from each other’s experiences.
Due to the variability of different eucalypt situations geographically, topographically, economically and socio-politically, this report can at best aid the decision-maker and not attempt to prescribe the ultimate eucalypt debarking system.

The standard South African mass to volume conversion for eucalypt species applies to this report: i.e., 1t = 0.94 m$^3$ (freshly felled) and 1t = 1.47 m$^3$ (all other).

1.2 Study objectives

The objectives of this study are:

1. to objectively summarise research and development in eucalypt debarking, nationally as well as internationally. Existing results are presented in a format aligned with the Southern African situation.
2. to highlight certain important aspects to consider when selecting debarking methods and equipment.
3. to establish the relative advantages and disadvantages of the different debarking methods in order to transfer the knowledge and experience to all stakeholders.
4. to objectively compare different systems primarily along the criteria of reported productivity: i.e., m$^3$/PMH and m$^3$/manday. In the light of the exchange rate and in some instances the time elapsed since the use of the specific equipment, this report will refrain as far as possible from cost comparisons, despite its obvious value as a decision-making criterion.
5. To summarise the view on different technologies and their applications and to highlight important considerations in the decision-making process.

1.3 Justification for the study

The forest industry, through Forest Engineering Southern Africa, identified eucalypt debarking as an area requiring focus. The specific need is compounded by various issues: i.e., escalating labour cost, exchange rate, globalisation, high unemployment and the HIV/AIDS pandemic.

These issues which individually would possibly require different solutions, jointly adds to the complexity of the decision-makers’ task in deciding on the appropriate technology to be employed. This study will attempt in assisting the industry as a turnkey reference to known technology.
2. FACTORS INFLUENCING THE DEBARKING ACTIVITY

The long-term sustainability of any debarking technology is influenced by the external and internal environment (figure 1) within which it functions as an activity of timber harvesting. Clear cognisance of this environment is required in the evaluation of appropriate debarking technology.

Figure 1. The timber harvesting operating environment (Hoefle, 1974)

Factors directly influencing the debarking activity are:

- Market requirements
- Utilisation of eucalypt bark
- Bark adhesion
  - Bark type
  - Season and moisture content
  - Tree species, age and vitality
  - Tree form
  - Piece size and state of conversion
  - Time elapsed between felling and debarking
- Appropriateness of technology
  - Debarking equipment
  - Debarking location
  - Training, experience and expertise
2.1 Market requirements

The different secondary processing industries (e.g., pole treatment plants, sawmills, and pulp and paper plants) have different debarking quality requirements and varying reasons for debarking logs. The following reasons are often given for debarking logs: i.e.,

- **Kraft pulping.** The presence of bark can reduce the pulp strength, yield and the brightness. It can also result in an increased chemical requirement and a high bleaching cost (Woodhead, 1969).
- **Basic value-adding.** Bark-free wood chips are more valuable and more readily marketable than unbarked roundwood (Haygreen et al., 1989).
- **Board products.** Some products (e.g., hardboard, particle board and insulation board) tolerate a 10% bark content without adverse effect. In these products bark can improve water resistance, depending on the species (Williston, 1988).
- **Sawmilling.** A debarked log enables a sawyer or scanner to clearly “see” log defects and grain direction (Woodhead, 1969; Williston, 1976). Thus, a debarked log can be cross-cut and sawn optimally.
- **Equipment wear.** The debarking of logs prolong the life of tools and save costs since sand and grit in the bark tends to dull and wear conveyors, chippers, cutters and saw blades (Woodhead, 1969; Williston, 1976; Williston, 1988; Haygreen et al., 1989; Denig, 1993).
- **Bark disposal.** Loose bark can jam equipment and clutter up the sawmill, thus causing safety, fire and disposal problems (Haslett, 1988; Williston, 1988). According to Woodhead (1969) and Williston (1988) a considerable reduction in the amount of mill cleaning costs and maintenance time may result when debarked logs are processed, since bark drops off barked logs and offcuts when they are moved around the mill.
- **Safety.** The fire hazard is exacerbated by the fact that most bark is flammable. Bark volatility depends on its oil and moisture content.
- **Bark as primary product.** E.g. wattle bark.
- **Other.** Logs are often debarked for phyto-sanitary reasons (i.e. protect them against insects that house themselves under bark) and when logs are exported (Denig, 1993).

2.2 Potential for bark utilisation

The utilisation of bark has enormous potential (Barbour, 1998) in the forest products and related industries. The investigation into technologies and potential uses are on-going, highlighting the potential opportunities locked up in bark as an important raw material: i.e.,

- energy generation (Haygreen et al., 1989; Griffin, 1989; Johnson, 1989)
- commercial chemicals (Woodhead, 1969)
- building boards
- filler for paints and resins (Scharfetter, 1982)
- packaging industry
- mulch and fertilizer in agriculture, landscaping and horticulture (Barbour, 1998; Johnson, 1989).

The soil nutritional value of eucalypt bark is often under-estimated. The nutrient content (kg/ha) of stemwood, bark and other biomass components of 10-year old *E. grandis* is shown in table 2 (adapted from Noble *et al.*, 1989).

### Table 2. The nutrient content (kg/ha) of different biomass components in 10-year old *E. grandis*.

<table>
<thead>
<tr>
<th>Nutrients</th>
<th>Biomass components</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Stem</td>
</tr>
<tr>
<td>-----------</td>
<td>------</td>
</tr>
<tr>
<td>N</td>
<td>237.4</td>
</tr>
<tr>
<td>P</td>
<td>7.7</td>
</tr>
<tr>
<td>K</td>
<td>80.0</td>
</tr>
<tr>
<td>Ca</td>
<td>66.7</td>
</tr>
<tr>
<td>Mg</td>
<td>20.5</td>
</tr>
<tr>
<td>S</td>
<td>52.3</td>
</tr>
<tr>
<td>Total</td>
<td>464.6</td>
</tr>
</tbody>
</table>

From the biomass/nutrient relationship for *E. grandis* (Figure 2), the effect of the removal of specifically bark and foliage can be deducted. Where as stemwood (72% of biomass) constitutes 34% of the nutrients, bark and foliage (18% of biomass) constitutes 63% of nutrients.

Biomass removal through intensive harvesting operations increases the nutrient removal and nutrient cost per unit weight of biomass (Morkel, 1990). The additional fertilizer cost to maintain site nutrition needs to be considered in the decision of debarking methods and location. Considering the fertilizer requirements to maintain fertility status, Noble *et al.* (1989) determined that the harvesting of barked *E. grandis* increases the fertilizing cost by 47.5%. Whole tree harvesting (stemwood, bark, branches and foliage) will increase fertilizer cost by 77.9%. Nutrient replacement constitutes a significant component of the total biomass production cost at 10 to 17% (Noble *et al.*, 1989).

The assumption that 1kg of nutrients removed in harvesting biomass can be replaced by 1kg of fertilizer is unrealistic when considering that: e.g., nitrogen needs to be replaced at twice the removed quantity to maintain equilibrium (Bengtson, 1978 ex Wise *et al.*, 1981).
Figure 2. The biomass/nutrient relationship for 10-year old E. grandis (adapted from Wise et al., 1981 ex Morkel, 1990).

2.3 Bark adhesion

Bark adhesion is the relative tendency of bark to cling to timber, and is a direct indicator of the debarking potential or stripability.

The CSIRO and the different Australian states’ Forestry Commisions have tested various methods of reducing bark adhesion. Woodhead (1969) and Krilov (1980) summarised the results: i.e.,

- **Chemicals.** Although thoroughly investigated by Schutt (1960 ex Woodhead, 1969), various disadvantages are associated with the use of chemicals: i.e., labour intensive, incomplete bark removal, only effective when sap is flowing freely, most effective chemical is highly toxic, and it is damaging to the residual stand. Truman (1969 ex Krilov, 1980) reported on chemical debarking trials in New South Wales using a number of different chemical substances. The trees died almost immediately although the bark took time to loosen and fall off, resulting in unacceptable timber deterioration.

- **Hot water.** Scandinavian studies found that the use of hot water can double the debarking capacity of the drum debarker in a spruce pulpmill. Billets of spruce on a slow-moving conveyor passed through water at 80°C for two hours. Woodhead (1969) found this to be a disadvantage for the disposal of the bark due to the low calorific value and resulting difficulty in burning wet bark.

- **Steam.** An experiment with the stringybark *E. obliqua* (Geaves, 1968 ex Woodhead, 1969) found that exposure to live steam enabled bark removal by
claw-hammer after 1½ hours, while three hours resulted in bark almost falling off. As the bark will be less wet, burning the bark as part of power cogeneration will be easier.

- **Spraying or ponding.** Spraying water on stockpiled timber or submersing logs in water are often used to prevent timber degradation. According to Woodhead (1969) such treatment over a period of a few months reduces the bark adhesion. Subsequent handling, as well as the use of basic tools effectively removes bark.

- **Bacterial action.** Although never tried (Woodhead, 1969), it has been suggested to inoculate bark or add bacteria to water during log sprays.

Bark adhesion is influenced by the following factors:

### 2.3.1 Bark type

Bark usually consists of two equally thick layers: i.e., inner and outer bark. The outer bark is normally fibrous, scaly or smooth. The inner bark is woody resembling low density wood, high in moisture content but is not significantly detrimental to strength, brightness, or yield of pulp (Woodhead, 1969).

Eucalypt bark varies with the age of the tree as well as the degree of furrowing, thickness, manner of shedding, hardness and colour (Brooker et al., 1990). Appendix 1 illustrates the different types and characteristics of bark in eucalypts and the recommended debarking methods.

Differences in bark type influence the debarking activity: e.g., stringybark tends to foul up the debarking machine with slabs or strings of bark (Krilov, 1980). Stringy-bark is relatively thick, containing long fibers oriented parallel to the axis of the stem. Thus the bark has to be cut transversely during debarking in order to stop the bark from wrapping around protruding and rotating parts of debarking machinery. Stringy-bark also tends to fluff-up and increase in volume if attempts are made to remove it in small pieces (Wingate-Hill et al., 1991). In general, eucalypts are not easy to debark mechanically, particularly those with stringy bark which tend to clog and form balls in debarking and hogging equipment (Haslett, 1988).

### 2.3.2 Season and moisture content

Debarking resistance is related to wood moisture content and varies with season and climate (Figures 3 and 4) (Tsoumis, 1992; Wingate-Hill et al., 1991).
Figure 3: Variation of debarking resistance of beech logs (Northern hemisphere) according to month of felling; 1-parallel and 2-transverse to log length (Tsoumis, 1992).

Figure 4: Relationship of bark moisture content to debarking resistance; 1-Scots pine, 2-Spruce, 3-Birch (Tsoumis, 1992).
According to Woodhead (1969) the adhesion between inner bark and wood varies considerably with the season, with a weak bond in the wet season resulting in easier removal of bark. In the dry season the bond between inner bark and wood becomes stronger than between the bark layers, requiring chipping to remove the bark.

