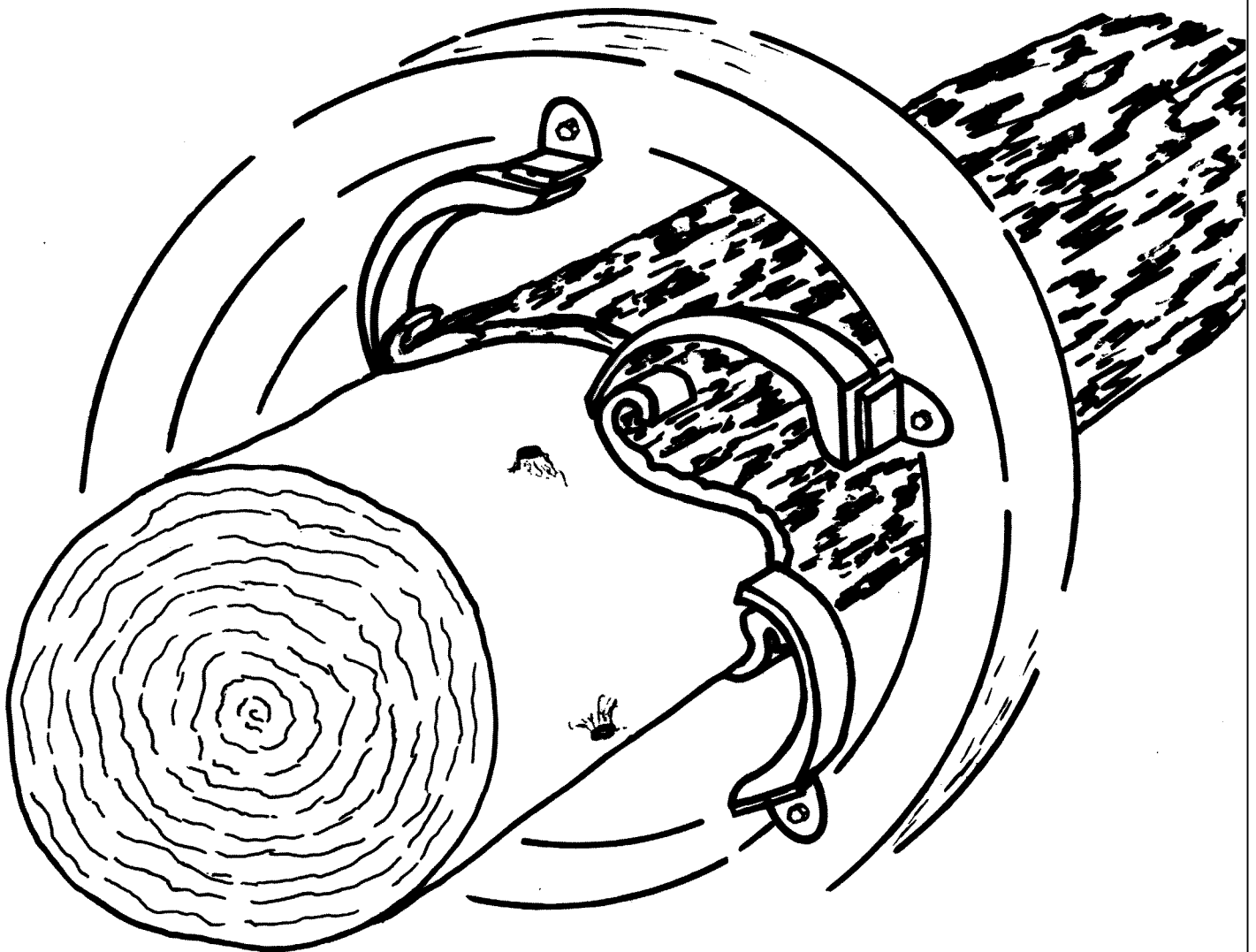


# The Use of Ring Barkers at Low Temperatures



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by

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Résumé en français

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## Abstract

Approximately 400 balsam fir and white spruce logs were processed through a commercial ring barker at ambient temperatures ranging from  $-31$  to  $+32^{\circ}\text{F}$ . The logs were appraised intensively both before and after barking, and machine factors were varied over a wide range. In general, the study indicated that at sub-zero temperatures pulpwood could be barked efficiently while sawlogs, because of their much lower volume of chippable material, would not meet residual-bark quality standards. In the zero to  $32^{\circ}\text{F}$  temperature range, sawlogs approached the standards. Barking quality increased as temperature, tool load, tool-hook angle, bark moisture content, log straightness, and log size increased and as cutting-edge radius and feed speed decreased. Balsam fir was more difficult than white spruce to bark successfully. A table of recommended machine settings is included.

## Résumé

On a fait passer environ 400 billes de sapin baumier et d'épinette blanche par une écorceuse à anneaux commerciale à des températures ambiantes variant entre  $31^{\circ}\text{F}$  au-dessous de zéro et  $32^{\circ}\text{F}$  au-dessus. Les billes ont été examinées attentivement avant et après l'écorçage, et on a beaucoup varié les détails de la machine. L'expérience a révélé qu'à des températures au-dessous de zéro, l'écorçage du bois à pâte demeurerait efficace; par contre, l'écorçage des billes de sciage, dont la proportion de bois à mettre en copeaux est beaucoup moindre, ne répondait pas aux normes établies quant à la quantité d'écorce restant sur la bille. Aux températures variant de  $0$  à  $32^{\circ}\text{F}$ , les billes de sciage approchaient des normes. On notait une amélioration dans la qualité de l'écorçage à mesure qu'augmentaient la température, la pression exercée sur l'outil, l'angle d'attaque de l'outil, la teneur en humidité de l'écorce, la régularité et la dimension de la bille, et que diminuaient le rayon de l'arête et la vitesse d'alimentation de l'écorceuse. Le sapin baumier était plus difficile à écorcer que l'épinette blanche. Ce rapport comprend une table de réglage suggérée pour la machine.

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# The Use of Ring Barkers at Low Temperatures

## Introduction

In 1965, the Canadian pulp and paper and lumber industries jointly requested that the Eastern Forest Products Laboratory undertake a research program on barking. The specific problem, submitted through the Advisory Committee of Industry on Research (now the Research Program Committee), was the difficulty of barking frozen wood.

