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SD Department of Transportation
Office of Research

Evaluation of Variable Curvature Snow Plow Blades

Study SD94-11
Final Report

Prepared by
South Dakota Department of Transportation
700 E Broadway
Pierre, SD 57501

June, 1996

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16. Abstract

The problem of highway accidents involving snow plows has arisen again and again over the years. Snow plow operators work in a harsh environment when winter winds blow snow across the road, and snow from the plow blows over the top of the hood, further obscuring visibility. Each winter, motorists travel at speeds higher than conditions dictate into conditions where visibility is reduced to nearly zero. It is during these harsh driving conditions that snow plow operators are most vulnerable to being hit by motorists. The results can be thousands of dollars in private and state vehicle damages, injuries and fatalities.

A flexible moldboard plow manufactured by Frink America was evaluated for its ease of use and effectiveness at reducing the snow cloud obscuring the plow. Video and interviews of snow plow operators reveal the flexible plow is simple to use and effective at directing the snow in a narrow column off of the roadway. The capability to adjust the plow's curvature and angle to centerline on the fly allows the operator to adapt the plow to changing conditions quickly. Narrowing the discharge end of the plow directs the snow away from the plow, rather than over the hood and windshield, greatly improving the operator's visibility. This allows the operator to drive faster, more closely matching the speed of traffic, and plowing more roadway in a given time. The higher cost of the plow can be recovered by plowing highways in a shorter time and avoiding accidents. It is recommended that the SDDOT purchase flexible moldboard plows when higher highway speeds and visibility are required, and the plow's cost can be recovered within three years.

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Executive Summary

The problem of highway accidents involving snow plows has arisen again and again over the years. Snow plow operators work in a harsh environment where winter winds blow snow across the road, and snow from the plow blows over the top of the hood, further obscuring visibility. Each winter, motorists travel at speeds higher than conditions dictate into conditions where visibility is reduced to nearly zero. It is during these harsh driving conditions that snow plow operators are most vulnerable to being hit by motorists. The results can be thousands of dollars in private and state vehicle damages, injuries and fatalities.

A flexible moldboard plow manufactured by Frink America was evaluated for its effectiveness and ease of use. Operators in Aberdeen, Mitchell, Pierre, and Rapid city regions used these plows for one to four winters. Video was taken to determine the plow's effectiveness at reducing the snow cloud obscuring the plow. The video and interviews of snow plow operators reveal the flexible plow is simple to use and very effective at directing the snow in a narrow column off of the roadway. The capability to adjust the plow's curvature and angle to centerline on the fly allows the operator to adapt the plow to changing conditions instantly. Narrowing the discharge end of the plow directs the snow away from the plow, rather than over the hood and windshield, greatly improving the operator's visibility. This allows the operator to drive faster, more closely matching the speed of traffic, and plowing more roadway in a given time.

Other Departments of Transportation have used flexible moldboard plows for more than seven years, and claim no major problems with their plows due to cold weather or hard use.

The flexible moldboard plows cost nearly twice as much as conventional steel plows. However, the higher cost of the plow can be recovered by plowing highways in a shorter time and by avoiding accidents. It is recommended that the SDDOT purchase reversible, flexible moldboard plows when higher highway speeds and visibility are required, and the plow's cost can often be recovered within three years.

Problem Description

The problem of highway accidents involving snow plows has arisen again and again over the years. Snow plow operators work in a harsh environment where winter winds blow snow across the road, and snow from the plow blows over the top of the hood, further obscuring visibility. Each winter, motorists traveling at speeds higher than conditions dictate drive into conditions where visibility is reduced to nearly zero. In South Dakota over the past 8 years, there have been from 7 to 22 accidents per year involving motorists colliding with state snow plows.[1] Table 1 shows accidents since 1988 where a private vehicle side swiped or rear ended snow removal equipment. Steel snow plows are capable of handling large volumes of snow because of their large curvature. This very feature is also what casts snow into the air and over the hood of the snow plow. When the operator's visibility is reduced, he must slow down, sometimes far below the speed of other traffic, until his visibility improves. It is during these harsh driving conditions that snow plow operators are most vulnerable to being hit by motorists. The results can be thousands of dollars in private and state vehicle damages, injuries and fatalities.

Table 1 Winter Accident Summary

Region	*Year* '88-'89	'89-'90	'90-'91	'91-'92	'92-'93	'93-'94	'94-'95	'95-'96
Aberdeen	0	1	3	5	4	12	4	2
Mitchell	2	3	4	2	2	5	9	6
Pierre	3	1	1	2	4	0	2	1
Rapid City	2	5	2	3	1	5	4	5
Totals	35	35	16	25	38	48	19	14
Labor hours plowing snow	58,136	38,864	45,412	40,469	77,610	104,233	69,588	55,662

95-96 Hours shown are as of April 26, 1996

Background Summary

SDDOT Research study SD91-06[2] attempted to address the problem of accidents involving snow plows by focusing on the reduced visibility problem. The study evaluated several lighting configurations and a flexible moldboard plow that can be changed on the fly by the operator to adapt to changing snow conditions. With this configuration, the chute of the plow can expel the snow farther and lower, resulting in less snow cloud. The study recommended that the SDDOT install a three light strobe system on all snow plow trucks statewide over a three year period. SDDOT took this action, but because of mild winters, the flexible plows did not receive a proper evaluation.

Also involving the visibility of snow plow operators is study SD95-05, *Improving Visibility for Snow Plow Operators*, scheduled for completion in the summer of 1996.[3] This study primarily concerns methods of improving visibility for snow plow operators such as heated windshields, wiper blades and mirrors. Part of the visibility problem cited by operators is the snow blowing over the plow, hood and windshield. The flexible snow plow could reduce these problems considerably.

The flexible moldboard plow, or Revers-A-Cast (Figure 1), manufactured by Frink America, was purchased for each DOT region in South Dakota. Specifications are shown in Appendix A. Mitchell, Rapid City and Aberdeen regions have had one since 1991, and Pierre acquired one in 1994. The benefits of using this type of plow are that the moldboard is made from a durable, flexible material called polyethylene. The moldboard can be shaped by two hydraulic cylinders operated from inside the cab. The plow can be opened or closed at either end, angled left or right, and raised and lowered by the operator at any time. This flexibility allows the operator to adapt the plow to changing conditions as they are encountered.

Figure 1 Frink Revers-A-Cast Plow

This study was to determine the curvature of the moldboard and angle of the plow most effective in reducing the snow cloud. The chute opening size depends on the moisture content of the snow, volume of snow, plowing speed and wind conditions. Several plow curvature configurations were to be tried for each set of conditions.

Another question to be answered was the efficiency of the plow. Does the Frink Revers-A-Cast plow use more or less energy to push than one of the plows SDDOT uses? If the plow is more energy efficient than the plows SDDOT is using, the Department can expect to save money over time, in addition to contributing to safer highways in South Dakota.

Literature Search

The summary of literature below represents the most relevant of articles and reports found through a search done within the SDDOT research library and the Transportation Research Information System (TRIS). This task was task two in the research project statement defined by the project's technical panel.

The Strategic Highway Research Program has done some work with snow plows to increase visibility and efficiency. This work was started in 1988, and a final report was published in 1993. The report SHRP-H-673, *An Improved Displacement Snowplow*, identified more efficient plow designs that reduced snow clouds and increased plow efficiency. The study was conducted at the University of Wyoming, and interestingly, consulted the chief engineer of Frink America, the same company who manufactured the snow plow we are evaluating. This study found a relationship between the ratio of the distance between the plow and the truck and the height of the hood, and the flow over the plow/truck combination. Also, a snow scoop placed at 45° to the pavement surface in front of the plow reduces the force required to push the snow plow by 34%. Rotating the plow from 90° to an 80°angle to the pavement surface removes compacted snow and ice more effectively and reduces chatter. A scoop was designed to be mounted on a modified Frink Revers-A-Cast plow. Reviews from North Dakota, New Hampshire, Vermont, Iowa, and California, indicated that the snow scoop clogs when encountering wet or drifted snow. Snow plow operators who have used them do not approve of them. The SHRP snow scoop was not used in this study.

SHRP-H-346, *Improved Cutting Edges for Ice Removal*, concentrated on cutting edges that remove ice from pavement surfaces, and contains no information related to snow plow design or reduction of the snow cloud.

TRR 1387, *Snow Removal and Ice Control Technology*, contains a paper entitled "Goals and Methods of Winter Maintenance in Finland". A rubber variation of the SHRP snow scoop, presented in SHRP-H-673, is used by Finland to clean the wet snow or slush left by the first blade. When dry snow is plowed, the plow is hydraulically lifted clear of the roadway. The concept Finland uses is: "A road that is as clean as possible requires less salt than one that has been plowed less efficiently".

In a telephone interview, Lee Smithson, Iowa Department of Transportation, July 1, 1996, stated that an attachment has been designed for deflecting the flow of snow from the plow away from the hood and windshield of the truck. This European design was photographed by Mr. Smithson and implemented in several areas throughout the United States. The advantages are low cost, greater visibility and longer life for radiators, windshields and wipers. Mr. Smithson videotaped plow operation using cameras on the hood, in the back, and in the cab of the truck. Information on the plow shield is in Appendix D.

Research Objectives

The first objective defined by the project's technical panel was to "Determine curvature and plow angle configurations to minimize the snow cloud and improve plowing efficiency." The panel wanted to identify specific amounts of curvature and angle of the plow relative to centerline for different conditions. Wet snow and dry snow, wind direction and snow depth might be handled better by adjusting the flexible plow to a unique configuration.

Objective two was to "Evaluate other methods which may be used separately or in conjunction with variable curvature snow plow blades to improve snow plowing safety and/or efficiency." This objective was defined to address suggestions that arose from study SD91-06. These suggestions were:

- Install air foil on top of plow to deflect snow downward.
- Install rubber flap on discharge end of snow plow.
- Install metal deflection fin to lower discharge height of snow.
- Install a metal panel on the nose end of a one-way snow plow to reduce snow coming around the end of the plow.

This portion of the study was not completed because the personnel responsible for doing the work were tasked with other higher priority work. This is discussed under "Other Research."

