Technical Report No. TR-20
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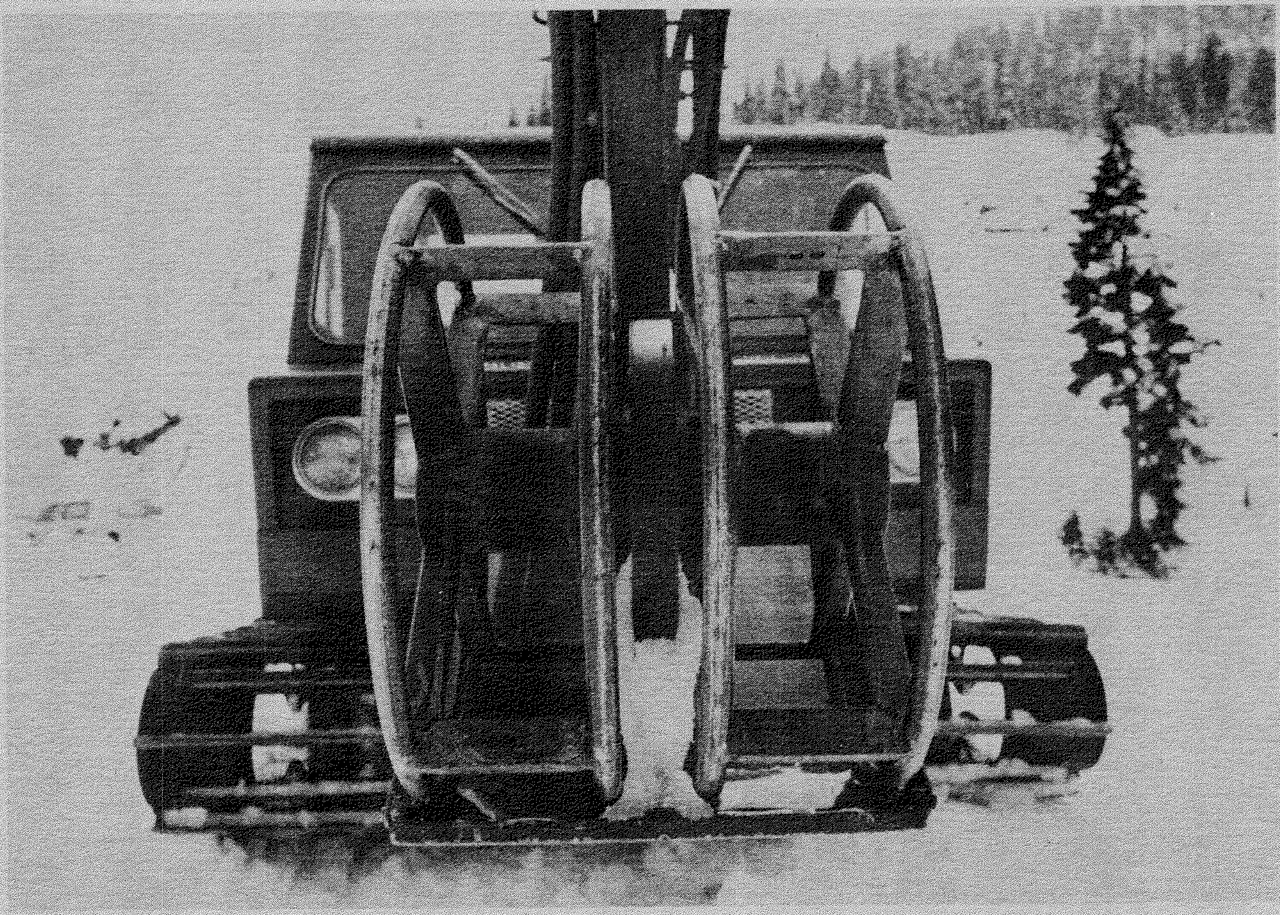
Tree-Falling in Snow

D.W. Myhrman



FERIC

FOREST ENGINEERING RESEARCH INSTITUTE OF CANADA

INSTITUT CANADIEN DE RECHERCHES EN GÉNIE FORESTIER

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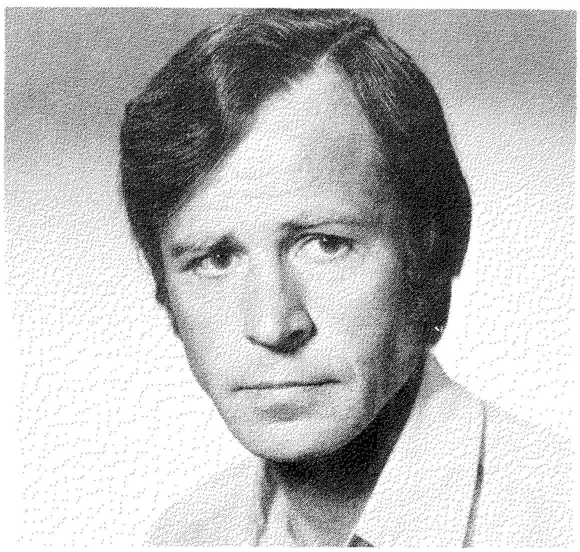

Dag W. Myhrman graduated in 1960 from the Mechanical Engineering Faculty of the Royal College of Technology in Stockholm, Sweden. He took an appointment with Svenska Rotor Maskiner AB, where he worked on design and testing of hydraulic transmissions for heavy-duty vehicles. He joined the Logging Research Foundation (Skogsarbeten) in 1967 as leader of the mechanical engineering research program. In the fall of 1975 he joined FERIC for a two-year period, to work on logging equipment design and development.

FOREWORD

In an effort to solve a persistent problem in winter logging, FERIC examined methods for felling trees in snow without leaving high stumps.

During the course of this study, FERIC designed and tested several snowblower heads for attachment to a portable brushcutter.

Further field tests are planned, possibly followed by more modifications and closer estimates of performance and operating costs. Nevertheless it was felt desirable that the author prepare this report, describing progress to date, before concluding his stay in Canada.

The author wishes to thank Sig's Machine Shop, Vancouver, and Cannon Machine Works, Burnaby, for their interest and support in manufacturing these attachments.

The assistance of these companies in the fabrication of a larger blower is also acknowledged, and our thanks go to Truckweld Equipment Limited, Burnaby, for the loan of a suitable carrier for this blower.

In addition, FERIC would like to express its appreciation to the British Columbia Department of Recreation and Conservation, for permitting preliminary field tests on Provincial Park lands.

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SUMMARY

Logging companies know that by continuing felling in winter they can maintain log inventories, utilize equipment better, and keep employment conditions stable; the problem they face is to find practical ways of removing the snow around the tree before felling.

There is no doubt that frozen ground supports machine weight better and is less affected by environmental impact. In addition, a previous study suggests that breakage losses are reduced in certain stands when snow cushions tree-fall.* Yet in spite of all these advantages the problem remains, and it is a serious one. Tree-falling in deep snow can leave excessively high stumps which have been cut at or above snow level. They are unsightly, wasteful of valuable wood, and an obstacle to subsequent skidding or yarding. Manual removal of snow down to ground level is laborious and it can also expose the faller to safety hazards by preventing quick escape when the tree falls or by exposing him to the danger of asphyxiation from chainsaw exhaust.

FERIC's first step in finding solutions to the problem was to consider the two-pass system: stumps of substantial height are deliberately left standing for later recovery in summer--a system which appears to be expensive and

* Powell, L. H. 1977. FERIC TR-15.

operationally difficult. Next we explored the various "one-pass" alternatives to hand shovelling. We found that snow removal by blasting was marginally effective but inherently hazardous and costly. Artificial melting of snow would require special equipment using considerable fuel per unit of snow volume. Resulting meltwater is another obstacle to the faller.