Moore (1987 ex Wingate-Hill et al., 1991) found sapwood moisture content to be a good predictor for bark/wood bond strength (BWBS). BWBS parallel to the grain was consistently greater than BWBS perpendicular to the grain, with difference increasing during drying.

### 2.3.3 Tree species, age and vitality

The BWBS also varies with age, between species and between vigorous and suppressed trees (Wingate-Hill et al., 1991): i.e.,

- Generally the BWBS increases with age, with older trees being more difficult to debark than younger ones.
- Trees under stress are more difficult to debark (Woodhead 1969). The stress occurs as a result of competition, drought and damage i.e., hail, lightning, mechanical damage, fire and disease (Table 2).

Table 2: Eucalypt tree diseases affecting debarking in Southern Africa (Coutinho, date unknown).

<table>
<thead>
<tr>
<th>Disease Family</th>
<th>Disease Name</th>
<th>Image</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cryphonectria spp</td>
<td>stem canker</td>
<td>![Image]</td>
</tr>
<tr>
<td>Coniothyrium spp</td>
<td>stem canker</td>
<td>![Image]</td>
</tr>
<tr>
<td>Bothryosphaeria spp</td>
<td>stem canker</td>
<td>![Image]</td>
</tr>
</tbody>
</table>

### 2.3.4 Tree form

According to Woodhead (1969) the main portion of the stem is generally round and easily debarked. Difficulty is often experienced with debarking of fluted
lower part of the trunk and base, as well as the branchier and often crooked tree tops.

2.3.5 Piece size and state of conversion

The effects of the law of piece volume (Engelbrecht, 1994) on the debarking activity are especially relevant in the following situations: i.e.,

- In industries requiring a specific permissible residual bark quantity, small diameter logs are required to be more completely debarked than large diameter logs, since the ratio of surface area (bark bond area) to log volume decreases with an increase in log diameter (figure 5).
- Most debarking equipment handle individual logs rather than batches or loads. In handling small diameter timber as opposed to large diameter timber, the productivity of small timber debarking is lower than that of large diameter timber.

Figure 5: The relationship between bark bond area and under-bark diameter (Wingate-Hill et al., 1991).
2.3.6 Time elapsed between felling and debarking

South African experience indicates that manual eucalypt debarking is done best immediately after felling. At least two references reported on the influence of time elapsed between felling and debarking: i.e.,

- Koskinen (1984 ex Wingate-Hill et al., 1991) reported increased difficulty of drum debarking four to six weeks after felling. The debarking improved again after four months with the onset of bark structure deterioration due to fungal and insect attacks.
- According to Fforde (1993) a lead-time of at least five days between felling and debarking improves the operation of the Demuth ring debarker due to reduced stoppages as a result of bark jamming the knives. However prolonged dry weather will reduce the required lead-time.

2.4 Appropriateness of technology employed

The five criteria for system evaluation (Brink et al., 1995 and Grobbelaar, 2000): i.e., technically possible, economically feasible, socially agreeable, environmentally and silviculturally acceptable, need to be borne in mind in the evaluation of appropriate technology.

2.4.1 Debarking equipment

The appropriateness of the debarking equipment involves numerous criteria: i.e.,

- *Harvesting method and system.* Debarking equipment forms part of a system supporting a specific harvesting method i.e., treelength, cut-to-length or full-tree.
- *Piece size range.* Debarking equipment handling individual trees or logs as opposed to bulk handling (e.g., drum, trough debarker) are usually extremely sensitive to piece-size.
- *Terrain conditions and climate.* For in-field applications, debarker selection has to take cognisance of accessibility in variable terrain conditions.
- *Labour supply.* The availability and cost of labour is an important consideration in Southern Africa.
- *Management, technical and labour expertise.*
- *Capital and operational cost.* Labour cost, capital cost, delivered timber price, fuel cost and exchange rate are but a few of the economic criteria influencing the appropriate technology.
- *Quality specifications.* Debarking quality is expressed as the % of bark remaining on the log and % of wood lost during debarking (Raymond, 1989)
- *Range of species or bark type to be debarked.* Ideally appropriate eucalypt debarking equipment needs to cope with a range of species because of the great variability in eucalypt bark characteristics.
• *Individual up-stream and down-stream activities.* Would the debarking equipment fit into existing harvesting system without detrimental impact on up- or down-stream activities. If the total cost (R/m³) is not improved, why change? This aspect can also consider the national and/or regional economic impact.

• *Loss of wood fibre and damage to logs as a result of the specific technology employed.*

### 2.4.2 Debarking location

Log debarking can be carried out at the stump area (in-field), at roadside or depot, or in the mill-yard. The optimal location of the debarking activity depends on available technology, local conditions, environmental constraints, energy source, bark utilization or disposal, labor availability, management objectives and log characteristics. Wingate-Hill *et al.* (1991) stresses the importance of determining the most suitable location considering the prevailing situation.

#### 2.4.2.1 Debarking in the stump area

The relative advantages and disadvantages of debarking in the stump area (in-field) are:

- Properly managed bark disposal can assist in weed control and protection of site against soil erosion and dispersement.
- Bark removal soon after felling is easier.
- Debarking equipment may be limited in its ability to handle large logs (Woodhead, 1969).
- The accumulation of bark and debris in-field can potentially increase the fire hazard (Wingate-Hill *et al.*, 1991; Tsoumis, 1992).
- The bark disposal practices influence the re-establishment after clearfelling.
- The accumulation of bark and debris in-field can potentially create favourable conditions for harmful insects or fungi (Tsoumis, 1992).

#### 2.4.2.2 Debarking at roadside or landing

According to Wingate-Hill *et al* (1991) it is difficult to see any merit associated with either debarking at roadside or landing. From an environmental and economic viewpoint debarking at roadside or landing often requires large landings and bark disposal problems.
2.4.2.3 Debarking at the woodyard

The relative advantages and disadvantages of woodyard debarking are:

- Debarking of logs in the woodyard shortly after felling can be physically and economically advantageous (Tsoumis, 1992).
- Stationary debarking equipment for woodyard installation requires a large capital investment (Wilson, 1976).
- Where there is a market for bark and the profit from selling the bark offsets its handling and transporting cost, as well as the fertilizer cost, debarking at the mill-yard could be a consideration.
- Depending on the scale of the operation (economy of scale), debarking in a central location can potentially reduce the debarking cost. Debarker installation cost as a percentage of total sawmill investment cost are (Krilov, 1980; Haslett, 1988):
  - 4 - 9 % for a large sawmill (>18 000m³/annum);
  - 15 % for a medium sawmill (6000 to 10 000 m³/annum);
  - 10 - 23 % for a small sawmill (3000 to 6000 m³/annum) (Krilov, 1980), and
  - 13 - 30% for a very small sawmill (<3000 m³/annum).
- Central debarking can potentially reduce the flexibility of the operation.
- Central debarking can reduce the labour force required. Although large volumes of timber might make central mechanised debarking feasible, smaller volumes might find the debarker installation cost restrictive.
- However, various debarking aids or accessories can be installed at the mill (e.g., scanners, standby debarkers and water sprays) to enhance debarking efficiency and quality (Williston, 1988).

2.4.3 Training, experience and expertise

Various studies have investigated the effect of experience and expertise on machine availability and utilisation. A potential threat is the loss of an operator to a competitor after incurring the cost of the learning curve i.e., lower productivity and equipment damage.

Trials with a Logma processor debarking and crosscutting *E. sieberii* (0.25m³ merchantable stem volume) investigated the effect of the learning curve on productivity (Wingate-Hill *et al.*, 1991). The two operators, one more experienced than the other, operating in the same conditions achieved 87 trees/PMH (21.8m³/PMH) and 58 trees/PMH (14.5m³/PMH) respectively.
3. MANUAL *EUCALYPTUS* DEBARKING METHODS/SYSTEMS

Manual debarking is one of the most labor-intensive activities in the forestry industry (Anon., 1988; Haslett, 1988 and Krilov, 1980). Hatchets are the most frequently used tools to manually detach bark either as long or short strips, or small plates (Brink, 1998).

Manual debarking has the following relative advantages and disadvantages:

- Low capital cost.
- High employment. Mechanization in South African forestry is progressively seen as a solution to the rising labour cost (Anon., 1988).
- Good quality.
- Low environmental impact.
- No substantial fibre loss.

3.1 Conventional manual treelength and shortwood debarking

The conventional gum harvesting system is based on a chainsaw operator with an assistant felling trees for individual manual debarkers. The two basic variations are the treelength and cut-to-length methods (De la Borde, 1990).

The factors influencing the decision between the two basic variations are: i.e.,

- *Log specifications*. The customer’s required log specifications.
- *Terrain*. Where the terrain is accessible to infield vehicles, a shortwood system is used (De la Borde, 1990).
- *Products*. Treelength debarking is preferred for pole production, reducing the losses through end splitting (De la Borde, 1990).

De la Borde (1990) uses the same debarking task for both basic variations. In both these situations each manual debarker is allocated a rack of four to five rows of trees. For the treelength method each chainsawyer fells for ±18 manual debarkers (De la Borde, 1990), while the shortwood method requires each chainsawyer to fell and finally crosscut for six manual debarkers. While individual debarkers wait for the chainsawyer to fell their racks, they commence rip-stripping the standing trees: i.e., using a hatchet to loosen the bark at the base and ripping strands of bark as high into the tree as possible. Bark is completely removed after felling.

During felling the debarkers should maintain a safe distance (two treelengths) from the chainsawyer or assist in pushing the trees. When the felled trees are at least a minimum of two treelengths from the chainsawyer, the debarker commences debranching and stacking the brush. The chainsawyer will return to crosscut the felled trees, allowing the debarker to rip-strip remaining standing
trees (if applicable). On completion of crosscutting the debarker continues to
debark the shortwood.

In the event of a treelength operation, the debarker will have a felling bar or
peevey hook to roll felled trees for debarking. The debarked stems are either left
in-field for drying or extracted to roadside for crosscutting. In the event of in-field
drying the stems are either crosscut in-field for shortwood extraction or extracted
as treelengths and crosscut on roadside.

De la Borde (1990) investigated the labour productivity of manual gum debarking
in South Africa and differentiated between five stripability classes (1 to 5) and
three stand qualities: i.e., poor (P), average (A) and very good (VG) for three tree
size groups. Normal daily task per debarking worker (trees per manday) for
three tree size groups and range of stripability and stand quality is shown in
figure 6.

