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INSTITUT CANADIEN DE RECHERCHES EN GÉNIE FORESTIER

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Evaluation of the Jerabek Cutting Attachment for Chain Saws

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PREFACE

This report presents the results of a FERIC evaluation on the Jerabek cutting attachment design for chain saws. The design concept was the subject of both short-term and limited field trials. The short-term evaluations describe the design's kickback magnitude, cutting performance and lubrication efficiency as measured under controlled conditions. The field trials outline the results obtained from the professional forest worker.

Details of the study procedures and analyses, plus results of limited interest, have been omitted from this report for the sake of reasonable brevity.

All saw chain dimensions are presented in Imperial units to conform with standard practice. All other quantitative data throughout the report are given in "SI" (Système International d'Unités) units. A table for conversion to Imperial units is provided in Appendix A.

The author would particularly like to thank the following companies for their help and cooperation during the study:

Omark Industries
Homelite-Terry Textron Ltd.
Prince Albert Pulp Company Ltd.
Nova Scotia Forest Industries

Grateful appreciation is also extended to FERIC employees D. MacGregor and K. Hadley for their technical assistance.

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SUMMARY

The advent and steady growth of mechanization since the early 70's has replaced many manual logging methods in all phases of woodlands' operations. However, the most important and versatile logging tool is still the chain saw.

Continuing efforts to increase chain saw safety have concentrated on reducing their weight, noise, vibration and kickback levels. It is recognized that ideally it is best to eliminate safety-related problems at their source. In relation to kickback, this focuses attention on the design of the guide bar and saw chain. The design problems encountered however, are not limited to safety concerns alone but include the product's cutting performance and reliability.

Attempts to bridge the gap between the losses in performance usually associated with increasing safety margins led a Canadian inventor to design the Jerabek cutting attachment for chain saws. The claim that the design minimized kickback energy while enhancing cutting performance and reliability led FERIC into the fabrication and evaluation of the concept.

The Jerabek concept basically consists of modifying the chain saw's cutting components including the bar, chain, drive sprocket and lubrication system. The design claims to reduce kickback through modifications to the saw chain which is mounted on a symmetrical, narrow nose, armor-tipped guide bar. Efficient lubrication of the bar and chain is achieved by the bar design's use of centrifugal force and is maintained by the system's reduced susceptibility to accumulate impurities. Moreover, efficient lubrication coupled with an increased contact area between the bar and chain is said to minimize chain expansion, thus providing a greater degree of control on the cutter's approach angle for optimum performance.

FERIC evaluated the Jerabek design in February 1983 at Omark industries research and development facilities located in Portland, Oregon. These initial short-term tests concentrated on measuring the experimental unit's performance in terms of kickback energy and cutting speed. Field trials were also conducted at Prince Albert Pulp Company Ltd. in April 1983 and Nova Scotia Forest Industries during the months of September, October 1983 and January, February 1984.

The short-term results supported the knowledge that narrow nose guide bars reduce kickback magnitude and probability, and that a further enhancement is achieved by removing the nose sprocket. However, while the experimental saw was safer than the average professional combination tested, it could not compete against new generation products in terms of kickback reduction.

In terms of cutting performance, the design suffered somewhat along the bar's longitudinal axis and was 50% slower at the nose area compared to the standard professional combination. This lack of aggressiveness could be made up by applying more feed force, thus demanding more work effort by the operator.

The lubrication system's incorporation of an "O" ring seal between the bar and mounting pad as well as the bar's self-cleaning characteristic proved to be most effective. However, the temperatures developed at the experimental bar's narrow nose exceeded other standard armor-tipped and sprocket nose bars in all nose-clear, nose-buried and boring cutting tests. In the boring test, the experimental bar reached temperatures in excess of 200°C compared to 160°C for the larger radius armor-tipped bar and 80°C for the sprocket nose bars. These results indicate that the superior contact area between the bar and chain could not adequately compensate for the greater heat generated by the design's use of a narrow, hard nose guide bar. Theoretically, more heat means greater friction and increased component wear. In addition, overheating translated into more chain expansion creating a tensioning problem and an additional safety hazard.

During the field trials, major concerns surrounding the design's reduced cutting speed, extra work effort required and the associated bar and chain overheating problems rendered the saw unacceptable for extended professional use, regardless of the safety levels obtained.

The results did demonstrate that significant reductions in kickback energy can be obtained with existing state-of-the-art products, but at some penalty in terms of production performance. Until the present trade-off in performance is eliminated through better design, the greater use of safer products by chain saw operators within the professional sector will only come with a change in attitude and/or work habits.

INTRODUCTION

The last decade has seen many changes with respect to the methods and machines used to harvest wood in Canada. The growth of mechanization in all phases of woodlands' operations has striven towards decreasing the amount of lost man days from injury and to increasing productivity. This strategy has proved viable in many areas. However, the predominant harvesting tool remains the chain saw.

In recent years, the chain saw has been the focus of much attention, especially in terms of safety. These safety concerns include the product's vibration, noise and kickback levels. While the effects associated with excessive noise and vibration are important, the kickback phenomenon continues to receive the most attention.

The chain saw development story has seen many advancements with respect to reducing accident and industrial disease rates from all of these sources. These developments include the promotion of protective clothing, additional eye and ear protection, anti-vibration handle bars, the installation of front and rear hand guards, as well as chain brakes, and the use of safer bar and chain designs. While some of these options are after-the-fact type remedies, it is recognized that the best gains could be achieved by controlling the problems at their source. In terms of kickback this meant the rationalization of bar and chain design. The dilemma faced by designers is how to achieve the elimination or minimization of kickback energy while maintaining acceptable performance and component life.

The claims of one Canadian concept of increased safety with no apparent loss in production or reliability received much industry attention. This interest led FERIC to fabricate a number of experimental saws for subsequent evaluation within the professional logging industry. This report describes the results of this evaluation.

THE JERABEK CONCEPT - A DESCRIPTION

New design concepts can be conveniently categorized into two groups; those designs that are revolutionary, and those that would be considered evolutionary. The Jerabek design for chain saws would fall into the latter category, that is evolutionary. The Jerabek design concentrates on modifying the chain saw's cutting components including the bar, chain, drive sprocket and lubrication system. Modifications to the power head are confined to the bar mounting pad area and geometry of the drive sprocket cover. These design changes are illustrated in Figure 1, and are further described below. A full and complete description of the concept's specifications can be obtained by referring to Canadian patent number 373-686.