The search turned finally to mechanical snow-removal, either by a portable manually-operated snowblower, or by a mechanized snowblower mounted on a self-propelled carrier. In the absence of a satisfactory portable device, FERIC designed and tested a snowblower modification of a Husqvarna 165 brushcutter. This "FERIC small snowblower" is limited by the engine power (4hp or 3kW), but is modest in cost. The brushcutter with snowblower attachment would cost about $1,000. Operating cost for average conditions was estimated at about $1.50 per tree. Because of power limitations, the small blower is recommended for snow depths from 3 to 4 feet (1 to 1.3m).

For snow depths over 4 feet (1.3m), and for more rapid clearing, FERIC also designed and briefly tested a "FERIC big snowblower" mounted on a large snowmobile, costing about $25,000 complete with vehicle, boom, controls, and blower. This vehicle would double as off-road transportation for men and equipment. Although hampered by lack of deep snow in the winter of 1976-1977, preliminary testing indicated that the machine should be highly efficient on falling operations.

Recommendations are made for further modifications to the hydraulic system, the geometry of the tilt parallelogram, the boom, and the controls. Both FERIC snowblowers still require field testing on felling operations in deep snow to determine operational performance, safety and costs. In mechanical felling, there could be advantages to attaching the FERIC big snowblower head, or one like it, to an existing felling machine, rather than to a separate carrier. FERIC hopes to arrange for a trial of this concept. Certainly results to date show that snowblowers have real potential for eliminating snow-removal problems.

SOMMAIRE

Les compagnies d'exploitation savent qu'en prolongeant la coupe durant l'hiver, ils peuvent équilibrer les inventaires de billots, mieux utiliser l'équipement et stabiliser les emplois. Il faut pour cela trouver des solutions pratiques pour déneiger le pied des arbres avant de les couper.

Il ne fait pas de doute que le terrain gelé est un atout, il offre un meilleur support au poids des machines et résiste mieux à l'impact écologique. De plus on a pu voir dans une étude précèdente que la neige épaisse amortit la chute des arbres dans certains peuplements ce qui les empêche de se briser et cause moins de pertes.* Mais malgré tous ces avantages le problème reste entier et de taille. Lorsqu'on fait la coupe dans la neige épaisse on laisse les souches très hautes parce que l'entaille est faite à la hauteur de la neige et même au-dessus. Le résultat est déplorable, cela occasionne en plus un gaspillage de bon bois et crée par la suite un obstacle au débardage ou au débusquage. L'enlèvement de la neige à la pelle jusqu'au sol est pénible et le forestier peut s'exposer à des conditions hasardeuses en étant emprisonné dans un espace restreint lors de l'abattage ou en s'exposant aux émanations de sa scie mécanique.

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*Powell, L.H., 1977. FERIC TR-15.

FERIC a d'abord considéré comme solution à ce problème de faire deux opérations successives: en premier lieu les souches sont laissées très hautes puis elles sont récupérées plus tard durant l'été - un système qui peut s'avérer dispendieux et plutôt difficile à réaliser. Ensuite on a étudié diverses façons de se passer de la pelle tout en coupant ras. On a trouvé qu'enlever la neige par dynamitage avait non seulement un effet marginal mais était même dangereux et dispendieux. Pour faire fondre la neige artificiellement il faudrait un équipement spécial qui utiliserait une quantité considérable de carburant par unité de volume de neige. L'eau ainsi produite causerait une nouvelle difficulté au forestier.

La recherche s'est finalement orientée vers l'enlèvement de la neige par une machine, soit une souffleuse à neige opérée à la main ou une souffleuse mécanisée installée sur un véhicule autopropulsé.

Un appareil portatif satisfaisant n'etant pas disponible sur le marché, FERIC a conçu et testé un 'Husqvarna 165 debroussailleur' modifié et équipé d'une souffleuse. Cette 'Petite souffleuse FERIC' a un moteur de 4 hp ou 3 kW qui en restreint l'usage mais elle est d'un coût abordable. Le 'débrousailleur' équipé d'une souffleuse peut coûter environ $1,000. On a estimé les coûts d'opération dans des conditions normales à $1.50 l'arbre. Vu sa faible puissance, on recommande d'employer cette petite souffleuse lorsque l'épaisseur de la neige est de moins de 4 pieds (1.3 m).

Lorsque l'épaisseur de neige dépasse 4 pieds (1.3 m) et pour une opération plus rapide, FERIC a aussi conçu et essayé, quoique très peu, une 'Grosse Souffleuse à neige FERIC' installée sur une grosse motoneige, au coût total de $25,000, comprenant le véhicule, la rallonge, les contrôles et la souffleuse. Ce véhicule tout-terrain peut aussi servir au transport des hommes et de l'équipement. Quoique entravés par le manque de neige durant l'hiver 1976-77, des essais préliminaires ont montré que cette machine pouvait être très efficace dans des opérations de coupe.

On a recommandé de faire des modifications additionnelles au système hydraulique, à la géométrie du parallélogramme d'inclinaison, à la rallonge et aux contrôles. Les deux souffleuses FERIC ont besoin d'être essayées sur des chantiers d'abattage dans la neige épaisse pour en déterminer le rendement opérationnel, la sécurité et le coût. Pour l'abattage mécanisé, il pourrait être avantageux de monter la 'Grosse souffleuse FERIC', ou une semblable, sur une abatteuse existante, au lieu d'utiliser une autre machine. FERIC espère pouvoir mettre cette idée à l'essai. Les résultats obtenus à date indiquent à coup sur qu'il y a vraiment lieu d'utiliser des souffleuses à neige pour surmonter les problêmes d'enlèvement de la neige.

SNOW FELLING SYSTEMS

I. Two-Pass Systems.

A. Two-Pass Manual Felling

Trees can be cut on top of snow, leaving high stumps to be cut in summer. The stumps would then have to be cut to a merchantable height, at least to eight feet (2.5 m). It is dangerous to operate a power saw held high, so it would be necessary to have a minimum snow depth of four to five feet (1.2 to 1.5 m). The depth of the snow would have to be measured frequently in order to decide where to cut trees to get stumps of equal height. Remaining high stumps would also make first-pass skidding difficult.

Summer recovery of the stumps would require skidding and hauling equipment suitable for shortwood logging. These short logs would be costly and give less revenue at the sawmill.

B. Two-Pass Mechanical Felling

The felling machine would have a carrier to go on top of the snow, but the felling head would not have to dig down to the ground. Instead, it could work on a higher level to leave the stump at a merchantable height. Again, snow depth should be measured often to keep stumps cut at an equal height. The felling head could be put up to 20 feet (6 m) above snow level, allowing butt logs of normal length to be recovered later. Like the manual two-pass system, this method should be used only in very deep snow--eight to ten feet (2.4 to 3 m). The carrier should be designed to go on top of the snow. To keep investment cost down, planners would have to make use of the machine in the summer and they would need an alternate undercarriage adaptable to bare-ground operations.

With their inherent disadvantages, neither the manual nor the mechanical two-pass system is likely to be used widely.

II. One-Pass Systems.

A. One-Pass Manual Felling

Felling can be done in the normal way with a power saw after snow is removed from the tree base. Two safety factors have to be considered: an escape route for a worker should the tree fall in an unexpected direction or kick back, and the problem of carbon monoxide asphyxiation and other discomfort from power-saw fumes.

Escape routes have to be dug according to Workers' Compensation Board Accident Prevention Regulations. The hole has to be big enough to provide a safe working space, greatly increasing the dig-out volume in holes deeper than two feet (61 cm). Discussion with the Workers' Compensation Board suggests that it would be enough to dig only one major escape route to bring the faller up on top of the snow where he can move in any direction.

No studies have been published in British Columbia on the subject of power-saw fumes. It is known that fallers sometimes complain about headaches when working in poorly-ventilated areas. An investigation of these complaints was made in 1965 by the Swedish National Board of Occupational Safety and Health, using 20 fallers working in snow depths of about 4.5 feet (140 cm) as subjects for study. None of the persons tested suffered a degree of exposure that should cause any symptoms, perhaps because carbon monoxide is lighter than air. The observers concluded that the risk of carbon monoxide asphyxiation is small for workers using a power saw at that snow depth. It might increase in deeper holes. The air stream caused by the cooling fan of the engine creates a certain circulation of air, even in deep holes.

