Use of Equipment Lighting During Snowplow Operations

Final Report

CLEAR ROADS

research for winter highway maintenance

Western Transportation Institute
Monte Vista Associates

Project 99006/CR14-06
October 2015

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Final Report

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16. Abstract

The Western Transportation Institute (WTI) conducted research on behalf of the clear roads research program and the Minnesota Department of Transportation (MnDOT) to develop a summary of best practices in the use of headlights, work lights, and warning light technology in snow plow operations. Specifically, this research focuses on different types of light bulbs, the color of the light, intensity of the light, mounting locations, flashing patterns and amperage requirements. In addition, this research gathers information about the mechanism to prevent snow blowing over the plow onto the windshield, mechanism to keep light clear of snow, retro-reflective markings, and day versus night settings for vehicle lights. To accomplish this, a literature review captured information from previous studies and currently available equipment and techniques used for equipment lighting during snow plow operations. Agency and operator surveys were used to capture information from winter maintenance practitioners on the current state-of-the-practice, best practices, and lesson learned. The information captured from the literature search and surveys were used to develop the best practice.

17. Key Words	Distribution Statement
Headlights, warning lights, work lights, mounting locations, retro-reflective markings, day versus night settings.	No restriction. This document is available to the public through the Clear Roads Organization and the Minnesota Department of Transportation.

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Executive Summary

The goal of this research project was to develop a summary of best practices in the use of headlights, work lights, and warning light technology in snow plow operations. Specifically, this research focuses on different types of light bulbs, the color of the light, intensity of the light, mounting locations, flashing patterns and amperage requirements. In addition, this research gathers information about the mechanism to prevent snow blowing over the plow onto the windshield, mechanism to keep light clear of snow, retro-reflective markings, and day versus night settings for vehicle lights. To accomplish this, a literature review captured information from previous studies and currently available equipment and techniques used for equipment lighting during snow plow operations. Agency and operator surveys were used to capture information from winter maintenance practitioners on the current state-of-the-practice, best practices, and lesson learned. The information captured from the literature search and surveys were used to develop the *best practice guide*. The best practice guide discusses the pros and cons of various lighting packages and configurations, mounting locations and new technologies for equipment lighting used by agencies engaged in winter maintenance operation.

Based on the information gathered from the literature search, agency survey, and operator survey, the following conclusions and recommendations were made regarding equipment lighting for snowplow vehicles.

- Halogen bulbs followed by LED bulbs are the most commonly used bulb types for auxiliary headlights. LEDs are favored for use in new vehicles, retrofits, and replacements due to improved visibility.
- Mounting the auxiliary headlights away from operator's line of sight with narrow beams (spot light) helps to reduce the light bounce-back during adverse weather conditions. In particular, mounting auxiliary headlights at the lowest possible location (above the plow or fender walls) is recommended.
- Yellow or other color auxiliary headlights may not have an impact in reducing the amount of back-scattered light.
- With the emergence of LEDs for auxiliary headlights, warning lights and work lights, it is important to have some mechanism to keep the lights clear of snow because LEDs do not produce enough heat to melt snow and ice off the light surface.
- A combination of wind deflectors and heated lens can be used to keep the warning lights and retro-reflective tape clear of snow. However, it is important to have a control switch that can turn on and off the heated lens based on the conditions.
- Over- plow deflectors have been found to be effective in keeping the front grill clear of snow.
- Amber is the color most commonly used for warning lights. However, agencies are using and/or testing blue, white, and green colors. Operators prefer white colored

warning lights because of perceived increased conspicuity during low visibility (e.g., fog, storm conditions, etc.) conditions.

- It is important to have both flashing lights and steady burning (constant burn) lights that are spaced apart for rear warning lights. Flashing lights helps to identify the presence of a plow and steady burn lights aid in the estimation of the relative speed of plow.
- Retro-reflective tape markings are very effective and provide an additional level of warning for approaching vehicles. However, keeping retro-reflective markings clear of snow, clean and therefore visible at all times is an issue during snow plowing operations.
- The issue of increased brightness introduced by warning lights can be resolved by using day-versus-night settings for lights on snowplow vehicles, but this feature is not commonly available.