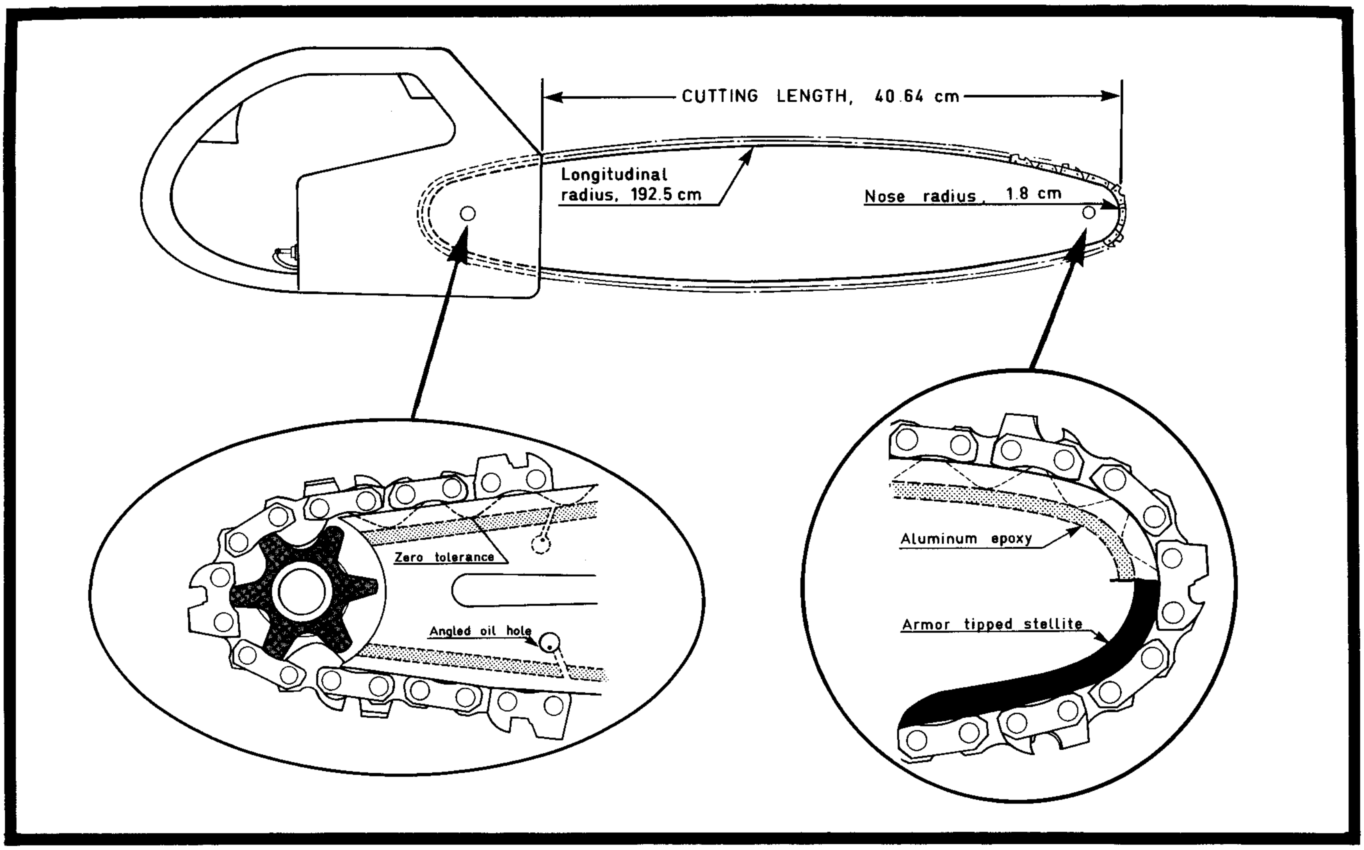


Figure 1. The main features of the Jerabek design include: A symmetrical guide bar having two radii of curvature with a narrow, armor-tipped nose to reduce kickback; a raised bar groove bottom to enhance lubrication and cleaning; the installation of an "O" ring between the mounting pad and bar for effective oil port sealing; a six-tooth, spur-type drive sprocket equal in radius to the bar nose; and a saw chain with its sliding surfaces contoured to match the guide bar's two curvatures.

Guide Bar Design

The Jerabek bar design has a few features which set it apart from existing products. First, the bar has two radii of curvature; one at the nose and another along the longitudinal axis. Curved bars are not new to the art, however most vary in curvature along their length.

As illustrated in Figure 1, to maintain symmetrical chain travel on both sides of the bar, the nose and drive sprocket radii are identical, 1.8 cm. The small nose radius is armor-tipped with a long wearing stellite material and contains no nose sprocket. The longitudinal radius is 192.5 cm giving an actual cutting length of 40.64 cm. The principle behind the constant radius of curvature is to facilitate the movement of lubricating oil to all parts of the chain by making use of the centrifugal force developed. These same forces would also assist in the removal of wood fibre from the chain as it exits the kerf area.

Saw Chain and Drive Sprocket Design

Design changes to the saw chain concentrate on altering the shape of the tie straps and cutters. As shown in Figure 1, the bottom edges of the tie straps and cutters are contoured with a pair of curved surfaces. The heel and toe area are given the same radius of curvature as the longitudinal axis of the guide bar. The second curved surface is centrally located and matches the radius of the guide bar nose and drive sprocket. The cutter dimensions are also changed to meet a 1:2 height to length ratio by extending their heel area to provide better stability.

The saw chain is driven by a six-tooth, spur-type sprocket which is mounted onto an inboard clutch assembly. An inboard, as opposed to outboard, clutch assembly is used as the design does not make use of a chain brake mechanism. To assure smooth chain transfer, the space provided between the drive sprocket and guide bar is minimal, and the top of each sprocket tooth has the same radius of curvature as the guide bar nose. The design aim is to mesh the contact points of the moving parts together properly to reduce wear.

Lubrication System

Ensuring continuous positive lubrication of the bar and chain required additional design changes. Lubricating oil is prevented from escaping between the mounting pad and guide bar through the installation of an "O" ring, thereby providing proper sealing (see Figure 2). In addition, to avoid blockage, the oil injection hole in the guide bar is positioned in the bottom of the bar groove or side rails, and is angled in the direction of chain travel (see Figure 1). The bar groove depth is also raised with aluminum epoxy to provide zero clearance between the chain's drive links and the guide bar groove bottom. Such close tolerances are designed to help prevent wood fibre and grit from entering the bar groove and to avoid lubricating oil drainage below the chain's drive links.

DESIGN OBJECTIVES

The objectives of the Jerabek design center on improving the safety, maintenance and performance characteristics of the chain saw's cutting components. These objectives are not met through the alteration of any one component, but through the sum of its parts.

In terms of safety, kickback magnitude is reported to be minimized through modifications to the saw chain which is mounted on a symmetrical narrow nose guide bar. In addition, the guide bar nose area is armor-tipped eliminating the need for a sprocket, thereby improving cutter stability while travelling through the kickback danger zone. While some sacrifice in component life and cutting performance is usually associated with narrow nose bars, the modified lubrication system claims to alleviate these trade-offs. Efficient lubrication of the bar and chain is achieved by the bar design's use of centrifugal force and is maintained by the system's reduced susceptibility to accumulate impurities. Moreover, effective unobstructed lubrication coupled with an increased contact area between the bar and chain is said to minimize chain expansion through good heat transfer, thereby controlling the cutter's approach angle for optimum performance.

Ultimately, it is the design's objective to create a more efficient cutting attachment for chain saws. By maintaining specifications through the elimination of present cutting element inefficiencies, the design is said to make optimum use of the power available thus, theoretically, leading to the use of smaller, lighter saws capable of doing equivalent work.

CHAIN SAW SELECTION AND MODIFICATION

The chain saw selected by the inventor to be modified was the Jonsereds model 520 SP, equipped with anti-vibration handle bar mounts. While the test saw with an engine displacement of 49 cc, was considered by FERIC to be underpowered, it met the inventor's reduced power requirement criteria because of the proposed cutting attachment's superior efficiency. Though a 49 cc saw has approximately 80% the power and weight of the average professional model used in eastern Canada, the potential benefits of reduced operator fatigue and increased shift productivity through the use of lighter saws was considered to be a major factor in the final saw selection.

In the fall of 1982, a total of six Jonsereds 520 SP powerheads were purchased by FERIC for subsequent modification by the inventor. Alterations to the powerhead included the complete rebuilding of the bar mounting area, and relocation of the oil port hole and the chain tensioning pin. To ease bar installation and removal, the standard two bar-securing studs were replaced by one central stud. The guide bar is mounted directly onto the mounting pad and secured with a single large diameter flange-type nut, eliminating the need for a inner and outer bar plate. The engine's crankshaft was re-machined to accommodate the inboard spur-type sprocket, and the outer cover was made to minimize fibre build-up by deflecting wood chips away from the kerf area.