The oil smoke from the engine lubricating oil might cause discomfort, however, because it tends to collect in the hole. The power saw should be run at the leanest possible oil-fuel mixture to reduce oil smoke. If proper caution is taken, removing the snow around the trees to allow manual felling should be a suitable method for snow depths up to about six feet (183 cm).

We examined the following methods of snow removal:

1. Shovelling

Manual shovelling has been commonplace for many years. It takes only a couple of minutes to dig a hole one to two feet (30 to 60 cm) deep on both sides of the tree, while a larger hole in deep snow around a big tree might take up to half an hour. The shovelling could be done by the faller or by specially-designated shovellers.

2. Portable Snowblower

In Russia, the Siberian Technological Institute of the Timber Industry has developed a self-propelled portable snowblower (Figure 1). It has a rotary impeller for blowing the snow away and is propelled by means of a vibration unit.

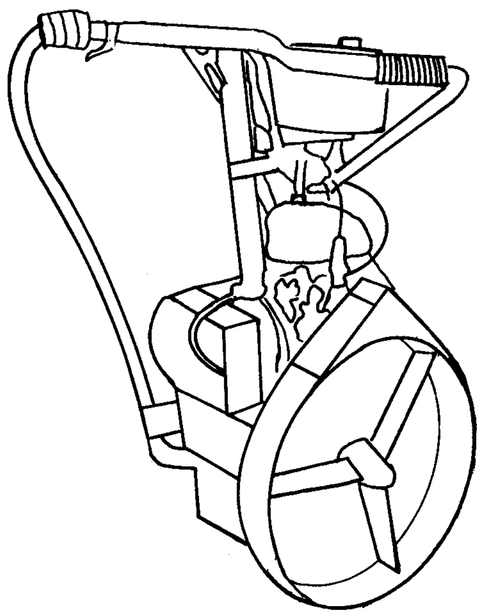

Fig. 1. Drawing of Russian portable snowblower, self-propelled by a vibration unit.

According to preliminary reports, it clears a two-foot-wide (60 cm) path at any snow depth. The productivity is reported to be approximately 35 to 40 trees per hour, and the operation requires only one person to replace the usual two, three or four people usually engaged in snow-removal.

FERIC requests for further information or an opportunity to test this blower have received no response.

Since the concept of a hand-held snowblower looked promising during our examination, it was decided to design and build a FERIC prototype machine (see Figure 2 and page 17 for discussion).

3. Snowblower On Small Snowmobile

A snowblower unit could be mounted on a boom on a snowmobile to remove the snow around trees (see Figure 3 and discussion on page 24).

This concept also looked promising and a snowblower attachment was designed and tested by FERIC.

4. Blasting

The snow around the trees can be blasted away with explosives. Because snow is a soft material, the efficiency of blasting it is poor. FERIC made a blast test in 18 inches (46 cm) of wet, heavy snow, resulting in a crater some three feet (90 m) in diameter and 18 inches (46 cm) deep.

Some snow slumped back into the hole following detonation. One stick (1/3 pound) of Forcite 40% was used.

Field tests of blasting snow at actual winter logging operations were made by MacMillan Bloedel, Squamish Division, in 1969. The snow depth was about four

Fig. 2. Prototype of FERIC Small Snowblower.

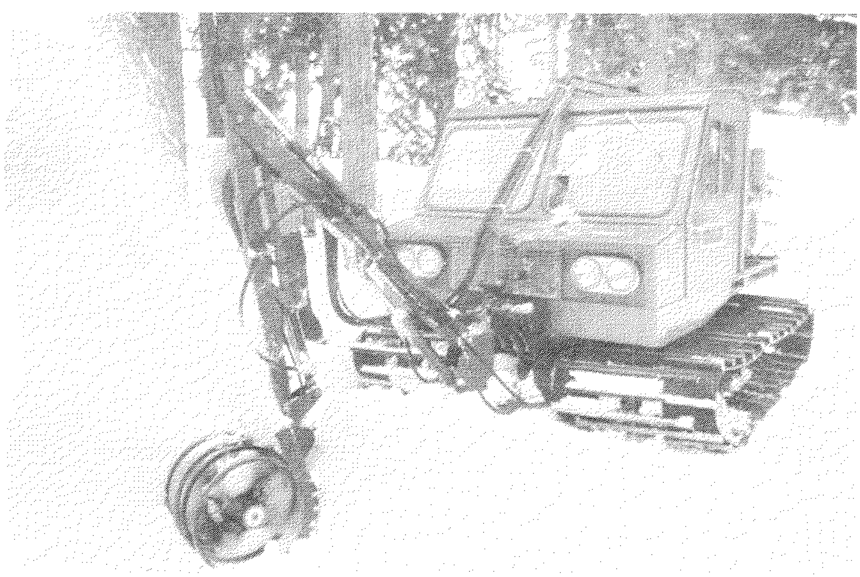

Fig. 3. FERIC Large Snowblower mounted on snowmobile.

feet (122 cm) and the snow was wet and hard. For each tree averaging 30 inches (76 cm) in diameter, three sticks (1 pound (0.45 kg) each) of dynamite 60% were used. After detonation on flat ground the snow was loosened and most fell back into the hole, necessitating further shovelling. On slopes, however, snow tended to clear the blast hole.

The cost of explosives was \$100-\$150 a day to blast about 100 trees. Three men were used for the work, one with a blasting permit, one helper and one shoveller. Although the cost was high, the company was satisfied with the results from the blasting experiments. (Today, the cost for a similar operation would be about \$500 a day.)

Blasting the snow away around the trees could be considered one possible solution to the problem, although the cost is very high--about \$5 a tree. It is labour-intensive and requires specially-trained workers.

5. Melting Snow

The snow around the trees could be melted away with a heating device, preferably one run on diesel fuel. The energy consumption, however, would be high. Preliminary calculations indicate that about 1.5 gal (6.1 litres) of diesel fuel would be required to melt a volume of 32 ft^3 (0.9 m^3) around a typical tree, at a rate equal to the digging rate of one man with a shovel.

An added problem with the melting of snow is that the hole is partly filled with water, especially when the ground is frozen. It is difficult and dangerous for the faller to work in a hole of freezing water. Melting snow is not practical. There is a high energy requirement and difficulty in getting rid of the melt-water.

B. One-Pass Mechanical Felling

Mechanical felling in deep snow can be done with a felling machine going on top of the snow, or through it, with a felling head which can dig down to the ground and cut the tree to leave a low stump. The machine could be a feller-buncher (Figure 4) which swings and bunches the trees after cutting, or a feller-director (Figure 5), which cuts the tree and directs its fall without lifting it.

1. Feller-Bunchers

A feller-buncher for deep-snow felling must have a felling head with a small bottom surface area because it is difficult to press a large horizontal surface into the snow. This problem might be overcome by provision for a digging movement at the head, which of course could be combined with the normal tilt-and-twist movements needed for alignment to the tree.

Possibly the felling head could be equipped with some device to remove the snow below it; for example, a snowblower.