To the firms in the industries mentioned, the problem is of long standing. With the widespread use of ring barkers, which began some 15 to 20 years ago, barking of logs during the winter months is an uncertain business.<sup>1</sup> Bark is strongly bonded to wood at temperatures below freezing. Attempts to weaken the bond before barking have been either unsuccessful or economically prohibitive. The most feasible and widely practised method entails thawing the log surface, but many mills cannot - for various reasons - maintain hot ponds or steam tanks during the winter. In consequence, either sawmills close during these periods, or barked logs are stockpiled to ensure an adequate supply of wood during cold weather. The pulpwood industry usually has recourse to drum barkers at the mill. However, there is a new trend in this industry to more mobile and intensive processing in the woods. These efforts are usually blocked by the poor barking quality attainable in cold weather.

In undertaking this work, the authors felt that an investigation of the cambium-shear barking principle would afford the most direct solution to the problem of barking frozen wood. If positive results were obtained, it was reasoned, operators of barkers could make simple adjustments to their machinery.

Parallel research in this field, at other laboratories, is currently under way. Some of these programs are based on the possibility of chipping the entire log, the tree stem, or the whole tree (including bark) and removing the bark fraction afterward. This involves two operations: (a) separating the bark from the wood in chip form and (b) segregating the bark from the wood after separation. Breakthroughs in this respect could revolutionize the industry (both at the mill and in the woods) and, of course, would be a particular boon to Canadian operators in overcoming the cold-weather problems outlined here.

It was recognized that intensive investigations on a commercial barker would be difficult for a number of reasons. Problems of instrumentation,

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<sup>1</sup>The barking of sawlogs is predicated on the use of barked slabs and edgings, representing some 12 to 27% of the log volume (Calvert and Johnston 1967), for pulp chips.

of maintaining or replicating ambient conditions, of interrupting the process, and of many other types were apparent. It was decided, therefore, that the experimental program should be carried out in two stages. Their first stage would involve physically simulating the ring barking process in the laboratory. The second, based largely on the results of the first, would be actual performance tests under field conditions.

The results of the first stage (the "Pilot Study") have been reported (Calvert and Garlicki 1972a). The present paper, which reports the findings of the second stage, refers frequently to the Pilot Study report. The experimental work was done at the Petawawa Forest Experiment Station during January, February, and March of 1970.

## Experimental Procedure

### EQUIPMENT

The barker selected for this study was the "Cambio 35."<sup>2</sup> This machine can process logs up to 14 inches in diameter and is used at many small-log sawmills and pulpwood operations. Fig. 1 indicates the terminology that describes characteristics of the tools used on this barker. The pertinent machine specifications are:

Number of tools.....	5
Rotor power.....	30 hp
Feed rolls.....	6/4 hp
Feed speed.....	90 to 130 fpm
Rotor speed.....	400 rpm
Tool loads are developed by tensioning rubber bands.	

### MEASUREMENT ON EQUIPMENT

Feed speeds were determined by stopwatch measurements.

Rotor speeds were determined by strobe-light measurements.

Tool tension (load on tool) was calibrated with apparatus built at the Laboratory. This load varied with the tool opening, corresponding to various log diameters from 4 to 14 inches. The loads were measured for the static condition and were converted to the dynamic condition by formula. Appendix I describes this procedure in some detail.

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<sup>2</sup>The Cambio 35 was selected as being widely representative of ring barkers in use in eastern Canada. This reference does not constitute an endorsement by the Department.

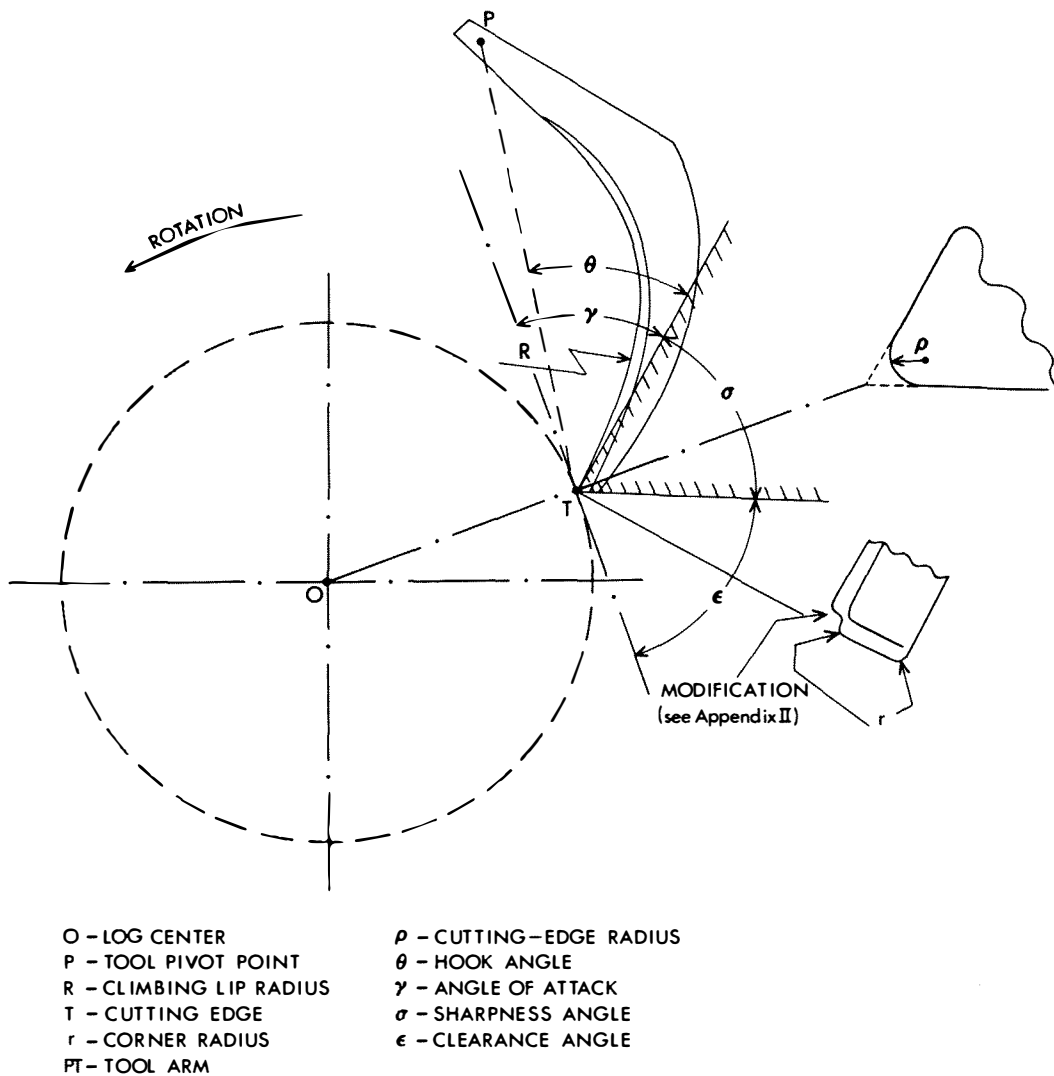


Figure 1. Terminology used to describe tool characteristics.