Assuming an average tree volume of 0.15m$^3$/tree (mean tree height of 22m and
dbh of 15cm) stripability class of 3 and average stand quality, the manual
debarking labour productivity is 31 trees/manday or 4.65 m$^3$/manday. Through
the use of incentive schemes an additional 33% can be added to the daily task.
Studies done for H.L&H Mining Timber (Glover, 1990), indicated a debarking labour productivity (six productive working hours per day) for the same tree size, stripability and stand quality assumptions of $4.5\text{m}^3/\text{manday}$ (treelength method) and $3.15\text{m}^3/\text{manday}$ (short-wood method).

Table 3. Comparison of De la Borde (1990) and Glover (1990) for the treelength and short-wood variations.

<table>
<thead>
<tr>
<th>m$^3$/manday</th>
<th>De la Borde (1990)</th>
<th>Glover (1990)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional treelength</td>
<td>4.65</td>
<td>4.50</td>
</tr>
<tr>
<td>Conventional shortwood</td>
<td>4.65</td>
<td>3.15</td>
</tr>
</tbody>
</table>

### 3.2 “New” manual debarking

Richardson (1993a and 1993b) was involved in a number of productivity improvement projects with H.L&H Mining Timber. This resulted in the development of other gum harvesting systems, essentially variants of the “semi-Nordfor” or short-wood system. Compared to tasks and tree lines allocated to individual debarkers in the conventional treelength and short-wood systems, the new variations advocated team tasks and the felling of a whole five or six row rack.

Richardson (1993a and 1993b) devised his own stripability index indicating the percentage of the log stripped clean. The first study at SATICO near Kaapmuiden, Mpumalanga, achieved a debarking labour productivity of 67 trees/manday. Based on a mean tree height of 20m, the average tree volume is $0.101\text{m}^3$/tree, resulting in debarking labour productivity ranging from 5.1 to 7.3 m$^3$/manday (eight productive working hours) for stripability ranging from 40% to 90%.

Richardson’s second study (Richardson, 1993b) largely supported these findings in *E. grandis*. Based on a similar tree size, stripability and 8.3 productive working hours, a debarking labour productivity of 64 trees/manday or $6.4\text{m}^3$/manday was achieved. Based on stripability ranging from 40% to 90%, the expected debarking labour productivity ranges from 3.7 to $7.1\text{m}^3$/manday (table 4). Figure 7 shows the relationship between debarking productivity and stripability (bark adhesion) of these studies.

---

1 Average dbh of 13cm and mean height of 20.8m. Species are not specified.
Figure 7. Normal daily debarking task (trees per manday) for a range of stripability (40 – 90%) for trees of 16cm dbh.

Table 4. Comparison of debarking productivity of the new manual eucalypt harvesting systems (Richardson, 1993a and 1993b).

<table>
<thead>
<tr>
<th>Study location</th>
<th>Stripability</th>
<th>trees/manday</th>
<th>m³/manday</th>
</tr>
</thead>
<tbody>
<tr>
<td>SATICO</td>
<td>40%</td>
<td>51</td>
<td>5.1</td>
</tr>
<tr>
<td></td>
<td>80%</td>
<td>67</td>
<td>6.7</td>
</tr>
<tr>
<td></td>
<td>90%</td>
<td>73</td>
<td>7.3</td>
</tr>
<tr>
<td>Graskop</td>
<td>40%</td>
<td>37</td>
<td>3.7</td>
</tr>
<tr>
<td></td>
<td>80%</td>
<td>64</td>
<td>6.4</td>
</tr>
<tr>
<td></td>
<td>90%</td>
<td>71</td>
<td>7.1</td>
</tr>
</tbody>
</table>

3.3 Other manual debarking

Other manual debarking tools include the debarking spud (figure 8 and 9) and the new rotary cutter and debarking spoon (figure 10). Both these concepts allow a less strenuous working posture (figure 8).
Figure 8. Typical manual debarking posture when using a hatchet (left), compared with the use of a debarking spud (right).

The two groups of debarking spuds include spuds with fixed blades and replaceable blades. A wide variety of blades can be used to suit the specific barking situation. Various designs have been investigated i.e., concave or convex cutting edges curved inwards or outwards, although the best results are apparently achieved with a flat blade with straight edge (figure 9A-D).

Figure 9. Debarking spuds showing (A) fixed blades, (B) replaceable blades, (C) flat, concave and convex blades, and (D) straight, inward and outward curved edges (Skogsarbeten, 1983).

A new manual debarking concept was developed by Mr. Eckart Küsel of Ihlati Logging in the south-eastern Mpumalanga. This consists of a rotary blade to split the bark longitudinally and a debarking spoon to remove the bark (figure 10). The historical debarking productivity was approximately 2.3m³/manday debarking *E. nitens* and *E. macarthurii* (no “rip-stripping”). The productivity achieved by the
utilisation of the new handtools amounts to 3m³/manday (30% increase) with no change to the basic team structure (1 chainsaw operator and 12 manual debarkers) (Küsel, 2000).

Figure 10. The Ihlati rotary cutter and debarking spoon.
4. MOTOR-MANUAL EUCALYPT DEBARKING

In the context of this report, the term “motor-manual” is extended to include a group of motorized debarking machines that assist the forest workers in log debarking. This terminology adjustment was deemed necessary to distinguish between number of workers and relative skills level required compared to fully mechanised machines. Most of the mobile PTO-driven machines: e.g., Greytown Engineering chain flail and ring debarkers, belong to this group (figure 11).

![Diagram of motor-manual debarkers]

Figure 11. Categories of motor-manual debarkers.

The relative advantages and disadvantages of motor-manual debarkers are:

- Relatively low capital cost.
- Mobile.
- Intermediate employment level.
- Higher productivity than manual debarking.

4.1 Chain-flail debarker

The flail-debarking concept has proven its value in its ability to debark crooked stems, branches and crown wood (Wingate-Hill et al., 1991) unsuitable for most other non-manual debarking equipment.

The basic chain flail debarker involves hydraulic rollers feeding logs between two contra-rotating shafts with chains flailing the bark and branches from the logs.

During the late-1980’s the PTO-driven Greytown Engineering flail debarker was developed in conjunction with the Research and Development team of H.L&H
Mining Timber (Anon8, 1988). Although the GE flail debarker was originally designed for debarking eucalypt tree tops that otherwise wouldn’t be utilised, the machine was suitable for log diameters not exceeding 300mm, and allowed a maximum throughput log speed of 1m/s. During the initial trials a team of one driver and four to five labourers successfully debarked \textit{E.camaldulensis}, \textit{E.roxyflora}, \textit{E.sideroxylon}, \textit{E.nitens}, \textit{E.fastigata}, \textit{E.maidenii}, \textit{E.maculata} and \textit{E.cloeziana} (Anon9, 1989 and Wingate-Hill \textit{et al}., 1991). The infeed and outfeed activities are shown in figure 12.

![Image](image1.png)

Figure 12. The infeed (left), outfeed and stacking activities (right) involved in the GE chain flail operation.

Working in areas too steep for in-field operation of the tractor-drawn debarker, a Greytown contractor extracted treelengths to terrain accessible for tractor and trailer combinations (Anon10, 1989). Motor-manual crosscutting to 2.4m preceeded self-loading of the tractor and trailer, and shorthaul (<1.5 km) to a depot accessible to longhaul trucks. The timber is debarked on depot by flail debarker, manned by a driver and four labourers, producing 90 m$^3$/shift. Assuming a shift of six productive machine hours this amounts to 15 m$^3$/PMH (18 m$^3$/manday).

Time studies by Sawyer (1989) of GE flail debarkers during implementation near White River, Mpumalanga, indicated an hourly productivity of 15.5 to 17 m$^3$/PMH. He recommended a task of 106 m$^3$/shift (17.7 m$^3$/PMH) for a shift of six PMH. Sawyer (1989) found that thick-barked eucalypt species flailed successfully with no fibre damage, using a five-link chain. Most of the chain energy was dissipated on removing the bark. In thin bark species e.g. \textit{E.grandis} fibre damage occurred with excess energy after bark removal. Training of the operator to effectively control the infeed speed reduced fibre damage.

By 1989 there were 30 GE flail debarkers in operation, with two export units destined for Australia. During short Australian trials (Wingate-Hill \textit{et al}., 1991) the debarking of \textit{E.diversicolor} was found to be good, with less effective
debarking of stringy-barked *E.marginata* *E.sieberi* and *E.obliqua*. Bark blockages were common in the latter.

According to Pitout (2000) potential safety hazard limited the GE chain flail to single log feeding. As a result the productivity and economy of the concept is very sensitive to piece size. The relationship between productivity (m³/PMH) and log diameter is shown in figure 13.

![Figure 13. Relationship between debarking productivity (m³/PMH) and log diameter for GE chain flail debarker (Anon9, 1989).](image)

A variation on the basic GE flail debarker involved fitment of a small Patu 2100 crane and 53kW four-wheel drive tractor. In two method studies (Anon13, 1990): i.e., timber stacked both sides of the rack and timber stacked only on left side of rack, daily productivity of 92 m³/shift (15.3 m³/PMH) and 86 m³/shift (14.3 m³/PMH) respectively was achieved. The difference is attributable to the additional travel required by the latter alternative. The 53kW tractor was found to be suitable for *E.grandis* but a larger tractor was expected to improve the productivity by 10% in stringy-bark species i.e. *E.elata*, *E.macarthuri* and *E.nitens*. 

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According to Anon13 (1990) the chain cost is significant, being the second highest variable cost component after fuel. Chain life was found to be 200 to 400 m$^3$/set, requiring replacement approximately every two to four days (Pitout, 2000). A FERIC study (Raymond et al., 1990) investigated the productivity and chain wear of a Malenfant chain flail delimber-debarker in Quebec. Damage was assessed by determining the relative wear of individual links in each chain, rate of wear relative to the chains position on the shaft and relative rate of wear between top and bottom shafts. Results of this study supported the “third-link” damage reported by Taylor (1978). Rate of wear relative to position on drum was highest for chains on the centre of the drum (400%), with rate of wear relative to position on the top or bottom drums highest for the top drum (100%). These results can help determine a chain management strategy to maximise the life of the chains through chain rotation.

Although the flail concept was reasonably successful, a number of factors resulted in its discontinuation (Pitout, 2000): i.e.,

- The manufacturer closed down with resulting technical back-up problems.
- Damage to the outside surface of the timber. Apart from the fibre damage, the rougher outside surface of the timber was more susceptible to picking up dirt.
- Chain was a significant cost and its replacement time consuming.
- As a result of the relatively small piece size of eucalypts harvested for the pulp and mining timber industries and the sensitivity of the flail to piece size, manual debarking was still less expensive than the flail operation.

4.2 Mobile ring debarker

According to Woodhead (1969) and Krilov (1980) ring debarkers are generally efficient except for stringy-bark species which require special modifications. The ring debarker basically consists of infeed and outfeed rollers, and a vertical debarking ring with attached debarking tools. Two mobile ring debarkers were in operation in South Africa: i.e., the Valon Kone 16E and the Demuth.