A total of twelve experimental guide bars were manufactured by Omark Canada Ltd., Guelph, Ontario. However, final preparation was performed by the inventor. This included the positioning and drilling of the oil holes, and the raising of the bar groove bottom with aluminum epoxy.

The only existing saw chain deemed to be appropriate by the inventor was the Omark model 91S (see Figure 4). This 3/8" pitch, .050" gauge saw chain has a low cutter profile with a contoured depth gauge to minimize kickback, and is designed for lightweight saws. Alterations to the saw chain consisted of providing the proper contours to the bottom edge of the tie straps and cutters. Figure 2 shows the modified Jonsereds 520 power saw with a close-up of its mounting pad area and narrow nose guide bar.

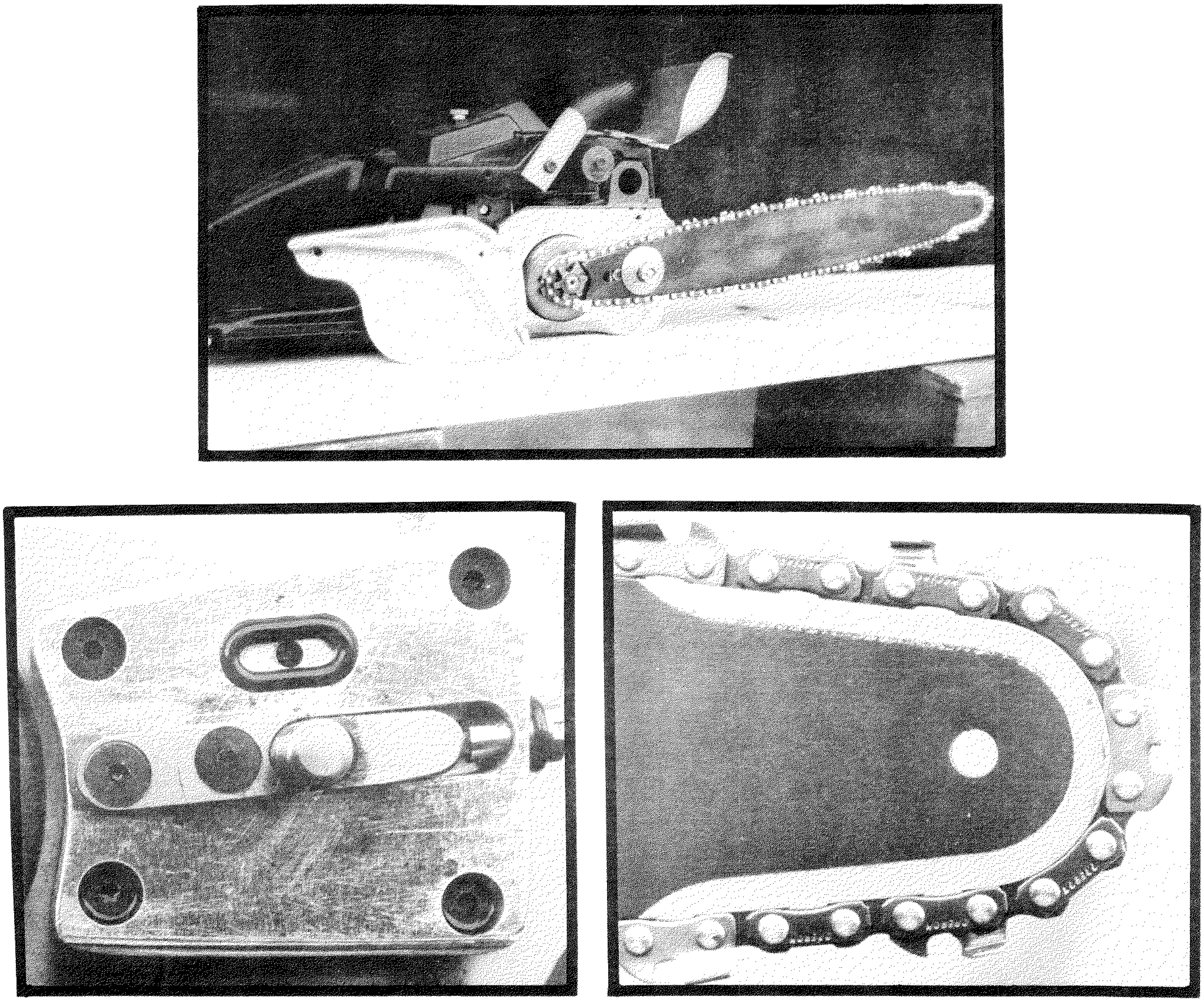


Figure 2. Modified Jonsereds 520 Power Saw.

STUDY RESULTS

Short-Term Studies

To help assess the potential benefits of the Jerabek design, FERIC evaluated the modified Jonsereds 520 saw during one week in February, 1983. These initial tests concentrated on measuring the experimental unit's performance in terms of kickback magnitude and cutting speed, under controlled laboratory conditions. All testing was conducted under FERIC supervision at Omark industries research and development facilities located in Portland, Oregon. For comparative purposes, several tests on existing bar and chain designs were also performed.

Kickback Magnitude

The measurement of kickback energy was performed on the United States, Chain Saw Manufacturer Association's (CSMA) standard test machine. As shown in Figure 3, this machine measures the maximum energy generated at the tip of the guide bar at the moment of kickback. The test saw is mounted in a fixed position so that it can only rotate. A kickback is induced by projecting a carriage mounted wooden composite sample towards the moving chain. The linear backward motion of the carriage, along with the rotational motion of the saw are recorded, then converted into a computed angle of rotation. This is an indication of how far the saw would be expected to travel in the hands of an "average" operator. By varying such factors as the approach angle, velocity and engine RPM, the test procedure attempts to simulate the worst case situation. As the results depict in Table 1, these variables are not constant for all of the test combinations, however the resultant angle of rotation is a measure of the highest energy levels developed.