#### TOOL PREPARATION

Seven different tool sets were employed during the study. Each set consisted of five tools. Reference to tool specifications (e.g., tool geometry, tool number) in this report refers to those of the set. Beginning with the factory tools, modifications were made to their geometry as shown in Table 1. This was achieved by welding or brazing material to the tool tips and grinding new angles and radii (Fig. 2). Some problems associated with tool modification are discussed in Appendix II.

#### SAMPLE MATERIAL

Approximately 400 white spruce (*Picea glauca* (Moench) Voss) and balsam fir (*Abies balsamea* (L.) Mill.) logs, described generally in Table 1,



TABLE 1. TEST CONDITIONS

Characteristics	Tool Data						
	Tool number						
	1	2	3	4 <sup>a</sup>	5 <sup>a</sup>	6	7
Tool width (in)	1.350	1.350	1.370	1.190	1.190	1.190	1.220
Corner radius (in)	0.129	0.129	0.129	0.079	0.079	0.079	0.100
Sharpness angle (deg)	57.5	57.5	54.5	42.9	42.9	42.9	58.9
Hook angle (deg)	76.75	76.75	81.75	91.33	91.33	91.33	84.45
Cutting-edge radius (in)	0.030	0.015	0.044	0.015	0.015	0.030	0.020
Tool arm (in)	8.740	8.740	8.740	8.563	8.563	8.563	8.701

Barker Data

Rotor speed: 390 rpm  
 Feed speed: 88 and 117 fpm  
 Tool dynamic load: from 94.8 to 202.5 lb  
 per inch of cutting edge

Log Data

Log length: 9.6 to 19.0 ft  
 Log large diameter: 5.3 to 12.7 in  
 Log small diameter: 4.0 to 11.0 in  
 Bark thickness at large end: 2/32 to 11/32 in  
 Bark thickness at small end: 2/32 to 9/32 in  
 Wood moisture contents: 41.2 to 200.8%  
 Bark moisture contents: 35.0 to 223.0%  
 Log temperature in cambial zone: -24 to +25°F  
 Ambient temperature: -31 to +32°F

<sup>a</sup>Tools 4 and 5 differed slightly in the contour of the leading-edge corner radius (notch). (See Appendix II.)



Figure 2(a and b). Modified tools used in this study.

were used. Characteristics of the logs, such as straightness and surface quality, were measured and recorded. All logs were cut during December and January at the Petawawa Forest Experiment Station and stored in outside piles.

#### BARKING PROCEDURE

Logs were fed to the barker with the small end foremost. The general procedure followed in the field work was to bark a number of logs at a given temperature, with one set of tools at various feed speeds and tool pressures (Table 1). Then the tools were changed and the process was repeated on another batch of logs. To develop comparative data on spruce and fir, batches of each species were processed alternately.

#### TEMPERATURE MEASUREMENT

Since the Pilot Study showed that a considerable lag (or lead) in temperature exists between the ambient condition and the condition at the bark-to-wood interface, temperatures were measured at that interface. To accomplish this, a dummy pile of 10 logs - five balsam fir and five white spruce - was fitted with thermocouples at the bark-to-wood interfaces. Leads were attached to a recording potentiometer. Before the barking of each log, the average of five thermocouple readings for the corresponding species was taken and recorded as the *barking temperature*. Ambient temperatures were recorded at the same time. During the study, ambient temperatures ranged from -31 to +32°F, while temperatures recorded at the interface ranged from -24 to +25°F. Differentials between ambient temperature and the temperature at the interface varied around 6 or 7 degrees. Balsam fir, because of its somewhat thicker bark observed during these tests, showed generally larger differentials than white spruce.

#### SAMPLING PROCEDURE

Samples of the residue generated during barking (bark and wood mixture) were collected and divided into two subsamples.

The first was weighed, oven-dried, and reweighed to measure bark moisture content. In the second subsample, bark and wood fragments were separated, oven-dried, and weighed. This yielded a measure of *wood loss percent* according to procedures developed earlier by the authors (Calvert and Garlicki 1972b).

Two randomly selected 1-foot sections were taken from the barked log. From these were removed any residual bark, which was weighed and oven-dried. The two clean sections were also weighed and dried. The resulting values were used to calculate *residual bark percent*.

A statistical test was designed to indicate any possible bias in the location of these samples. The test result was negative.

#### REGRESSION ANALYSIS

The principal objective of the analysis was to obtain information on the *relative* importance of the variables under study. The data thus obtained could then be compared with the results of similar trials in the Pilot Study so that stronger inferences could be made. Regression-analysis techniques were used for this purpose.

### Results and Discussion

#### REGRESSION ANALYSIS

##### Residual Bark

Table 2 shows the results of regression analysis for residual bark percent. The eight factors listed in order of importance are significant at the 95% level and account for slightly more than 60% of the variation in the system (out of a total explained variation of 63%). As expected, characteristics of the tool (tool geometry) emerge as the most important. The analysis reveals that the type of tool employed (Table 1) is largely the reason for the differences in the levels of residual bark. It does not indicate which tool is best and, moreover, it does not indicate which one (or which combination) of the tool characteristics is the cause of the differences. These results are useful nevertheless. They indicate where further analysis should be focused. More will be said later with regard to tool geometry, including the important contribution of angle of attack.

The second most important variable over the range tested is the moisture content (MC) of the residue, which shows a strong negative correlation with residual bark percent. (This factor was found to be very important during the Pilot Study, and its effect was discussed in some detail in that report.) The effect of moisture in the cambium is well documented for temperatures above freezing. At temperatures below freezing, the bond at the interface is governed by the strength of the resulting ice (Voronitsin and Vorob'ev 1965). Berlyn (1965b) describes some of the seasonal differences in bark adhesion, which correspond to moisture levels in the cambium (and bark) at various times of the year.

The third most important variable is species. The average value of residual bark for each species gives a strong indication of this effect. The values are 1.68% residual bark for white spruce and 4.76% for balsam fir.