Chapter 1
Introduction

Report Purpose

This document is the final report for the Clear Roads project entitled *Use of Equipment Lighting during Snowplow Operations*. The project team was led by researchers at the Western Transportation Institute at Montana State University (WTI) on behalf of Clear Roads, an ongoing pooled fund research effort focused on winter maintenance materials, equipment and methods. Clear Roads research projects are managed and administered by the Minnesota Department of Transportation (MnDOT). This report summarizes all tasks and research conducted over the course of the project.

Research Problem and Background

There is a need to find the right balance between making trucks as visible to the traveling public as possible and ensuring that their drivers have the best possible visibility of the road and vehicles around them. Snowplow vehicles often perform in conditions with limited visibility. Visibility is the ability of the operator to see the roadway ahead, which is influenced by weather conditions (primarily precipitation type and intensity), time of day, and the lighting systems on the plow vehicle. Lighting systems on snow-plow vehicles also provide conspicuity, or immediate recognition, by other roadway users. Supplemental warning lights of different configurations and placement, including on the sides of vehicles, increase the ability of other drivers to immediately recognize a snowplow vehicle. This is a critical safety measure because snowplow vehicles are usually moving at slower speeds than other traffic during winter maintenance operations which can be potentially hazardous to other motorists who get too close. Providing sufficient forward illumination for the snowplow vehicle operator in adverse conditions and a high level of conspicuity of the truck itself is a major concern of agencies responsible for snow and ice control.

Despite the recent development and availability of various types of headlights, work lights, and warning light technology, a large number of crashes are still attributed to the inadequate conspicuity of winter maintenance vehicles. For instance, Ohio Department of Transportation (ODOT) reported 63 crashes statewide involving snowplows in just one month of winter (December, 2010), compared to 57 crashes in the previous winter (2009). Kent County, Michigan reports on average six rear end snowplows related crashes every year. Previous studies have reported that rear end crashes due to poor visibility contribute to more than 70% of the snowplow related crashes.

It is therefore important to summarize the best practices used by state Departments of Transportation (DOTs) and local public work agencies with regard to auxiliary headlights, work

lights, and warning light technology specifically for snowplow vehicles, with applicability to all roadway maintenance vehicles used in all seasons.

Research Goals and Approach

The overall goal of this project was to summarize the state-of-the-practices of lights used and configurations and to make recommendations on the use of various lighting technologies and mounting techniques on snowplow vehicles.

To create the report, the basic approach consisted of information gathering using a literature search, surveys and synthesis of the information gathered from literature search and survey.

Research Scope

The research scope was comprised of six primary tasks:

- Task 1 – Literature Search
- Task 2 – Survey for Agencies
- Task 3 – Survey for Operators
- Task 4 – Synthesis (Best Practices Guide)
- Task 5 – Final Report and Presentation

These tasks are described in greater detail in Chapter 2 (Methodology).

The primary deliverable for this project is the *Best Practice Guide* based on the gathered information from literature search and surveys (agency and operator) about the use of equipment lighting during snowplow operations. This includes summarizing the pros and cos of various lighting packages and configurations, mounting locations and new technologies used by agencies engaged in winter maintenance operation. Additional deliverables include this final report, and a PowerPoint presentation summarizing recommendations in the manual, for the use of Clear Roads members at conferences and other meetings.

The research project was conducted from January 2015 – August 2015.

Report Organization

Chapter 2 describes the project methodology, while Chapter 3 summarizes the results of each task. Chapter 4 presents the conclusions and recommendations based on the information gained from Tasks 1 through 4. The Task 4. *Best Practices Guide* has been provided as a stand-alone document.

Chapter 2
Methodology

This chapter describes the research approach for each of the five primary tasks.