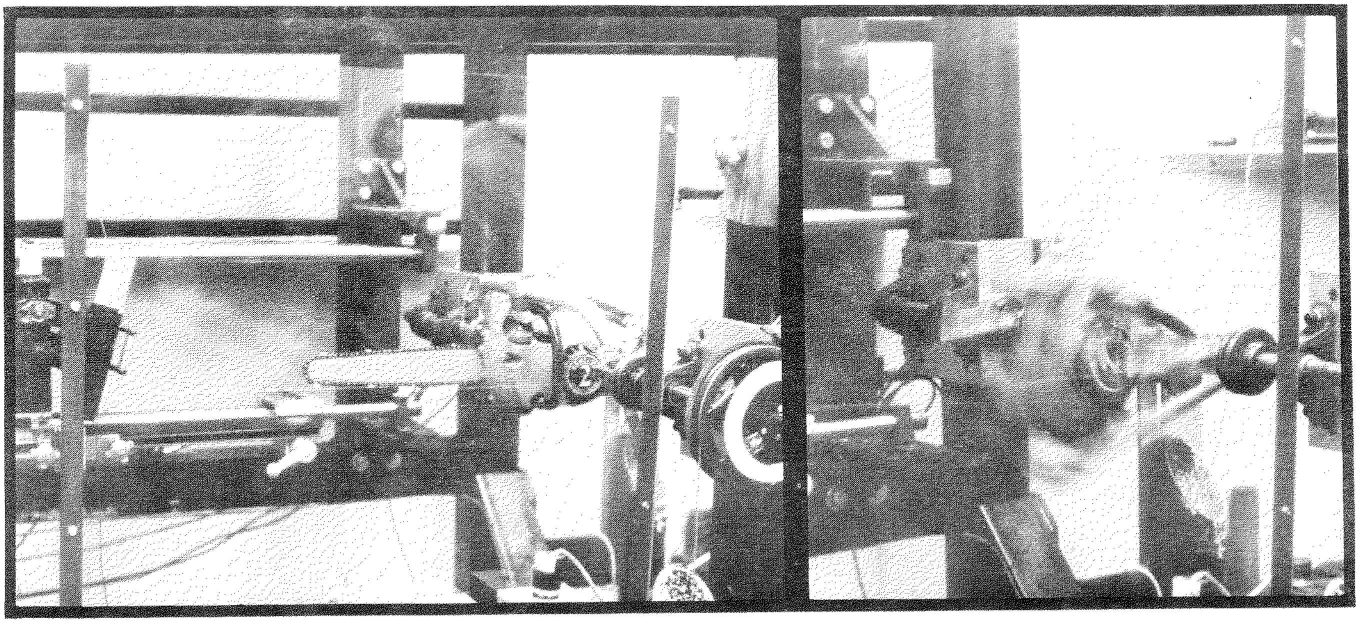


Figure 3. The CSMA kickback machine.

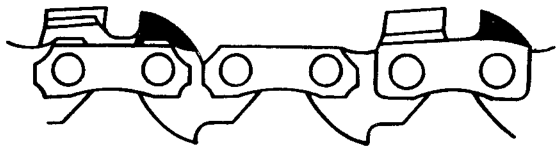
In terms of kickback, a total of six combinations of bars and chains were tested. To avoid possible powerhead variation, all combinations were mounted on the same modified Jonsereds 520 saw. Because of their availability at the testing location, all comparative performance measurements were done against standard off-the-shelf Omark products. This is not to be construed as an endorsement for or against any particular product or manufacturer, merely a matter of testing convenience.

The results of the CSMA kickback tests are presented in Table 1. Time constraints did not permit all of the trials to be run through the complete CSMA test sequence in effect as of February, 1983. The abbreviated test sequence used only the 0.762 m/sec. carriage impact velocity omitting the 0.508 and 0.635 m/sec. impact speeds. Past experience has shown that the highest energy levels almost always occur at the 0.762 m/sec. impact velocity. In addition, all chains were filed to factory recommended angles and depth gauge settings prior to testing.

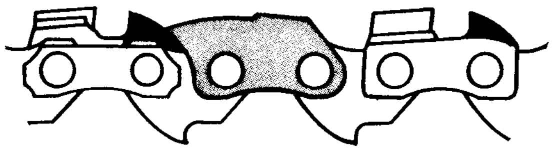
As shown in Table 1, the derived angle of rotation for the Jerabek design is 48^{o} (see test # 1). This represents a 16% reduction compared to the professional combination (see test # 2) using 76 LG chain (see Figure 4) on a 2.34 cm sprocket nose, guard tip bar. While this decrease in kickback angle appears to be significant, it must be remembered that the Jerabek design uses a 1.8 cm hard nose bar and a consumer chain which is inherently less aggressive. The professional combination tested does not represent the highest or lowest energy levels capable of being generated with the multitude of products available, but would be considered to be average. The study did not attempt to establish the present range in kickback angles by surveying the type of products being utilized in the professional sector. As Canada's current certified chain saw standard does not place limits on kickback angles, users have access to high, moderate and low-kickback products.

More importantly, in addition to measuring kickback energy levels, the six product combinations were selected to assess what effect chain design, bar nose radius, and bar nose sprockets have on kickback magnitude.

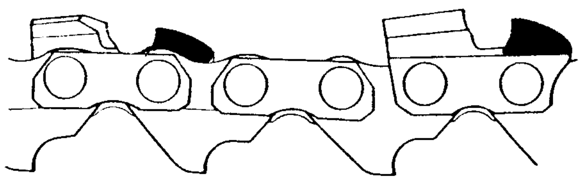
First, to evaluate the effect of chain design, in test number 3, the modified 91S type chain was replaced with a new generation model 91SG saw chain. As illustrated in Figure 4, the only difference between these two chains is that the SG model has a special guard link shield installed between the cutters. These elongated guard links help prevent jamming by allowing the chain to ride out of kickback causing binds, thereby providing extra operator protection. With this safer chain design mounted on the Jerabek bar, the resultant angle of rotation (test # 3) was reduced from 48 to 4 degrees. This significant reduction in kickback clearly demonstrates the safety levels achievable with today's state-of-the-art chain designs.



Consumer Model 91S: This Jerabek modified chain is designed with a low-profile cutter and a ramped depth gauge to minimize kickback.



Consumer Model 91SG: This safer chain design is identical to the 91S with the addition of a guard link between the cutters for extra kickback protection.



Professional Model 76LG: This lightweight professional chain has low chisel-style cutters with curved depth gauges to reduce kickback.

Figure 4. Illustration of the three chain models used in the kickback comparison tests. All models have a pitch of 3/8" and a gauge of .050".

Test combinations number 3 and 4 in Table 1 show the effect of bar nose radius on kickback magnitude. The Jerabek saw (test # 3) with a bar nose radius of 1.8 cm, was compared to a bar having a nose radius of 2.34 cm. Both tests were performed with type 91SG chain, and the standard nose sprocket in the larger diameter bar was removed. The resultant kickback angle with the narrow prototype bar is 4 degrees, or 8 degrees less than the larger radius bar.

TABLE 1. CSMA Kickback Test Comparison Results

	COMPONENT DESCRIPTION				TEST CONDITIONS			RESULTS		
Test #	Chain Model	GUIDE BAR TYPE Model	Nose Radius, cm	Nose Sprocket	Contact Angle (Degree)	Approach Velocity (m/sec)	Engine RPM	Rotary Energy (Joules)	Linear Energy (Joules)	Derived Angle of Rotation
1	Oregon 91S Modified	Jerabek 40.64 cm	1.80	NO	10	0.762	11,000	13.33	1.7	48^o
2	Oregon 76LG	Slim-line GT 40.64 cm	2.34	YES	5	0.762	11,000	13.56	0	57^o
3	Oregon 91SG	Jerabek 40.64 cm	1.80	NO	10	0.762	11,000	2.15	0	4^o*
4	Oregon 91SG	Slim-line GT 40.64 cm	2.34	NO	5	0.762	10,000	3.73	0.34	12^o*
5	Oregon 91SG	Consumer GT 40.64 cm	1.80	NO	0	0.762	9,000	2.49	0	6^o*
6	Oregon 91SG	Consumer GT 40.64 cm	1.80	YES	10	0.762	10,000	4.52	0	17^o

* Abbreviated test sequence.

In addition to reducing kickback magnitude, narrow nose bars also decrease the critical kickback danger area on a bar nose. This occurs because the kickback hazard area on a bar nose varies in proportion to nose radius. As illustrated in Figure 5, the critical danger area of the 1.8 cm Jerabek bar is approximately 85 percent as large as a 2.34 nose radius, or 40 percent smaller than a bar having a nose radius of 3.1 cm. Therefore, product safety is enhanced through a decrease in kickback energy and by reducing the probability or frequency of occurence.