Perhaps this difference in residual bark results from the difference in characteristic bark-to-sapwood relative density. Lamb and Marden (1968)

TABLE 2. FACTORS AFFECTING DEGREE OF BARK REMOVAL (RESIDUAL BARK %)

Variable <sup>a</sup>	Description	R <sup>2</sup>	Cumulative R <sup>2</sup>
Tool geometry	An identification of gross tool characteristics, including hood angle, sharpness angle, and various radii	0.205	0.205
Residue MC	Moisture content of bark and wood that are removed during barking	0.129	0.334
Species	An identification of either one of the two species; white spruce, balsam fir	0.081	0.415
Barking temperature	The temperature at the bark/wood interface	0.055	0.470
Dynamic force	The computed dynamic load on each tool	0.058	0.528
Species x temperature	An expression of the interaction of species and barking temperature	0.037	0.565
Feed speed	The speed of the log through the barker head (fpm)	0.024	0.589
Cutting-edge radius	The radius of the tool cutting edge, which is also included above in "Tool geometry" (this implies a very strong effect)	0.012	0.601
Other factors		0.032	
Total		0.633	0.633

<sup>a</sup>The eight variables are significant at the 99.5% level.

show that the bark of balsam fir is denser than its sapwood while the bark of black spruce is less dense than its sapwood. If we assume that white spruce is similar to black spruce in this property and that strength is related to density for bark and wood, we see one possible effect immediately: balsam fir is likely to have a much less abrupt change than spruce in tangential shear strength (and deformation) between bark and wood. In white spruce, on the other hand, bark deformation is likely high compared with that in the last-formed latewood, thus causing a stress concentration in the cambial zone (i.e., in what is presumably the weakest zone).

Furthermore, because of the relative-density differences, the bark that *is* left on the balsam fir has a higher weight *in relation to the wood* than that left on the spruce for any given volume.

Log size as a source of bias is discussed in the Pilot Study report. It has been essentially minimized in this work by a large, normally distributed sample. It is well to recall that bias exists only in an analytical sense. For industrial purposes, values in units of weight are perfectly valid.

Barking temperature is the fourth most important influence. As in the Pilot Study, temperature is regarded as a basic condition assumed to have a strong effect. Although its range is considerably greater than in the former work, its mean value is a relatively low +2.3°F.

The influence of the remaining factors is evident from Table 2. The results shown confirm those obtained in the Pilot Study, although, because of experimental differences, the factors do not appear in the same order of importance.

#### Wood Loss

Table 3 shows the results of the regression analysis for wood loss percent. First of all, it may be seen that the variance accounted for by regression is low. This is largely explained by a very low average value for wood loss of 0.668% (which included a large number of zeros). The remainder must be attributed to factors that were either unaccounted for or inefficiently expressed in regression. Significantly, however, the low mean value is a desirable and commercially practicable level; consequently, the implications of attempting to lower it are rather academic. For this reason, the remainder of this report will deal with the removal of bark, per se, with comments on wood loss only where appropriate.

As an aside, the authors have heard it said that tool vibration aids in barking at low temperatures. This statement was made concerning a specific ring barker, and the authors had an opportunity to examine logs emerging from it. There were, in fact, "vibration" marks that were regular enough to be interpreted as a natural frequency of the system (i.e., the interaction of tool and wood). In that equipment relatively light, spring-steel tools were employed, while in the machine described in this report heavier forged-steel tools were used. The latter did not vibrate in any detectable way.

#### OPTIMUM COMBINATIONS

The second part of the analysis concerns an examination of the variables indicated as significant by regression analysis and a determination of what practical combinations are important. For an understanding of the results from an industrial viewpoint, the reader is again referred to the Pilot Study report. For example, the amount of bark tolerated by a variety of pulping processes varies considerably. In this work a value of 0.5% to

TABLE 3. FACTORS AFFECTING DEGREE OF WOOD LOSS (WOOD LOSS %)

Variable	Description	R <sup>2</sup>	Cumulative R <sup>2</sup>
Dynamic force	As in Table 2	0.088***	0.088
Average diameter	Mean, inside-bark diameter	0.053***	0.141
Cutting-edge radius	As in Table 2	0.045***	0.186
Residue MC	As in Table 2	0.035***	0.221
Species	As in Table 2	0.017***	0.238
Tool geometry	As in Table 2	0.015***	0.253
Sweep	Deviation of the log from straightness	0.013**	0.266
Sharpness angle	Defined in Fig. 1	0.009*	0.275
Other factors		0.049	
Total		0.324	0.324

Level of significance

\* 97.5%

\*\* 99.0%

\*\*\* 99.5%

1.0% by weight (oven-dry) is used as a tentative target. Berlyn (1965a) has indicated that the first value is representative of groundwood and sulphite mills in eastern Canada.

Temperature Range

In this study we were particularly interested in low-temperature barking. The Pilot Study indicated that at -10°F barking became extremely difficult. The experimental design of the present study did not permit precise determination of a corresponding critical temperature. Consequently, to be conservative, we gave the recommended machine settings in Table 4 only for below-zero and above-zero conditions.

Tool Characteristics

Tool characteristics were most important in determining barking quality. Of the seven tools, number 7 produced the least residual bark. Tool 3 was the original set from the factory and was distinguished primarily by a comparatively large cutting-edge radius (i.e. 0.044 inch). At temperatures above freezing this tool proved very efficient. However, at low

TABLE 4. RECOMMENDED SETTINGS TO OBTAIN OPTIMUM BARKING QUALITY<sup>a</sup>

Species	Angle of attack (deg)	Dynamic tool load (lb/in)	Cutting-edge radius (in) <sup>b</sup>	Feed speed (fpm) <sup>c</sup>
Below Zero				
White spruce	60 to 70	180 to 200	0.010 to 0.015	90 to 100
	70 to 85	180 to 200	0.015 to 0.020	90 to 100
Balsam fir	70 to 85	180 to 200	0.010 to 0.015	90 to 100
Above Zero				
White spruce	70 to 85	180 to 200	0.01 to 0.02	130 to 150
	70 to 85	120 to 160	0.01 to 0.02	90 to 100
	60 to 70	180 to 200	0.015 to 0.02	90 to 100
	60 to 70	160 to 180	0.01 to 0.015	90 to 100
Balsam fir	70 to 85	180 to 200	0.015 to 0.02	130 to 150
	70 to 85	160 to 180	0.015 to 0.02	90 to 100
	60 to 70	160 to 180	0.01 to 0.015	90 to 100
	70 to 85	120 to 160	0.01 to 0.015	90 to 100

<sup>a</sup>In descending order of relative ease of obtaining the recommended settings within each category (not barking quality).