4.2.1 VK16E.

The VK16E is PTO-driven and mounted on a two-wheel chassis (figure 14). The standard VK16E ring debarker is fitted with two cutting and two abrading tools on the vertical PTO-driven rotor. These tools are held in contact with the log by springs in the tool mountings, and the tool pressure can be hydraulically adjusted.

The VK16E requires a crew of five i.e. two to load, two to unload and one driver supervisor. At a feed speed of 0.35 m$^3$/s (average piece size not specified) the theoretical debarking rate, assuming fast log handling and no blockages, is 28 m$^3$/PMH.
According to Anon (1981 ex Wingate-Hill, 1991) almost 100% bark removal was experienced with a VK16E mobile ring debarker 4 to 8 weeks after felling in *E. maculata*, *E. hemiphloia*, *E. muellerana* and *E. paniculata*. According to Valon Kone information (Wingate-Hill, 1991) the VK16E experienced difficulty in debarking *E.obliqua*, *E.pilularis* and *E.sieberi*. In South Africa the VK16 was mainly used in the debarking of softwood, although limited application in eucalypt debarking showed the following results:

- Easy debarking of *E.cloeiana*, *E. grandis*, *E. saligna* and *E.maculata*.
- Efficient debarking of *E. nitens*.
- Efficient debarking of *E. fastigata* provided within six weeks of felling.
- Efficient debarking of *E. macarthurii* provided within two weeks of felling.

Figure 14. The PTO-driven VK16 debarker in an in-field application (A), with schematic drawings showing feed rollers (B) and debarking assembly (C).

In a South African investigation (Brown, 1982) good debarking quality was achieved (species not specified). However some concerns were raised regarding the productivity, low ground clearance, poor infeed/outfeed operation, the excessive operating space required and the breaking of drive shaft shear pins. Compared to the manual debarking productivity of 5.9 m³/manday, the VK16E achieved 12.2 m³/manday (7.96m³/PMH) debarking 2.4m pulpwood logs.
Shell Forestry operated a pre-owned VK16E on a double shift in a stationary application at a rail siding (SA Forestry, 1988). They experienced a productivity of 118 m$^3$/shift (14.8 m$^3$/PMH) but expressed concern about the robustness of the machine.

Wingate-Hill (1991) concluded that the VK16E’s potential productivity is high when debarking non-stringy, easy debarking species, and sufficiently rapid log feeding. The machine is not satisfactory in *E. obliqua, E. sieberi* and *E. fastigata*, and doubt exists regarding its commercial application in *E. regnans* due to the variability of debarking quality and occurrence of bark blockages.

4.2.2 Demuth

During 1993 H.L&H Mining Timber’s Southern Region imported a Demuth ring debarker from Brazil (figure 15). This PTO-driven machine was towed and powered by a Ford 6610 2x4 agricultural tractor with a Loglift 50 crane mounted on the tractor’s cab. A driver, two infeed assistants and an outfeed assistant staffed the unit, with the crane assisting the infeed assistants in accumulating timber within its reach to the infeed position.

![Demuth PTO-driven debarker](image)

Figure 15. The Demuth PTO-driven debarker.

Fforde (1993) studied the operation of this equipment combination during day and night operations on level and sloped terrain. He found the major factors influencing productivity to be:

- Unproductive time as a result of low concentration of timber requiring frequent movement and repositioning, accounted for approximately 18% of the working shift.
• Double shift operations are feasible since no noticeable reduction in throughput was observed during night operations provided adequate lighting is supplied.
• The high degree of preventative maintenance to sustain the unit’s productivity, accounted for 5% of the working shift.
• The removal of bark jams accounted to 2% of the working shift. A lead time of at least five days between felling and debarking reduces stoppages due to bark jams. In prolonged dry weather this can be reduced to under four days. The supervision and control of both the felling and debarking operations to prevent bottle-necks and ensure optimum presentation.
• The combination was found to limit the available range of terrain conditions. The unit operated optimally up to 18% slope (slope class 2).

Fforde (1993) found the Demuth debarker’s average debarking time to be 0.1369 min/log. Assuming eight PMH/day and an average of 50 logs per m$^3$, the throughput is 70.1 m$^3$/shift or 8.8 m$^3$/PMH. With a 100% reduction in movement and repositioning time (i.e., depot debarking) the throughput could theoretically increase to 82.6 m$^3$/shift or 10.3 m$^3$/PMH. Any level of timber concentration between that reflected in the study and depot debarking would result in a theoretical throughput of between 8.8 and 10.3 m$^3$/PMH.

Factors contributing to the discontinuation of eucalypt debarking with mobile ring debarkers are:

- Insufficient technical back-up as a result of number of machines in operation.
- Sensitivity of productivity and cost to piece size.
- Productivity was not sufficiently improved to warrant the capital expenditure, with manual debarking still less expensive.

### 4.3 Motor-manual debarking summary

The VK16E and Demuth ring debarkers appear to have very similar performance (figure 16), with the Greytown Engineering chain flail offering 48% higher labour productivity (table 6).

The key factors that resulted in the discontinuation of the use of motor-manual eucalypt debarking equipment in South Africa include: i.e.,

- Insufficient technical back-up.
- Sensitivity to piece size.
- Manual debarking at the time still less expensive.
Figure 16. The relationship between debarking productivity ($m^3$/PMH) piece size (logs/$m^3$) for the VK16 and Demuth mobile ring debarkers (adapted from Fforde, 1993 and Wingate-Hill et al., 1991).

Table 6. Productivity comparison of motor-manual eucalypt debarking systems.

<table>
<thead>
<tr>
<th>System</th>
<th>PMH/shift</th>
<th>$m^3$/shift</th>
<th>$m^3$/PMH</th>
<th>$m^3$/manday</th>
</tr>
</thead>
<tbody>
<tr>
<td>GE Chain flail</td>
<td>6</td>
<td>93</td>
<td>14-17</td>
<td>18</td>
</tr>
<tr>
<td>VK16E</td>
<td>6</td>
<td>57</td>
<td>8-11</td>
<td>12.2</td>
</tr>
<tr>
<td>Demuth (in-field)</td>
<td>6</td>
<td>57</td>
<td>8-11</td>
<td>12.2</td>
</tr>
</tbody>
</table>
5. MECHANISED DEBARKING

For this report the mechanised debarking equipment under discussion can be categorised as stationary and mobile equipment (figure 17).

![Diagram of categories of mechanised debarking]

Figure 17. Categories of mechanised debarking.

5.1 Stationary equipment

5.1.1 Rosser-head

Rosser-head debarkers consist of a framework for rotating the log and a carriage-mounted debarking head rotating with its axis parallel to the axis of the log (figure 18).
Figure 18. The Rosser-head debarker concept showing (A) the mechanism for rotating the log and (B) debarker head rotating parallel to the log rotation.

Krilov (1980) reported that rosser-head debarkers working in Australia are mostly locally designed and developed for Australian conditions, successfully debarking both stringybark and ironbark species.

Although designed as stationary mill installations, Cumberland (1974 ex Wingate-Hill et al., 1991) reported on the development of a mobile machine for 15 to 64 cm over-bark diameter logs. This machine achieved 0.2m/s in thin-barked logs with good form and 0.1m/s in fibrous bark, malformed logs.

The development of a cutting tool suitable for stringybark species was discontinued despite some promising results (McKenzie et al., 1973 ex Wingate-Hill et al., 1991).

Wingate-Hill et al. (1991) found that the rosser-head’s single log debarking mechanism makes it very sensitive to piece size, with throughput ranging from 4.6m³/PMH (0.1m³ logs) to 51.5m³/PMH (1.07m³ logs).

Rosser-head debarkers operate best with straight logs (Woodhead, 1969), although poor stem form can be accommodated by crosscutting the logs to shorter, straight logs.
The average wood volume loss from Rosser-head debarkers in a softwood application reached 9.5% compared to 1.1% for ring debarkers (Raymond, 1989).

5.1.2 Valon Kone ring debarkers.

Waterton Timbers operated a centrally situated stationary VK450 at a rail siding outside Kwambonambi (figure 19). They achieved an average productivity of 160 m\(^3\)/shift or 20 m\(^3\)/PMH, employing 25 people for feeding and loading of rail trucks (Anon2, 1988).

![Figure 19. The Waterton Timbers' VK450 installation at railway siding (A) showing the infeed line (A1), debarker (A2), outfeed line (A3) and railcar loading (A4). A conveyor loads the bark for transport back to the plantation (B).](image)

With 25 people per shift the off-loading, debarking and railcar loading resulted in a labour productivity of 6.4 m\(^3\)/manday. This relatively high employment coupled to the double-handling of timber, cost of returning bark to plantation and capital cost resulted in manual in-field debarking being more cost-effective. This operation is probably a good example of the potential pitfalls of mixing technologies within the same system.

The debarking of stringy-bark logs were tested with a VK800 (figure 20) installed at a pulp mill’s chipper infeed line (Wingate-Hill, 1991). During a short trial an average feed speed of 0.2 ms\(^{-1}\) were achieved. Of the total process time, 70% accounted for the removal of bark blockages (58%) and crooked or jammed logs (12%). The debarking quality was 52% measured as the proportion of bark by area left on the logs. Feeding two or three easier debarking species after every one or two stringy-bark logs reduced the blockages.
5.1.3 Tandem ring debarkers

The debarking problems of stringy-bark species resulted in a new design incorporating tandem rotors, separating the cutting and scraping functions to eliminate blockages (Wingate-Hill et al., 1991). The cutting knives in the first ring were replaced by rotary cutting heads to mill helical grooves in the tight bark with abraders removing the remaining material (figure 21).

Figure 21. The operating principle of the tandem ring debarker’s first ring is shown (A), with (B) showing the rotary cutters of the Nicholson A5A debarker. The second ring operates similar to previously discussed ring debarkers, scraping the bark from the stem.
During tests in Oregon with a container load of 0.1 m$^3$ stringy-bark logs (mostly *E. sieberi*), all the bark was removed at a feed rate of 0.85 ms$^{-1}$. The log diameter ranged from 9.5 to 22.5 cm (average 14.8 cm), with a log length of 5.8m. No bark blockages occurred but bark disposal conveyors were unable to handle the volume of small pieces of bark and occasional long bark strands.

Two Australian trials assessed the debarking of small-diameter eucalypt logs with Nicholson and Brunette tandem debarkers. The Brunette’s performance was reported to be superior to the Nicholson (Wingate-Hill *et al.*, 1991). Wingate-Hill’s (1991) conclusion is that the only successful ring debarkers are the tandem debarkers with rotary cutting head on the first ring. Generally the available models require installation at large mills providing sufficient throughput.