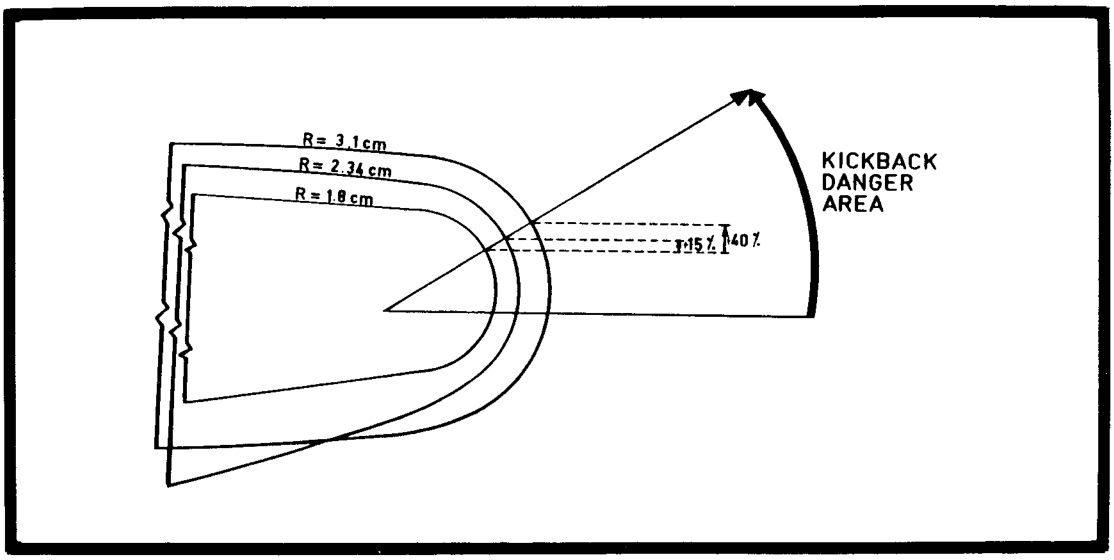


Figure 5. The effect of nose radius on kickback force and probability.

Finally, test combinations 5 and 6 in Table 1 demonstrate the influence bar nose sprockets have on kickback intensity. Both tests were run on the same consumer bar with 91SG chain. The only difference between the two tests was that the nose sprocket in test number 5 was removed. The results clearly indicate that while the chains are still running on an equal radius, the removal of the nose sprocket reduced kickback from 17 to 6 degrees of rotation.

From a kickback stand point, it is clear that the Jerabek design helps reduce kickback magnitude and probability because of its use of a sprocketless, narrow nose guide bar. However, the results also demonstrate that chain design has a much more significant effect on reducing kickback than bar design. Moreover, practical limits are placed on bar and chain design by the market place's expectations of a particular product's cutting performance and component life. While the design objective is to produce the safest, most efficient product possible, some compromise between kickback intensity, cutting speed, and component life must be reached. This dilemma is heightened within the professional sector where high demands are placed on productivity.

Cutting Performance

The second phase of the laboratory tests concentrated on measuring the experimental bar and chain's cutting performance. Again, the results are compared to the same standard bar and chain combinations used in the kickback tests. All tests were performed on a special swath machine designed to measure the cutting speed, feed effort and power requirements of bars and chains independent of operator and powerhead variables.

Two separate types of performance tests were carried out with each bar and chain combination. As shown in Figure 6, the swath machine measures cutting performance along the bar's longitudinal axis with the nose area in a clear position, and with the nose-buried. Because the swath machine could not be fitted with a 6-tooth, spur-type drive sprocket as specified in the proposed design, a 7-tooth rim sprocket was used. While this increased the cutting speed of the Jerabek design, it insured that all test combinations were run at the same chain speed.

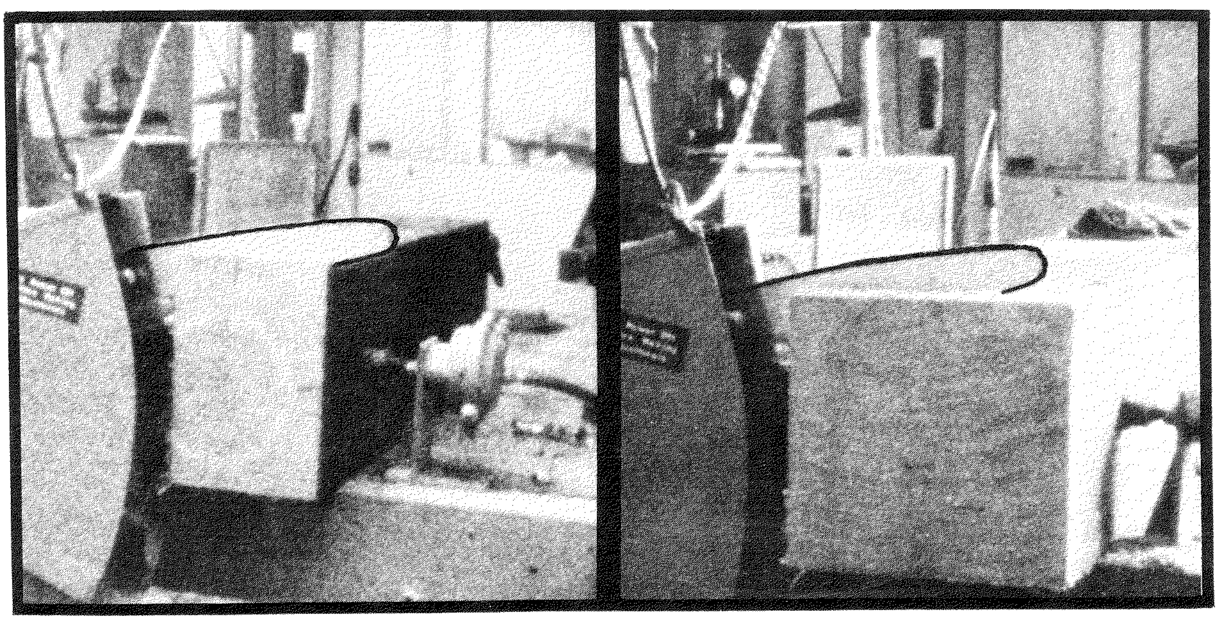


Figure 6. Cutting performance as measured on the swath machine included both nose-clear (left) and nose-buried (right) cutting modes. The machine is not capable of performing a boring type cut.

As shown in figure 6, the nose-clear tests were made in a 20 x 30 cm Douglas Fir cant, and the nose-buried cuts were performed in a 30 x 30 cm Douglas Fir cant. To compensate for the differences in the amount of wood cut because of bar length in the nose-buried mode, the cant was positioned such that an equal amount of wood was cut with each test combination. For each test a minimum of three cuts were done, all within 5% of each other, at feed force pressures of both 35.6 and 71.2 Newtons. In addition, all chains were filed to recommended specifications. The results of the cutting speed tests for the nose-clear mode are summarized in Table 2.

Table 2: Summary of the swath machine cutting performance results for the nose-clear cutting mode.

		AVG. TORQUE (N.m)		AVG. POWER (kW)		CUTTING RATE (cm^2/sec)		EFFICIENCY (cm^2/sec/kw)	
Test #	PRODUCT COMBINATION \ FEED FORCE	35.6N	71.2N	35.6N	71.2N	35.6N	71.2N	35.6N	71.2N
1	Jerabek bar 91S chain, modified	2.96	4.84	1.98	3.22	69.7	110.9	35.2	34.4
2	Consumer GT bar 91S chain, modified	2.64	4.51	1.76	3.00	67.4	108.7	38.3	36.2
3	Consumer GT bar 91SG chain	2.53	4.27	1.70	2.84	60.6	101.1	35.6	35.6
4	Professional GT bar 76LG chain	3.25	5.11	2.17	3.39	80.4	121.0	37.1	35.7

As presented above, the cutting performance of the professional combination (test # 4) was the fastest, and the new generation 91SG guard link chain (test # 3) was the slowest. The Jerabek (test # 1) and the consumer GT bar, 91S chain (test # 2) combinations fell approximately in between the highest and lowest cutting products.