Task 1 Approach: Literature Search

The research team's approach to the Task 1 literature search sought information on the auxiliary headlights, warning lights, work lights, mechanism to prevent snow blowing over the plow on to the windshield, mechanism to keep lights clear of snow, retro-reflective markings and day versus night settings. The review also documented impacts of different type of light bulbs, color of light, intensity of light, mounting locations, flashing patterns, and amperage requirements. In addition, Task 1 focused on recent literature and literature useful to develop the agency and operator survey questionnaires.

Task 2 Approach: Agency Survey

For this task, the research team's approach was to conduct an online survey of winter maintenance agencies (supervisors and managers) to capture information on the current state-of-the-practice, best practices, and lesson learned in areas of equipment lighting and specifications for auxiliary headlights, warning lights and working lights used for snowplow operations. The survey questions were developed based on the finding from literature search and inputs from Technical Advisory Committee (TAC). The survey targeted Clear Roads member states, as well as U.S. snow and ice control agencies. The survey was open for responses from March 23, 2015 – April 17, 2015 and received 58 responses representing 26 states within U.S. Survey results were incorporated into the Best Practices Guide. The survey questionnaire can be found in Appendix B of this document and a summary of the agency survey results can be found in the Appendices of the *Use of Equipment Lighting during Snowplow Operations* Best Practice Guide.

Task 3 Approach: Operator Survey

For this task, the research team's approach was to conduct an online survey of snowplow operators on the current state-of-the-practice, best practices, and lesson learned in areas of equipment lighting and specifications for auxiliary headlights, warning lights and working lights used for snowplow operations. The survey specifically focused on the pros and cons on the use of equipment lighting for the snowplow vehicle which operators currently use. A pilot survey was conducted with the TAC members and feedback was used to develop the final survey questionnaire. The survey was sent to supervisors and managers who responded to agency survey as a point of contact to further distribute the survey to their snowplow operators. The survey was open for responses from April 20, 2015 to May 11, 2015.and received 369 responses representing 11 states within U.S. Survey results were incorporated into the Best Practices Guide. The survey questionnaire can be found in Appendix B of this document and a summary of the operator survey results can be found in the Appendices of the *Use of Equipment Lighting during Snowplow Operations* Best Practice Guide.

Task 4 Approach: Synthesis of Information

For this task, the research team's approach was to develop a best practice guide based on the information gathered from literature search and surveys. The goal of the best practice guide is to communicate the impacts of different lighting packages and configurations, mounting locations, and new technologies, as well as the current best practices in use of equipment lighting during snowplow operations. The audience for this manual will be winter maintenance field supervisors or managers, with a focus on modifying or improving upon existing practices. The content was designed to address proactive strategies and highlight their effectiveness, limitations, and other considerations, while providing specific recommendations for implementation; but also addresses some key reactive strategies. The intent of the manual is to facilitate the adoption of the identified best practices into mainstream use by the intended audience.

Task 5 Approach: Final Report and Presentation

For this task, the research team's approach was to prepare a final report of the work completed, including an executive summary, introduction, methodology, results for each task, and concluding remarks. The research team's approach also included coordinating a meeting with the TAC to present the draft final report findings, and preparing a PowerPoint™ to support presentations at conferences or national and regional meetings by Clear Roads members.

Chapter 3
Task Results

This chapter describes the results of each of the five primary tasks.

Task 1 Results: Analyze and Review Research

The research team compiled, reviewed, and analyzed available literature on the use of auxiliary headlights, warning lights and work lights during snowplow operations. In addition, the literature search sought information on the currently available mechanism to prevent snow blowing over the plow onto the windshield, mechanism to keep lights clear of snow, retro-reflective markings, and day versus night settings for lights. The review also documented impact of different types of light bulbs, the color of the light, intensity of the light, mounting locations, flashing patterns, and amperage requirements. The literature search was conducted to document the state of the practice and the state of the art related to equipment lighting on snowplows, with a focus on recent literature and literature useful for developing a best practice guide, specifically the identification of best practices used in equipment lighting specifically used for snowplow operations.