Pedersen Holdings Ltd, New Zealand, operates an outsourced debarking and chipping operation for Carter Holt Harvey based on a Nicholson A5A tandem ring debarker (Anon18, 1998). The bark is fed through a knife hog, breaking it down for use in a co-generation plant. Previously debarking was done in-field using chain flails and Waratah harvesters (Riddle, 1995), proving to be too expensive for the debarking of 240000 m$^3$/annum.

The A5A debarks at 80m/min for 90% of the debarking time (Anon4, 1998). Considering its productivity of 680m$^3$/shift (average log diameter of 20cm and assuming average log length of 10m), the theoretical influence of piece size is shown in figure 22.

![Figure 22](image_url)  
*Figure 22. The relationship between eucalypt debarking productivity (m$^3$/shift) and piece size (log mid-diameter) for the Nicholson A5A debarker (adapted from NFT, 1998 and NZI, 1998).*
5.1.4 Drum debarking

Drum debarkers are usually large, expensive stationary installations. They operate either on a batch processing or a continuous process, and are thus less susceptible to piece size (Wingate-Hill et al., 1991).

Some problems with drum debarking of eucalypts (Anon17, date unknown) include bark discharge resulting in higher bark content and wear of the inner drum surface as a result of contaminants. The cushioning effect of the retained bark can also reduce the debarking efficiency. The “dropping and tumbling” operation (figure 23) of the drum debarker results in increased breakage of small-diameter timber, resulting in a higher fibre loss.

![Figure 23. A drum debarker installation (A) showing the “dropping and tumbling” effect of the timber in the drum (B) that increases the breakage of small-diameter timber during debarking.](image)

Drum debarking of *E.globulus* and *E.grandis* in Brazil, Spain and Portugal (Koskinen, 1984 ex Wingate-Hill et al., 1991) indicated easy debarking up to four weeks after felling. From four to six weeks the difficulty of debarking rapidly increased becoming almost impossible. After four months, with onset of bark structure deterioration due to fungal and insect attacks, drum debarking without pre-treatment again becomes possible.

Early trials by Berlyn (1965 ex Wingate-Hill et al., 1991) concluded that the edges of intact bark are most vulnerable in the debarking process since bark removal occurs in two stages: i.e., breaking bark/wood bond at bark edges and detaching loosened bark.

Various trials were conducted aimed at increasing the bark edge through pre-treatment methods: e.g., ultra-high pressure water jets, mechanical severing of bark (e.g. rotating knives and flails). In Spain effective bark removal (up to 94%)
was achieved with ultra-high pressure water jets making spiral cuts in logs of dry *E.globulus* and *E.rostrata*. The more exposed bark edges increased the potential drum throughput rate by 45 to 50% (Heikkinen, 1979).

Trials in Portugal made use of pre-treatment rotors to tear and hit the bark on the rotor teeth. Increased effectiveness with eucalypt debarking required drum modifications to effectively expel the bark: i.e., increased open area (>5%), change in orientation of bark expelling slots, more rotor teeth, larger drum diameter (>5m) and faster rotation speed (0.15-0.17 rev/s) (Wingate-Hill *et al.*, 1991).

The productivity of a dry drum debarker (5m diameter, 25m long, 5.4% open area and 0.08rev/s) in Brazil, debarking fresh three meter *E.grandis* and eucalypt hybrid logs (45mm to 70 mm diameter) without pre-treatment was 140m³/PMH.

### 5.1.5 Trough debarkers

Trough debarkers can be mobile or stationary with the former operating on a batch process, while the latter normally operate on a continuous process. The basic machine consists of a container (trough) holding the logs while an agitation/bark removal system rotates the logs, knocking-off bark and ejecting it through the base of the container. The modular design allows extensions to the debarker with resulting increased productivity.

Trough debarkers usually have a smaller holding container with a more gentle rotation of logs as opposed to large drum debarkers’ “dropping and tumbling” operation (figure 24). As a result breakage of small-diameter eucalypts (diameter of 50mm) experienced with drum debarking has been reduced.

The Fuji King trough debarker effectively debarks stringy bark eucalypt species (Anon17, 1995). According to the manufacturer stringy bark is cut by the bark cutters on the rotor and removed by the debarking plates through the longitudinal and vertical slits between the rotor and fixed drum. This ensures a steady debarking efficiency while reducing the wear caused by contaminants in the bark. Araki (1996) found that the Fuji King debarker can produce 8.5 BDU²/PMH debarking logyard aspen waste.

The Fuji King debarker was investigated in 1995 for the South African industry (de Wet, 2000 and Howe, 2000). They observed the equipment in operation in New Zealand, Chile and Indonesia where the continuous process eliminated the piece size sensitivity with a productivity of 140m³/PMH in tree size ranging between 0.08 and 0.5m³/tree. The factors that prevented the import of this technology were the capital cost of R2 million (1995) and the envisaged bark

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² BDU = Bone Dry Unit i.e. wood residue weighing 2400 lbs (1088.6 kg) at 0% moisture. 8.5 BDU equates to 9.25 BDT or bone dry tons of chipped residue.
disposal problems. Considering the production cost savings these factors might require further investigation.

Figure 24. The Fuji-King trough debarker is shown in (A), with (B) illustrating the operating principle of the trough debarker.

Dehlen et al (1982 ex Wingate-Hill et al., 1991) reported on a Swedish mobile trough debarker removing 80% of the bark from 15m$^3$ spruce and pine in 20 minutes. Increasing the bark removal to 95% requires an additional 20 minutes. No references of mobile trough-debarking of eucalypts are available.

Reports of a stationary trough debarker at a chipping plant in Tasmania (Wingate-Hill et al., 1991) indicate a throughput of 35 m$^3$/PMH (in the absence of blockages) for 100-390mm diameter logs of 2.5m. The length can be increased to 3.5m provided the logs are straight. The debarking quality is reported to be good.

5.1.6 Cradle debarking

Sasko et al (1993) reported on the cradle debarker as a solution to the limitations of the flail, ring and drum debarking technologies. The operating principle is similar to the trough debarker with rotating chains turning the timber in the cradle causing between-log friction that removes the bark. The key advantage of the cradle debarker is its modular 13m-sections (figure 25), allowing continuous feeding of timber as opposed to single log feeding.
Figure 25. The cradle debarker showing continuous feeding Sasko *et al.*, 1993).

Similar to the drum and trough debarkers the cradle debarker’s continuous debarking process overcame the sensitivity to piece size of single log debarking technologies. Although Sasko *et al* (1993) believes that the cradle debarker’s theoretical throughput of 1530m$^3$/PMH is unrealistic, a throughput of 510m$^3$/PMH has been attained (tree size and species not specified).

Other advantages of the cradle concept are: i.e.,

- Less expensive than drum debarking.
- Debarking units are portable.
- Low noise level.
- Reduced stripability can be addressed through extra cradle sections.
- Low fibre loss.
- Although continuous feeding, the logs exit singly.

No reference was obtained to the application of cradle debarking in eucalypt operations.
5.1.7 High-pressure water debarking

A high-pressure water debarker normally consists of a set of variable speed trunnion wheels that support and rotate individual logs. A high-pressure water jet (~8Mpa), situated above the trunnion wheels (figure 26), can be raised and lowered to accommodate different diameters and forms (Wingate-Hill, 1991).

A Tasmanian high-pressure water debarker debarked logs, mid-diameter of 0.25 - 1.8 m (u.b), at 93 to 309 m³/PMH (Cumberland, 1969). Some benefits of hydraulic debarking include the use for stringy-bark and poor form logs (Woodhead 1969 and Krilov 1980). Some drawbacks were the high initial machine and running cost, water filtration requirements, wet bark disposal and a high water requirement of 67l/s.

Wingate-Hill et al (1991) mentions a high-pressure water debarker modified for logs of 0.15 -0.5 m³ (u.b) that achieved an output of 65 - 90 m³/PMH while supplying water at 90l/s at 11Mpa.

Figure 26. High-pressure water debarking showing the water jets in 1 and 2.

Krilov (1983) successfully tested debarking of different bark types (including stringybark species) known for its difficult debarking with water consumption between 0.12 and 0.68 l/s per meter of log length. Despite large variation in cleanness of debarking between species tested, the debarking quality is generally superior to that of any other equipment.

Filtration and recirculation can reduce water consumption by 80%, making this a feasible research field (Krilov, 1985). Despite apparent opportunity, no development progress have been made (Wingate-Hill, 1991).
5.1.8 Bark separation from chipped wood

According to Woodhead (1969) the problem of debarking timber of poor form, including branchwood, can be alleviated by chipping and subsequent bark removal.

Different methods have been utilised for separating bark and chips: i.e., air jet and vacuum flotation, and adhesion methods. The former makes use of the difference in bark and wood density to separate the bark from the chips through flotation. The latter is based on the difference in adhesion of bark and wood to steel when passing the chips through squeeze rollers. The bark tends to stick to the steel, while the chips fall free.

Disadvantages of this technology when attempting to achieve a high degree of bark and wood separation (<5%) are the associated loss of wood fibre and poor chip quality. The latter results from the rapid blunting of chipper knives due to dirt and stone in the fissures of the bark, obviously less of a problem with smooth bark species and branchwood.

5.2 Mobile debarking equipment

5.2.1 Modified log-loader

Wingate-Hill et al. (1991) reported the application of the crab-grab loader for debarking of eucalypt sawlogs and pulplogs. This modified log loader consists of a tracked excavator chassis with a fixed grapple or crab-grab attachment (figure 27) on its boom. The machine is normally used for debarking as well as loading.

The basic method involves the loader travelling on a brush-pile with boom and crab-grab perpendicular to the direction of travel, allowing the debarking of trees parallel to the direction of travel. The debarked timber is stacked behind the loader, parallel to the barked timber. To loosen the bark the loader lifts and drops a log or bunch of logs from full boom height. With a weak bark/wood bond this treatment is sufficient to remove the bark. In conditions of ‘tight’ bark this process can be repeated a number of times, with the underside of the crab-grab rubbed against the log to remove remaining bark. Debarked logs are picked out individually from pile of partly debarked logs and bark, slewed through 180° and stacked behind loader. The accumulated bark are piled and returned to the stand by skidder or forwarder.

Wingate-Hill (1991) reports a debarking and loading productivity ranging from 75 to 115 m³/shift (eight productive machine hours) or 9.4 to 14.4 m³/PMH.
5.2.2 Debarking by harvester head

Wingate-Hill et al (1991) carried out various tests with the application of compressive forces to the outside of a log to break the bark/wood bond. Tests carried out on logs smaller than 17cm diameter indicated success with freshly cut and dry logs of smooth and rough-barked eucalypt logs including *E.viminalis*, *E.fastigata*, *E.obliqua* and *E.sieberi*.