In terms of cutting rate, the Jerabek design (test # 1) was 13% slower than the professional combination at the 35.6 Newton feed force pressure, and 8% less at the 71.6 Newton feed force. The Jerabek design cut slightly faster (3 and 2% depending on feed force) than the same chain mounted on the standard consumer GT bar (Test # 2). However, this apparent improvement is within the accuracy level of the test machine, thus is not considered to be significant. Compared to the low-kickback 91SG chain, consumer GT bar (test # 3) combination, the Jerabek concept demonstrated a 13% and 9% improvement respectfully. Figure 7 shows these results plotted graphically.

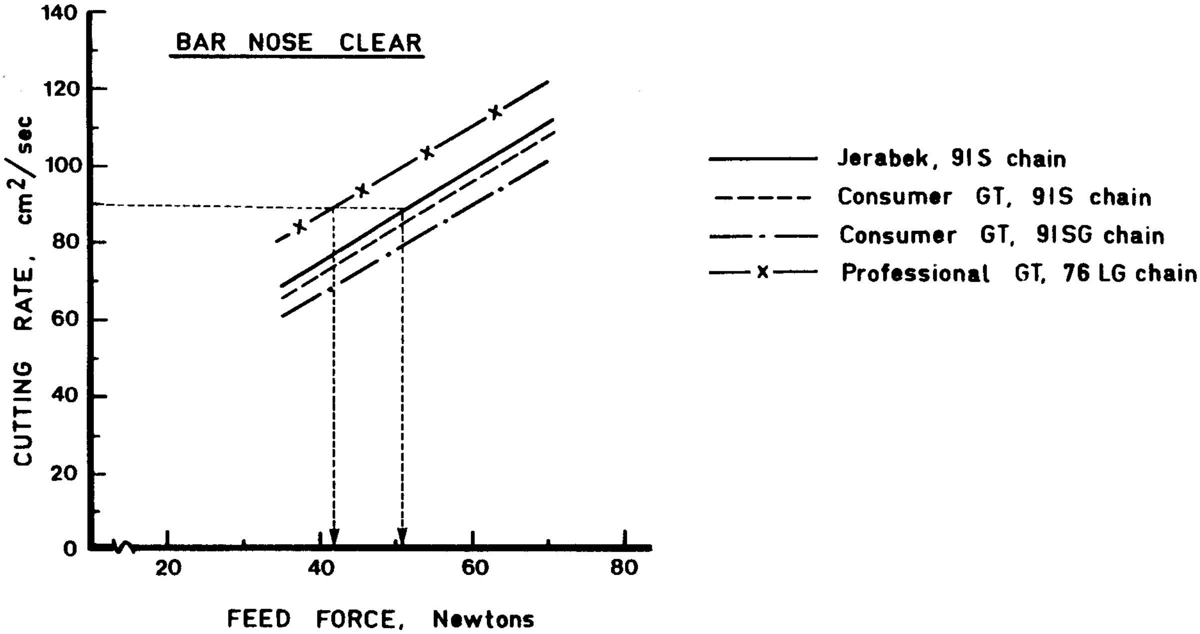


Figure 7. Graphic illustration of cutting rate vs feed force for the nose-clear cutting mode.

In addition to illustrating the slower cutting speed of the experimental design as compared to the professional combination, Figure 7 shows that this lack of aggressiveness can be made up by exerting more feed force. For example, to achieve a cutting rate of 90 cm^2/sec with the professional combination requires 41 Newtons of force. For the experimental design, this same cutting rate requires a feed force of 51 Newtons, representing a 24% increase in work effort by the operator. For the new generation low-kickback 91SG chain incorporating guard links, the extra effort required would be even higher.

As demonstrated, the Jerabek design may have an incremental effect on performance compared to the consumer systems tested, however the performance obtained is not nearly enough to meet the expectations of the professional. More importantly, to the consumer, the decrease in kickback protection awarded with the Jerabek concept may be a large penalty to pay for such an incremental increase in cutting performance.

For the nose-buried results (see table 3), the differences in performance are much more significant.

Table 3. Summary of the swath machine cutting performance results for the nose-buried cutting mode.

Test #	FEED FORCE / PRODUCT COMBINATION	AVG. TORQUE (N.m)		AVG. POWER (kw)		CUTTING RATE (cm^2/sec)		EFFICIENCY (cm^2/sec/kw)	
		35.6N	71.2N	35.6N	71.2N	35.6N	71.2N	35.6N	71.2N
1b	Jerabek bar 91S chain, modified	1.62	3.38	1.10	2.26	24.6	70.9	22.4	31.4
2b	Consumer GT bar 91S chain, modified	2.25	4.05	1.51	2.70	51.7	102.7	34.2	38.0
3b	Consumer GT bar 91SG chain	2.05	3.67	1.38	2.45	44.2	86.6	32.0	35.3
4b	Professional GT bar 76LG chain	2.15	3.99	1.45	2.66	47.7	100.9	45.4	37.9

As presented in table 3, for the nose-buried swath results, the Jerabek design (Test # 1b) has about one-half the cutting rate of the professional (Test # 4b) and the consumer GT bar, 91S chain (Test # 2b) combinations at the light feed force pressure, and is 30% less at the heavier feed force. Compared to the low-kickback 91SG chain (Test # 3b) combination, the cutting rate of the Jerabek concept was 44 and 18% slower respectfully.

Again, as illustrated in Figure 8, to maintain a cutting rate of 70 cm^2/sec with the professional bar and chain requires 48 Newtons of feed force. For the Jerabek unit this same cutting rate requires 68 Newtons of force, representing over a 40% increase in work effort to maintain the same productivity.

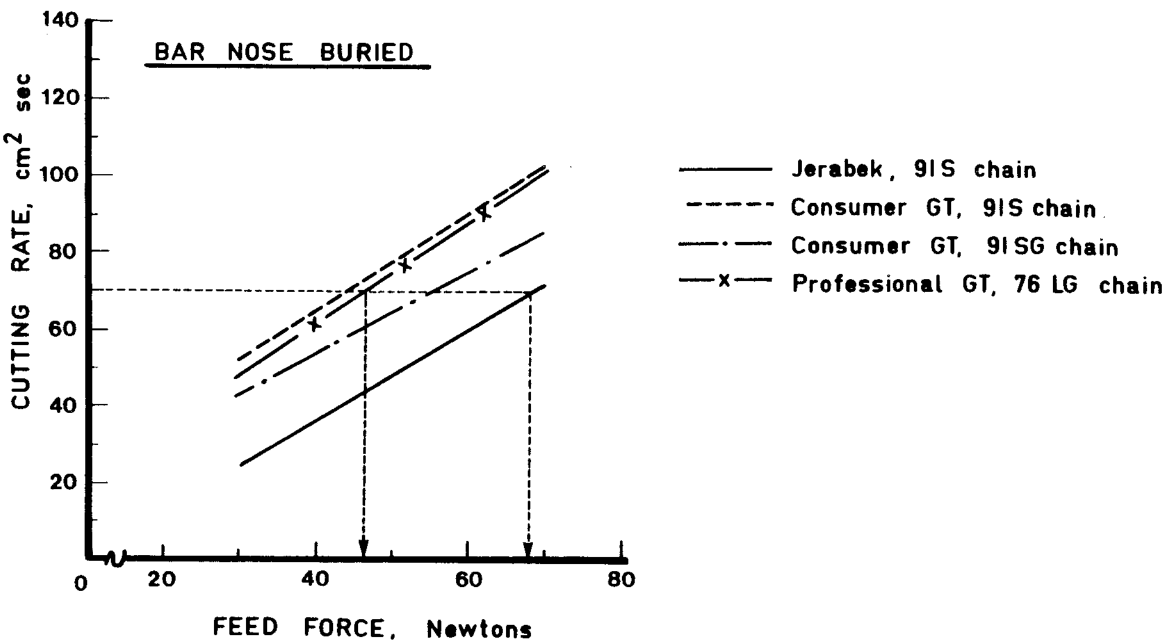


Figure 8. Graphic illustration of cutting rate vs feed force for the nose-buried cutting mode.

