SNOWPLOW LIGHTING STUDY
FINAL REPORT

Prepared by
The Minnesota Department of Transportation
Snowplow Lighting Taskforce

In Cooperation With: Maintenance Section and Research Administration and Development Section
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John Hale – Editor

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The Minnesota Department of Transportation (Mn/DOT) formed a Snowplow Lighting Task Force to look into a state-wide problem of snowplow/motorist related accidents and make recommendations to reduce this type of accident. A review of accident records showed that an average of 54 such accidents occurred each winter season involving its snowplow trucks, 54% of those accidents listed the snow cloud created during the snowplowing operation as the contributing factor by obscuring the snowplow and its warning lights. Based on the results of this study, the task force was given the responsibility to study the snowplow visibility problem; specifically, the snowplow lighting.

The task force reviewed the issues of warning lights and plowing equipment in detail. It was determined that the snowplow and wing shapes were large contributors to the poor visibility problem by generating snow clouds. Warning lights mounted on the trucks could not be seen because of these clouds. A literature search was conducted but provided no recent studies on the reduction of snowplow accidents through the use of snowplow visibility enhancements.

Comparisons of different lighting configurations during snowplowing operations were video taped in the winter of '87-'88. Mn/DOT learned that regardless of the type of light or configuration, it is possible for the snow cloud to obscure the snowplow truck for a period of time. Comparison tests were run during the winter of '88-'89 between an experimental light configuration recommended by the vendor and the present configuration for warning lights generally used by Mn/DOT. The experimental lights proved to be far more visible, but were also obscured by the snow cloud for a period of time. A limited study on a small strobe light mounted on a wing was also made.

Conclusions drawn from this short study are that warning lights alone will not solve the snowplow accident problem. Plow and wing design should be studied; snowplow operation procedures should be reviewed; public awareness should be broadened.

## Abstract (Limit: 200 words)

The Minnesota Department of Transportation (Mn/DOT) formed a Snowplow Lighting Task Force to look into a state-wide problem of snowplow/motorist related accidents and make recommendations to reduce this type of accident. A review of accident records showed that an average of 54 such accidents occurred each winter season involving its snowplow trucks, 54% of those accidents listed the snow cloud created during the snowplowing operation as the contributing factor by obscuring the snowplow and its warning lights. Based on the results of this study, the task force was given the responsibility to study the snowplow visibility problem; specifically, the snowplow lighting.

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Conclusions drawn from this short study are that warning lights alone will not solve the snowplow accident problem. Plow and wing design should be studied; snowplow operation procedures should be reviewed; public awareness should be broadened.
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I INTRODUCTION

In response to a legislator’s inquiry during the winter of 1985-86, C. M. Christie, State Maintenance Engineer for the Minnesota Department of Transportation (Mn/DOT), asked the Area Maintenance Engineers Operations Policy Committee to look into the statewide problem of snowplow/motorist related accidents and make recommendations to reduce this type of accident.

A review of snowplow/motorist accidents was conducted by Ms. Janelle Fowlds, Detroit Lakes District for the Mn/DOT Employee Services Section, Health and Safety Unit, to determine the specific causes of and conditions leading to the accident. The review was done using an accident report questionnaire and interviews by the District Safety Officers. The review included 136 snowplow accidents over a three-year period from 1984 through 1986. Appendix A contains the final report on this study.

The major findings of the study as summarized by Ms. Fowlds were:

- Mn/DOT experienced an average of 54 accidents each winter involving its snowplow trucks and motor vehicles.
- Eighty (80) percent of those accidents occurred between 6:00 A.M. and 6:00 P.M.
- Of the 80 percent, 35 percent occurred between 10:00 A.M. and 12:00 noon.
- Increased traffic volume and snow removal operations occurred during the 10:00 A.M. to 12:00 noon hours.
- Seventy-four (74) percent of the accidents involved vehicles rear-ending the snowplow truck.
- Twelve (12) percent involved the other vehicles hitting the blade or wing.
- Other types of accidents (sideswipe, broadside, front-end, etc.) made up the remaining 14 percent.
- Fifty-four (54) percent of the accidents listed the “snow cloud” created by the snowplowing operation as a contributing factor.
- Survey responders felt that the effectiveness of the warning lights mounted on the snowplow trucks decreased appreciably during the daylight hours. Specifically, the blue lights were cited as having the least visibility.
- The “snow cloud” created by the snowplow trucks obscured the snowplowing vehicle and its warning lights.

Based on the results of this study, the Operations Policy Committee formed a Task Force to study the snowplow visibility problem. Members of the task force included a district maintenance engineer (chairman), maintenance superintendents, district safety officers, equipment unit personnel and research personnel. The responsibility of this committee was to study the snowplow visibility problem; specifically, the snowplow lighting.

II BACKGROUND

Task Force Action

The task force met on several occasions to discuss the snowplow visibility accident problem. Several issues were identified as directly relating to the problem:

- Effective visibility of snowplow truck warning lights related to the number and type of lights.
- Public awareness of the snowplowing operations and how they related to motorist safety.
- Plowing operations relative to weather conditions and their impact on snowplow visibility.
- Snowplowing equipment, i.e., plow and wing design, and its effect on snowplow visibility.
The task force reviewed the issues and determined that the issues of public awareness and plowing operations were beyond the charge of the task force. These issues were referred to the operations policy committee for further action as parts of a solution to the overall snowplow accident problem.