The problem of compressing the whole outer surface of the log was addressed by feeding the logs through an experimental roller mill. A knife was added to one of the rollers to spiral-cut the bark for removal. A prototype was tested in 1991 envisaging future construction, after further development, as a felling/debarking head for butt-end diameters (over bark) of 350mm.

Harvesting heads in general make use of the compression principle to loosen the eucalypt bark. In South Africa, like Australia, eucalypt debarking by harvester largely made use of harvesting heads imported from northern-hemisphere countries and not designed for eucalypt debarking. The standard (non-modified) harvesting heads proved to be reasonably effective for poor bark/wood bond if deliming knife pressure is increased. A general problem appears to be the blockages with long bark strands.

Figure 27. The crab-grab used to debarking eucalypts.
5.2.2.1 Maskiner SP450, SP550 and SP650.

The first Bell harvester in the early 1990’s involved a Maskiner SP450 head mounted on a Bell three-wheel logger (figure 28A).

The Maskiner SP 450 and SP 550 heads fitted to the Bell range of harvesters (figure 29) were the most prominent harvester heads in Southern African eucalypt debarking before 1999. Manufactured in Sweden, these heads were modified by fitting steel feed rollers with helical grooves to rotate the stem, changing the cut angle of the knives and adjusting the delimbing knife pressure. In some instances structural modifications were required due to higher wear-and-tear resulting from eucalypt debarking.

During 1991 H.L&H Mining Timber purchased the prototype tracked harvester, modified from the tracked feller-buncher carrier and supplied with a slew-boom. After a fairly steep learning curve, operators, technical and management, the first purpose-built Bell TH100 harvester was built in 1992 (figure 28B). Richardson (1992) found the productivity of the Bell TH100 (SP 450 head) in *E. grandis* of 0.16 to 0.24 m³/tree to range between nine and 19 m³/PMH as shown in figure 30. The Bell harvester range was expanded to include the TH120 with the SP550 head.

![Figure 28. The Bell WH100 wheeled harvester (A) and TH100 tracked harvester (B).](image-url)
During the early 1990’s the cost of mechanical harvesting of eucalypts was generally higher than that of labour-intensive operations. This can largely be attributed to the learning curve, relatively inexpensive labour, ownership by large companies and constraints with harvesting contracts. As a result a lower-cost option was provided in the wheeled Bell WH100 harvester without the on-board computer and suitable for harvesting treelengths only (figure 24A).

In some situations the Bell WH100 was used solely to debark, with motor-manual felling and crosscutting (Anon19, 1998). According to Louw (2000) this increased the productivity by 10 to 15%, although the main motivation for this method appears to be the reduced in-field travel and resulting lower site disturbance.

In 1999 Bell Equipment Company, in conjunction with a contractor, tested the 20-ton Kato excavator with a SP650 head in Zululand (Hartley, 2000). Although this machine proved to be successful in harvesting 5.5m pulpwood logs, the contractor indicated the lack of a contract commitment from the grower and the grower prescribing equipment as the reasons preventing him from purchasing the machine.
According to Wingate-Hill et al. (1991), the performance of the Lako head in eucalypt species was encouraging after basic modifications allowed the weakening of the bark/wood bond. The productivity achieved during Tasmanian trials (Beardsell et al., 1987 ex Wingate-Hill et al., 1991) are shown in Table 7.

Table 7. Results of Tasmanian trials with Lako harvesting head.

<table>
<thead>
<tr>
<th>Site</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Species</td>
<td>E. obliqua</td>
<td>E. obliqua</td>
<td>E. obliqua</td>
<td>E. obliqua</td>
<td>E. delegatensis</td>
</tr>
<tr>
<td>Age(yrs)</td>
<td>24</td>
<td>25</td>
<td>16</td>
<td>-</td>
<td>48</td>
</tr>
<tr>
<td>m³/tree</td>
<td>0.25</td>
<td>0.28</td>
<td>0.10</td>
<td>0.23</td>
<td>48</td>
</tr>
<tr>
<td>min/tree – 5.5m</td>
<td>1.28</td>
<td>1.86</td>
<td>1.00</td>
<td>0.96</td>
<td>0.90</td>
</tr>
<tr>
<td>– 11m</td>
<td>1.29-1.40</td>
<td>1.29-1.40</td>
<td>0.96</td>
<td>0.90</td>
<td></td>
</tr>
<tr>
<td>m³/PMH – 5.5m</td>
<td>11.6</td>
<td>12.0-12.8</td>
<td>5.8</td>
<td>14.4</td>
<td>26.8</td>
</tr>
<tr>
<td>– 11m</td>
<td>7.9</td>
<td>12.0-12.8</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
During these trials the debarking capability varied from 100% bark removal after one pass to 70% bark removal after five to seven passes. Some problems experienced included the bark removal from the butt of the tree due to separation between chainsaw and rollers, and lack of full rotation of tree leaving two strips of bark on opposite sides of tree.

In 1993 trials took place in the Mpumalanga province of South Africa with a Lako harvesting head mounted on an excavator carrier. The original 20-ton carrier of Russian origin was upgraded to a 30-ton Liebherr carrier (figure 31). The machine was used in both softwood and hardwood sawtimber applications, with average tree size between 1.5 and 2 m³/tree. Lubbe (2000), directly involved in the machine’s feasibility studies, is of the opinion that the Lako is one of the best harvesting heads for eucalypt harvesting. The critical factors influencing the non-feasibility of the Lako were: i.e.,

- Tree size. The trees were too large (1.5 to 2 m³/tree), with better performance expected for trees of 0.7 to 0.8m³/tree.
- Technical expertise to minimise downtime. The operational cost of a mechanised operation needs to include close-proximity technical expertise, either as employed technicians or through maintenance contracts.
- Cost. At the time of the trials, motor-manual felling and manual debarking of eucalypt species still proved to be less expensive than mechanised harvesting.

Although largely successful in eucalypt debarking, the non-feasibility of the Lako at the time resulted in its export to Chile where it is harvesting Pinus radiata for two skylines (Lubbe, 2000).

![Figure 31. The Lako head (B) mounted on a Liebherr excavator (A), operating in eucalypt sawtimber in Mpumalanga, South Africa.](image)
5.2.2.3 Pika.

In the late 1980’s Peoria Logging imported a Pika harvesting head. Although it was never tested in eucalypt harvesting, it proved to be reasonably successful in softwood. Structural deficiencies as a result of large tree size required modifications which eventually resulted in availability problems (Lawrie, 2000).

Trials with Bacell in Brazil, using a Pika 4500 harvester (figure 32) to harvest eucalypts of 0.18 m$^3$/tree, experienced a productivity of approximately 9m$^3$/PMH when converting to 4.8m logs (Anon, 19**). According to the manufacturer the eucalypt debarking is efficient, meeting the stringent requirements of the Bacell manufacturing process.

Figure 32. The PIKA 4500 harvester operating in Brazil (A), showing the head in fell-position (B).

5.2.2.4 Timberjack 1270B with 762B head.

Wingate-Hill et al. (1991) reported on modifications required to an ÖSA 762 head (later became the Timberjack 762) for effective bark removal. The modifications involved welding sharp bars to the feed rollers and small metal inserts inside the delimbing knives to cut through and loosen the bark. The modified head achieved a productivity of 10.4 m$^3$/PMH and 93% bark removal in 25-year old E. regnans with mean merchantable stem volume of 0.52 m$^3$.

A series of studies was done in South African conditions with the Timberjack 762 harvesting head mounted on the Timberjack 1270B carrier (figure 33). In a cut-to-length application in conjunction with a Timberjack 1010 forwarder, this harvester achieved an hourly productivity of between 7.7 and 12.6 m$^3$/PMH in average tree size of 0.15 to 0.29 m$^3$/tree.

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3 The Timberjack study involved volumes measured and recorded by the harvesting head and timber loaded over the weigh-bridge to determine the average tree size (tons). The Waratah study obtained piece size from weigh-bridge measurements and no volumetric data measured.
For the Southern African situation the cost of the purpose-built Timberjack 1270B carrier is high, at approximately R1 million more expensive than an excavator-based harvester (Hollins, 2000 and Dell’Oca, 2000). The Waratah 620 harvesting head, dedicated to eucalypt harvesting, is too heavy for the 1270B carrier (more than 1 ton heavier than the Timberjack 762). Considering the cost constraints Mondi (1998) found that the basic Timberjack 1270B is best suited to softwood operations involving larger piece size and exclude debarking.

Preliminary results (Hattingh, 1999) of South American flat terrain eucalypt harvesting with the Timberjack 1270B harvester indicate a productivity of 60 trees/PMH in tree size ranging between 0.15 and 0.2 m$^3$/tree, i.e. 9 to 12 m$^3$/PMH.

5.2.2.5 Waratah H620 harvester head.

A New Zealand study (Gadd et al., 1995) investigated the application of the Waratah 240 HTH as a landing-based treelength processor in *E. regnans*. This study achieved a productivity of 25.2 m$^3$/PMH in an average tree size of 0.82 m$^3$/tree (range 0.08 to 3.61 m$^3$/tree).

During 1999 Mondi Forests evaluated the Waratah H620 harvesting head fitted to a 107 kW Fiat-Hitachi tracked excavator (figure 34) (Mondi, 1999). The study was done in the same compartment as one of the Timberjack 1270B studies, resulting in an hourly productivity of 9.96 m$^3$/PMH compared to 9.37 m$^3$/PMH for the Timberjack 1270B (average tree size 0.20 m$^3$/tree and Zululand coastal flats).
Figure 34. The Waratah H620 harvesting head (B) mounted on a CAT excavator (A) as opposed to the Hitachi excavator used in South Africa.

At present two excavator-based Waratah H620 harvesters are successfully operating in the KwaZulu-Natal province, producing 5.5m pulpwood logs. Hollins (2000) reports productivity of 13 m$^3$/PMH for the more experienced operation. According to Rapson (2000) his operators have achieved 10 m$^3$/PMH within six weeks of commencing the operation.

The first Hitachi/Waratah combination as tested by Mondi Forests (Mondi, 1999) was fitted with an excavator boom. The machine now used by Rapson (2000) is fitted with the correct harvesting boom. A 15 to 25% productivity increase is expected from this new machine configuration.

Provided the machine utilisation is greater than 70%, the cost of mechanised harvesting of trees larger than 0.20m$^3$/tree with the Hitachi/Waratah combination, will be similar to motor-manual felling and manual debarking. For trees smaller than 0.15 m$^3$/tree, motor-manual felling and manual debarking is more cost effective. (Rapson 2000).

5.2.2.6 Harvester debarking summary.

When comparing the harvester with other debarking technology it is important to keep in mind that the harvester’s productivity not only refers to debarking but also includes felling, debranching, crosscutting and in-field stacking/bunching or any combination of these activities. As such the economic feasibility of the harvester cannot be objectively determined through direct hourly productivity comparisons with other equipment without considering the other felling and preparation activities involved in non-harvester operations.