<sup>b</sup>If the sharpness angle is less than 45 degrees, the radius can be increased by 0.010 inch.

<sup>c</sup>For a machine with five 1-inch tools and a rotor speed of 400 rpm.

temperatures, within the tool-tensioning capability of the machine, the large radius was simply too blunt to keep the tool at the proper depth, and high residual bark values were obtained.<sup>3</sup>

Only tools 2, 6, and 7 gave consistently good results (i.e. less than 1.0% residual bark) below zero. Tools 1, 3, and 4 gave consistently higher values, while tool 5 provided a few readings within the acceptable range. With the exception of tool 6, all "successful" tools had cutting-edge radii in the 0.010- to 0.020-inch range. Tool 6 had a 0.030-inch cutting-edge radius, but this was combined with a large hook angle. Tool 4, while showing a low cutting-edge radius, was not used often at temperatures below zero (because of the difficulty of replicating weather conditions), and therefore did not have an opportunity to yield much information.

#### Barking Quality

Since barking quality depends on two values (residual bark and wood loss), it is difficult to evaluate as a single response. Both factors must

<sup>3</sup>It should be noted that criticism of the tool is not intended here. The manufacturer's shop manual describes techniques for modifying these tools for low temperatures.

be considered simultaneously to obtain the most desirable trade-off between the two extremes of high wood loss with no residual bark and high residual bark with no wood loss. Residual bark is unquestionably the more important value, and the pulp mills have rigid specifications in this regard. Consequently, it becomes a matter of assigning relative importance to the two factors realistically.

During the study, a hypothetical measure combining both factors was developed in terms of *dollar loss per ton*. It was based on two assumptions:

- (1) bark in the pulp furnish costs a certain amount of money to remove or bleach and utilizes chemical without yield; and
- (2) fiber loss can be accounted for in terms of pulpwood prices.

This was in no way intended to represent an economic standard but to serve as an index for comparison.

For analytical purposes, we chose to consider 1% the maximum acceptable residual bark content and assigned it a processing cost per ton of \$4.50. At a wood furnish cost of \$33.60 per ton the equivalent wood loss would be 13.4%. Between the two extremes of 1% residual bark with no wood loss and 13.4% wood loss with no residual bark a "constant loss" (\$4.50) curve was developed (Anon. 1971). Pairs of observations (residual bark and wood loss) *for each condition* were then checked against this curve to produce Table 4.

Of the logs barked at temperatures between -24 and 0°F according to Table 4 specifications, 75% actually met the 1.0% residual-bark criterion. Their weighted mean residual-bark content was 0.4%, while the weighted mean residual bark of all logs barked according to the recommendations was exactly 1.0%. This implies that if our run of logs was a representative sample, following Table 4 recommendations would produce an acceptable *carload* average of 1% residual bark. In the "above zero" category (0 to +32°F) 85% met the criterion with 0.36% average residual bark.

It may seem unrealistic to equate a 1% residual-bark value with a 13.4% wood loss. This, of course, is the result of arbitrarily weighting each factor and could easily be changed to suit new circumstances. It should also be added that actual wood loss measured during the study was low and never reached this percentage. The average value for the below-zero samples was about 1.5%.

#### Feed Speed

The recommendations shown in Table 4 are made in terms of the machine used in the study. However, from results of both the Pilot Study and the present report, the values can be modified for general application. Feed speed, for example, is not actually a machine parameter. It is limited by two factors: the rotor rpm and tool width. To illustrate this, the machine used had a rotor speed of approximately 400 rpm. With five tools,



each with a net cutting-edge width of about 1 inch, the total maximum length per minute is

$$\frac{400 \times 5 \times 1}{12} = 167 \text{ ft}$$

This is the maximum rate of feed, at this rotor speed, for any condition. The recommended feed speed at low temperature is around 100 fpm, which results in an overlap of approximately 0.40 inch per tool. This is required at low temperature.

### Angle of Attack

Angle of attack, rather than specific tool geometry, is shown in Table 4. Angle of attack is governed by three factors: the hook angle, the pivot position of the tool arm, and log diameter. The hook angles shown in Table 1 indicate that for a given pivot point and log diameter, angle of attack increases from tool 1 to tool 6, and drops again for tool 7. Similarly, in machines with different pivot points, angles of attack can be controlled to some degree by altering the hook angle. The angle of attack increases with decreasing log diameter (Fig. 3).

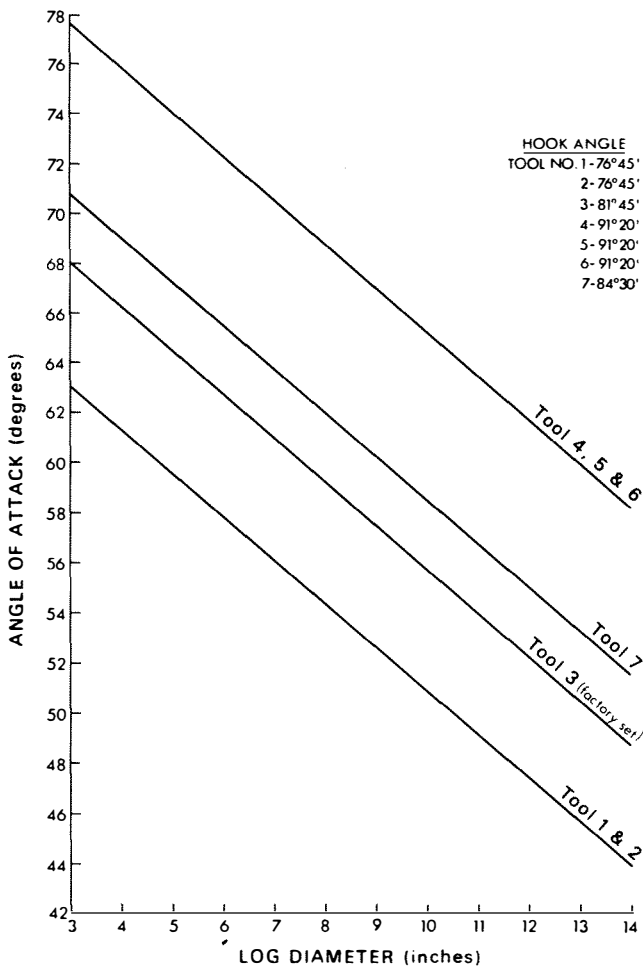


Figure 3. Angle of attack in relation to diameter and hook angles for tools used.