The task force reviewed the issues of warning lights and plowing equipment design in greater detail. These reviews determined that the snowplow and wing shapes were large contributors to the poor visibility problem as snow clouds were being generated during plowing operations. Warning lights mounted on the trucks could not be seen because of these clouds. The type and number of warning lights were not the same on all of the snowplowing trucks. These varied between districts and within districts depending on the year and type of truck.

As a result the following studies were initiated:

1. A study of the current lighting systems on our snowplow trucks.
2. A survey of selected states and Canadian provinces to determine what efforts have been made for snowplow accident mitigation; specifically, using lighting and other equipment modifications.
3. A literature review for research related to warning lights used on emergency vehicles.
4. A field study based on the results of the three studies above.

The review of the warning light configurations presently being used on our snowplow trucks revealed that no single lighting pattern was being used. All types of lighting were in place — from a single blue strobe or rotary beam on the cab or cab shield, to a combination of yellow strobes on each door mirror, blue strobe on center of cab shield, and blue strobes on the rear corners of the truck box.

**Equipment**

Mn/DOT's present warning light configuration, prior to 1988, generally consisted of:

A. A single yellow strobe, producing a 360 degree light pattern, mounted on each door mirror.

B. A single blue strobe, producing a 360 degree light pattern, mounted on a slide pole center-front of the box.

or

A single blue strobe, producing a 360 degree light pattern, mounted on each side of the stationary cab shield.

C. A single blue strobe, producing a directional burst of light, mounted on each rear corner of the truck box and pointing towards traffic approaching from behind. Use of these strobes was optional and some trucks did not have them mounted.

This standard was a compromise of various configurations Mn/DOT used in its nine districts throughout the years. The configurations varied between districts, and within districts, depending on the year and type of truck, and different maintenance operations. Table 1 lists pertinent information for the various warning lights.
The survey sent to state and provincial agencies in the “snowbelt” area provided little new information. Responses were received from Colorado, Illinois, Iowa, Kansas, Montana, Nebraska, North Dakota, Wyoming, Ontario, and Saskatchewan. (See Appendix B for survey results.)

The only information significant to this study was from Saskatchewan. Their response included a report on the use of air foils and a flat surface (board) mounted on the tailgate, painted with a checker-board pattern. This report indicated that the air foil kept the flat tailgate board free from snow accumulation. The checker-board pattern (Black and Yellow) was considered to be effective in snowplow recognition by motorists.

The survey showed that none of the agencies experimented with and/or developed their own design for a snowplow wing.

The literature search provided no recent studies on snowplow accident mitigation through snowplow visibility enhancements. Three studies related to warning lights were found. These studies were:

“Emergency Vehicle Warning Systems” A.I. Rubin, G.L. Howett, National Bureau of Standards, Washington D.C. May, 1981. This study provided information on signal effectiveness, signal visibility, factors contributing to a good warning system and reaction of drivers to warning signals. The key points were that recognition of warning signals depended on where they appeared in the driver’s field of view and how easy they were to identify. This involved the effective intensity, flash rate, duty cycle-ratio of on to off, pulse shape and form, color, angular dimension of the beam, area of light-emitting surface, motion of the light source, number and spatial arrangement and the pattern in time of the flashes. The report recommended standardization of the lighting; using effective colors in combination, specifically alternating with white; greater intensity and more effective duty time.

“Information Transfer Characteristics of Moving Light Signals” J. Berkhout, Human Factors Laboratory, Department of Psychology, University of South Dakota, Vermillion, S.D. 1979.

This study evaluated eight different configurations and color combinations of rotating-beam emergency vehicle lights in terms of information conveyed about rate and direction of travel when viewed at night. The key points were that the information transmission was only 25% - 33% perceived; twin beacon performance gave good indication of direction and travel of vehicle when in motion but gave a false impression that vehicle was moving away when actually it was standing still.

This study provided a series of graphs comparing the various type and color warning lights under varying ambient lighting conditions. The key result indicated that the rotating orange beacon appeared to be most effective under the greatest number of lighting conditions.

The task force felt that a field study was necessary after reviewing the results of the three studies. The studies did not provide any solutions but were used as input for the field study.

III 1987-1988 WINTER FIELD STUDY

The objective of the 1987-1988 winter field study was to determine what lighting configurations were the most effective in penetrating the snow cloud. A second phase of the study was to evaluate a prototype snowplow wing which had the potential of reducing the snow cloud during winging operations.

The study design included the following considerations:

1. How many field sites were needed and where were they to be located.
2. What lighting configurations were to be included.
3. Control (trucks) used for making comparisons.
5. Study duration.
6. Redesign of the wing.

The initial study conducted during the winter of 1987-88 was to visually determine the effectiveness of the various lights under actual operating conditions during critical light and snow conditions.

Basically, the work plan was to video tape a snowplow in the rural and metropolitan areas under different daytime plowing conditions. The tapes would then be viewed by a rating panel at the end of the winter season to determine which lighting configuration was the most effective.

The work plan consisted of the following:

1. A video camera would be mounted in a trailing vehicle from which the snowplow would be video taped under actual plowing operations.
2. Video taping was to be from a distance of 900 feet behind the snowplow. This distance was considered to be the worst case scenario.
3. Video taping would be done during the daytime hours.
4. Through use of two-way radio the snowplow operator was to be instructed to switch from one light configuration to another using panel switches in the cab.
5. The study would be conducted during the 1987-88 winter season; additional study would be determined based on results obtained.