In deep snow, the operator cannot see the felling head operating. Therefore, it has to be designed to be

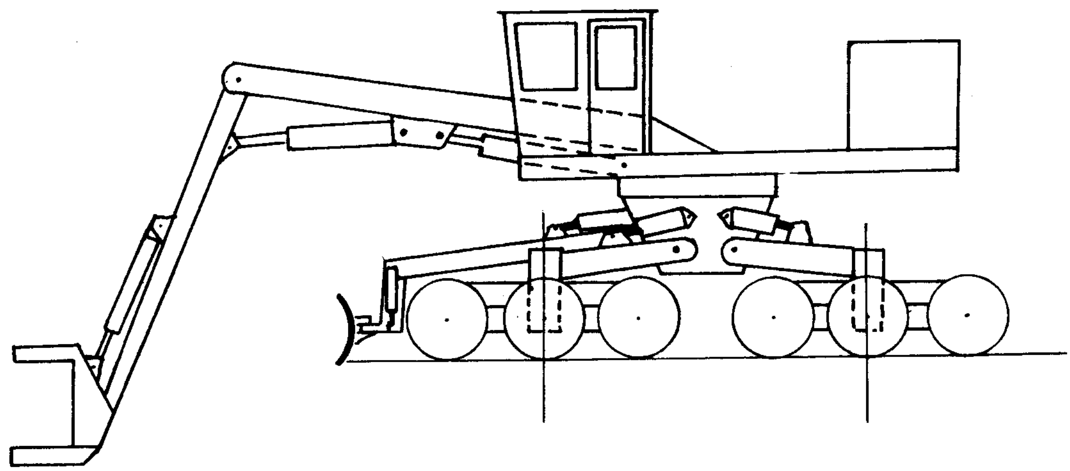

Fig. 4. Feller-buncher with head depressed below grade and with blade for snow ploughing.

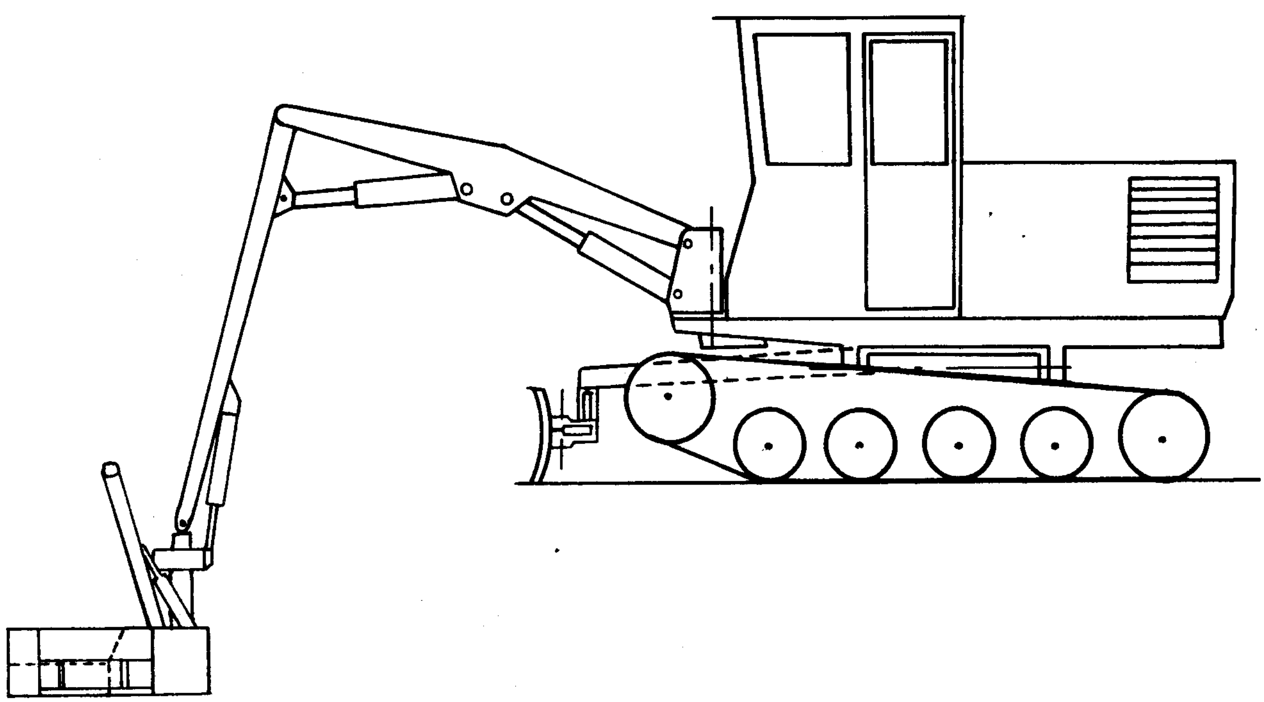

Fig. 5. Feller-director with stump clamp, pusher-arm and snow plough.

foolproof against all the mishaps which could occur. It has to be well-protected from hidden stones, snags and undergrowth. It must not get clogged by snow and ice. The cutting device could be a shear or a chain-saw, probably the latter because it eliminates butt-end damage and gives a smaller and lighter head. The size of the trees felled by a feller-buncher in deep snow is limited to about 20 inches (51 cm), since larger sizes would call for a very heavy base vehicle, and this kind of vehicle would be difficult to move in the snow.

The base vehicle could be designed to go on top of snow or to clear a path through the snow. To go on top of snow, the ground pressure must be less than one psi (7 kN/m^2), based on the weight of both machine and tree being lifted. With the boom in central position, the average ground pressure has to be less than 0.5 psi (3.5 kN/m^2).

Alternatively, the vehicle could operate at higher ground pressure by clearing a path through the snow by blowing or ploughing. Power requirements would be increased, but stability on the cleared path would also be improved.

For wide application in snow-belt areas, the vehicle would need capability to operate on slopes up to 40 percent, and would then require a levelling device for safety and ease in swinging of the boom.

The feller-buncher we have described would be expensive--about $200,000 to $250,000. To be economical, it needs to operate efficiently in summer as well as in winter. For that reason it should be equipped with easily changeable winter and summer tracks and other specific winter-use attachments.

Many of today's fellers can operate on flat ground in snow depth up to three and four feet. The big bottom surface area of the felling head compacts snow below it when it tries to press the snow down and this leaves high stumps. If the snow could be pushed away from under the head as it is lowered, the remaining height might be acceptable.

One way to do this is to put hydraulically-oscillating arms with a shovel-shape under the feller head (Figure 6). A snowblowing device could also be used. Both units should be attachments. Either unit would require 5 to 15 seconds to dig from three to four feet of snow, and this has to be added to the felling time. The big snowblower developed by FERIC could be attached to a felling head to experiment with this technique.

2. Feller-Directors

A feller-director is a felling machine which cuts the tree and directs its fall. It has limited ability to move the butt end of the tree away from the stump. An example of a feller-director is a tractor-mounted shear. For big trees, a feller-director is easier to design than a feller-buncher because it does not have to lift the tree. A chain saw cutting device will