### Tool Load

In machines with rubber tensioning bands the load on the tool increases with increasing log diameter, thus showing a desirable tendency to offset the centrifugal force of the tool. In machines where the tool opening has no effect on the preset tool loading, the latter should be decreased with diminishing log size.

### Sawlog or Pulpwood

One matter that should be considered in interpreting or evaluating the results of this study is whether barking is to be carried out on sawlogs or on pulpwood. The significant point here is that for sawlogs only about 15 to 25% of the original log volume will be chipped. From this viewpoint barking must be of higher quality for sawlogs than for pulpwood, which requires the chipping (or grinding) of the entire log. By the same token, more care must be taken in barking small logs than in barking large logs.

Since the presence of residual bark is a surface phenomenon, it is clear that if the same amount of bark remains while only one-quarter of the wood is used (for chips), the percentage will increase fourfold. Obviously, the 1% value achieved in the roundwood sample described earlier will not apply for sawlogs. These studies, then, show that it will not be possible to meet the 1% specification in barking sawlogs at below-zero temperatures.

What of the sample of logs barked at temperatures between 0 and +32°F to 0.36% residual bark? In estimating what the equivalent would be for sawlogs we assumed (1) that 25% of the log volume would be chippable residue and (2) that 20% of the log surface was removed by either headsaw or edger saw. The residual bark percent corresponding to these conditions was 1.1%. Thus, for sawlogs barked in the 0 to +32°F range, the 1% criterion can be closely approached. However, the two foregoing assumptions are probably extreme. Perhaps it would be more realistic to assume 15% and 15% respectively, in which case the specification would not be achieved (the result would be 2.0% residual bark).

One way in which the residual bark specification could be met under these circumstances would be to deliberately remove more wood than is ordinarily desirable. With the basic recommendations in Table 4, this could be achieved by increasing the load on the tool, sharpening the cutting edge to a smaller radius, or a combination of the two.

### Uncontrollable Factors

Why do some logs show higher values? In the foregoing exercises we were relying on controllable machine variables to produce the desired result. We know, as revealed in Tables 2 and 3, that other factors have a significant bearing on the result. These include MC and, to a lesser extent, log size and straightness. It is not practical, however, to assume that these factors can be controlled even though they are important. Consequently, in using the recommended settings, we expect variation in the result because of inherent variation in those uncontrollable log factors.

Mateev (1967) conducted laboratory experiments on the resistance of bark to removal by shear. Although he carried out this work at temperatures above freezing, he found that as bark MC decreased, resistance increased, on index, from 1.50 to 1.77 depending on species and maximum MC. The results of the present study as well as the Pilot Study have indicated that this trend holds at below-freezing temperatures.

For ring-type barking of sawlogs at low temperatures, Pokryshkin (1965) recommended tool loadings of the order of 195 to 250 lb/inch of edge combined with a cutting-edge radius of 0.8 to 1.0 mm. However, feed speeds of 52 fpm and rotor speeds of between 170 to 190 rpm (giving a tool overlap of 0.25 inch) were considerably lower than in the present study. Also, he did not define barking standards except to say that they were acceptable.

#### Potential for Improvements

The most feasible area of improvement probably lies in some pre-treatment of the logs (i.e. treatment before they enter the barker). The use of conventional hot ponds and steam tanks has been mentioned. Under certain economic and technical operating conditions, these are clearly most efficient techniques. However, the ideal solution to the problem of pre-treatment lies in a method that would not be restricted to large, permanent sawmills or pulpmills. The constraints are: (1) water may not be used (since freezing limits its use and availability) and (2) the machinery must be portable (or semiportable). Other people have been working along these lines. Berlyn (1970) experimented with cutting slits lengthwise through the bark of frozen logs with some success. Simonov (1969) reports on experimental work carried out in the Soviet Union, where frozen logs were "squeezed" before barking. According to the report squeezing destroys, or considerably weakens, the mechanical bond between wood and bark. The Eastern Forest Products Laboratory has also begun investigations into various methods of pretreatment in the broad-type thermal, mechanical, chemical, and electrical categories and any combination thereof.

### Conclusions

By using recommended machine settings, it is possible to obtain 1.0% residual bark or less in below-zero conditions.

For sawlogs this would not be good enough since only 15 to 25% of the log is chippable.

Future work should probably concentrate on some form of pretreatment.

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## Appendix I

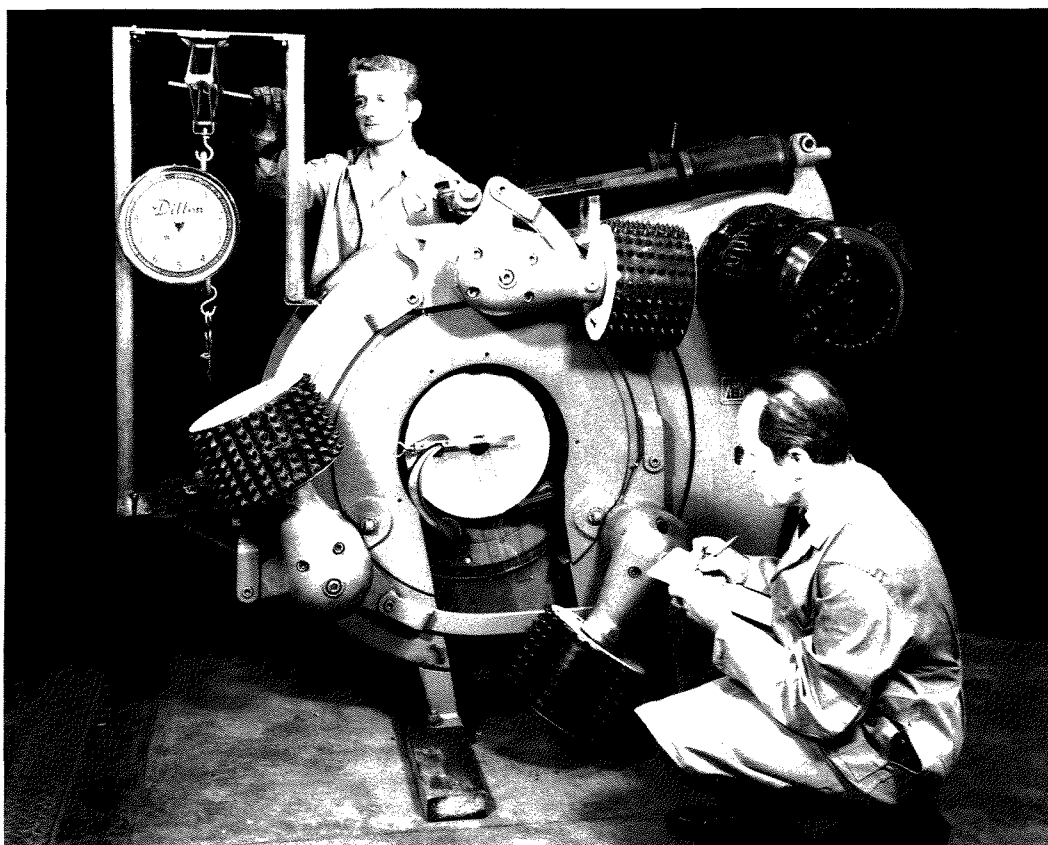
### Measuring Static and Dynamic Loads on Tools