Weather and snow condition information was to be collected during the field tests. The information was to be recorded on paper or "voiced in" onto the video tape. The data recorded is found in Table 2.

The warning lights used in the field study included lights currently in use by Mn/DOT and a new strobe light made by WHELEN Engineering Company, Incorporated. This company held the current warning light contract with Mn/DOT. The new model introduced by WHELEN was the DOT-2H. This is a rectangular strobe light assembly (Figure 1) that is mounted in a heavy duty steel housing for protection. It distributes light in an effective pattern of 180 degrees along a vertical axis and a 10 degree pattern along the horizontal axis. Within the 180 degree vertical pattern the strobe focuses 1½ million peak candle power of light in a 45 degree arc. (Figure 2)
Figure 2
The DOT-2H light assemblies plus a power supply make up what WHELEN identifies as a DOT3 system. The DOT3 system is further identified according to the combination of various light assemblies and power supplies available from the manufacturer.

Two Class 33 snowplow trucks were used for the 1987-88 winter testing program. The snowplow used in the metropolitan area (Figure 3) had the following experimental light configuration:

- Yellow strobe (360 degree pattern) mounted on each door mirror.
- Blue strobe (360 degree pattern) mounted on each side of the stationary cab shield.
- Yellow Rota-Beam mounted on each side of the stationary cab shield.
- Blue, yellow and white WHELEN DOT-2H rectangular strobe head assemblies (Figure 4) mounted vertically on each rear corner of box. Flash rate: 70 double bursts/minute.
- White and Yellow WHELEN DOT-2H rectangular strobe head assemblies (Figure 5) mounted vertically on each side of cab shield. Flash rate: 70 double bursts/minute.

![Figure 3](image)

The snowplow used in the rural area had the following light configuration:

- Yellow strobe (360 degree pattern) mounted on each door mirror.
- Blue strobe (360 degree pattern) mounted in center of a movable cab shield.
- Yellow Rota-Beam mounted on each side of the movable cab shield.
- Blue, yellow and white WHELEN DOT-2H rectangular strobe head assemblies mounted vertically on each rear corner of box. Flash rate: 70 double bursts/minute.
- Yellow WHELEN DOT-2H rectangular strobe head assembly mounted vertically on each side of cab shield. Flash rate: 70 double bursts/minute.

(NOTE: A white lens was interchanged with the yellow lens for some comparisons)
Each truck was equipped with a complete set of switches mounted on a panel board so that any lighting configuration could be turned on. These configurations are described in Table 3.

<table>
<thead>
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<th></th>
<th>Cab Shield</th>
<th>Mirrors</th>
<th>Truck Box</th>
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<td>1. (Basic)</td>
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<td>5.</td>
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<td>6.</td>
<td>Blu Strobe(360)</td>
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<td></td>
<td>Yel Rota-Beam</td>
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Table 3


The video tapes taken by maintenance employees while riding in trailing vehicles produced valuable documentation. During testing several items became apparent. Snow clouds generated by the plow, wind and traffic have a very serious affect on any lighting configuration that is used. The video observations did not differentiate between the colors of any of the new WHELEN lights. All strobes appeared to be white when seen by the video camera. Either the distance was too great between the plow truck and the camera or the snow cloud created a filtering effect to the different colors.

The camera car in the rural area maintained a video distance of approximately 900 feet. This distance was used as it corresponded with the motorist's stopping distance normally required at highway speeds upon confrontation with an object in the traveled roadway. Video taping in the metropolitan area was recorded at approximately 300 feet so that traffic could not come between the snowplow and the camera vehicle.

**IV CONCLUSIONS: WINTER 1987-1988**

After review of the video tapes the task force concluded that:

1. A very slight snow cloud can temporarily block out any lighting configuration mounted on the trucks.
2. Yellow strobes (360 degrees) mounted on door mirrors are ineffective.
3. Blue strobes (360s or directionals) are ineffective during daytime operations.
4. The WHELEN DOT-2H strobe with white lens is very visible.
5. Lights should be mounted on top of the cab shield, or higher, because the snow cloud is less dense at this height.
6. The dancing effect created by out-of-sync flashing strobe lights mounted on the cab shield and truck box “outlines” the snowplow.
7. Rotary lights perform well because they revolve slowly and thus the light is seen for a longer period of time by the observer.

8. It was not possible to distinguish the three different colors when viewed from a distance. Only the light burst was visible.

9. The standard round blue strobes (directional) Mn/DOT uses on the truck boxes focus the light downward when the box is raised and are hard to see from a distance. The WHELEN DOT-2H rectangular strobes remain visible, when mounted vertically, due to the 180 degree light pattern. The public is, therefore, able to see the warning lights when the box was in the “travel” position or in the “dump” position.

10. Changes in plowing and winging operations should be considered.

Some recommendations for further study were:

1. Use only white rectangular strobes (WHELEN DOT-2H) on truck box. These are directional and face to the rear.

2. Use white or yellow rectangular strobes (WHELEN DOT-2H) on cab shield. These are directional and face to the rear.

3. Mount blue strobe (360 degree pattern) and yellow rotary on top of cab shield.

4. Research other rotaries.

5. Determine if candle power can be increased on strobes.

6. Make comparisons of new and old plow and wing.

V 1988-89 WINTER FIELD STUDY

 Modifications For 1988-1989 Study

After reviewing the 1987-88 videos the committee met with engineers from WHELEN. The engineers were shown the video tapes of the snowplows in action while using the WHELEN DOT-2H lights and recommendations were requested by the committee.