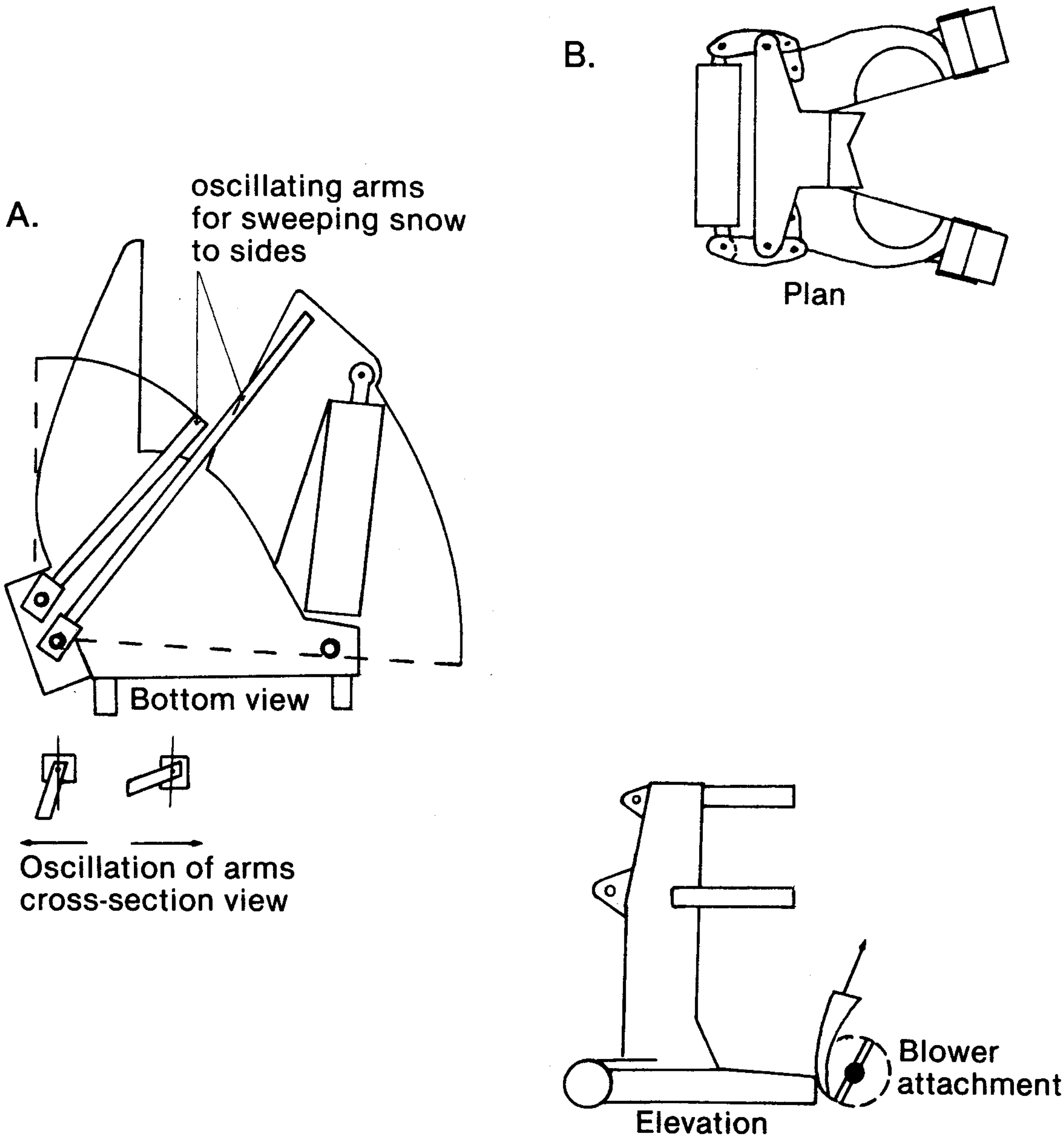

Fig. 6. Concepts for snow removal attachments on feller heads:
A. Oscillating sweeping arms under head.
B. Snowblowers mounted on shear blades.

reduce butt-end damage and give a light felling head (Figure 7). The directional force can be applied by a wedge or a pushing arm. By using a grapple to hold the stump, the operator can get the stump to act as a reaction body for the directing forces. To follow a chosen felling pattern, the operator must be able to control the direction of the tree's fall. The felling head must be freely-hinged on the boom at the fall of the tree so there is no stress on the boom.

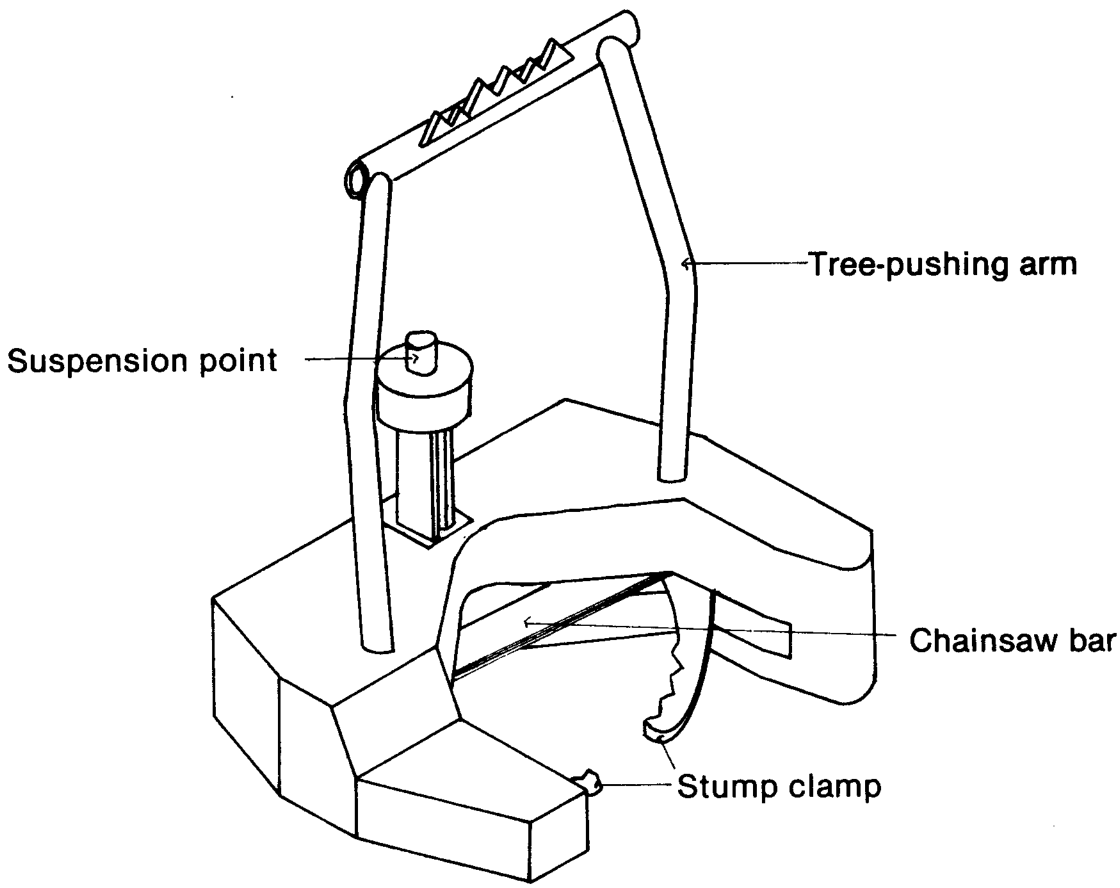

Fig. 7. Sketch of Light Feller-director Head.

The felling-directing heads available on the market today--the OSA 640, the DYKA, and the Albright 36"--have too big a bottom surface area to get down in deep snow.

The base vehicle for a feller-director must be small so that it can pass between the trees. On the other hand, the stability requirements are much less than those for a feller-buncher because the feller-director carries only the weight of the felling head and boom. The demands for operating in deep snow are the same as those for the feller-buncher. Reduced bottom surface area, or snow-removal attachments, or both, should be sought in future feller-director heads designed for deep snow.

SNOWBLOWER DEVELOPMENT

I. FERIC Small Snowblower.

Digging big holes for safe falling in deep snow with a hand shovel is slow and tiring work. We decided to try different powered devices to remove snow. A literature study and a patent search were carried out to bring forward ideas on hand-held equipment, but not much information was found.

Pre-tests

FERIC looked into existing snowblowers to see if any of these would be possibilities. The most promising was the Toro Snow Pup. It has a 2.5 hp (1.8 kW) engine, driving a 14-inch (35 cm)-wide, two-bladed impeller at about 1,000 rpm. The weight is 23 pounds (10.5 kg). The Snow Pup was tested late in 1975, but was found to be ineffective and cumbersome to use. It did not blow the snow out of the hole, and although it was not particularly heavy, the operator found it a strain to carry. At that time, it was suggested that a blowing attachment be made for a power saw, but that would also be cumbersome to use for either function. A brushcutter power unit was found to be much better. It hangs in a harness over the shoulders and balance quite well with the power head behind the operator. A brushcutter was used as the basis for development work.