Recent research conducted by international sources was reviewed wherever available, along with the ongoing research and existing documents published by the Clear Roads, Aurora, and Pacific Northwest Snowfighters (PNS), the Transportation Association of Canada (TAC), university transportation centers (UTCs), the Strategic Highway Research Program (SHRP), Federal Highway Administration (FHWA), National Cooperative Highway Research Program (NCHRP) and Airport Cooperative Research Program (ACRP), the American Public Works Association (APWA), (AASHTO), relevant state and local transportation agencies (city and county), the Environmental Protection Agency (US EPA), state Departments of Environmental Quality (DEQ), National Association of County Engineers (NACE), automotive/trucking industry, DOTs, and other key agencies and organizations.

The research team conducted keyword searchers of several databases to gather relevant information including:

- Google (https://www.google.com)
- Google Scholar (http://www.scholar.google.com)
- ScienceDirect (http://www.sciencedirect.com/)
- TRID (http://trid.trb.org/)
- NACE (http://www.countyengineers.org/Pages/default.aspx)
- Patent Office (http://patft.uspto.gov/netahtml/PTO/search-adv.htm) or Google Patents
- Montana State University Library (http://www.lib.montana.edu/)

Through the review and analysis, the team identified extensive and up-to-date information for inclusion in the best practice guide, and identified information gaps to be addressed in the surveys. The results of the literature search were used to develop the survey questionnaires and the content of the best practice guide.

Task 2 Results: Agency Survey

The research team developed a survey questionnaire that targeted identified experts at state and local agencies to capture information on the current state-of-the-practice, best practices, and lesson learned in areas of equipment lighting and specifications for auxiliary headlights, warning lights and working lights used for snowplow operations. The survey questionnaire was reviewed by the Clear Roads Technical Advisory Committee, and then placed in an online survey tool and tested. Following testing, the survey was distributed to Clear Roads member states, as well as to individuals and organization identified in the literature search. The survey was open for three weeks and received 58 responses. The survey results were submitted to Clear Roads TAC committee for review. Survey results were incorporated into the Best Practices Guide. The survey questionnaire and results can be found in the Appendices of the Best Practice Guide.

Task 3 Results: Operator Survey

For this task the research team developed a survey questionnaire that targeted state and local agency snowplow operators. Individuals from state and local agencies who responded to agency survey were contacted to distribute the online survey among their snowplow operators. The survey specifically focused on the pros and cons of the use of equipment lighting for snowplow vehicles which the operators currently use. The survey questionnaire was reviewed by the Clear Roads Technical Advisory Committee, and then placed in an online survey tool and tested. Following testing, the survey was distributed. The survey was open for three weeks and received 369 responses. The survey results were submitted to Clear Roads TAC committee for review. Survey results were incorporated into the Best Practices Guide. The survey questionnaire and results can be found in the Appendices of the Best Practice Guide.

Task 4 Results: Synthesis of Information

Utilizing the information and research compiled from the previous three tasks, the research team synthesized the captured information into the *Use of Equipment Lighting during Snowplow Operations Synthesis of Information – Best practice guide.*

The format of the final best practice guide includes the following components:

- Introduction and Summary of Survey Results
- Auxiliary headlights
    - Type of Auxiliary headlights
    - Impact of mounting location and beam width on visibility during snowy conditions
    - Impact of color of bulbs on visibility during snowy conditions
- Mechanism to prevent snow blowing over the plow onto the windshield
- Warning lights
    - Type of warning headlights
    - Color of warning lights
    - Intensity of warning lights

    - Flashing patterns
    - Amperage requirements for various lighting packages
    - Mounting locations for warning lights
- Work lights
- Mechanism to keep light clear of snow
- Retro-reflective markings
- Day versus night settings.

The synthesis of information has been provided as a stand-alone document.