WHELEN recommended that Mn/DOT install two units on the cab shield to replace the old mirror and cab shield strobes that were mounted on each side of the truck. Each unit (Figures 6 & 7) consists of two modified WHELEN DOT-2H rectangular shaped strobes joined back-to-back (in a horizontal configuration) with lenses forming four sides — blue lenses on the inboard side and yellow on the front, rear and outboard side.

The internal construction of each strobe is such that a thin glass tube, 5mm in diameter and filled with xenon gas, extends the length of the strobe and bends at an angle of approximately 45 degrees at each end. The inboard and outboard lenses are, therefore, “slaves” and radiate the light burst emitted from the bend in the xenon tube. Each unit projects an effective light pattern of 220 degrees along its horizontal axis and a 10 degree pattern along its vertical axis towards the front and rear of the snowplow. Within the 220 degree horizontal pattern the strobes focus 1½ million peak candle power of light in a 45 degree arc. A separate power supply is used to drive the lights facing forward and another to drive the lights facing to the rear.

WHELEN also recommended that one WHELEN DOT-2H strobe head assembly with a yellow lens be mounted vertically on each rear corner of the truck box (Figure 8) to replace the old blue focused strobes. Each strobe would provide 1½ million peak candle power. The engineers from WHELEN indicated that 99% of the light burst is transmitted by white lenses, 70% by yellow, 40% by blue, and 20% by red. The committee chose yellow for the front and rear facing lenses because white is illegal at night. A separate power supply would be used to drive this pair of lights.
During the winter study of 1987-88 the light intensity on the test vehicles was only about 3/4 million peak candle power because too many strobes were being driven by the power supplies (3 sets on the rural truck, 4 sets on the metropolitan truck). For the new, untested, light configuration WHELEN recommended 3 separate power supplies, each powering 2 strobes. Using fewer strobes on a circuit will automatically increase the light intensity to $1\frac{1}{2}$ million peak candle power per strobe. This would provide a total of 3 million peak candle power if used with one set of two strobes, $1\frac{1}{2}$ million with two sets, or 3/4 million with four sets. The company can also increase the cycle rate from 70 cycles to 80 cycles/minute (2 bursts per cycle) with minor modification when only 2 sets of lights are on a power supply. The light intensity of the second burst is estimated to be approximately 30% of the initial burst. The lifetime of a strobe is approximately 1,100 hours of power supply time, not the summation of burst time.

WHELEN would also build a new control box (Figure 9) with switches to activate the three light systems separately. As previously mentioned, the front and back strobes on the cab shield lights are powered as two individual systems. This allows the driver to activate the front or back strobes separately or together. With this arrangement the rear-facing strobes can be turned off during gang plowing (multiple plowing) operations so that the drivers in the following plows are not blinded. Gang plowing is used on the freeways in the metropolitan area where one snowplow closely follows a preceding snowplow in an adjoining lane. The snow is moved across the multi-lane roadway, from the median onto the shoulder, in one pass of the plows. As many as eight snowplows have worked together during this type of operation. Only the last plow has the rear strobes activated.
The switch box would also include a Hi-LO dimming switch for the lights. This dimming feature provides an 80 percent reduction in candle power and is necessary during night time operations. The new strobes would, otherwise, blind motorists if run at full power.

WHELEN estimated that each truck could be outfitted with the above 6 strobes for about $1,000 per truck, excluding labor. These units would be shipped to Mn/DOT as a prefabricated package and include the lights, the panel box, and a complete wire harness cut to length. Labor costs for installing the lights is estimated to be about 15% of material costs. Currently Mn/DOT is spending $1,200 per truck.

Snowplow Wings
The present wing design (Figures 10 & 11) that Mn/DOT is using is a great contributor towards creating the snow cloud. As was shown on video tape, taken during the winter of 1987-88, the wing creates a snow cloud that frequently obliterates the snowplow from the view of following vehicles. A cross-sectional profile of the wing shows a slightly curved surface. After viewing the tapes the task force appointed a sub-committee to develop a new wing design. The wing would be shaped with more curl so as to make the snow “roll” rather than “fan” out as it exited the end.
Two wing designs were built by Darryl Cameron from District 3B, St. Cloud, Minnesota, in consultation with the equipment office. Experience with the new wings was somewhat limited during the winter of 1987-88, however, due to the time required for development.

A 9 foot right-hand wing (Figures 12 & 13) was constructed which utilizes a 40 degree cutting angle and rolls the snow rather than fan it out as the old wings do. The right-hand wing was made first and is called the Cameron #1 wing.

A left-hand wing (Figures 14 & 15) was fabricated in similar manner; however, it is slightly longer (10 feet) and has more roll than the Cameron #1 wing. This new design is called the Cameron Wing #2.

Figure 12

Figure 13
points the box was raised and lowered to determine if the lights were visible in both positions, thus simulating sanding operations. Efforts were made to make comparisons before and after the first snowfall and with and without snow conditions.

The video camera was mounted on a tripod and pictures were taken as the trucks moved away from the camera. Footage was taken at a fixed focal length so that the viewers could see the reduction in light visibility, regardless of new or old configuration.