The variability in eucalypt debarking productivity of harvesters is largely due to its ability to effectively debark different species. As a rough benchmark it appears
that a harvester can fell and process (debark, debranch, crosscut and stack) one
tree per minute independent of tree size.

As a result of the very similar productivity of different harvesters, purchase price
becomes a critical factor to the cost efficiency of the operation. This was clearly
shown in a comparison of three harvesters operating in similar terrain and tree
size, producing 5.5m logs (Mondi, 1999). The impact of the purchase price on
the harvesting cost considering similar tree size and very similar productivity is
shown in table 8.

Table 8. Comparison of three harvesters in similar South African conditions
(Mondi 1998).

<table>
<thead>
<tr>
<th></th>
<th>Bell TH120</th>
<th>Timberjack 1270B</th>
<th>Waratah H620</th>
<th>Max-min</th>
</tr>
</thead>
<tbody>
<tr>
<td>R (purchase)</td>
<td>975 000</td>
<td>2 300 000</td>
<td>1 400 000</td>
<td>36%</td>
</tr>
<tr>
<td>min/tree</td>
<td>0.918</td>
<td>0.957</td>
<td>0.901</td>
<td></td>
</tr>
<tr>
<td>m³/PMH</td>
<td>11.02</td>
<td>10.57</td>
<td>11.24</td>
<td>6%</td>
</tr>
<tr>
<td>R/PMH</td>
<td>228.80</td>
<td>430.75</td>
<td>277.08</td>
<td>47%</td>
</tr>
<tr>
<td>R/m³</td>
<td>20.76</td>
<td>40.75</td>
<td>24.65</td>
<td></td>
</tr>
</tbody>
</table>

Based on the productivity (min/tree) in table 8 and a range of tree sizes, the
sensitivity of the harvesters’ production cost (R/m³) to tree size is shown in table
9. The expected 15% productivity improvement from the new boom configuration
is also included in table 9.

Table 9. The sensitivity of the harvester’s productivity and cost per unit volume
to tree size (adapted from table 8).

<table>
<thead>
<tr>
<th></th>
<th>Bell TH120</th>
<th>Timberjack 1270B</th>
<th>Waratah H620</th>
<th>Waratah H620 (new config)</th>
</tr>
</thead>
<tbody>
<tr>
<td>min/tree</td>
<td>0.918</td>
<td>0.957</td>
<td>0.901</td>
<td>0.766</td>
</tr>
<tr>
<td>m³/tree</td>
<td>7.84</td>
<td>29.17</td>
<td>7.52</td>
<td>57.25</td>
</tr>
<tr>
<td>m³/PMH</td>
<td>14.38</td>
<td>15.91</td>
<td>13.79</td>
<td>31.23</td>
</tr>
<tr>
<td>R/m³</td>
<td>17.65</td>
<td>12.97</td>
<td>16.93</td>
<td>25.45</td>
</tr>
<tr>
<td>R/m³</td>
<td>20.92</td>
<td>10.94</td>
<td>20.06</td>
<td>21.47</td>
</tr>
<tr>
<td>R/m³</td>
<td>24.18</td>
<td>9.46</td>
<td>23.20</td>
<td>18.57</td>
</tr>
</tbody>
</table>

4 This excludes the potentially longer useful life of the Waratah head and the recent revised boom
configuration.
From communication with a number of contractors and corporate staff involved in eucalypt harvesting a number of factors crucial to the success of mechanised eucalypt harvesting with harvesters became apparent: i.e.,

- **Shared risk.** The general feeling is that the contractor cannot be expected to be solely responsible for the risk. In the latest mechanised contracts this issue is addressed with shared risk between the grower, equipment supplier and contractor.
- **Technical support.** Poor back-up and resulting downtime were responsible for operational inefficiencies blamed on the equipment. This seems to be addressed in the above shared risk option.
- **Management expertise.** Successful mechanisation requires expertise and appreciation by the contractor as well as the grower. In some cases the contractors are not involved in equipment trials and selection, but dictated to by the grower as to what technology and specific equipment is required. Unless specific environmental issues are at stake it is believed that the contractor should be allowed to exercise his/her choice of equipment.
- **Motivation for mechanisation.** The specific reasons for mechanisation are important. Most contractors agreed that mechanisation is probably a future reality, although most are of the opinion that labour-intensive operations are in the worst case not more expensive than mechanised operations. The opinion was raised that individual egos should not be the sole motivation for mechanisation without due consideration of all values: i.e., economic, social and environment.
- **Operator competence.** With expensive equipment and a steep learning curve to master its operation, quality training as well as time to develop competence is important.
- **Contract.** A suitable term contract is essential to allow the contractor the opportunity to depreciate the equipment, recover his cost and make a profit. This appears to be addressed in the recent mechanised contracts with shared risk.
- **Terrain, species and tree size.** Accept the constraints of the physical stand: i.e., terrain, species and tree size, and apply the appropriate technology for the situation.
- **Harvest planning.** Accurate harvest planning is crucial for efficient mechanised operations.
6. SUMMARY - CHOICE OF DEBARKING METHOD

As shown in previous chapters a clear-cut solution to the eucalypt debarking question in South Africa is not possible. The range of variables across different situations is indicative of the need for sound planning and decision-making.

The absence of a standard study protocol requiring certain basic key information to be recorded and reported in all work and productivity studies in Southern Africa, made it extremely difficult to make sensible comparisons without making assumptions i.e., ton definition, shift length, tree size and species.

According to Burrus (1993) the technological choice, timing of its implementation, as well as the management of change, are critical to ensure successful application of selected technology.

Developing countries should mechanise with great caution (Sundberg, 1974), rather focussing on the optimum use of resources adapted to socio-economic conditions. This can however display great variation resulting in technology ranging from fully manual to fully mechanised.

Considering the equipment discussed, the following relative advantages and disadvantages can be useful in guiding the decision process:

6.1 Manual debarking.
- High employment requirement.
- Sensitive to labour cost escalation.
- Reasonably flexible with regards to location, tree size and market changes.
- Log or tree form not critical.

6.2 Flail debarking.
- Intermediate employment requirement.
- Log or tree form not critical.
- Piece size sensitive although less so than mobile ring debarkers.
- Chain wear is a significant cost.
- Stringybark eucalypts potentially a problem.
- Log surface damage prohibitive in certain markets.
- In-field application reduces nutrient removal and bark disposal problems.

6.3 Mobile ring debarker.
- Intermediate employment requirement.
FESA – EUCALYPT DEBARKING

- Requires reasonably straight logs.
- Highly sensitive to piece size.
- Stringybark eucalypts potentially a problem.
- In-field application reduces nutrient removal and bark disposal problems.

6.4 Rosser-head.
- Large capital investment.
- Requires reasonably straight logs.
- Highly sensitive to piece size.
- Stationary installation could reduce flexibility.
- Nutrient removal and bark disposal considerations.
- Stringybark eucalypts potentially a problem.

6.5 Stationary ring debarker.
- Large capital investment.
- Requires straight logs.
- Highly sensitive to piece size.
- Mechanical availability critical.
- Stationary installation could reduce flexibility.
- Nutrient removal and bark disposal considerations.
- Stringybark eucalypts potentially a problem.

6.6 Tandem ring debarker.
- Large capital investment.
- Requires straight logs.
- Highly sensitive to piece size.
- Stationary installation could reduce flexibility.
- Mechanical availability critical.
- Nutrient removal and bark disposal considerations.
- Cutting of helical grooves in bark resolves stringybark problem.

6.7 Drum debarker.
- Large capital investment.
- Log form not critical.
- Less piece-size sensitive than single tree or log equipment.
- Stationary installation could reduce flexibility.
- Mechanical availability critical.
- Nutrient removal and bark disposal considerations.
- Capital cost can be prohibitive for satellite debarking considering the double-handling compared to mill-installation.
6.8 **Trough debarker.**
- Large capital investment.
- Log form not critical.
- Less piece-size sensitive than single tree or log equipment.
- Stationary installation could reduce flexibility.
- Mechanical availability critical.
- Although mobile units are possible, debarking will be at roadside or depot with associated nutrient removal and bark disposal issues.
- Capital cost can be prohibitive for satellite debarking considering the double-handling compared to mill-installation.

6.9 **Cradle debarker**
- Large capital investment.
- Log form not critical.
- Less piece-size sensitive than single tree or log equipment.
- Equipment is portable.
- Capital cost less prohibitive than drum debarker.
- High productivity.
- No known eucalypt experience.

6.10 **High pressure water debarking.**
- Requires access to water, but consumption can be minimised through filtration and recirculation.
- Log form not critical.
- Highly sensitive to piece size.
- Investment is largely a function of the scale.
- Stationary installation could reduce flexibility.
- Mechanical availability critical.
- Although mobile units are possible, debarking will be at depot with associated nutrient removal and bark disposal issues.

6.11 **Chips.**
- Large capital investment also involves modifications to harvesting and transport systems.
- Log form not critical.
- Less piece-size sensitive than single tree/log equipment.
- Satellite installations could reduce flexibility, although mechanical availability risk is potentially spread.
- Mechanical availability critical.
• Although mobile units are possible, debarking will be at roadside or depot with associated nutrient removal and bark disposal issues.
• Threat of wood/fibre loss in bark separation process.

6.12 Harvesters.
• Reduced handling.
• Capital investment involves felling and preparation and not only debarking.
• More flexible than stationary installation.
• Highly sensitive to piece size.
• Sensitive to capital cost.
• In-field application reduces nutrient removal and bark disposal problems.
• Mechanical availability critical to individual harvesting operations but less critical to the total supply-chain.

6.13 Modified log-loader.
• Sensitive to piece size.
• No specialised debarking equipment required.
• Very crude method of debarking.
7. CONCLUSION

The aim of this study is not to dictate or specify an “optimum” eucalypt debarking method as specific situational factors will dictate appropriate technology for sustainable development. Efficient and effective eucalypt debarking technology has for many years been a question in the international eucalypt industry, with the variability in different bark types, specifically stringybark, and sensitivity to piece size offering the greatest challenge. In many instances debarking equipment from non-eucalypt industries was adapted with some degree of success, although seldom offering a total solution.

In brief communication with a number of persons involved in eucalypt debarking a range of opinions was offered. In most cases manual debarking still remains the preferred method because of cost and labour availability, while the “hassle factor” in other situations are making mechanisation a feasible alternative despite its high capital investment.

In Southern Africa the preferred debarking method for many years has been manual debarking due to its relatively low labour cost and operational flexibility. Apparent low labour productivity, escalating labour cost, global competition, HIV/AIDS threat, restrictive labour legislation and forward and/or backward system requirements, are factors threatening the future of labour-intensive forestry operations. However the socio-economic problem of unemployment, especially in rural areas, are a concern shared by many contractors and foresters. Without focussed attention by all stakeholders, including organised labour, future mechanisation is inevitable.