The major reason for the Jerabek unit's poor nose-buried cutting speed is attributable to its small bar nose radius. The superior cutting performance of the three conventional combinations is largely due to the non-symmetrical GT bar design. This bar design has two nose radii, a small radius along the kickback danger area to minimize the potential hazard, and a longer radius on the underside section of the bar nose to maintain cutting efficiency. Clearly, the results support the knowledge that narrow nose bars help reduce kickback, however a penalty for this gain is paid in reduced cutting performance.

In terms of cutting efficiency or the cutting rate per kilowatt of power required, the Jerabek design is somewhat inferior in the nose-clear mode and greatly inferior when cutting nose-buried.

Bar and Chain Lubrication

Naturally, the objective of lubrication is to reduce friction, heat and wear of machine parts which move relative to one another. As described on the following page, a series of simple but effective tests was performed to measure the efficiency of the experimental design's lubrication system.

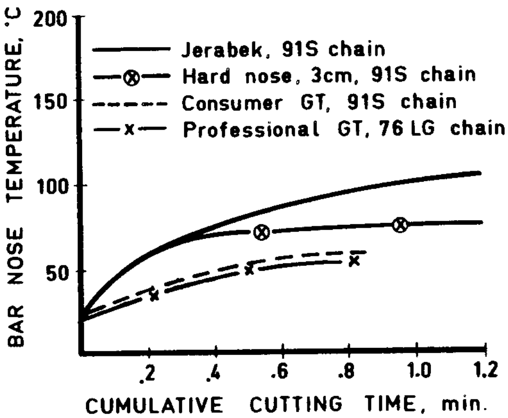


Figure 9a. Bar nose temperature, nose-clear cut.

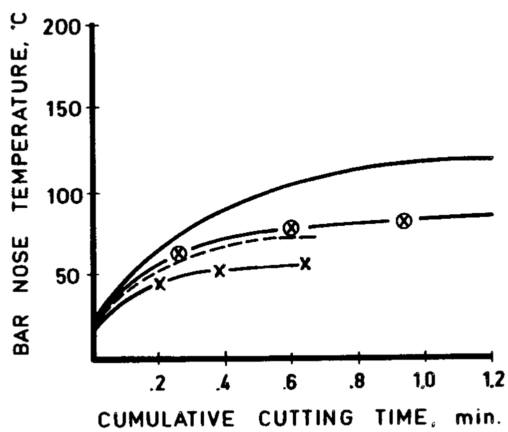


Figure 9b. Bar nose temperature, nose-buried cut.

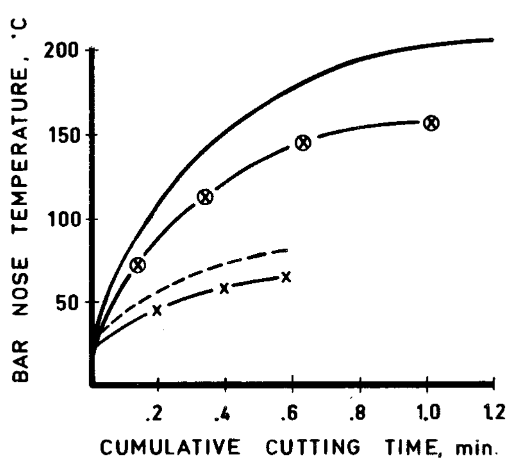


Figure 9c. Bar nose temperature, boring cut.

Figures 9a, 9b, and 9c graphically illustrate the temperatures developed at the bar nose area for armor-tipped and sprocket nose bars of different nose radii. All test combinations are identical to those run on the kickback and swath machines, with the addition of a 3 cm nose radius armor-tipped bar. The test products were mounted on the same modified Jonsereds 520 powerhead and were driven by a six-tooth sprocket, except the professional combination which required a seven-tooth drive sprocket.

All three cutting modes were performed on sound, unfrozen (12°C), yellow birch having an average diameter of 35 cm.

For each cutting mode, a minimum of three to a maximum of nine successive cuts were made with a temperature reading taken between each. The time taken to complete each cut was also recorded. The successive bar nose temperatures reached for each cutting mode were then plotted against the actual cumulative cutting time.

The results clearly illustrate the higher temperatures developed with the Jerabek bar. The other armor-tipped bar was somewhat cooler due to the larger nose radius of 3 cm compared to 1.8 cm for the Jerabek. The sprocket nose bars never surpassed the 80°C point demonstrating their effectiveness in reducing friction.

A total of four bar and chain combinations were tested including two sprocket and two armor-tipped bars. All combinations used 91S chain except the professional bar which used 76LG chain. Each cutting attachment was mounted on the same modified Jonsereds 520 powerhead. All combinations were subjected to a number of successive performance tests in the nose-clear, nose-buried and boring cutting modes. After each cut, the temperature at the bar nose was recorded along with the cutting time.

As illustrated in Figures 9, the results demonstrate the higher temperatures developed with the Jerabek bar in all three cutting modes. For the nose-clear cutting results (see Figure 9a), the narrow nose Jerabek bar reached a maximum temperature of just over 100°C, whereas the larger radius armor-tipped bar leveled out at about 80°C, and the two sprocket nose bars did not exceed 55°C. The temperatures reached in the nose-buried cutting mode (see Figure 9b) were slightly higher for all combinations, however a similar pattern remained. As expected, the boring tests produced the highest temperatures (see figure 9c). The experimental bar reached temperatures in excess 200°C compared to 160°C for the larger armor-tipped bar, and 80°C for the sprocket nose bars. In all cases, the experimental bar developed considerably higher temperatures than the larger radius armor-tipped bar, and at least double the temperatures obtained with the sprocket nose bars.

Theoretically, greater friction means higher temperatures and increased component wear. The superior contact area between the Jerabek bar and chain should allow for a better oil film, reduced load per unit area, and better heat transfer, thus reducing local heat. However, the results indicate that the superior contact area could not adequately compensate for the greater heat generated by the design's use of a narrow, hard nose guide bar. More importantly, the results are compounded by the Jerabek saw's reduced cutting aggressiveness especially at the bar nose area. Thus, to maintain the same cutting speed requires an operator to exert more feed effort, creating more friction and heat.

Moreover, as the temperature rises, the lubricating film gets thinner and there is a greater possibility of metal-to-metal contact, and hence more friction. The higher the temperature, the smaller the bar gap reducing the amount of oil available for lubrication and cooling. This therefore translates into greater chain expansion creating a possible tensioning problem.

Clearly, the results demonstrate the dilemma facing the designer of chain saw cutting attachments. While narrow, hard nose bars decrease kickback, they also reduce performance and increase friction and wear. The installation of a nose sprocket increases reliability while sacrificing safety somewhat. In either case, a compromise must be reached. Unfortunately, the Jerabek design does not appear to bridge the gap significantly.

FIELD TRIALS

April 1983

In April 1983, FERIC attempted to introduce the experimental saws into a logging operation to gather additional information on long-term production and mechanical performance. Prince Albert Pulp Company Ltd., in Saskatchewan was approached and agreed to cooperate in the trials. Two primary reasons were instrumental in selecting Prince Albert for the initial field trials. First, the company had a considerable history of experimentation with new chain saw products and secondly, the relatively small tree size at this location would minimize the influence of the reduced cutting performance obtained.