VI CONCLUSIONS: WINTER 1988-1989

Three trucks were used when making comparisons in the rural area. One truck had the old light configuration; the other two had new configurations. On all of the videos, the trucks started approximately 5 feet from the camera and then proceeded to a point 1/4 mile and 1/2 mile from the camera. Each truck would stop and then raise and lower the truck box at those points.

Two of the trucks were based in Detroit Lakes, Minnesota. One was a 1988 truck that had the new “Minnesota DOT Design” lighting system on it. Taping was done on a clear day and background was bright (snow on roadway shoulders and in the fields). Under these conditions the new recommended lighting system did not appear to be very effective when the truck kicked up a light snow cloud. At the 1/4 mile point, the lights were visible but hard to see when the box was up. At the 1/2 mile point, the lights were somewhat obscured and could not be seen when box was up; possibly because of the light background.

The second truck was videoed on the same day and on the same roadway as the first truck. It had the old lighting system (360 degree blue strobes on top; round directional blue lights on the box facing to the rear). At 1/4 mile, it was very difficult to see the lights. The directionals on each box corner could be seen, but not the top lights; possibly because of the light background. At 1/2 mile, the directionals were slightly visible. Neither the top or the box lights could be seen when the box was raised at the 1/4 and 1/2 mile points.

The third truck was a 1987 snowplow based in Alexandria, Minnesota. This truck also had the new “Minnesota DOT Design” lighting system on it. The lights were hard to see on this truck when under bright background conditions. There was a 1/2 inch of snowfall and the wind was blowing at approximately 12 mph. At 1/4 mile and 1/2 mile all of the lights were visible while the box was up or down. The box lights were a little brighter than cab shield lights possibly because the shield was painted black.

The same truck from Alexandria put a new WHELEN DOT-2H rectangular white lens on each box corner and retained the new yellow/blue on each side of the cab shield. The white lens was quite visible. At 1/4 mile and 1/2 mile all lights were visible and showed while the box was raised. At 1/4 and 1/2 mile the white lights on the box were more visible than the yellow lights on the cab shield, whether the box was up or down.

The trucks from Detroit Lakes had a very light background. The sky was clear, snow was on the shoulders, patches of snow was on the fields. This could explain why the new lights were hard to see. The cab shield lights had the sky as a background most of the time due to a level roadway. The roadway in the Alexandria area was rolling and presented a dark background to the camera.

The truck from the metro area was video taped with a yellow lens on the left side of the truck box and a white lens on the right side of the box. As the truck moved away from the camera the video appeared to show that the yellow light was brighter. The video was taken on a cloudy day.

Two snowplow trucks in the metro area with the old and new light configurations were video taped while traveling side-by-side on I-35. The camera also videoed winging operations with a small strobe light mounted on the wing. The conclusions drawn from these videos were that it didn’t matter what
lights were on when the snow cloud occurred - all of the lights (wing light and new/old warning lights) were obscured for a period of time. White, blue or yellow - a snow cloud will wipe out the flashes of either color.

VII SUMMARY

Warning Lights

The new “Minnesota DOT Design” lighting system is much more visible than the old system. If the box is raised at the 1/4 mile point, all of the new lights remain visible. At the 1/2 mile point, the “Minnesota DOT Design” lighting system diminishes greatly. If the background is dark the cab shield lights on the new system show up at 1/2 mile but are difficult to see if the background is bright.

When viewing the tapes the committee noticed that when the trucks were only a short distance from the camera the color of the strobe bursts appeared to be white. Each strobe has 1½ million peak candle power. A white color is perceived from any lens (blue, yellow, or white) at more than 200 feet. However, only the white lens transmits 99% of the generated light. A question arises: does the human eye perceive color at this intensity or is the “white” color something that occurs only on the video tape? If “white” is something that the eye perceives then it doesn’t seem to matter if the lenses are white, yellow or blue during daytime operations.

Although white light is definitely brighter than yellow, the committee felt Mn/DOT should use yellow. The concern of the committee is that the drivers might use the white lights during nighttime operations or non-plowing situations (both conditions are unlawful at this time). If white was selected for daytime use the drivers might forget to turn it off at night.

Blue lights are excellent at night even though the blue lens transmits only 40% of generated light. White would have the tendency to blind the motoring public at night. Therefore, Mn/DOT should set a policy regarding this if white lights are permitted.

Wing Lights

An evaluation was also made on video tape of a wing clearance light. WHELEN developed a strobe/aluminum casting assembly (Figure 21) that is designed for mounting on the wings and furnished Mn/DOT with a demo for use on a trial basis. The light was mounted on a wing that had an old curvature design so that the maximum snow cloud would be created.

At the time of video taping there was a 1/2 inch of snowfall and the wind was blowing at approximately 12 mph. The winging operation produced constant white-outs. The wing light could be seen when the wing was in the down position and there is no snow cloud, but not as well as the lights used in the “Minnesota DOT Design” light system. This is because the wing light was smaller in size and had less candle power. When the wing kicked up a snow cloud the wing light was obliterated.

Positive comments have been made as to the durability of the wing light — no damage has been found to the light or the frame after its use. However, the committee feels the light needs a brighter bulb. The committee also felt that the left wings need the light more than the right wings because most of the winging accidents occur on that side of the snowplow. This unit serves as an excellent running light as it can be seen while the wing is raised and in a carrying position. A separate power supply is also used to energize this light.