To date the mechanisation of eucalypt debarking in South Africa has been largely unsuccessful for various reasons: i.e.,

- High capital investment as a result of an unfavourable exchange rate.
- Relatively low labour cost compared to risk of capital investment.
- High availability of unskilled labour in rural areas.
- Low utilisation due to technical support problems.
- Sensitivity of single-stem equipment to piece-size.
- Product not meeting the customers’ quality specifications.
- Variability of bark characteristics between species.
- Management vs. ownership.
- Insufficient contract concentrating the risk on the contractor.
- Lack of expertise in management (grower and contractor), operator and equipment supplier.
- System and terrain constraints.
- Equipment unsuitable to local conditions.
- Resistance to change.
Some of these issues appear to be addressed in recent contracts, with risk sharing between the grower, contractor and equipment supplier. Considering the past experiences and situational factors: i.e., relatively small piece-size of eucalypt pulpwod in South Africa, the following technologies show the most promise in the South African context:

- **Labour-intensive operations.** With on-going training, incentive schemes, the use of labour-saving devices and attention to the human physiological issues: i.e., nutrition, labour-intensive debarking will continue to be of value in many applications. The opinion of many contractors and company representatives highlighted their preference (from experience) for manual debarking operations.

- **Harvester/processor technology.** Currently this is the most favoured alternative debarking method, with the benefits largely systems related. Of the technology covered in this report, the harvester requires the most expertise (operator, technician and management). Its sensitivity to piece-size is critical with feed rate already at an optimum, prohibiting any great future productivity improvements within the small-diameter eucalypt timber in South Africa. The high capital cost coupled to the in-field conditions would probably require replacement every three to five years. A great advantage of this technology is the absence of bark disposal problems and its resulting disposal and plant nutritional cost. From the experience of some of the involved parties the actual cost is currently at best on par with motor-manual felling and manual debarking.

- **Tandem ring debarker.** This technology seems to have solved the debarking problem of stringybark species. Although it is also sensitive to piece-size a higher productivity can be achieved. The Nicholson A5A are successfully operating in a New Zealand contract operation. With its high capital cost the stationary installation might allow a higher useful life (>10 years), potentially reducing debarking cost. Comparing the ring debarker to the harvester the additional timber handling and bark disposal cost of the former need to be carefully considered.

- **Fuji King trough debarker.** The trough debarker is largely piece-size insensitive pointing to enormous benefits for the local industry. The Fuji-King debarker is successfully operating in several countries, offering the greatest proven debarking productivity improvement. The stationary installation’s potentially higher useful life and productivity makes its high capital cost a feasible investment in certain situations. However the bark disposal cost also need to be considered.

- **Cradle debarker.** Although no eucalypt references available, the benefits are the same as the Fuji-King with even higher potential productivity.

The most appropriate technology for eucalypt debarking will be specific to a situation and requires consideration of the three core values that the forestry industry subscribes to: i.e., economic, social and environmental. As such there are situations favouring mechanisation and others favouring more labour
intensive operations. Grower management and the harvesting contractor are jointly responsible for the objective evaluation of the contract situation and to base technology and equipment selection on a sound assessment of all the relevant criteria influencing the three core values.
8. ACKNOWLEDGEMENT

The authors acknowledge the valuable input of various persons, as referred in text, involved in the harvesting of eucalypts in South Africa.

We also acknowledge the time, effort and support provided by the review panel: i.e., Messrs. Pierre Ackerman (University of Stellenbosch), Michal Brink (SAFCOL), Roy Engelbrecht (Mondi), Russell Morkel (Mondi) and Carl Pitout (SAPPI).

The following people are acknowledged for the use of pictures and photographs in the text: i.e.,

Photo 8 – Harold Richardson, Productivity Management Services
Photo 10,19,28A and 31 – Roger Grafton, SA Forestry
Photo 12 – Carl Pitout, SAPPI
Photo 21 – Young Eucalypt Report, CSIRO Australia
Photo 14 and 20 – Valon Kone
Photo 15 – Demuth
Photo 24 – Fuji King
Photo 27 – Michal Brink, SAFCOL
Photo 28B – Erik Grobbelaar, Ecotech
Photo 29 – Maskiner
Photo 32 – PIKA
Photo 33 – Timberjack
Photo 34 – Waratah

A special word of thanks to Ms. L. Louw for grammatical editing and assistance with the manuscript.
9. LITERATURE REVIEWED


Anon6, Date unknown. Valon Kone debarkers. Specification sheets for VK16ST, VK16STE, VK600/800, VK600E debarkers. Finland.


Anon12. Date unknown. Chain flail operating method, productivity standards and maintenance schedules.


Anon17. 1995. Fuji King Barker. Information pack by Fuji Kogyo Co Ltd.


Coutinho T.A. Date unknown. Tree Pathology Co-operative Programme information brochures. University of Pretoria.


<table>
<thead>
<tr>
<th>Bark type</th>
<th>Smooth (gum) bark</th>
<th>Peppermint</th>
<th>Iron bark</th>
<th>Stringy bark</th>
<th>Half bark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Examples</td>
<td>E. grandis,E. tereticornis,E. camaldulensis,E. cladocalyx,E. globulus,E. saligna</td>
<td>E. radiata</td>
<td>E. pilularis</td>
<td>E. paniculata</td>
<td>E. robusta</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>E. sideroxylon</td>
<td>E. cloeziana</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>E. nitens</td>
</tr>
<tr>
<td>Winter debarking</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Tight</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
<tr>
<td>Bark characteristics</td>
<td>Bark is shed annually, giving a smooth surface. Short fibre strands in outer bark &amp; long in inner bark. Bark comes off in strips.</td>
<td>Sub-fibrous bark with a reticulate appearance. Bark comes off in platelets.</td>
<td>Thick, rough and deeply furrowed bark, often corky with kino pockets.</td>
<td>Rough, spongy, think &amp; furrowed bark. Long fiber strands, bark comes off in strips (strings).</td>
<td>Bark is partly smooth and partly rough in almost equal proportions.</td>
</tr>
</tbody>
</table>
### Appendix 2. Bark removal techniques (Woodhead, 1969)

<table>
<thead>
<tr>
<th>Method</th>
<th>Debarking equipment</th>
<th>Length</th>
<th>Log characteristics</th>
<th>Species</th>
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<tbody>
<tr>
<td>Motor-manual</td>
<td>Chain flail</td>
<td>Any</td>
<td>$^5$All sizes</td>
<td>All forms</td>
</tr>
<tr>
<td>Mechanical</td>
<td>Cradle debarker</td>
<td>Short</td>
<td>Small</td>
<td>All forms</td>
</tr>
<tr>
<td>Mechanical</td>
<td>Disc</td>
<td>Any</td>
<td>Limited</td>
<td>Straight</td>
</tr>
<tr>
<td>Mechanical</td>
<td>Drums</td>
<td>Short</td>
<td>Small</td>
<td>All forms</td>
</tr>
<tr>
<td>Mechanical</td>
<td>Harvesting head</td>
<td>Any</td>
<td>Limited</td>
<td>Straight</td>
</tr>
<tr>
<td>Mechanical</td>
<td>Hydraulic (water)</td>
<td>Any</td>
<td>Large</td>
<td>All forms</td>
</tr>
<tr>
<td>Manual</td>
<td>Hand tools</td>
<td>Any</td>
<td>Medium</td>
<td>All forms</td>
</tr>
<tr>
<td>Motor-manual and mechanical</td>
<td>Ring debarker</td>
<td>Any</td>
<td>Limited</td>
<td>Straight</td>
</tr>
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<td>Mechanical</td>
<td>Rosser head</td>
<td>Any</td>
<td>Limited</td>
<td>Straight</td>
</tr>
<tr>
<td>Mechanical</td>
<td>Trough debarker</td>
<td>Short</td>
<td>Small</td>
<td>All forms</td>
</tr>
</tbody>
</table>

$^5$This refers to the broad chain flail concept. The GE chain flail used in South Africa was limited to a maximum 30cm diameter (Pitout, 2000).
## Appendix 3. Summarised debarking equipment comparison.

<table>
<thead>
<tr>
<th>Method</th>
<th>Equipment</th>
<th>Location</th>
<th>Spp</th>
<th>Work object</th>
<th>Productivity</th>
<th>Location</th>
<th>Reference</th>
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<td>Drum</td>
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<td>ns</td>
<td>ns</td>
<td>510</td>
<td>?</td>
<td>USA</td>
</tr>
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<td>Drum</td>
<td>25m long, 5m diam</td>
<td>static</td>
<td>Egra, hybrids</td>
<td>ns</td>
<td>140</td>
<td>?</td>
<td>Brazil</td>
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<td>Flail</td>
<td>Chain flail (crane) A</td>
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<td>Eela</td>
<td>0.09</td>
<td>9.66</td>
<td>4.8</td>
<td>Lothair</td>
</tr>
<tr>
<td>Flail</td>
<td>Chain flail (crane) B</td>
<td>in-field</td>
<td>Eela</td>
<td>0.09</td>
<td>9.01</td>
<td>4.5</td>
<td>Lothair</td>
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<td>ns</td>
<td>8.8</td>
<td>1.8</td>
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<td>Chain flail (manual)</td>
<td>in-field</td>
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<td>ns</td>
<td>11.3</td>
<td>2.3</td>
<td>Greytown</td>
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<td>Chain flail (manual)</td>
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<td>Esbl, Edel</td>
<td>0.1-0.4</td>
<td>5.8-26.8</td>
<td>5.8-26.8</td>
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<tr>
<td>Harvester</td>
<td>Ösa 762</td>
<td>in-field</td>
<td>Ereg</td>
<td>0.52</td>
<td>10.4</td>
<td>10.4</td>
<td>Australia</td>
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<td>Harvester</td>
<td>Pika 4500</td>
<td>in-field</td>
<td>ns</td>
<td>ns</td>
<td>9.38</td>
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<td>9.1</td>
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<td>Egra</td>
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<td>range</td>
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<td>Modified Logma delimber</td>
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<td>Esie</td>
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<td>8.8</td>
<td>2.2</td>
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<td>logs &gt;3m</td>
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<td>Rosser-head</td>
<td>static</td>
<td>Ediv. Emar</td>
<td>ns</td>
<td>shortwood</td>
<td>4.6-51.5</td>
<td>?</td>
</tr>
<tr>
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<td>Trough</td>
<td>static</td>
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<td>ns</td>
<td>35.0</td>
<td>?</td>
<td>Tasmania</td>
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</table>

ns = not specified

? = depends on staffing

**Work object**
- m³/tree
- conversion

**Productivity**
- m³/PMH
- m³/manhr