## Appendix I

### MEASURING STATIC AND DYNAMIC LOADS ON TOOLS

The tools of the barker are attached to pivot shafts, which in turn are mounted in bearings in the rotor ring. Tension is achieved by rubber bands looped between the crank of the pivot shaft and the tensioning ring. Tool pressure is controlled by rotating the tensioning ring with respect to the rotor ring.

Static loads were measured tangentially to the arc described by the tool at its intersection with the tool-opening circle. The resulting lines, corresponding to various log diameters, were drawn on a circular chart clamped to the rotor (Fig. 4). Tools were deflected from the central position by pulling their tips with a hook and cable the other end of which was fastened to a scissors jack. At a given tool opening, the rotor was positioned so that the tangential force was indicated on a dynamometer installed between the hook and the jack.



*Figure 4. Measuring static tool loads.*

Static loads were measured for different tool openings (log diameter) at several tension settings. Variation among tools at given settings was less than 5%. Calibration showed an increase in load with tool opening, for a given setting. These measurements were taken periodically to determine whether loss of tension occurred in the bands over the period of study.

The actual load on the tool during barking (P) is equal to the static load, as measured, less a component due to inertia force, and may be represented as follows:

$$P = P_{\text{stat}} - \Delta \text{ dyn}$$

The dynamic component was evaluated as follows:

First, the center of gravity was determined experimentally for each tool; variations among tools proved to be negligible. Next, the distance r between the tool center of gravity (A) and the rotor center (O) was measured for a given tool opening. The angle  $\theta$  was also measured (Fig. 5). The dynamic force component, whose line of action coincides with that of the static force component, equals

$$\Delta \text{ dyn} = \frac{PB}{PT} \cdot F_c \cos \theta + \frac{AB}{PT} \cdot F_c \sin \theta$$

The tool inertia force was determined from the formula

$$F_c = \frac{W}{g} r \omega^2$$

where  $F_c$  = tool inertia force (lb)

$W$  = tool weight (lb)

$g$  = acceleration due to gravity ( $g = 386 \text{ in/sec}^2$ )

$r$  = radius of rotation of the center of gravity of the tool (in)

$\omega$  = angular velocity (rad/sec)



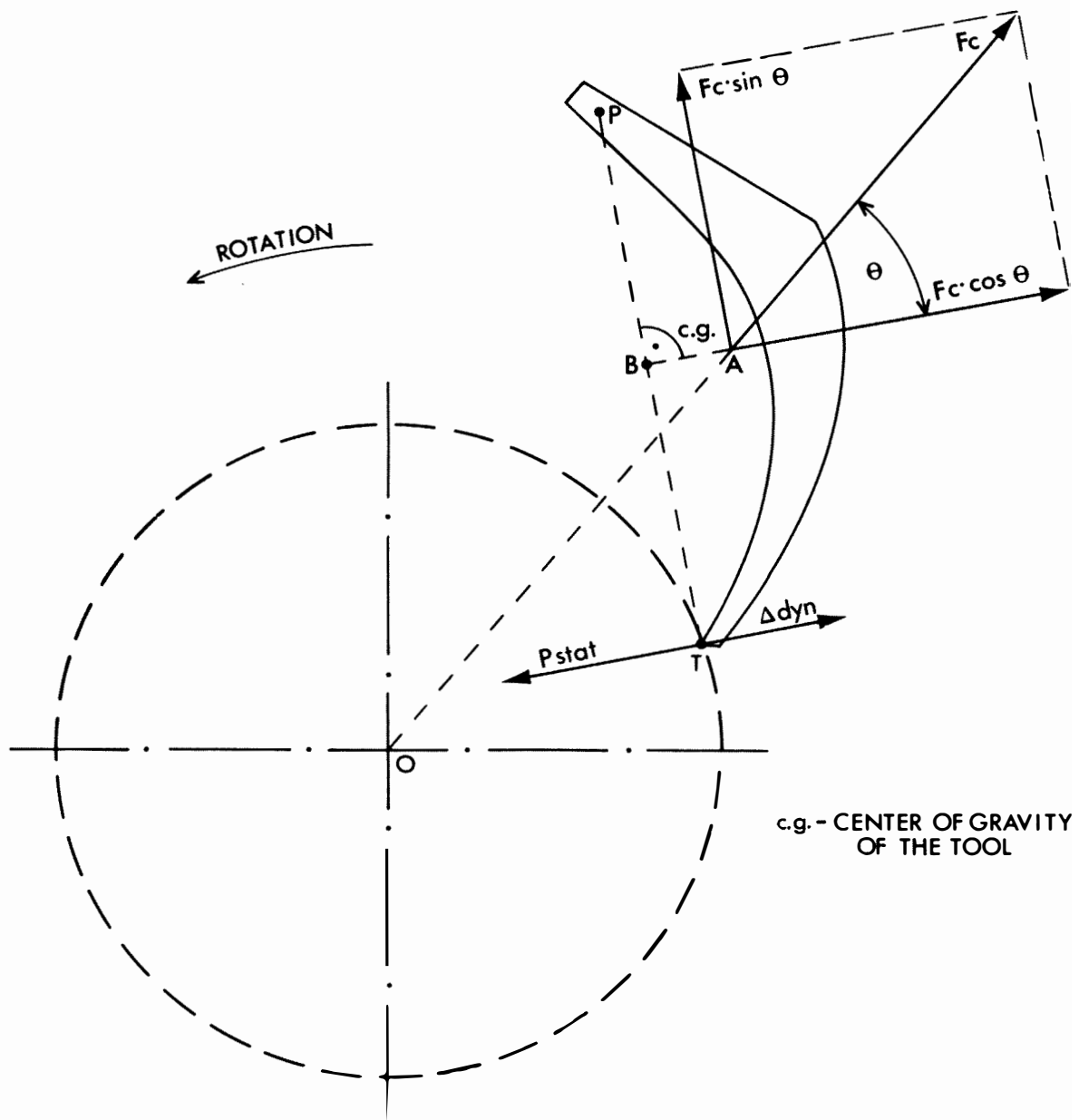


Figure 5. Geometric model used to estimate tool dynamic-load component  $\Delta_{dyn}$ .