Brushcutter

The brushcutter was a Husqvarna 165R, chosen because of its good power-to-weight ratio. The 65-cc engine develops

4 hp (3 kW) at 7,500 rpm and the weight is 23 pounds (10.3 kg) complete. The power head and drive shaft are about 19 pounds (8.5 kg). The fuel tank holds 0.22 gallons (1 ℓ), which gives about one hour's running time.

Vibration is reduced by rubber mounts. The sound level in clearing work is 94 dB (A), tolerable without ear protection for up to 25 hours per week of continuous operation.

Mk I

The first snowblower attachment (Figure 8) was put directly on the output shaft of the angular gear, which has a reduction of 1:1.25. The impeller speed was high: 6,000 rpm at maximum engine power, and maximum unloaded speed

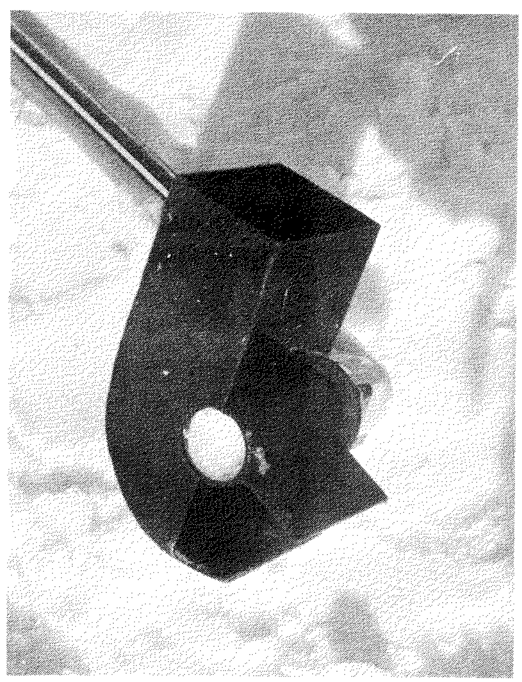

Fig. 8. Mk I Snowblower Attachment.

close to 10,000 rpm. Therefore the blower had to be made small, with a two-bladed impeller 6 inches in diameter (15 cm), and 4 inches in width (10 cm). Although the blower was made of steel, the weight increase was only 5 pounds (2.2 kg).

The tests carried out with this Mk I head showed that the general principle would work, but the impeller was too small and turned unnecessarily fast. It also showed that it would be necessary to open up the cover more to expose the impeller to the snow. A Mk II variant was made to try a fully-exposed impeller turning in the opposite direction. This was not any better. Without a spout on the equipment, the snow was not well-directed.

Mk III

The Mk III (Figure 9) variant used a gear from a British Seagull outboard motor with a reduction of 1:3.5.

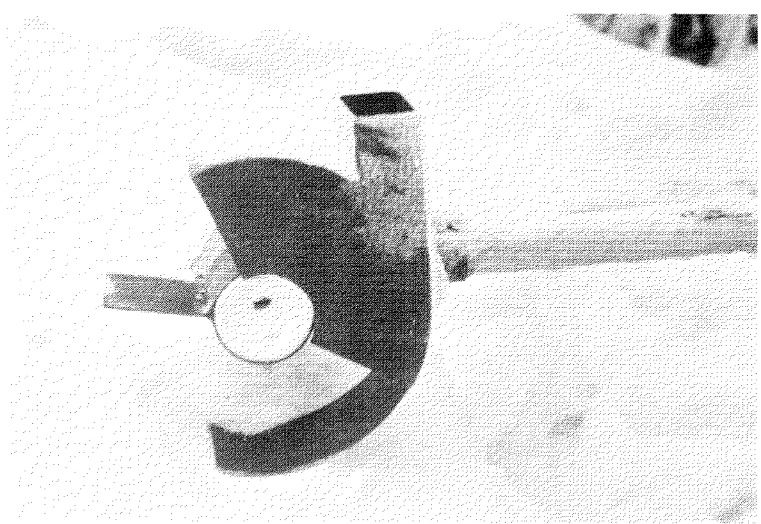

Fig. 9. Mk III Snowblower.

The much lower impeller speed made it possible to use a bigger impeller with a diameter of 9.75 inches (25 cm) and a width of 4 inches (10 cm). The weight increase of the unit was 7 pounds (3.2 kg), giving a total weight of 30 pounds (13.6 kg).

This unit was found to be much more efficient than the earlier ones and was tested in the field by one of the fallers in the snow-falling studies reported in Technical Report TR-15. The faller was generally satisfied with the unit but wished it could have been more efficient. Furthermore, the output shaft from the Seagull gear is only 0.5 inches (12.7 mm) in diameter, and it bent when the impeller hit solid obstacles. The capacity was about 10 cubic feet/min (283 litre/min) in hard snow. It blew the snow about 15-20 feet (4.5-6 m). A Mk IV variant (Figure 10) was made with a more open cover-spout to improve digging into the

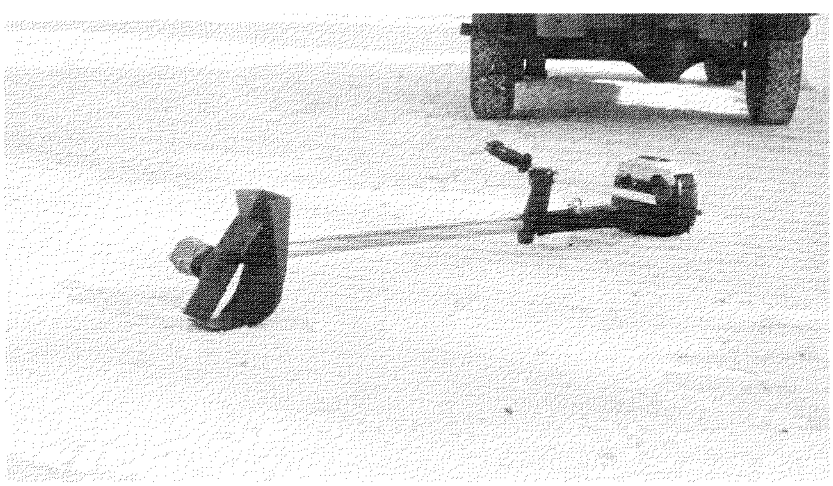

Fig. 10. Mk IV variant of small snowblower.

snow. This was easier to use and capacity was better. However, it still had a weak impeller shaft and stalled easily. It was felt that still more reduction should be used in the gear to get more digging power and less ventilation from blowing air. A gear ratio of about 1:6 was considered the optimum.

Mk V

It would be expensive to fabricate a gear with a given ratio, and we searched the market for a suitable gear. The best one was the Cannon Tree Planter gear, which has a 4.25 or 8.25 gear ratio. The 8.25 ratio was chosen for the Mk V (Figure 11) snowblower attachment. With the impeller now turning only about 1,000 rpm, it could be made bigger, with a diameter of 13 inches (33 cm) and a width of 6 inches (15 cm). The unit was fabricated from welded aluminum, but the weight of the complete snowblower was still increased to 32 pounds (14.5 kg). The impeller had rubber blades made

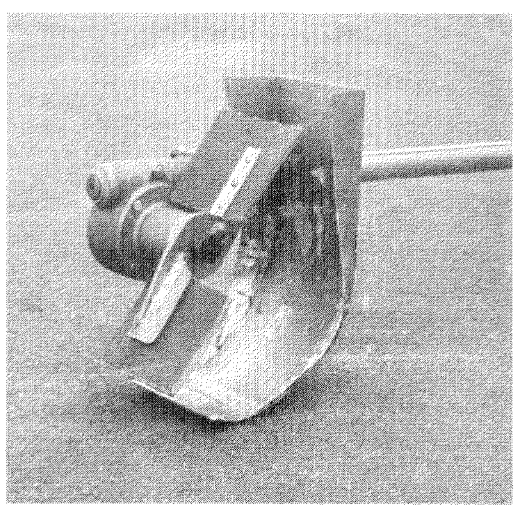

Fig. 11. Mk V Snowblower.

from ordinary conveyor belt 0.375 inches (10 mm) thick. This was effective in loose snow and tended to dampen obstacle-vibration and shock. In hard, icy snow however, the blades bent back and capacity was low. Nylon blades were tested and found to be effective in very hard snow, although vibration increased. Rubber blades should be used for soft snow, with nylon being reserved for hard snow.