The study tasks were as follows:

1) Prepare a work plan for this research project.
2) Review and summarize relevant literature to determine previous work, policies, and/or procedures from other sources.
3) Determine methods for observing and evaluating the equipment in operation.
4) Observe the equipment in field conditions and determine the following for given snow conditions:
    a. Blade Height
    b. Blade Curvature
    c. Blade angle with respect to roadway centerline
5) Determine if the blade configuration would adversely affect the operator or motorists.
6) Prepare an interim report summarizing progress of research and findings by May 1, 1995.
7) Submit a final report which should include an executive summary, literature summary, research methodology, findings, and conclusions, and recommendations concerning implementation of variable curvature snow plow blades.
8) Present findings and conclusions to SDDOT Research Review Board upon completion of the project.

Observation Methods

"Determining methods for observing and evaluating the equipment in operation" was task three in the project statement. To evaluate the performance of the flexible plow, a reference plow was to be evaluated—a steel plow commonly used by SDDOT. Video was to be taken of both plows, running under similar conditions. Due to the lack of snow accumulations, only the flexible plow was taped. The snow cloud was video taped and observed from behind and from the front. The wind speed and direction was recorded, type of snow, depth of snow, direction of plowing, openings of both ends of the flexible plow,

angle of the plow relative to the road centerline, and plowing speed. The curvature of the plow was measured by using a ruler mounted vertically on the plow. The ruler was marked in inches of plow opening.

Observation of Equipment

Observe the equipment in field conditions and determine the following for given snow conditions:

Plow Height
Plow Curvature
Plow angle with respect to roadway centerline

The equipment was observed in new dry snow on the unused taxiway at the Pierre airport. This way, observations were made while the plows operated without the concern for other traffic. This evaluation was done during the winters of '94-'95 and '95-'96.

Before video taping began, a steel rod was attached to the plow to allow a reference to be made when watching the video to determine optimum plow height, curvature and angle. After several runs videotaping the plow, the rod was removed because it was obvious that the maximum curvature caused the largest cloud, the narrowest opening caused the smallest snow cloud.

Through discussions with snow plow operators, it was discovered that conditions vary so much during plowing that it would be impossible to recommend one plow angle and curvature setting for each set of conditions. While an operator plows snow, he adapts to changing conditions by constantly adjusting his plow. The setting that gives him best visibility and cleanest plowing ability is what he uses. Knowledge about what plow settings to use for a specific amount and type of snow or ice would not help the operator. The plow's angle relative to centerline was also not an issue because the most effective angle for cutting snow and ice changes with conditions. The operator can change this angle until the most effective one is found. The reversible plow is a necessity when cleaning intersections.

In the photographs, taken from the video, it is clear that while the plow was fully open, similar to the steel plow, snow traveled over the top of the plow, hood and windshield (Figure 2). The wind was less than 10 miles per hour on the day of videotaping, so direction of travel was not a factor. Note that in the first frame, the plow is fully open, is cycled fully closed in the fourth and fifth frames, and opened again. Only 2 to 4 inches of dry, undisturbed snow were on the ground.

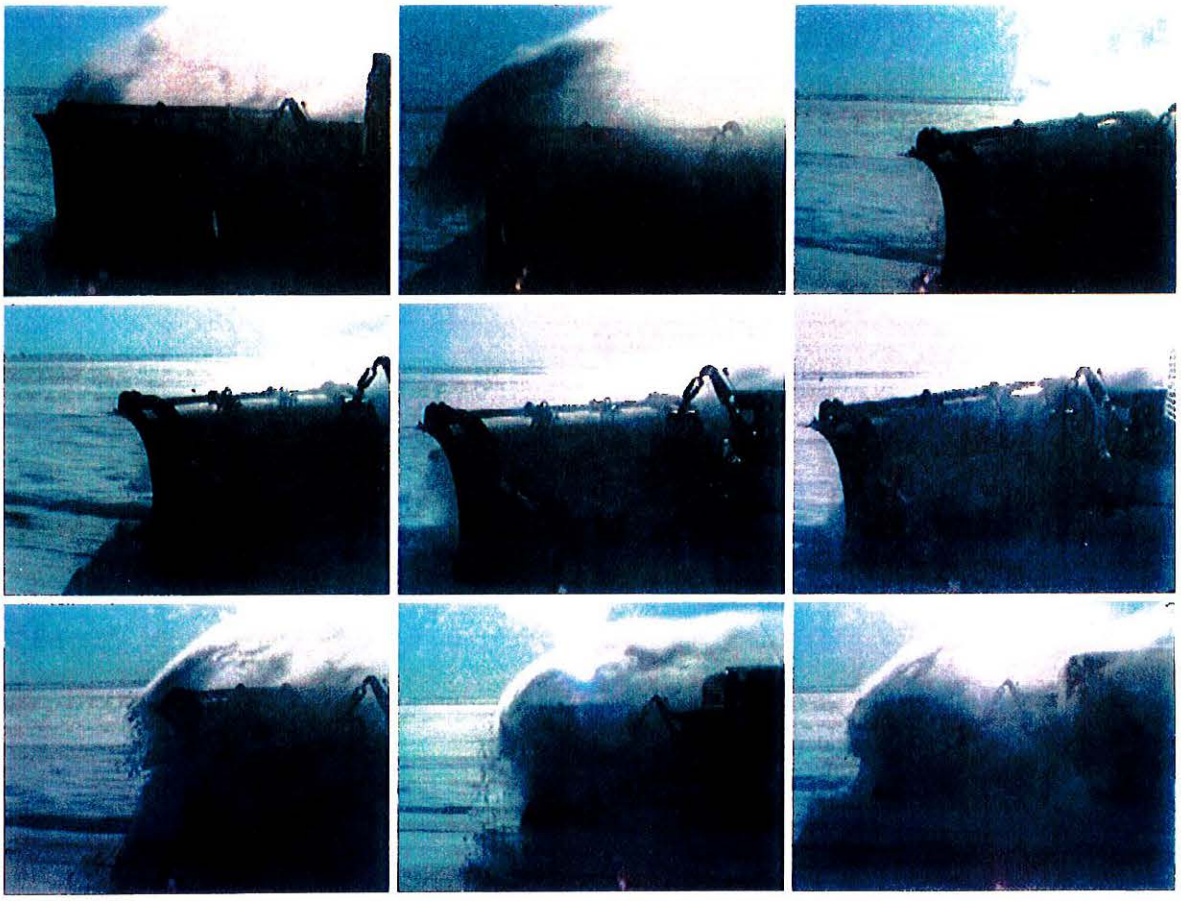


Figure 2 Photos taken from beside plow

Figure 3 shows the plow from a slightly different angle. The first frame shows the plow closed. In frames 3,4,5 and 6, the plow is open, and closed again in the final frames. Again, the wind was light, and there was 2 to 4 inches of dry snow.

Figure 3 Photos taken from beside plow

Figure 4 Plow from the front

Frame 1 of Figure 4 shows the plow closed. As the plow opens in frame 2 and 3, the snow can be seen surrounding the truck rather than being ejected to the side. Snow is 2 to 4 inches deep.

Figure 5 Snow cloud seen from behind truck

The top photo in Figure 5 shows the back of the truck while the plow is fully closed on the discharge end. The bottom photo shows truck while the plow is open. The truck nearly disappears from view.

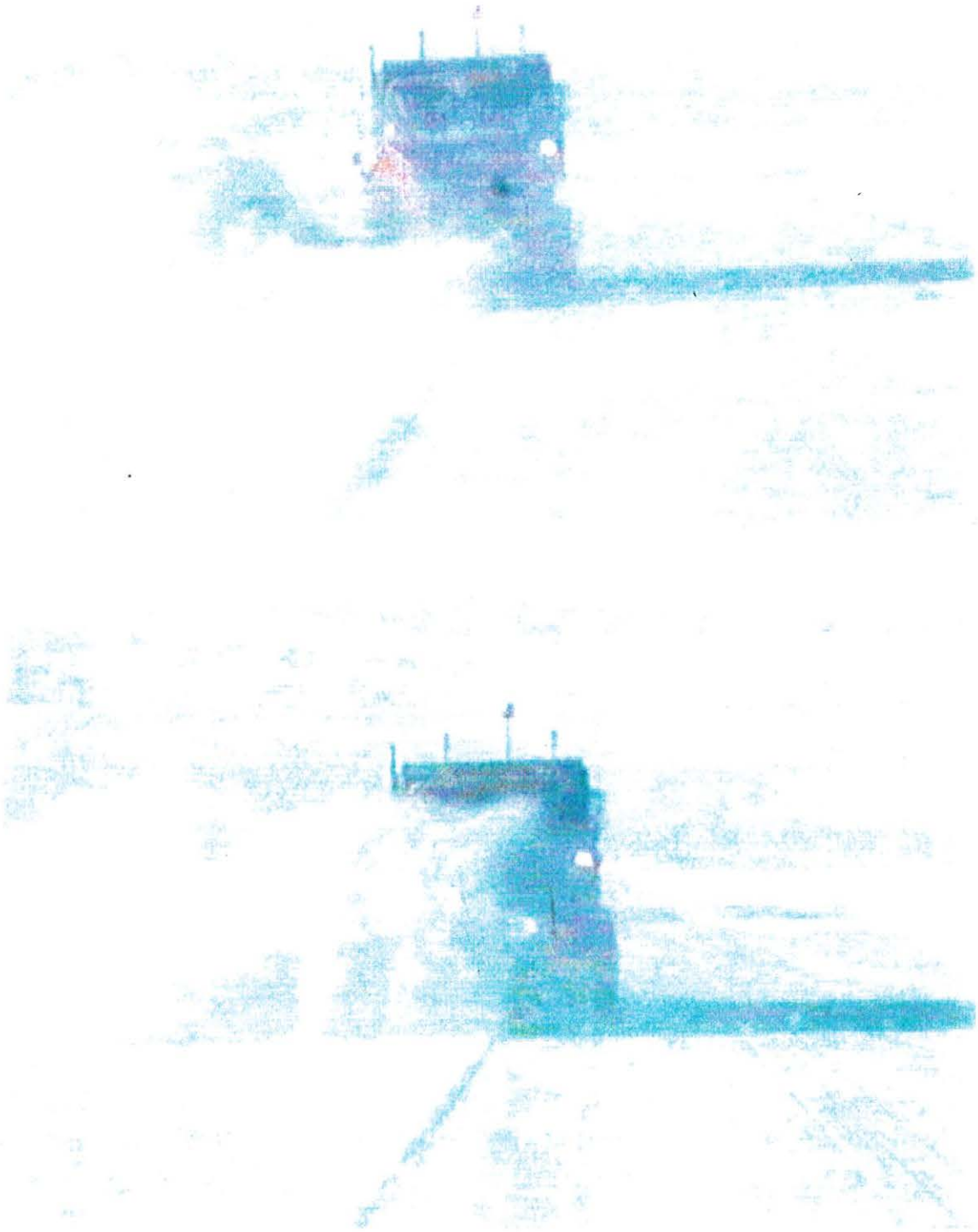


Figure 6 Snow cloud seen from in front of truck

Figure 6 shows the plow closed in the top photo, and open in the bottom photo. Note the snow blowing over the top of the plow and hood, obscuring the operator's vision.