## Appendix II

## Appendix II

One of the features of barking tools in many ring-type machines is their self-opening capability, which is usually due to a "climbing lip" on the leading edge. This edge has a prescribed radius (or series of radii) that is carried almost to the tool tip. The climbing lip is filed sharp and functions as follows:

As the log is forced against the face of the rotating tool, the climbing lip engages (and notches) the log face presented. Because of the rotary movement of the tool and the longitudinal movement of the log, the tool is forced to open and "rides" this notch for its entire length. The opening operation is terminated when the tool rides up onto the bark surface. It is at this point - the transition from the climbing lip engaging the cross section to the cutting edge engaging the log surface - that trouble can occur. Since the tools have a corner radius, the climbing lip is not faired into the cutting edge. The corner radius thus acts as an inclined plane, which forces the tool laterally up onto the log surface for this last short distance. Usually there is no problem. However, with modification and the use of high tool tensions (loads), a set of these tools occasionally does not "ride" to the surface but cuts well below. This "pencil sharpening" action, of course, damages the log severely. It also puts extreme stress on the tools and can break them.

One way to overcome this, in building up the inside of the tool to give a greater hook, is to retain the original radius (radii) of the climbing edge. Toward the tip, because of the buildup of material, a blunt edge will result. A small grinding wheel can be used here to remove a hollow-ground notch faired into both the climbing edge and the cutting edge. A slight corner radius is then put on the climbing-edge portion and another on the cutting edge. These constitute two inclined planes, or can be thought of as a single curvilinear plane. These areas are blunted and polished. Grinding the notch, of course, somewhat reduces the width of the actual cutting edge of the tool. Fig. 2 shows this, and Fig. 6 shows the opening action.

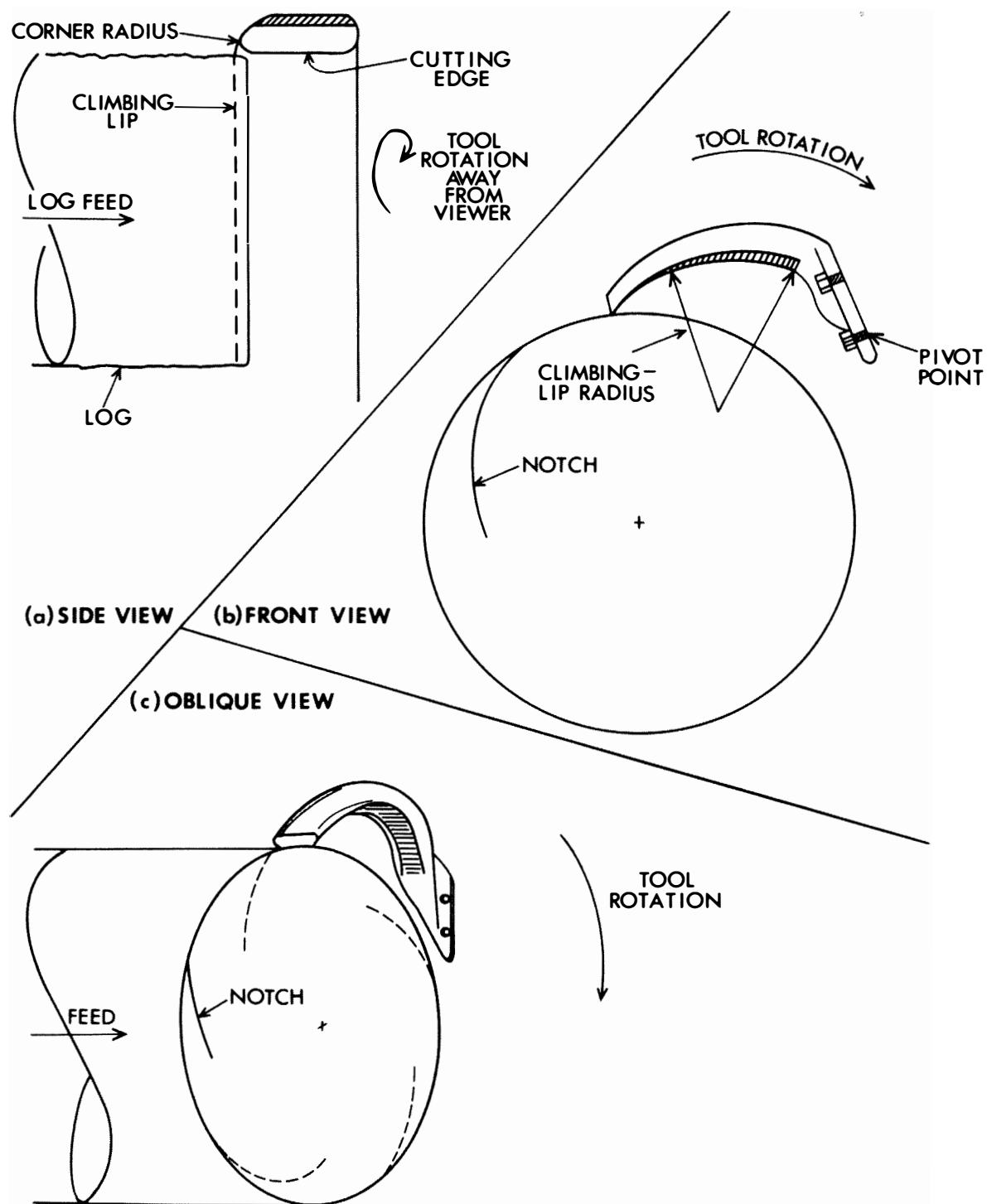


Figure 6. Opening action of tool as log enters debarker.

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