This light has seen only limited field testing. The committee therefore recommends that this light should be studied further during the upcoming winter.
VIII  TASK FORCE RECOMMENDATIONS
The following recommendations are based on review of the field study results and task force discussions:

1. Install the WHELEN "Minnesota DOT Design" strobe light system at 1.5 million peak candle power per strobe on all 1988 and newer trucks.

2. Continue to monitor the use of a single strobe clearance light on the left wing during the 1989-1990 winter. This strobe may prove beneficial while carrying the wing in its upright travel position.

3. Continue to monitor the two Cameron wing designs.

4. Build additional new wings (Cameron design — left-hand and right-hand) and use in other districts during the '89-'90 winter season.

5. Attempt further improvement of the plow and wing designs so as to help minimize the snow cloud.

6. Review snow plowing operation procedures so as to reduce generation of the snow cloud and the potential for snow cloud accidents.

7. Develop public information items.
   a. Make use of Public Service Announcements on prime-time commercial TV stations.
   b. Develop training packages for driver training classes.
   c. Revise the Minnesota Driver's Manual to include snowplow information.
   d. Promote public awareness through the use of billboard ads.
   e. Prepare Speaker's Bureau packets on this subject.

8. Paint the cab shields on the snowplow trucks black so as to provide more color contrast and enhance the new lighting configuration.

9. Study the use of mounting flags on each rear corner of the truck box.

10. Consider a proposal to the Minnesota State Legislature to allow the use of white warning lights for all day and nighttime maintenance operations.
STATE OF MINNESOTA
Office Memorandum

DEPARTMENT: Transportation
Division of Field Operations

DATE: September 3, 1986

TO: J. K. Elletson, P.E.
Area Maintenance Engineer

FROM: Janelle Fowlds, E.I.T.
Graduate Engineer II

PHONE: Extension 515

SUBJECT: Snowplow Accident Study
I have studied the accident reports involving snow removal operations from January 1, 1984, through March 14, 1986, and have compiled the following facts and figures:

GENERAL
There were 136 accidents during this time for an average of 54 per year.

By District:

<table>
<thead>
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<th>District</th>
<th>1A</th>
<th>1B</th>
<th>2A</th>
<th>2B</th>
<th>3A</th>
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</table>

The most accidents occurred, on the average, in the month of December - 15 per year, followed by November at 12 per year, March at 10 per year, January at 9 per year, and February at 8 per year. One accident occurred in October during the study. 80% of the accidents happened between 6:00 a.m. and 6:00 p.m. Of these, 35% happened from 10:00 a.m. to 12:00 noon (28% of total).

84% of the drivers of the other vehicles were men and 16% were women. The average age was 32. 9% of the other vehicles involved were semis. 9% of the accidents were charged "Preventable" by the snowplow driver and 91% were charged "Non-Preventable."

TYPE AND LOCATION OF ACCIDENT
74% of the accidents were rear-end collisions with the other vehicle rear-ending the plow and 12% involved the other vehicle hitting the blade or wing. Other types of accidents made up the remaining 14% (sideswipe, broadside, front end, etc.).
82% of all accidents took place on the Interstate or 4-lane highways. Of these, 57% occurred in the passing lane, 26% occurred in the driving lane, and 17% occurred on ramps, shoulders, turn lanes, crossovers or other lanes.

18% of the accidents took place on 2-lane roads. Of these, 60% occurred in the driving lane, 20% on the shoulder, and 20% in intersections, turn lanes, or by-pass lanes.

WEATHER

54% of the accidents involved "snowcloud" as a contributing factor. 66% listed snow or blowing snow as a weather condition and 60% reported icy or snow covered roads contributed to the accident. Some days had multiple accidents (i.e., November 30, 1985 had 8 accidents throughout the state) and these were almost always weather-related.

INJURIES

30 accidents (22%) reported injuries. Six involved injuries to the state unit driver, 22 involved injuries to occupants in the other vehicles, and 2 involved injuries to both drivers. Most injuries were minor and involved bumps, bruises, cuts, and soreness. One accident involved incapacitating injuries to the occupants of the other vehicle and one involved broken bones - a broken arm and clavicle. The accident involving the broken bones was a 5-vehicle accident and injuries were reported in every vehicle except the State unit.

DAMAGES

114 of the 136 accidents reported damages (84%). The others may have had damages but no estimates for repairs were given. 111 State units reported an estimated dollar amount for repairs as did 85 other vehicles. 10 other vehicles were reported as a total loss. The range of estimates for the State units was $0 to $3,000. The range for the other vehicles was $75 to $30,000 (a semi). The average estimate for repairs on the State units was $380 and for the other vehicles was $1,900.

LIGHTING

Studying the lighting on the State units involved in accidents proved to be inconclusive. All types of lighting were in place from a single blue strobe on the cab to amber strobes on each mirror, blue strobe in center of cab shield, and blue strobes on rear corners of box. One unit that was hit during a snow removal operation on a clear day was an arrow board pulled by a pickup.