According to operators, the flexible plow efficiently moves light, fluffy snow as well as wet, heavy snow. The video was taken while plowing 2-4 inches of dry snow. It clearly shows that an operator's control effectively reduces visibility problems.

Operators also liked the flexible plows because they were easy to operate and install, requiring no more maintenance than steel plows. In fact, the snow plows require less time to maintain than steel plows because snow doesn't stick to the moldboard. Steel plows require time for the snow to melt off the plow before maintenance can be performed. There have been no leaks in the cylinders and no breaks in the welds. It is a very heavy plow, which helps keep it on the road and cuts snow and ice down to the pavement. The only feature each operator disliked about the plow is that it was 11' long rather than 12' as the steel plows are. At the time the flexible plows were purchased, the manufacturer could only acquire polyethylene in 11' sheets. The manufacturer is now able to supply plows using 12' sheets.

The reversible plows are useful as a push blade to remove snow from intersections, which eliminates the need to bring in a loader. In light of the cut in forces for snow removal, the reversible plows can be used at other maintenance units when needed most.

Improved Efficiency

According to the Frink brochure, fuel efficiency is improved by the low coefficient of friction of the polymer moldboard. The company claims that because snow won't stick to the plow's slippery surface, the plow may be operated at a smaller angle relative to the centerline, resulting in a wider cutting path.[4] Because the plow would have to make fewer passes to clean a patch of pavement, fuel savings of 25-33% can be realized compared to steel plows. The sales brochure claims these savings based on a study done at a London airfield in 1977. The text of this report can be found in Appendix B. A 19' Frink polymer plow was compared to a 19' steel plow. Because the comparison was made on an airfield, it is not directly comparable to plowing snow on state highways. Nevertheless, it demonstrates the concept that less energy is used because snow and ice does not stick to the moldboard.

Table 2 Plow Affect on Mileage

	Summer	*Winter*	*Δmph*
Rapid City Frink	5.81	4.39	-1.42
Steel	6.00	4.14	-1.86
Pierre Frink	5.54	4.84	-0.70
Steel	6.39	5.33	-1.06
Mitchell Frink	5.08	4.70	-0.38
Steel	5.40	5.30	-0.10

Through queries of the SDDOT Equipment Management System (EMS), snow plow miles traveled and quantity of fuel used were extracted for a truck with and without the Frink plow attached, and for a similar truck with and without a steel plow.[5] The data in Table 2 shows that in each case, the flexible moldboard plow reduced the mileage of the truck to a lesser extent than did the steel plow. This is indicated by the smaller changes in miles per hour (mph) from summer to winter in the Frink plow than the steel. Note that the summer and winter estimates include various types of work, and that the mileages shown are averages. Also, in Mitchell Region, the truck used in the winter was a manual transmission, whereas the truck with the steel plow was an automatic. This might explain the difference in trends from summer to winter. The Frink plow weighs 2400 pounds, roughly the same as the steel plows, so mileage is not adversely affected by the weight of the plow. The moldboard is light, but the steel framework and hydraulic cylinders are heavy.

Operators have observed that the plow seems to cut ice and snow using less power. This may be because the cutting edges are more efficient, the operator has the ability to control the angle of the plow, and snow does not stick to the plow's surface.

Economic Analysis and Evaluation

The Frink plow costs $7,885. This is roughly $4000 above the cost of the Monroe and Wausau steel plows SDDOT has commonly been purchasing, ranging from $3544 to $4663. A replacement moldboard for the 11' plow costs $955. An 11' Frink reversible now lists for $8700, but a bid price should be lower. 12' Frinks now list for $9830, and 14' list for $10,390.

Snow plow operators state that they can plow faster using the flexible plow than with the steel plows in the same conditions due to increased visibility. During a 12 hour day, a flexible plow traveling 30 mph can plow 120 more miles than a steel plow traveling 20 mph. It would take a steel plow an additional 6 hours to cover the same amount of highway as a flexible plow. At $9 per hour plus $3.60 (40% benefits) that a snow plow operator works, $75 a day is saved by covering more highway using the flexible plow. At this rate, in 53 days of plowing, the additional $4000 plow cost over the steel plow cost would be recovered.

FHWA Technical Advisory 7570.1[6] provides a basis for what property damage, injuries and deaths cost. From these numbers, SDDOT Local Government Assistance calculated that when all types of traffic accidents are taken into account statewide, vehicle contact type accidents average about $18,000 per accident. Fatal accidents cost $1.5 million or more. The Department averaged 14.5 snow plow rear-end or side-swipe accidents per year from 1993 through 1996. Using these figures, if the flexible plow reduced accidents by 5.6 per year, or 38% of the annual snow plow rear-end and side-swipe accidents, the additional cost of the flexible reversible plows would be offset. Additional benefits would be realized if other types of accident reductions were included in the analysis. For example, snow cloud related accidents involving only private vehicles are not included in the average number of accidents.

Safety

Task 5 of the problem statement was to determine whether the plow configuration would adversely affect the operator or motorists. Videotaping the plow from a variety of angles reveals no adverse effects of the flexible plow concerning motorists. Interviews with snow plow operators verify this.

Operators feel safer using the plow as a result of having better visibility and being more visible to other traffic. The lighting system recommended in study SD91-06 contributes to better visibility. Having better visibility seems to reduce the fatigue factor of operators as well as allowing the operator to operate more safely. The higher visibility for the operator allows him to travel faster, more closely matching the speed of traffic.

Other States' Experience

Interviews were conducted with two states regarding performance and life of their Frink flexible snow plows. David Fraser, maintenance superintendent for Denver, Colorado, stated his organization has had flexible plows for eight years. They have had no problems with them outside of the normal maintenance

that is performed on conventional plows. Twenty of their ninety plows are flexible moldboard plows. As steel plows wear out, they are replaced with flexible plows.

Bruce Hanson, Maintenance Superintendent for the Twin Cities metropolitan area of the Minnesota DOT, said his area has used flexible moldboard plows for seven years. Only six of their 251 trucks use flexible plows. No cracking has been observed on the plows, but in once instance, the moldboard has elongated around the bolts. It has not caused reason for concern. In the Twin Cities area, flexible moldboard plows are being placed on routes where it is considered most important to reduce snow clouds.

Other Research

During the course of study SD91-06, several ideas were discussed about the use of a deflection fin bolted to the steel moldboard of plows presently used by SDDOT. Personnel from the Sioux Falls area were to experiment with this concept during the winter of '94-'95. With this fin in place on the discharge end of the snow plow chute, snow would be deflected downward in a narrow column, reducing the number of snow particles picked up by the wind to produce a snow cloud. In addition to the metal fin, a rubber flap may be mounted to the chute of the plow to narrow the column of snow being discharged. The ideas may be tried to determine whether SDDOT's existing snow plows may be cost-effectively altered to reduce the snow cloud. Will Rishling of the Sioux Falls Area office has done some initial work on the concept. Unfortunately, maintenance personnel are most busy during and after times of snow fall. Mr. Rishling did not find time to try any of the suggestions from the previous study. Nor did personnel from Rapid City or Mitchell video tape snow plow operations in their areas. The video taken in the Pierre area is sufficient to show the effects of changing the geometry of the flexible moldboard.

The department has already purchased three more flexible plows manufactured by Viking. These were purchased for use on the interstate south of Pierre, and have not yet been used in a winter storm. The Viking plows cost $10,293 each. Specifications are shown in Appendix C.

Conclusions

The flexible mold board Frink plow is a significant improvement over conventional steel plows. The versatility provided by the plow allows the operator to quickly adapt the shape of the plow to changing conditions to improve his own visibility as well as making his vehicle more visible to traffic. The improved visibility not only allows him to see more clearly, but allows him to travel faster, decreasing the speed difference between his plow and other traffic. These issues provide not only safety, but increased efficiency by allowing an operator to plow more highway within a given period of time.

Recommendations

It is recommended that the Division of Operations should continue to purchase flexible moldboard plows when a reduction in snow clouds is important and higher highway speeds justify it. The plows have a higher initial cost compared to conventional steel plows, but cost is recovered within two or three winter seasons, and safety is improved for the operator and the traveling public.