In spite of the relatively low impeller speed, the snow was blown 10-15 feet (3-4.5 m), which seems adequate for most cases. The spout bent upward 10° to direct the snow thrown up from the hole. To lessen vibration in hard snow, the two-bladed impeller was exchanged for a three-bladed one. The Mk V was tested in the field and in Vancouver during spring and summer in 1976 with generally good results.

Mk VI

We decided to make a small series of ten blowers for trials in the field during the winter of 1976-1977. They were designated Mk VI (Figure 12) and incorporated all

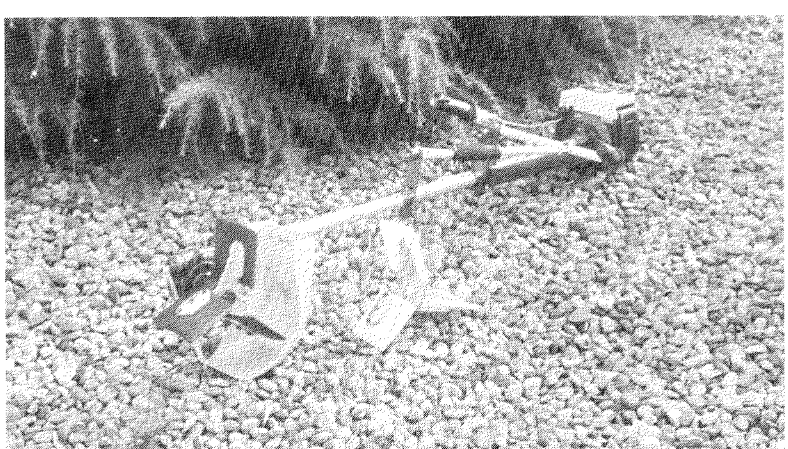

Fig. 12. Mk VI Snowblower.

modifications made to the Mk V, with a slightly different design to optimize strength, weight, and cost. Added details and strengthened construction resulted in a weight of 35 pounds (16 kg). This included the extra handle on the shaft tube controlling the blower. The weight of the blower head would be decreased by three to five pounds (1.5-2.5 kg) by using magnesium alloy instead of aluminum and making the gear casing and cover bracket in one piece. This would be too expensive to do in a small test series, however, because casting patterns would have to be made.

Tests of Mk V and Mk VI

The Mk V was tested near Vancouver in March, 1976 in wet, loose snow, and had then a capacity of about 40-50 cu ft/min (1100-1400 ℓ/min). During later tests in hard, icy snow, capacity was down to about 15 cu ft/min (420 ℓ/min). Tests in Parsons, B.C., in three feet of very hard snow showed about three to five minutes digging-time per tree, 10-15 inches dbh, at about 45% slope. Manual digging was difficult in hard snow.

At Squamish in May, 1976, a 5-foot (153 cm) dbh cedar was dug out in 10 minutes from four to five feet (122-153 cm) of hard snow. Later tests in June showed good performance and demonstrated the possibility of using the Mk VI for clearing snow around guyline stumps.

During the winter of 1976-1977, eight Mk VI blowers were delivered to different logging companies in the B.C. Interior for trials. Unfortunately very little snow fell that winter and only one was used. That was in Slocan in about three feet of loose, powdery snow where it was found to be slower than manual shovelling. We hope the weather next winter will allow more use of this series so its performance can be evaluated.

Our tests indicate that the snowblower should be at least twice as fast as manual shovelling, with less strain on the operator.

The relative digging speed of the blower would be even greater in hard snow, where manual digging becomes extremely slow.

Cost Estimate

The price of the brushcutter without angular gear is about $500, and the attachment is another $500, making a total of around $1,000. This investment is low, and the brushcutter may also be used for clearing work in the summer.

Assuming 10 trees per hour could be dug with the snowblower--including walking between trees and delays, in three feet (92 cm) of snow--about 80 trees per shift could be cleared. The cost for the snowblower is assumed to be twice that of a power saw, giving about $5 per hour. At a labour cost of $10 per hour, the total cost per hour is $15. Cost per shift is $120, or $1.50 a tree.

II. FERIC Big Snowblower.

This snowblower was designed as an alternative to the small blower, with greater digging capacity and hydraulic propulsion. It has a rotary-type blowing unit mounted on a boom on a snowmobile (Figure 13). It could also be mounted on a feller-buncher.

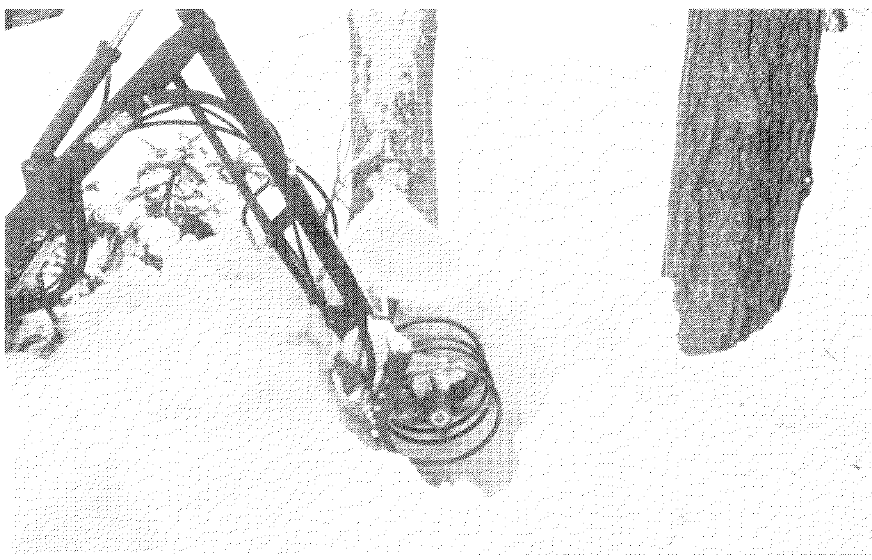

Fig. 13. FERIC Big Snowblower.

Blower

The blower consists of two 20-inch (51 cm) diameter impellers rotating at about 750 rpm. The total width of the two impellers is 15 inches (38 cm). The impellers are driven by a central roller chain fully enclosed in an oil bath. The gear ratio is 1:2.62. A hydraulic motor of about 20 hp (15 kW) at 2,000 psi (14 MPa) drives the small sprocket. A spout is mounted on the back of the unit to direct the snow throw. Each impeller has two peripheral tubes to prevent snags from getting caught by the blades. The impellers have rubber bushings connecting them to the shaft to provide shock-damping and overload protection. The weight of the blower head is 160 pounds (73 kg).

Boom

The boom is a knuckle type. The blower is attached with a parallelogram system but also has a hydraulic cylinder for tilting it and directing the throw of the snow. Maximum reach of the boom is 10 feet (3 m), and it can reach down to six feet (1.8 m). The side swing of the boom is $\pm 22^{\circ}$. The 250-pound (113 kg) boom operates at 2,000 psi (14 MPa) hydraulic pressure and has a gross lifting moment of 4,000 ft lb (5.5 kNm).