District 2B mentioned that they did a little study on their own and found that the orange flags mounted on the box and blade are the easiest to see. They had the patrol follow a plow and take pictures and observe.
APPENDIX B
SURVEY RESPONSE SUMMARY  
(From Snowbelt Area)

1. Have you developed any statistics on snowplowing accidents?  
   Yes: 4  No: 6

2. What time of day did the majority of the plowing accidents happen?  
   Daylight: 5  Nighttime: 1  Dawn: 1  Dusk: 0  N/A: 4

3. On what type of roadway did the majority of your plowing accidents happen?  
   2-lane rural: 3  2-lane urban: 0  4-lane rural: 0  4-lane urban: 0  Interstate: 2

4. Are there guidelines set forth for snowplowing operations? If so, may we have a copy of them?  
   Yes: 9  No: 1  Guidelines Provided: 7

5. Has the “snow cloud” or insufficient lighting been considered as a reason for accidents happening during snowplowing operations?  
   Yes: 8  No: 1  Both: 1  N/A: 1

6. What have you done to alleviate accidents between your snowplows and the driving public?  
   Training: 3  Public Relations: 4  Improved Lighting: 8  Legislation: 1

7. Do you use more than one warning light configuration? Please indicate where you locate your warning lights and what color and type they are. (yellow, blue, strobe, rotary, directional, etc.)  
   Yellow Rotating: 7  Yellow Strobe: 4  Blue Rotating: 2
   Corner of box: 5  Cab: 4  Cab Shield: 4  Wing Clearance: 1

8. Do you mount flags on your boxes?  
   Yes: 1  No: 9  If yes, where do you mount them? Front of box.

9. What type of plow do you use?  
   One way: 9  Two way: 10

10. Are your plows equipped with a wing?  
    Yes: 4  No: 2  Special Equipment/operations: 5

11. Do you use any traffic control devices (lighted arrow boards, etc.) to control the plowing area?  
    Yes: 1  No: 9  
    If yes, please describe the plowing operation and traffic control device. During rotary plowing operations (flag man)

12. Have you redesigned your plows and/or wings to alleviate the “snow cloud” affect?  
    Yes: 0  No: 10  If yes, how well have they performed?

13. Any other comments?  
    Mount flags on each side of plow. 2  
    Mount flag on plow (leading edge). 1  
    Mount flag on wing (trailing edge). 1  
    Paint approx. one foot on each end of plow with florescent paint. 1  
    Use air foils on tail gate. 1  (Saskatchewan)  
    Experimenting with air foils. 1  (Arizona)  
    Use checker-board tailgate. 1  (Saskatchewan)  
    Mount mirrors on both sides of rotating light. 1
APPENDIX C
TRUCK QUESTIONNAIRE
Truck Rodeo (St. Cloud, Minnesota)

1. Compare the three trucks. What specific differences do you see as you look at the trucks?

- Number 1 has better lighting.
- Impressed with the white strobes mixed in. Very visible.
- Number 1
- Too much light on number 1.
- Truck #1 is the brightest one of the bunch and would be seen faster by a car.
- #1 has a closer group of lights.
- #1 more visible.
- #1 is more visible.
- #1 is more visible.
- The lighting set-up on #1 truck.
- #1 stands out better.
- #1, very high visibility.
- #1, too many.
- #1, more lights (color difference is good).
- Number 1 has more lights.
- #1, because of all the color lights.
- #1, too many lights.
- #1, too many lights, amazed at what going on.
- Lights on #1 more seeable.
- #1, too many lights, white would blind at night.
- #1, truck could blind or hypnotize when following more than #2 or #3; #1 is brighter but white can’t be used at night which makes #3 more visible.

- #2, very low visibility.
- #2, too few.
- #2, poor.
- Number 2 does not have enough lights.
- #2, not enough lights.
- #2, like no cab shield, yellow should be to rear of box.

- During the day black shows on #3 truck.
- Brightness.
- #3, black cab shield good in snow.
- #3, I like.
- #3, lights are higher, visibility is better.
- #3, some-what ok, mix two blue.
- #3, higher lights.
- Number 3 has the lights higher.
- Good height on number 3.
- Number 3 has better lighting.
- Truck #3 has too high of stack and strobes.
- #3, like lights extended above cab shield, amber to rear on back of box.
- #3, lights are high and distinct.
- More lights on #1 and #3.
- Number 1 and 3 have a better lighting system.
- 1 and 3 have better lights than #2.
- More rear lighting on #1 and #3.
- #1 and #3 have more visible lights.
- White strobe on #1 with high blues on both sides; #2 has only center blue; no blue visible on #3; higher strobes on #3 effective; rear strobe on #1 and #3 effective.
#1, more noticeable due to more contrast in lights; #3, not bad, being high in the air helps; #2 not as noticeable.
#1, a lot of lights; #3, black cab shield; #2, an old truck.
One has more lights (#1) flashing and one (#3) has black liner, shows up more; blue seems the poorest.
The height the lights are mounted and the colors that are used.
The lighting of the trucks and the size. Number 3 has higher lights, but not as bright. Can barely see number 2 compared with the other two.
Height of light placement.
Number of lights.
Amount of lights and location.
Flashing lights; number 3's high and low lights; better contrast.
Light system.
Different light set-up and locations on the trucks. _ No response. _ No response. _ No response.
Lighting.
Warning lights.
Warning lights.
Lights.
More lights are certainly better.
Assortment of colors.
From not enough light to way too much light.
Lights.
Two trucks are new and one is old. New ones have better lights.
The newer trucks are so much more comfortable and better quality materials in the making of them.
The strobes on the truck I run doesn't show up nearly as well as new units.

2. In comparing the warning lights between the three trucks, which truck (from left to right) has the best? Circle your choice.

1 2 3 All the Same

Forty-one (41) said #1.
Seventeen (17) said #3.
No one indicated #2.