[1] SDDOT, South Dakota Division of Operations Employee Injury and Accident Report, 1989-1995
[2] SDDOT, Snow Plow Safety Study, October 1993
[3] SDDOT, Improving Visibility for Snow Plow Operators, Summer 1996
[4] Frink, America, Report on 19' Polymer Frink Plow, 1977
[5] SDDOT, South Dakota Equipment Management System, 1994-1996
[6] FHWA, Technical Advisory T 7570.1, Motor Vehicle Accident Costs, June 30, 1988

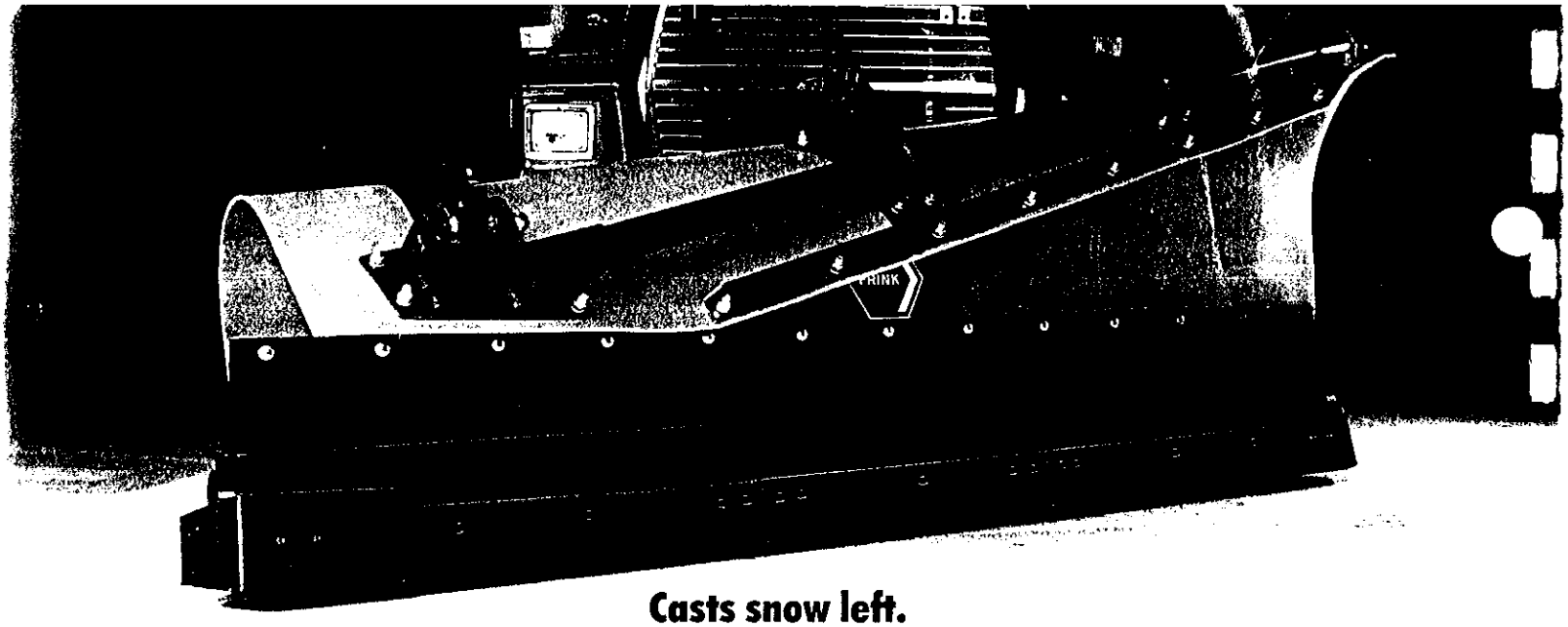
Appendix A

Frink Plow

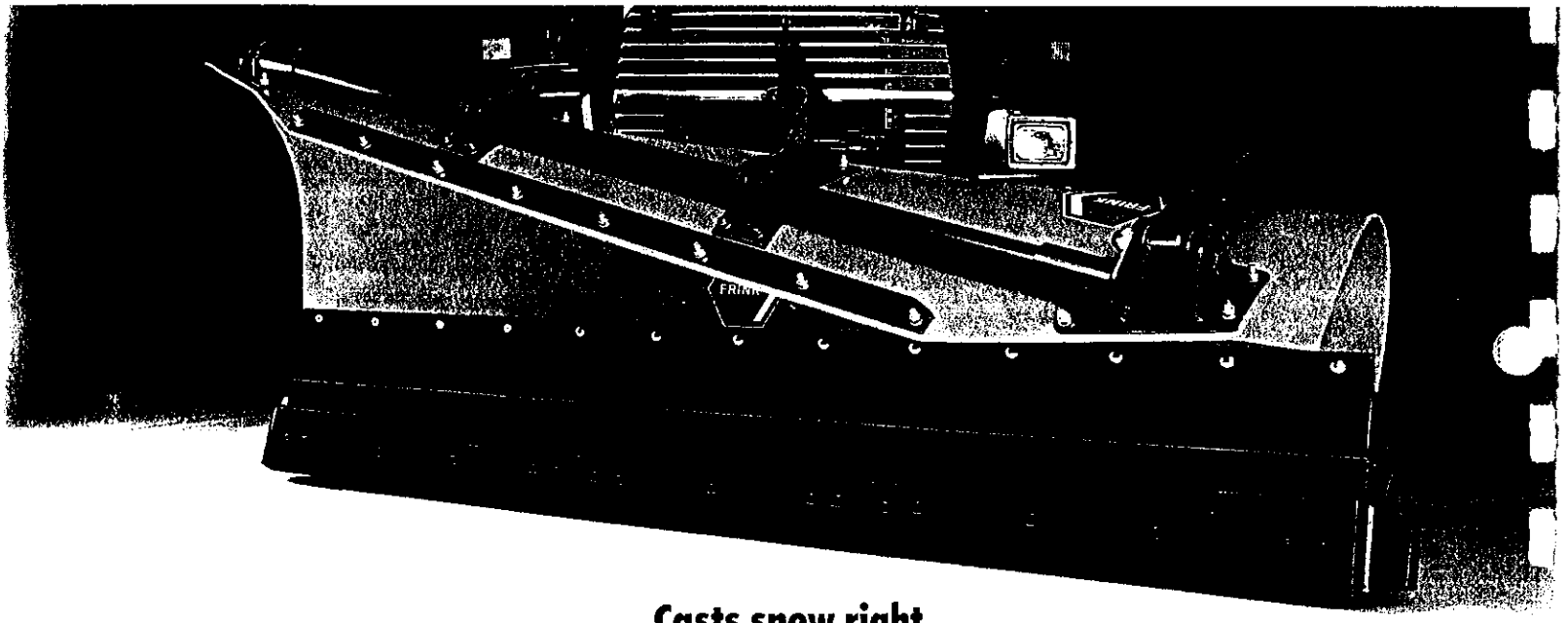
FRINK REVERS-A-CAST PLOW

Exclusive flexible moldboard changes shape and position for maximum versatility. Adjustable from 33″ to 51″ high, it also reverses in any position. Uses Frink worm gear or ram reverse drive frames; performance-proven features include fuel-saving polymer moldboard and trip edge design.

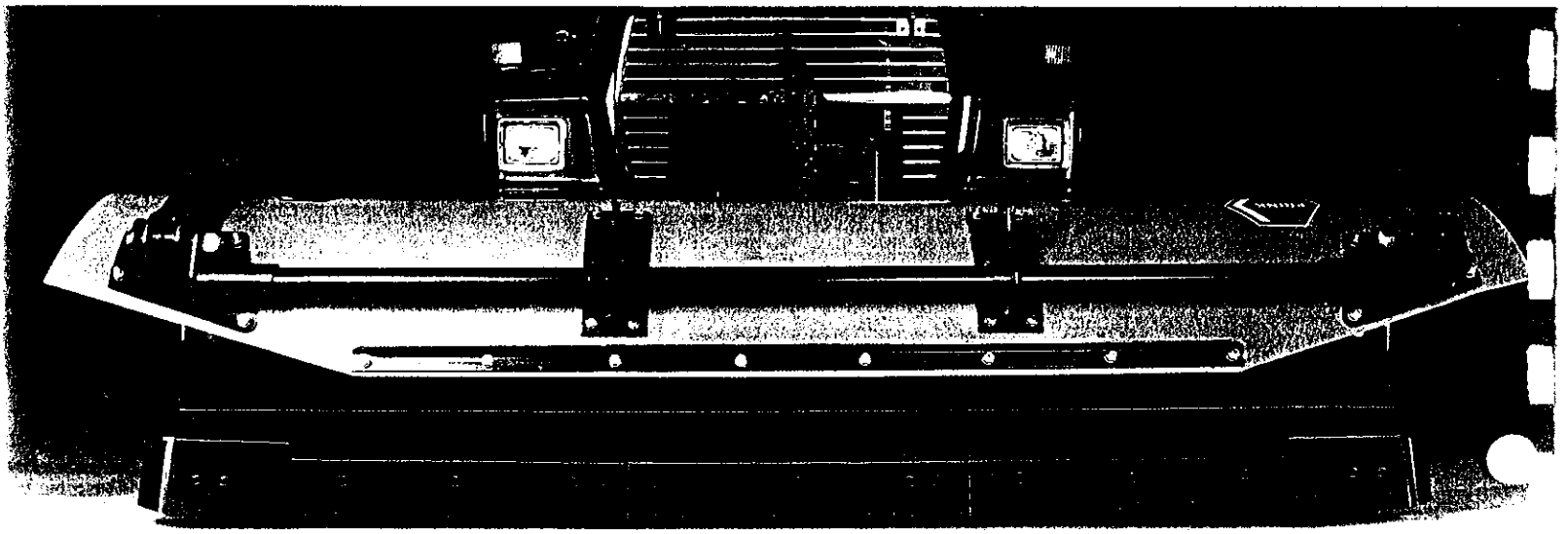
FRINK AMERICA



Casts snow left.



Casts snow right.



Casts snow anywhere you want it.

Revers-A-Cast is flexible and reversible, to put snow anywhere you want it.

You've never seen a plow like Revers-A-Cast before. Because there's never been a flexible moldboard before.

This exclusive Frink innovation lets you change casting distance, direction and moldboard shape, anytime. From inside the cab. With the plow in any position. Without even slowing down.

It's a revolutionary development which means faster, easier, more cost-effective plowing for jobs of all sizes and types.

With our unique hydraulic mechanism, you can adjust the curvature of the moldboard to fit whatever plowing conditions you face. For dry, blowing snow, curl it down to 33" straight across. For heavy, wet snow, open the discharge end to 51". Or, flatten it out again to 33" straight across to reduce casting distance and blow-back.

Revers-A-Cast also lets you form a maximum-casting One-Way plow by simply reversing the moldboard completely. For one-way plowing in the opposite direction, just reverse the moldboard completely to the other side.

Plus, you can reverse the plow whenever you like, whether it's in the one-way position, curled down, flat or whatever.

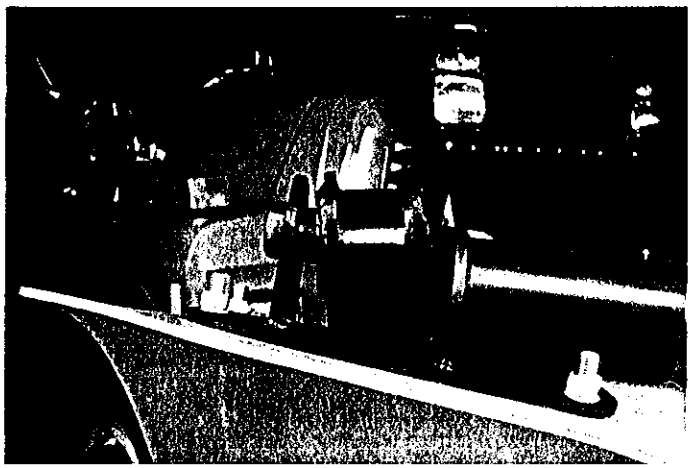
Two 3½" x 6" hydraulic cylinders work automatically, in conjunction with the reversing mechanism, to form a one-way cone in whichever direction the plow is angled. This rugged, yet clean, scissor device provides an uncomplicated means of moldboard shaping.