Carrier

The carrier is a Thiokol Imp Model 1404 medium size snowmobile provided by Truckweld Equipment Limited in Burnaby, B.C. The length is 116 inches (2.95 m), width 84 inches (2.13 m), and height 75 inches (1.9 m). Vehicle weight is 2,475 pounds (1125 kg) and payload 1,400 pounds (635 kg). Loaded ground pressure is 0.9 psi (6.2 kN/m^2). It is powered by a Ford V4 engine rated at 88 hp (65 kW). The transmission is a 3-speed synchromesh ahead of a 4-speed standard, giving 12 speeds forward and one reverse. Steering is by planetary differential brakes. Tracks are rubber with spring steel cross-members; drive is at the rear. Four support wheels on each side have semi-elliptical spring-type walking beams. The cab at the front is fully enclosed and seats two. The cargo platform in the rear is 5 by 5 feet (1.5 by 1.5 m). The machine has an engine-driven hydraulic pump, delivering 5 gallons (19 ℓ) per minute and a maximum pressure of 2,000 psi (14 MPa). A 4-spool control valve is mounted to the right of the operator. The hydraulic system is designed to operate auxiliary attachments like snowplows. The standard system is used to drive the boom.

Power Pack

For the snowblower itself, a separate power-pack was placed on the rear platform of the carrier (Figure 14). It has a 30 hp (22 kW) Wisconsin air-cooled gasoline engine. The hydraulic pump delivers 25 gallons (97 ℓ) per minute at 2,000 psi (14 MPa) pressure. A control valve electrically-operated from the cab controls the rotation of the blower. A pressure-relief valve protects the blower from overload should it get stuck. The weight of the power pack is about 1,000 pounds (450 kg), making the total weight of the snowblower attachment about 1,400 pounds (635 kg).

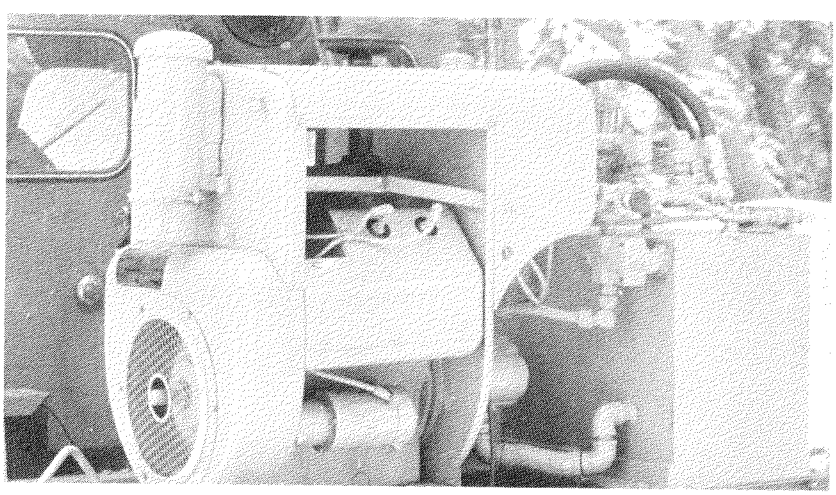

Fig. 14. Power-pack for FERIC Big Snowblower.

Price

The price of the Imp is $18,000 with wide tracks. Price including the boom and snowblower would probably be around $25,000.

Testing at Mount Baker, Washington

The blowing unit was first tested, mounted on a trailer, at Mount Baker in February 1977. Owing to the lack of snow, testing took place in a plowed snow wall about two feet (60 cm) high. The snow was wet and hard. The blower worked satisfactorily although it stalled if pushed too fast into the wall. The wet snow clogged between the impeller peripheral tubes and the spout. The snow was thrown 15 to 20 feet (4.5-6 m) high. The impeller speed was about 700 rpm at engine speed 2,100 rpm and oil pressure about 1,900 psi (13 MPa).

We found that the clearance between the impeller and the spout narrows from the leading edge of the spout backward, probably causing the clogging and stalling. We altered the shape of the spout to get better clearance.

Testing at Cypress Provincial Park

The complete unit was tested in the Cypress Provincial Park in April 1977. The snow was hard, with ice layers, and the depth varied from four to six feet (122-183 cm). The blower head worked well and stalled only once. The impellers were not hurt by touching the tree, the ground, or debris covered by the snow. The machine threw the snow well out of the holes.

The boom was found to be underpowered and very difficult to operate. Increase of hydraulic pressure from 1,200 psi (83 MPa) to 2,000 psi (14 MPa) seemed to give sufficient power, but manoeuvring was still difficult. Lack of hydraulic capacity made the boom move too slowly, and the blower was actually working at full power only a fraction of the total time. Because the controls had been placed to one side of the operator, the boom was difficult to operate. There were no check valves in the control valve to prevent a function from moving in reverse when the pressure was too low to move it forward.

To operate the snowblower properly, the main boom, the stick, and the tilt have to be manoeuvred simultaneously. This would be less difficult with a "joy-stick" arrangement and dual-circuit hydraulic system (the type found on modern feller-bunchers). The boom could have more reach to avoid some manoeuvring of the vehicle and to improve vision when working in very deep snow. The Imp carrier seems to be a suitable vehicle to carry the snowblower. It can manoeuvre between the trees with the existing manual transmission, but a hydrostatic-drive model would make this easier. A parking brake should be fitted to the Imp for further tests, possibly with the brake fitted to the drive shaft. A hand throttle would be helpful in operating the boom.

The shape of the snow excavations was discussed with the Workers' Compensation Board to incorporate designs for safe falling and escape routes. It was agreed that a Y-shaped trench would give ample space for cutting the undercut and the backcut, with the "stem" of the Y providing an escape route.

Suggested Future Modifications

Before extensive field testing of performance, the following prototype improvements are recommended:

- -- Improve the hydraulic system for the boom. It would be better to fit the system pump to the powerpack, which would then need a bigger engine, more than 50 hp (37 kW). The system should be of the dual-circuit type with "joy-stick" controls, mounted in front of the operator. A pressure relief valve should be fitted to the rod side of the tilt cylinder.

- -- Check the boom bearings for wear from the higher pressure used, and put in bushings if necessary.

- -- Check geometry of tilt parallelogram for easier direction of snow-throw.

- -- Increase boom reach by adding 12 inches (30 cm) to both main boom and stick.

- -- Equip the Imp with a parking brake and hand throttle if the boom is to run from its engine.

- -- Reduce powerpack noise level.

PROPOSED FUTURE WORK

Future work on the snowblower development program should be devoted to expanded field testing of the current models and further modifications in response to test results.

The winter of 1976-1977 in British Columbia had very little snow; most of the planned tests of the snowblower and studies on deep-snow felling had to be cancelled. Both the small and large snowblowers should be tested in logging operations as soon as possible. Production and cost should be evaluated. Safety aspects--including the risk of carbon monoxide asphyxiation--should be checked.

An impeller with holes in the middle of the blades could be tried on the small snowblower. This should decrease the weight and the ventilation losses and give more digging power. The big snowblower should be modified according to the list given earlier in our report, with further modifications if testing so indicates.

The big snowblower head should also be tested while mounted on a feller-buncher head or a front-end shear. The tests would determine whether the head is sufficiently rugged, and whether it will significantly reduce stump heights.

Studies should also be made on felling machines in deep snow to find out what the limitations are and to suggest ways to make them better-suited for deep snow work. Both felling head and carrier performance should be examined.

CONCLUSION

There are obvious advantages to continuing tree felling during winter, but new methods are needed in deep snow to accomplish this without excessive stump waste, additional cost, or safety hazards. This FERIC report indicates some of the options explored.

The small manually-operated FERIC snowblower appears effective, inexpensive, and considerably faster than hand shovelling. Final tests on felling operations are still needed to determine operating costs and the degree of industry acceptance.

The big (snowmobile) FERIC snowblower appears highly effective and mobile in timber. Capital investment and operating costs are higher however.

This problem might be overcome if the carrier could be used for alternate purposes when not needed for snow removal. Again, field tests are needed to determine the value to industry.

The success of the big snowblower as a separate unit suggests that it should be tried as an attachment on feller-bunchers or feller-directors. This approach would obviate the need for a separate unit and operator.

More research, development, and testing is required to improve winter felling. This study has exposed several options, pursued two of these to the prototype stage, and indicated the directions which further FERIC study might take.