3. Why do you think it is the best?

Snowplow #1
• Attention getter.
• I like the strobe flashers.
• The lights on the box rotate from blue, white and amber which gives you better depth-of-field from behind.
• Has the best lighting of the three. Helps to show the size of the truck.
• I like the white flash mixed in.
• More intense. Better attention getter.
• Combination of blue, yellow and white strobes is very effective; the white strobes are most effective.
• It has a lot more lights that are noticeable.
• Seems to stick out the best (probably because of the number of lights).
• Variation.
• Variety of color and intensity.
• The multi-colored lights on the back of the box.
• Brighter and more lights.
• More lights on rear of unit.
• More lights and more color.
• More visible.

C-3
• Brighter.
• More lights.
• More lights and brighter.
• Has more lights; sharper lights.
• More visible at long distance.
• Can be seen better.
• No response.
• More flashing light (yellow).
• Blue and amber strobes.
• From the standpoint of visibility.
• More visible.
• Seems to be more steady lights on at one time.
• Seen it first.
• The white light on #1 shows up better in the day time.
• Best sight from distance.
• Brightest.
• #1, but leave white light out, too confusing for public following.
• Intensity and total number.
• I believe in the combination of colors.
• Most visible.
• Most versatile brightness and color for different conditions.
• The white light on the unit really shows up better.
• Most visible.
• Because white is a color that is most noticeable.
• Combining blue and yellow.

Snowplow #3
• You can adjust the two outside lights higher or lower.
• Yellow comes out or is seen better.
• High in the air.
• Enough lights, but not too many.
• No response.
• Height.
• Should show up better in snow cloud.
• All around use for night or day, snow, etc.
• Have to look at during snow or dark.
• Lights higher above cab would be seen better when plowing.
• No response.
• Tell you after a snow storm.
• Amber lights.
• Brighter lights.
• Stands out about right.
• Well lit without being overly light.
• Good lighting; not too many lights; shows up real good at a distance.

4. **Circle which color of the light is the brightest.**

   **White  Yellow  Blue**

   Forty-four (44) said “white.”
   Thirteen (13) said “yellow.”
   Five (5) said “blue”
5. **Is there a noticeable difference between: (If YES, circle the brightest).**

(Number of responses to question)

<table>
<thead>
<tr>
<th>Pair</th>
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<tr>
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</tr>
<tr>
<td>Yellow and Blue</td>
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<td>4</td>
</tr>
<tr>
<td>Blue and White</td>
<td>2</td>
<td>8</td>
</tr>
</tbody>
</table>

I believe this is a good light package but we have to get away from the splices in the wires. The splices are the major problems we have. I know it can be done because we have rewired some of our 86 and 87s direct from light to the power box.

Yes, at night. Not during the day because blue was hard to see - yellow was easy to see in daylight.

Yes, at night; no, during the day!

Only one new unit in area.

Blue is much better in blowing or falling snow.

Lights should have a quick disconnect so we can take them off as they are too high to get under the bituminous plants up here.
APPENDIX D
WARNING LIGHT QUESTIONNAIRE
(State Patrol)

1. Have you seen the new truck lighting system in use?
   - Yes  19
   - No

2. Have you seen the new truck lighting system being used during snowplowing or winging operations?
   - Yes  18
   - No  1
   - When?  Day  Night  Both
     - Day  1
     - Night  17

3. What is your opinion of the new lighting system versus the old lighting system?

   The new lighting system is the best I have seen in 12 years of law enforcement. Visibility of the lights is great.
   There is no comparison; the new system is much brighter. It has been noticed and commented on by many employees and have heard comments from public.
   New lighting system seems to be much better and brighter during the daylight hours. Blue is ineffective during the daylight.
   New lights very good; old lights very poor.
   More visible – good idea.
   100% better – they are more visible and eye catching. The drivers even like them better. Should change all plows and sand trucks over to the new system.
   In checking with some of the 60 stations they and I agree they catch your eye quicker.
   Much better – need to dim the frost part of the strobes. Reflects off hood at night. Otherwise, good job, fellows.
   The lights on corners do show more (of cab). At night it does a good job of lighting.
   Much better.
   A lot brighter than before; also it gets motorists attention sooner, making for a greater safety factor.
   The different lighting stands out very well in all weather. The blue and amber combination makes people more aware.
   It is more efficient and can be seen through snow cloud a lot better.
   The new lighting system is good for the traveling public to see. Operator has options according to weather conditions and for types of roadway usage.
   The lighting system is very good, except for the mounting. Get rid of the cab shield and it will be excellent.
   Better; shows up “better” during limited visibility.
   By far the best system to date. Yellow penetrates through most snow cloud conditions.
   Much brighter - improved visibility.
   The new lights can be seen at a greater distance. Position of the truck is better identified in blowing snow. Much better than the single blue light.
4. Were you able to distinguish between blue and yellow colors?

Yes  No
16  4

This blue stands out twice the distance of the yellow! But yet the one does not cover the other. Keeping the snow from the rest of the rear of the trucks while plowing would stop a lot of rear end accidents. I know that's hard or almost impossible to do.

Not enough blue lens to tell the difference. This is good. Amber you can see better.
Could hardly see the blue lighting in daytime.
Could not see blue in snow cloud.

Yellow shows by far the best in blowing snow conditions. Blue does not show in daytime operations nor in snow cloud conditions. Blue visible only in cloudy or night time conditions when no blowing snow.