Complete plowing flexibility.

All these shape and position options mean Revers-A-Cast can handle many jobs which used to require more than one plow. Now you'll have an assortment of plows at your fingertips, and you can change from one to another at the touch of a lever.

No more wasting time and money by going back over a section of road with a second type of plow. No more unhitching and rehitching various plows to the same truck.

With Revers-A-Cast, you can plow one-way streets, residential streets, parking lots, culs de sac, highways, airport runways and more. You'll have the flexibility – literally – to handle all of these jobs with speed, efficiency and economy.



Massive, self-aligning bearings allow for proper positioning, while eliminating torsional stresses on the moldboard's structural supporting members.

Save fuel with the polymer moldboard.

Flexibility and reversibility aren't the only qualities you'll appreciate about Revers-A-Cast.

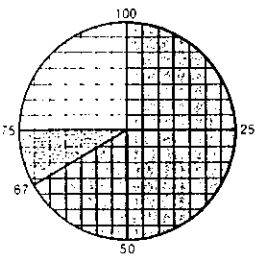
You'll also get performance-proven components like Frink's patented polymer moldboard. With its extremely low coefficient of friction, this time-tested material is loaded with advantages.

It's tougher than steel but lighter than aluminum, and has demonstrated real fuel savings of 25-33%. Snow won't stick to its slippery surface – no matter what the temperature – which means plowing is faster and more efficient.

In addition, the moldboard is practically maintenance-free. It's corrosion resistant and never needs painting.

And if you're wondering about durability, consider this: We ran the Revers-A-Cast moldboard through a grueling 44,000 flex tests at −40°F (that's about eight times what you'll ever do with it) and it is still going strong!

The Frink polymer moldboard revolutionized plowing more than 10 years ago. Now, as an integral part of our new Revers-A-Cast, it's doing it all over again.



Proven fuel savings.

Fuel consumption, truck with a steel plow = 100.

Fuel consumption, truck with a polymer plow = 67-75.

NOTE: Chart is based upon gallons of fuel consumed per square unit of linear distance. Figures may vary with engine torque, gear ratios and other factors.

Protect equipment with trip edge.

Another proven part of Revers-A-Cast is the trip edge design. This Frink innovation minimizes shock loads by deflecting whenever it meets an obstruction on the pavement.

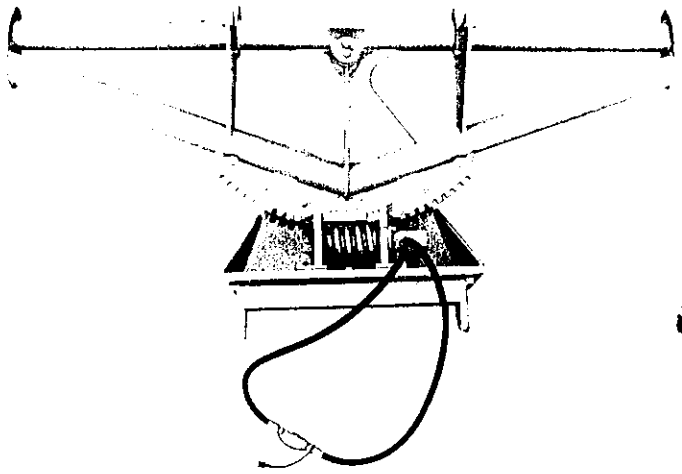
The benefits of trip edge are obvious: Equipment is protected, driver safety is improved, and the long life of your Revers-A-Cast plow is ensured.

Plus, thanks to Frink's rugged torsion springs, you can always be sure of proper blade alignment.

Choice of Frink drive frames.

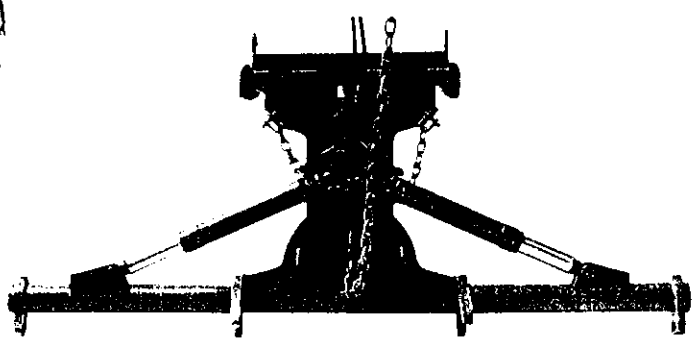
Those of you who already know the value of Frink's Worm Gear or Ram Reverse Drive Frames will be glad to know Revers-A-Cast fits either one (WG or RR85).

The hydraulically powered worm gear is infinitely variable. It locks in place wherever you want, up to 37° left or right.



The Ram Reverse features the same infinite variation, controlled by two powerful 3½" x 16" hydraulic cylinders. With a minimum burst pressure of 8,000 PSI, it can handle even the heaviest snow conditions.

Either way, you'll get powerful, dependable reversing action with Revers-A-Cast.



REVERS-A-CAST SPECIFICATIONS

Plow Models	Moldboard Height Max.	Moldboard Height Min.	Moldboard Material	Path cleared at following angles 0°	10°	20°	30°	37°	Reversing Mechanism	Standard Cutting Edge	Trip Activation	Approx. Weight
RAC 3351-RR	51"	33"	⅜" thick polyethylene	11'-0"	10'-10"	10'-4"	9'-6"	8'-9"	(Qty. 2) 3½" x 16" hydraulic cylinders	(Qty. 1) 1090 steel ½" x 8" A.A.S.H.O.	¾" wire torsion springs	1650
RAC 3351-WG	51"	33"	⅜" thick polyethylene	11'-0"	10'-10"	10'-4"	9'-6"	8'-9"	Hydraulic motor w worm gear	(Qty. 1) 1090 steel ½" x 8" A.A.S.H.O.	¾" wire torsion springs	1845

If It's Innovative, It's From Frink.

FRINK AMERICA
Clayton, New York 13624
TEL: 315/686-5531 FAX: 315/686-5527

PRINTED IN USA

Appendix B

Report on 19' Polymer Frink Plow

REPORT ON 19' POLYMER FRINK PLOW

The 19' Polymer Plow purchased from Frink of Canada in 1977 - 78 has become a very valuable addition to our string of snow removal equipment at London Airport.

The Polymer moldboard has cut our operating costs by approximately 1/3. With the steel 19' moldboard severe snow spill at the nose was general at slow speeds, as snow would stick to the moldboard and pile up, resulting in nose spill.

Snow does not stick to the Polymer moldboard, resulting in a nice rolling motion of plowed snow, enabling at least a 1/3 wider cut, therefore the 1/3 saving in fuel and time. The plow is lighter therefore less horse power is required to push it permitting higher truck speeds. The pushframe in its final stage is a beautiful thing to behold due to its simplicity of construction and fingertip hydraulic angle control. It is considerably lighter in weight than the 19' steel moldboard with hydraulic motor gear type angling. Hydraulic cylinder angle control permits for greater stability, and instant angle change at the touch of a lever, making it a very versatile snow plow for clearing intersections and ramp areas where short turns would normally delay the snow removal operation due to loss of angle on turns.

We at London Airport take this opportunity to thank Frink of Canada and their engineer for this improved snow plow.

J. Kopetski
Supervisor
Equipment Maintenance

Jan V

FYI

POLYMER - LINED PLOW MOULDBOARDS

DURING THE LAST MOBILE EQUIPMENT MAINTENANCE CONFERENCE AT WINNIPEG, MR. JAN VERSEETH WHO IS A DESIGN ENGINEER WITH FRINK, CANADA, INTRODUCED A MATERIAL CALLED POLYMER. POLYMER IS A PLASTIC MATERIAL THAT WEIGHS 1/8 THAT OF STEEL AND ITS COEFFICIENT IS 1/3 THAT OF STEEL. IT IS VERY TOUGH, VIRTUALLY UNBREAKABLE AND HIGHLY RESISTANT TO WEAR.

FRINK HAD BEEN USING POLYMER FOR THE MOULDBOARD ON LIGHT-DUTY PLOWS FOR SOME TIME WITH EXCEPTIONALLY GOOD RESULTS. IT WAS SUGGESTED AT THE SEMINAR THAT THE DEPARTMENT OF TRANSPORT MIGHT BE ABLE TO MAKE GOOD USE OF POLYMER WHEN APPLIED TO A STEEL MOULDBOARD. DALT CLELAND AGREED AND ADVISED THAT THE DEPARTMENT WOULD INVESTIGATE THE USE OF POLYMER.

THIS PROPOSAL WAS DISCUSSED BETWEEN DALT CLELAND AND MYSELF AND IT WAS SUBSEQUENTLY AGREED THAT OTTAWA WOULD FUND THE COST OF THE POLYMER APPLICATION AND THE ONTARIO REGION WOULD MONITOR THE EVALUATION. LONDON AIRPORT WAS CHOSEN AS THE EVALUATION SITE BECAUSE THEY HAVE TWO IDENTICAL MODEL 4844-D WHITE PLOW TRUCKS BOTH EQUIPPED WITH FRINK MODEL 4219 PWK PLOWS. USING THIS TYPE OF EQUIPMENT WE WERE ABLE TO OBTAIN AN EXCELLENT COMPARISON BETWEEN THE POLYMER AND STEEL MOULDBOARDS.

FRINK BUILT A NEW 19' PLOW USING A 3/8" SHEET OF POLYMER IN LIEU OF A STEEL MOULDBOARD. THIS PLOW WAS ALSO EQUIPPED WITH TWO 2" HYDRAULIC REVERSING RAMS TO OVERCOME THE PROBLEM ENCOUNTERED WITH THE WORM AND SECTOR MECHANISM.