Because of the experimental saw's shortcomings in terms of lubrication and especially cutting performance, it was felt important to emphasize the design's reduced kickback potential to achieve product acceptability. In addition, the experimental unit's lighter weight was considered to be an important factor in possibly reducing operator fatigue, thereby compensating for the reduction in cutting performance.

Six crews varying in age and experience were selected to take part in the trial. Early field reaction quickly confirmed the short-term laboratory results. While the experimental units were acceptable from a kickback standpoint, major complaints centered on the design's reduced cutting speed and lack of power. The saw chain also has a tendency to fly-off the guide bar creating an additional safety problem. This can be explained by the higher bar and chain temperatures developed which increased chain expansion and slackness. This unstable situation is further compounded by the design's omission of the conventional inner and outer chain guide plates, and the use of a spur instead of a rim-type drive sprocket.

While maintaining proper chain tension was considered a problem requiring more attention, the major concern remained the unit's inferior cutting speed. The operators liked the saw's reduced weight, but had to compensate for its lack of aggressiveness by exerting more feed force to try to maintain the same productivity.

Attempts to improve product acceptability by installing a more aggressive professional saw chain proved fruitless as the larger kerf area further exemplified the lack of power available. Increasing the chain speed by fitting the unit with a 7-tooth instead of the 6-tooth drive sprocket further aggrevated the chain retention problem, thereby rendering the product unacceptable for extended use.

August 1983 - February 1984

In August 1983, a second attempt at collecting comparative long-term data was carried out on the limits of Nova Scotia Forest Industries in Port Hawkesbury, Nova Scotia. The product acceptability problems encountered in the first trial were considerably reduced because of this company's earlier introduction, and continued use of lighter power saws. In fact, many operators used saws having an engine displacement 10% less than the experimental saw's 49 cc rating. This permitted the test units to be appraised strictly on performance rather than size differences.

Initial demonstrations given to company safety and training personnel satisfied any questions concerning the experimental saw's kickback intensity. As the company did not permit saws without chain brakes to be operated on their limits, this was of primary importance. Demonstrations were then given to operators and FERIC's long-term study objectives were explained.

A test unit was used intermittently during the months of September and October 1983 in a commercial thinning operation, and again in January and February 1984 in a conventional cut and pile shortwood operation. The unit worked a total of 27 days and was operated by both training personnel and operators. As experienced in the Prince Albert trial, no problems were encountered concerning kickback and the relative safety provided with the Jerabek saw. However, major problems concerning decreased production remained along with the bar and chain overheating aspects. Again the design was deemed unacceptable by the professional forest worker, regardless of the safety levels obtained.

On the positive side, the operators were satisfied with the bar's self-cleaning quality and the single flange-type securing nut design. The "O" ring seal between the mounting pad and guide bar proved most effective as no blockage of the oil port was encountered.

CONCLUSIONS

The designer's claims of eliminating chain saw kickback while enhancing cutting performance and extending component life could not be supported by the tests conducted in this study. However, the results are instructive in obtaining a clearer understanding of the design parameters associated with producing a safe, productive and reliable cutting attachment for chain saws.

While it is true that kickback magnitude and probability are minimized by the design's use of a small nose radius guide bar, and that a further reduction is achieved by removing the nose sprocket, it remains that major reductions in kickback intensity can and are being realized through design changes to the primary recoil causing agent: *the saw chain.*

Moreover, the practical limitations placed on guide bar and saw chain design are not limited to safety concerns alone, but include the overall reliability, maintainability and cutting speed obtained. The degree to which the benefits of superior safety apply to the professional logger are weighed against these performance criteria. Often, as with the Jerabek design, along with the benefits come a number of compromises. To the professional, the trade-offs measured in terms of reduced cutting performance and the related extra work effort required, as well as the bar and chain overheating problems encountered, all contributed to the design's unsuitability. Questions concerning the saw's actual influence on long-term productivity, reliability, and operator fatigue could not be assessed because of the field trials relatively short duration and thus, will remain a point of discussion. However, the results clearly demonstrate that any product with significantly inferior performance will not be accepted voluntarily by cutters who demand products to withstand sustained rugged use with a high emphasis on productivity, even at the expense of superior safety margins.

Efforts to reduce the compromises between safety and performance has sparked considerable development into the design of more acceptable saw chain and guide bars. Symmetrical and non-symmetrical guide bars of various nose radii are standard items. While armor-tipped bars are available, most incorporate nose sprockets. Sprockets increase kickback somewhat but they have proven to be effective in reducing friction, heat, and wear, thereby increasing reliability while permitting further nose radius reductions. As illustrated in Figure 10, these efforts have also produced a new generation of safety chains for the professional and consumer markets. These chains incorporate many design features which ultimately help minimize the kickback causing agents while trying to maintain acceptable performance levels. Safety enhancement is achieved through the incorporation of such features as low-profile cutters, ramped depth gauges, wider triple rakers and guard links between cutters. While the design shapes and approaches vary between manufacturers, their goal is a common one, to reduce the tendency of the depth gauges to bury themselves in the wood, thus providing a greater degree of control on the amount of bite taken with each cutter. Naturally, maximum effective protection can only be achieved through a design balance between bar and chain.

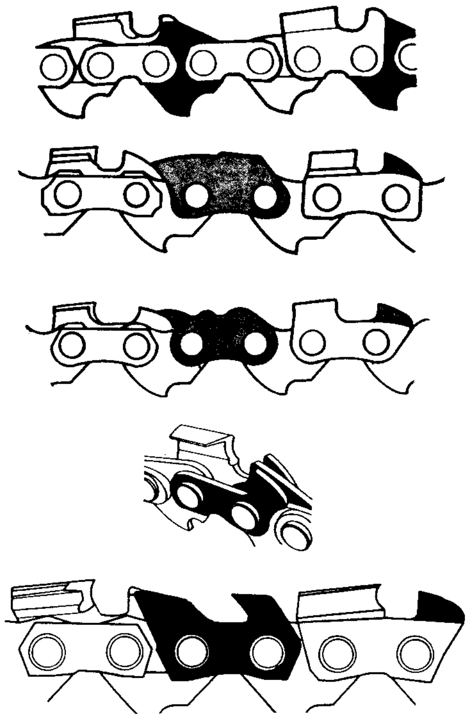


Figure 10. Different types of safety chain

Safety chains utilize different features such as side straps, drive links, depth gauges, and cutters of various design to reduce kickback. Design approaches vary depending on the manufacturer, however all try to reduce kickback and maintain acceptable performance. Safety chains help but proper operating procedures still provide the best protection against kickback.

It is clear that all of these new generation products have the ability to decrease kickback energy levels significantly, but at some penalty in terms of production performance. While this reduction in cutting ability may vary somewhat between manufacturers, it remains that at the present time, the greater use of safer products within the professional sector will only come with a change in attitude and/or work habits. Until the present trade-off in performance is eliminated through better design, users must come to there own best conclusion in choosing a proper balance between production, safety and reliability.

The Jerabek design tested was subject to the same predicament. While its self-cleaning characteristic and the seal between the bar and mounting pad proved effective, the design could not compete against existing products primarily in terms of productivity.

APPENDIX A

CONVERSION TABLE

1 cm (centimetre)	0.39 inch
1 m (metre)	3.28 feet
1 J (Joule)	0.737 foot pounds, energy
1 cc (cubic centimetre)	0.061 cubic inches
1 N (Newton)	0.2248 pounds, force
1 N•m (Newton•metre)	8.85 inch pounds, torque
1 kW (kilowatt)	1.34 horse power

$$\frac{9}{5}{}^{o}C + 32 = {}^{o}F$$