THIS PLOW WAS PUT INTO OPERATION AT LONDON IN DECEMBER 1977 AND DURING THAT WINTER OPERATED FOR 108 HRS. SOME MINOR PROBLEMS WERE EXPERIENCED BUT NOTHING CONSIDERED SERIOUS. WITH THE EXPERIENCE DURING THE WINTER IT WAS DECIDED THAT THE PLOW WOULD BE MORE EFFICIENT IF THE HYDRAULIC REVERSING RAMS WERE ABLE TO CHANGE THE PLOW DIRECTION WHEN THE MOULDBOARD WAS LOADED. AT THIS POINT THE 2" RAMS WERE NOT ABLE TO DO SO.

.../2

FRINK INSTALLED A PAIR OF 4" HEAVY DUTY TELESCOPING RAMS. THIS PLOW WAS PUT BACK INTO SERVICE IN LONDON FOR THE WINTER OF 1978/79 AND PERFORMED EXCEPTIONALLY WELL. WITH THE HEAVY DUTY REVERSING RAMS THE OPERATORS WERE ABLE TO REVERSE AND CHANGE THE PLOW DIRECTION WHEN THE MOULDBOARD WAS LOADED RESULTING IN A MORE EFFICIENT SNOW REMOVAL OPERATION AT THE BUTTON AREAS, AT INTERSECTIONS AND ON THE RAMP.

AT THIS POINT, WE DECIDED THAT THE POLYMER SHOULD HAVE SOME EXTREME COLD WEATHER OPERATION. THE COMPLETE PLOW ASSEMBLY WAS SHIPPED TO S.S. MARIE WHICH IS ABOUT 800 KM NORTH WEST OF LONDON. IT HAS OPERATED AT S.S. MARIE FOR THE LAST THREE WINTERS WITH ONLY MINOR MAINTENANCE REQUIRED.

DURING THE FIVE YEARS WE HAVE USED THIS POLYMER PLOW, IT HAS ACCUMULATED 2121 HRS. OF SERVICE. THERE HAS BEEN VERY LITTLE PROBLEM WITH THE MECHANICAL AND HYDRAULIC COMPONENTS AND NO PROBLEM WITH THE POLYMER MOULDBOARD.

THE CONDITION OF THIS PLOW CURRENTLY IS THAT THE FRONT SURFACE OF THE MOULDBOARD IS COVERED WITH SCRATCHES AND MINOR ABRASIONS FROM CONTACT WITH SAND. WITH THIS WEAR RATE, MOST OF US HERE WILL NOT LIVE TO SEE THE POLYMER WORN OUT. THE EDGES OF THE POLYMER ARE MARKED FROM CONTACT WITH OTHER OBJECTS BUT NO PIECES HAVE BEEN BROKEN OUT.

AS MOST OF YOU ARE AWARE OF, THE TEST RESULTS FROM TWO SITES ARE NEVER IDENTICAL. IN ASSESSING THE CONSOLIDATED EVALUATION DATA FROM THESE TWO SITES WE HAVE PROVED CONCLUSIVELY THAT THE 19' POLYMER PLOW WILL TAKE A 25% WIDER CUT THAN THE 19' STEEL PLOW. IN OTHER WORDS, THE POLYMER PLOW IS 25% MORE EFFICIENT THAN THE STEEL PLOW.

THIS IS POSSIBLE BECAUSE OF THE LOWER COEFFICIENT OF POLYMER COMPARED TO STEEL. THE SNOW SLIDES ALONG THE MOULDBOARD EASIER AND FASTER AND THEREFORE LEAVES THE DISCHARGE END FASTER. SOME WEIGHT SAVING IS ACCOMPLISHED BY USING POLYMER IN LIEU OF STEEL AND WHILE BEING MINIMAL AT MOST, WE ARE PRESENTLY OVERLOADED ON PLOW TRUCK FRONT AXLES.

THERE WAS NO BUILD UP OF SNOW ON THE MOULDBOARD WHICH HAS ELIMINATED CONSIDERABLE TIME IN HAND CLEANING THE MOULDBOARD SNOW ACCUMULATION.

AFTER SOME EXPERIENCE WITH THE 19' PLOW, WE DECIDED TO EXPERIMENT WITH A ONE-WAY PLOW AND WING COMBINATION. IN NOVEMBER 1978, WE ARRANGED WITH FRINK TO HAVE A 1/4" POLYMER LINER INSTALLED ON THE MOULDBOARDS OF A FRINK MODEL 440 SKB PLOW AND A 30 SBT WING. THIS POLYMER LINED PLOW AND WING WAS PUT BACK INTO SERVICE IN WINDSOR AND OPERATED THERE FOR THE WINTER OF 1978/79.

THIS UNIT WAS THEN MOVED TO TIMMINS TO ACQUIRE SOME EXTREME COLD WEATHER OPERATION. THIS PLOW AND WING HAS OPERATED AT TIMMINS FOR THE LAST THREE WINTERS WITH NO PROBLEMS WHATSOEVER. DURING THE FOUR-YEAR LIFE OF THIS UNIT, IT HAS ACCUMULATED 2094 HOURS OF OPERATION AND OTHER THAN SOME SURFACE SCRATCHES IT IS STILL IN EXCELLENT CONDITION.

THE PERSONNEL IN TIMMINS FOUND THAT THE POLYMER-LINED PLOW WAS MORE EFFICIENT THAN THE STEEL PLOW. AND IN ADDITION THEY MADE SOME EXTENSIVE FUEL CONSUMPTION COMPARISONS. THEY CAME UP WITH A FIGURE OF FUEL SAVINGS OF $300.00 FOR THE WHOLE SNOW REMOVAL SEASON. THIS IS QUITE SIGNIFICANT BECAUSE THE SNOW-FALL THAT WINTER WAS ABOUT 60% OF THE NORMAL SNOW-FALL.

SOME ADVANTAGES ARE MORE DIFFICULT TO QUANTIFY HOWEVER THEY ARE STILL VALID. BY THE VERY NATURE OF POLYMER THERE IS LESS MAINTENANCE EXPENSE. THE WORK CAN BE DONE FASTER ALLOWING MORE TIME FOR SOME OTHER AREA OF AIRFIELD MAINTENANCE. WHEN WE ARE CONSTANTLY BEING ASKED TO DO MORE WORK ON THE AIRFIELD WITH LESS PEOPLE, I DON'T HAVE TO TELL YOU HOW IMPORTANT THIS IS.

THE ONTARIO REGION IS CONVINCED THAT THE INVESTMENT IN POLYMER FOR MOULDBOARDS AND MOULDBOARD LINERS IS A GOOD ONE. THE MANAGEMENT HAS APPROVED A PROJECT FOR A T.E.C. OF $111,000.00 TO INSTALL POLYMER LINERS ON 31 SNOWPLOWS THROUGHOUT THE REGION. LAST YEAR WE PUT INTO SERVICE AT S.S. MARIE A NEW TRUCK WITH A 19' POLYMER MOULDBOARD.

Appendix C

Viking Plow

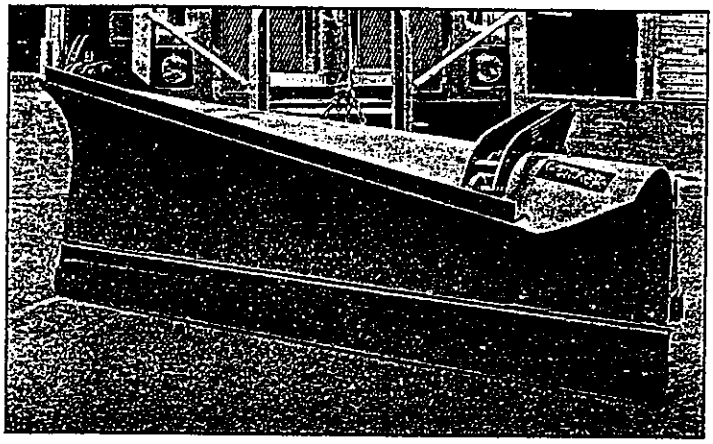
FLEXPLOW 2000

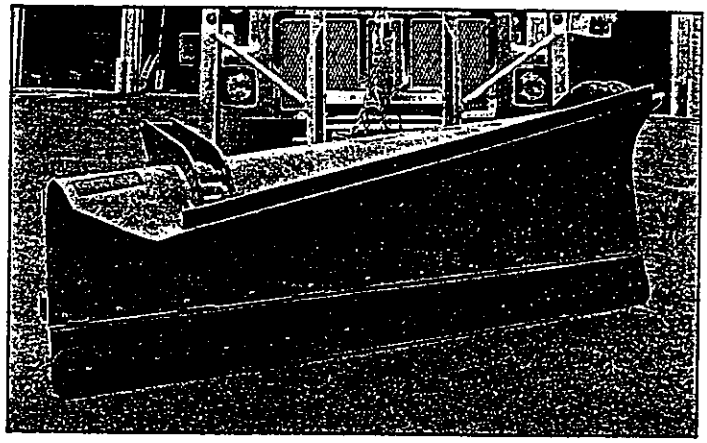
Ready now for the 21st Century

Have the efficiencies of a one way with the versatility of a reversible

Finally you can enjoy complete plowing flexibility. You can always discharge "Downwind". Just change the angle of your plow and send the snow wherever nature wants it. It's as simple as that, just pull the lever.

Now from VIKING you can have it both ways





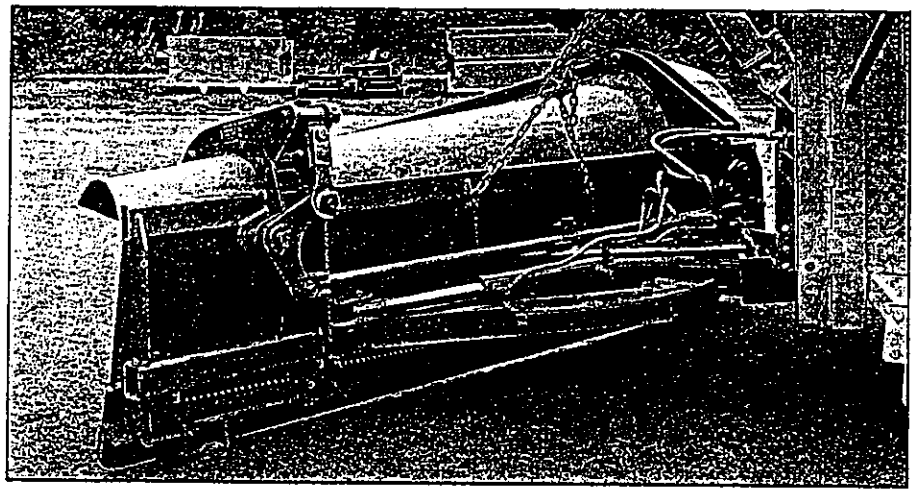
Simply angle the plow to the right and you have a right hand one-way, then angle to the left and you have a left hand one-way. It's simple, no additional hydraulic valves or cylinders to increase your cost or down time. Only from VIKING you can get these features. Take these advantages and couple them with a proven trip edge design with polymer moldboard and you're ready to take on whatever winter offers today or even into the 21st Century.

VIKING-CIVES (USA), RR#2 BOX 36-1/2, HARRISVILLE, NY 13648
Phone (315) 543-2321 Fax (315) 543-2366

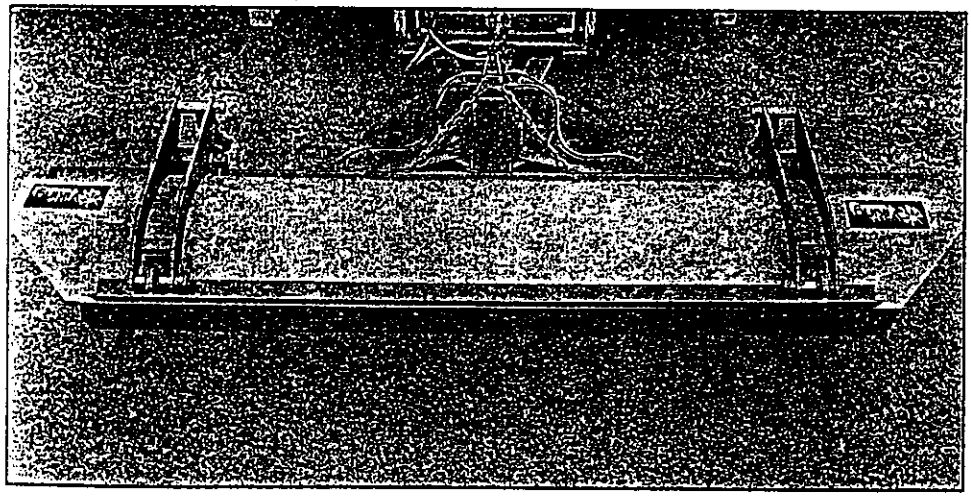
Viking Cives (USA)

(5) 7/8" wire torsion springs provide safe sure trip action

* PATENTED mechanical linkage provide low cost moldboard flexibility without costly hydraulic components.



Clean, efficient and most of all SIMPLE design



Moldboard is 3/8" thick UHM polyethylene 1 piece sheet, secured top and bottom. Both mechanical ribs are provided with zerk fittings to insure lubrication.

SPECIFICATIONS*

Model	Trip Springs	Clearing Path	Weight
FL 1042	(4)-7/8" wire	8-1/2 to 10'	2,200 lbs.
FL 1142	(5)-7/8" wire	9-1/2 to 11'	2,300 lbs.
FL 1242	(5)-7/8" wire	10-1/2 to 12'	2,400 lbs.

MIKE GREEN

All models come standard power reverse with (2) 3" x 15" DA cylinders and cushion valve. Backer angle is 4" x 4" x 3/4" material.

* Note: Specifications subject to change without notice

Dealer:

VIKING-CIVES (USA), RR#2 BOX 36-1/2, HARRISVILLE, NY 13648

Viking Cives (USA)

* U.S. PATENT #5,079,866, CANADA PATENT PENDING

Appendix D

Snow Plow Shield

Iowa Department of Transportation

800 Lincoln Way, Ames, IA 50010

515-239-1556
515-239-1005 FAX

July 15, 1996

Ref. No.: 324

Mr. John Becker
South Dakota DOT
700 East Broadway Avenue
Pierre, SD 57501-2586

Dear Mr. Becker:

Enclosed are photos and drawings of the snowplow shield Iowa tested the last two winters and a copy of the article that appeared in the February 1995 issue of Technology News.

The shield in the photos is shown on a 42 inch high, 11 foot reversible snowplow. The snowplow lights on this truck were raised about 6 inches to clear the snowplow shield.

The mounting system consists of welding two angle iron mounts to the plow frame. The upright supports are bolted to the angle iron mounts for easy removal. The mounting system and adjustment points permit use on almost any plow. Adjustment points will require pinning or spot welding to prevent movement during usage.

The snowplow shields are fabricated per Iowa DOT prototype by a local welding shop and tent company and cost approximately $200.

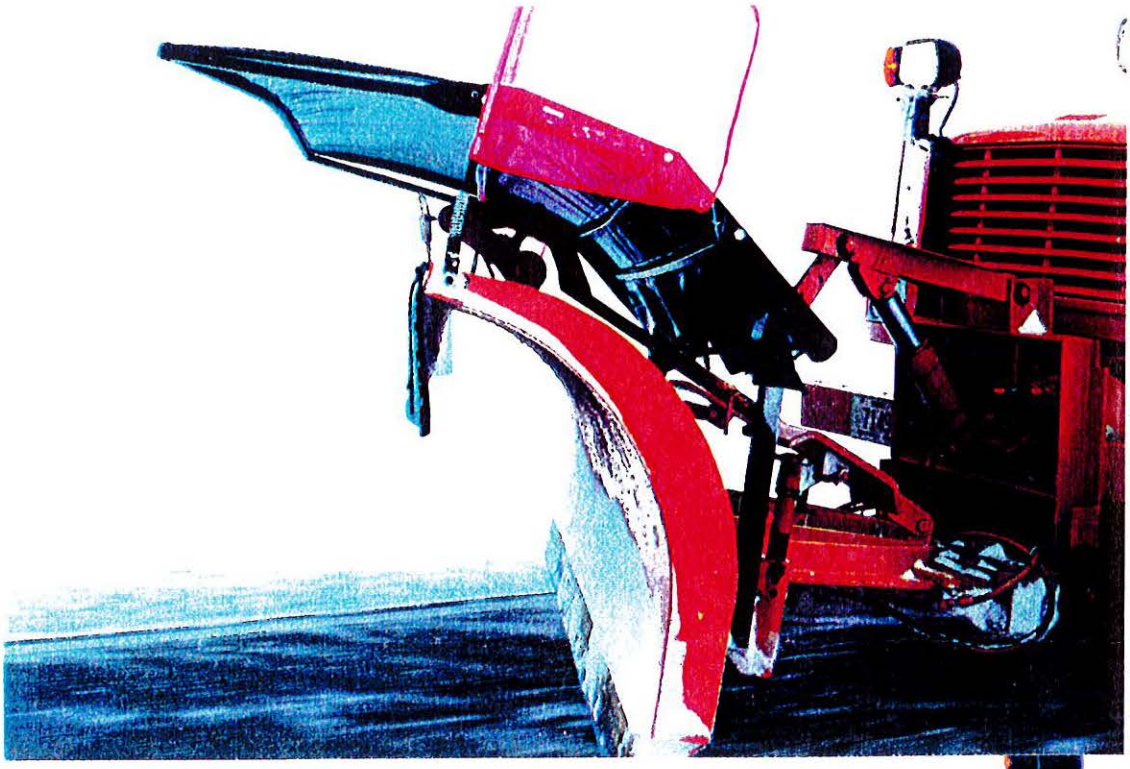
Please feel free to call if you have any questions.

Sincerely,

Brad Osborne

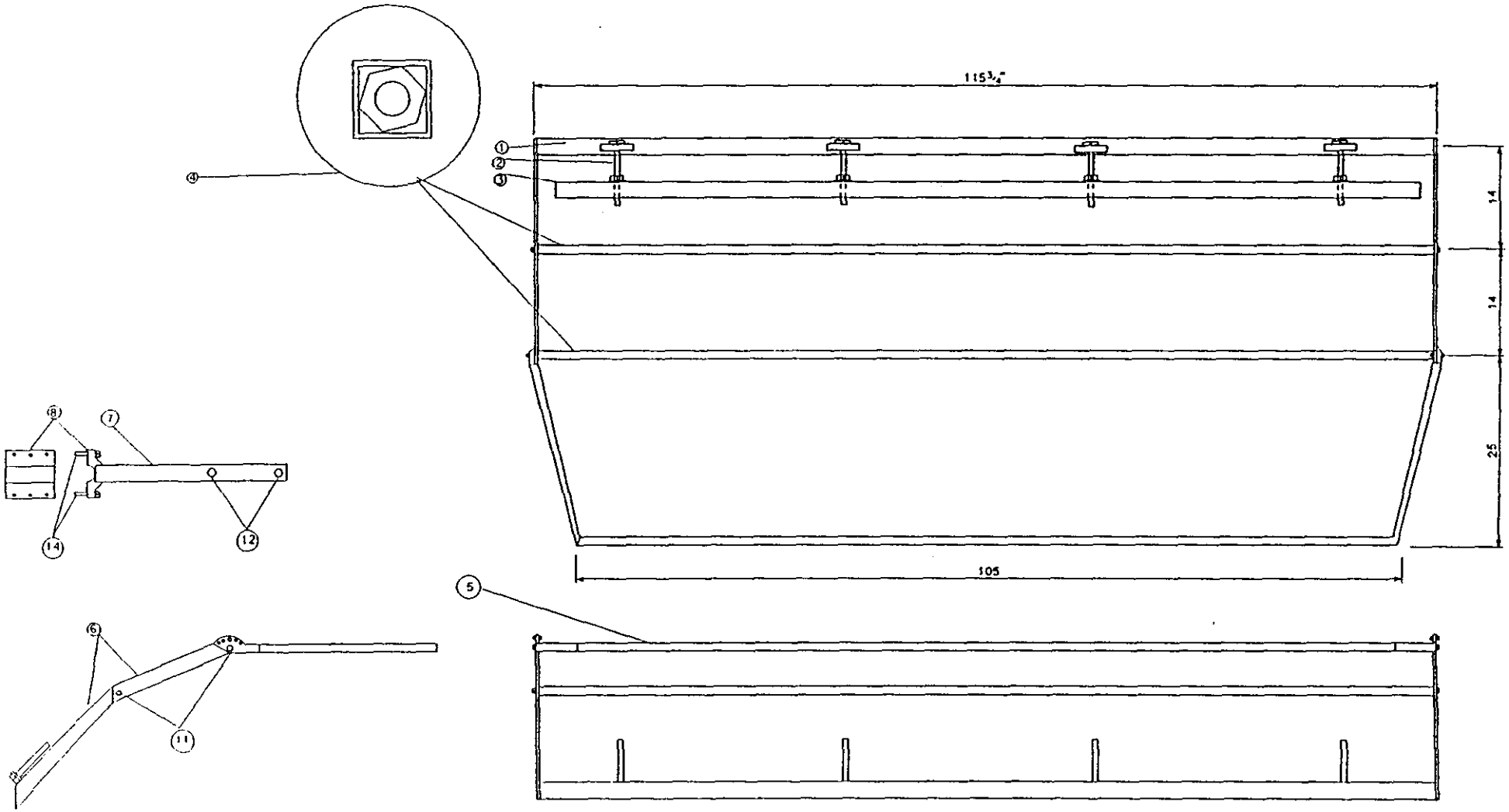
Brad Osborne
Office of Maintenance Programs
Maintenance Division

BHO:jah
Enc.
cc: Tom Donahey
Lee Smithson

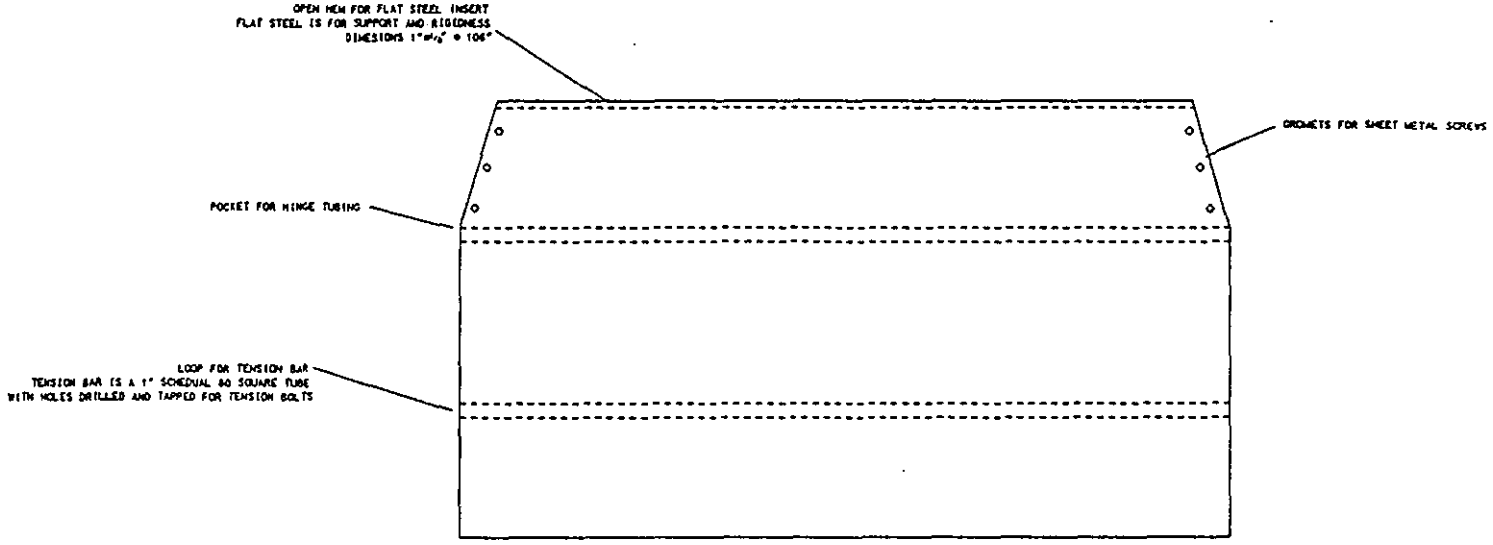


Iowa Department of Transportation

DETAILS OF
SNOW PLOW SHIELD



PART #	QTY	DESCRIPTION
1	1	MOUNTING PIPE. 1¼" ID SCHEDUAL 80 PIPE 115" WITH TABS WELDED ON AND DRILLED FOR TENSION BOLTS
2	4	TENSION BOLTS. ¼" ø 3" NC THREAD GRADE 8 BOLTS WITH NUTS AND WASHERS
3	1	TENSION BAR. 1" SCHEDUAL 80 SQUARE TUBING DRILLED AND TAPPED FOR THE FOUR TENSION BOLTS
4	2	HINGE TUBING. 1" SCHEDUAL 80 SQUARE TUBING WITH A ¼" NC THREADED NUT WELDED AND RETAPPED IN EACH END
5	1	ONE-1" SCHEDUAL 80 SQUARE TUBE 108"LONG AND TWO-1" SCHEDUAL 80 SQUARE TUBES 21"LONG
6	2	¼" ø 2" PLATE STEEL TWO-18" LONG. TWO-11" LONG. AND TWO-3"½ LONG
7	2	MOUNTING TUBES. 2" SCHEDUAL 80 SQUARE TUBING 24" LONG WITH TWO¾" HOLES DRILLED NEAR ONE END FOR MOUNTING TO PLOW
8	2	TWO 2" STEEL PIPE BRACKETS TO BE WELDED ONTO MOUNTING TUBES
9	2	¼" ø 2" ANGLE IRON 14" LONG WITH HOLES DRILLED TO MATCH MOUNTING TUBES AND WILL BE WELDED TO PLOW
10	1	FRONTAL PLATE STEEL (NOT SHOWN). TO BE SLID INTO CANVAS HEM FOR STRENGTH ON LEADING EDGE OF SHEILD
11	6	HINGE BOLTS.¼" ø 1" NC GRADE 8 MACHINE BOLTS AND TWO SELF LOCKING NUTS
12	4	MOUNTING BOLTS AND NUTS. BOLTS-½" ø 2" NC THREADED MACHINE BOLTS NUTS- ½" NC THREADED SELF-LOCKING NUTS
13	20	NO. 8 #3/8" SELF-TAPPING SHEET METAL SCREWS (NOT SHOWN) FOR HOLDING CANVAS TO FRONT OF SHEILD
14	12	PIPE BRACKET BOLTS.½" ø 1" NC GRADE 8 MACHINE BOLTS AND SELF- LOCKING NUTS



Shield improves visibility for snow plow operators

European design passes muster in Iowa.

"When can we have more of these?"

This is the reaction of Chuck Mann, snow plow operator at the state maintenance garage in Cherokee, to a new snow plow shield.

Poor visibility is a snow plow operator's enemy, and not just during a storm. Even when skies are blue, operators often have to squint through "whiteouts" of snow stirred up by their own blades.

The Iowa Department of Transportation is testing a prototype snow plow shield designed to eliminate or greatly reduce the cloud of snow from coming over the plow and onto the truck windshield. Based on a design used in Austria and Germany, the innovative shield creates an air foil that draws snow spray away from the cab and under the wheels of the plow.

Leland Smithson, deputy director of the maintenance division at the Iowa DOT, brought pictures of the shield back to Iowa after participating in the International Winter Scanning Program in March 1994. The program was a cooperative effort with the Federal Highway Administration's Office of International Outreach Programs.

Smithson showed the pictures to Rex Brown, a fabrication welder for the state services and maintenance shop in Ames. Together, they discussed specifications for the design. Working mostly from the pictures and Smithson's description, and after discussing the concept with several snow plow operators, Brown designed a similar shield.

Using a bracket welded to the main frame of the snow plow, the shield's basic, universal mounting can be installed on different kinds of blades. The shield's angle is adjustable to allow operators to fine-tune the air foil for maximum effectiveness.

"These shields are inexpensive [about $260] and should make snow plow operators' jobs a lot easier and safer," says Smithson.

Prototype shields are being tested by Iowa DOT snow plow operators in Williams, Latimer, Forest City, Leon, Cherokee, Rock Rapids, Urbana, Avoca, Atlantic, Ames, and DeWitt. Operators are documenting the shield's effectiveness under various situations:

- changing the degree of shield angle,
- testing the most effective length of the shield's "tail" (some tails are 12 inches, some are 22 inches),
- sliding the shield to the right or left,
- testing plows with and without the shield under identical conditions,
- checking visibility in front of and behind the plow, and
- checking motorists' visibility.

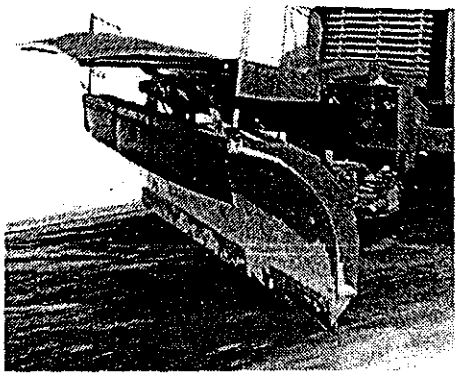
So far the prototype shields have undergone some pretty rigorous conditions, and preliminary feedback from operators has been positive. "Snow over the cab is diminished," says Mark Wright, resident maintenance engineer in Rock Rapids.

In fact, the shield has resulted in at least one unanticipated benefit: less wear on the windshield.

"The biggest benefit comes from eliminating most of the sand spray that usually gets on the windshield," says Steve Botos, highway maintenance supervisor in Avoca. He has traditionally had to replace snow plow windshields every three or four years because sand under the windshield wipers scratches the glass so severely.

Richard Johnson, highway maintenance supervisor in Williams, has had a similar experience. "It keeps the wipers free of ice, which makes for a lot less use of wipers—which means less scratching on the windshield," he says.

Mounting the shield has not been difficult. "It was as easy as we were told,"



says Jack Olson, mechanic at Cherokee.

"It went on easy," agrees Ray Isom, maintenance supervisor in DeWitt. "It would be no major problem to move it to a different plow."

This year's snowfalls have been wet and mildly heavy, and operators are eager to test the shields against a light, fluffy snowfall when poor visibility is really a problem.

For information about shield specifications or for detailed test results, contact Leland Smithson at 515/239-1519. ■