Task 5 Results: Final Report and Presentation

This document has been prepared and submitted as the final report for this project. The contents include all the components called for in the approach.

The information presented in the manual and final report has been developed into a PowerPoint™ presentation for use by Clear Roads. The PowerPoint™ presentation has been submitted to the Clear Roads TAC, and is included in this report Appendices.

The meeting with the TAC will be scheduled upon approval of this report.

Chapter 4
Conclusion and Recommendations

Agencies responsible for snow and ice control need to find a balance between making snowplow trucks visible to travelling public and ensuring that their drivers have the best possible visibility of the road and vehicles around them. Snowplow often operate under conditions of limited visibility. In addition, snow plow vehicles travel at lower speeds than other traffic during winter maintenance operations. It is therefore important to select the right lighting package, mounting location and available technologies to improve the illumination for snow operators and travelling public.

LEDs are favored for use in new vehicles, retrofits, and replacements due to improved visibility. However, it is important to have some mechanism to keep the lights clear of snow because LEDs do not produce enough heat to melt snow and ice off the light surface. Wind deflectors and heated lens can be used to keep light clear of snow. Mounting the auxiliary headlights away from the operator's line of sight (possibly at the lowest possible location of snowplow) is important to reduce the light bounce-back

For warning lights, amber is the color most commonly used for warning lights. However, agencies are using and/or testing blue, white, and green colors. Operators prefer white colored warning lights because of perceived increased conspicuity during low visibility (e.g., fog, storm conditions, etc.) conditions. It is important to have both flashing lights and steady burning (constant burn) lights that are spaced apart for rear warning lights. Flashing lights help to identify the presence of a plow and steady burn lights aid in the estimation of the relative speed of plow.

Retro-reflective tape markings are very effective and provide an additional level of warning for approaching vehicles. However, keeping retro-reflective markings clear of snow and visible at all times is an issue during snow plowing operations. The issue of increased brightness introduced by warning lights can be resolved by using day-versus-night settings for lights on snowplow vehicles, but this feature is not commonly available.

Appendix A: Power Point Presentation

Use of Equipment Lighting During Snowplow Operations

Anburaj Muthumani, Laura Fay,
and
Dave Bergner

Outline

- Introduction
- Methodology
- Auxiliary Headlights
- Mechanism to prevent snow blowing over the plow onto the windshield
- Warning lights
- Work lights
- Mechanism to keep light clear of snow
- Retro-reflective markings
- Day versus night settings
- Conclusions

Introduction

- The goal of this research project was to develop a summary of best practices in the use of headlights, work lights, and warning light technology in snowplow operations.

Introduction

- The project, specifically focuses on different types of light bulbs, the color of the light, intensity of the light, mounting locations, flashing patterns and flashing interval, and amperage requirements.
- In addition, the study captures mechanism to prevent snow blowing over the plow onto the windshield, mechanism to keep lights clear of snow, retro-reflective markings and day versus night settings.

Methodology

- Literature search
  - Used to develop survey questions and the best practices guide
- Agency survey
  - 58 responses representing 26 states within U.S
- Operator Survey
  - 369 responses representing 11 states within U.S
- Synthesis of Information
  - Summary of literature search and survey findings
  - Identifies the Pros and Cons, and makes Recommendations

Auxiliary Headlights

- Typically located on the front of snowplow vehicles and provide supplemental illumination of the road surface during plowing.

Types of Auxiliary Headlight Bulbs

- Incandescent
  - Rarely used
- Halogen
  - Most commonly used
  - Mixed opinion about the performance
- High-Intensity Discharge (HID)
  - Not commonly used
  - Positive comments about the performance
- Light-Emitting Diode (LED)
  - 2nd most commonly used
  - Positive comments about the performance

Types of Auxiliary Headlight Bulbs

- Winter maintenance agencies are moving towards use of LEDs in their vehicle for auxiliary headlights.
- LEDs produce light appears closer to daylight
- Energy efficient
- Long service life
- Do not produce enough heat to melt snow

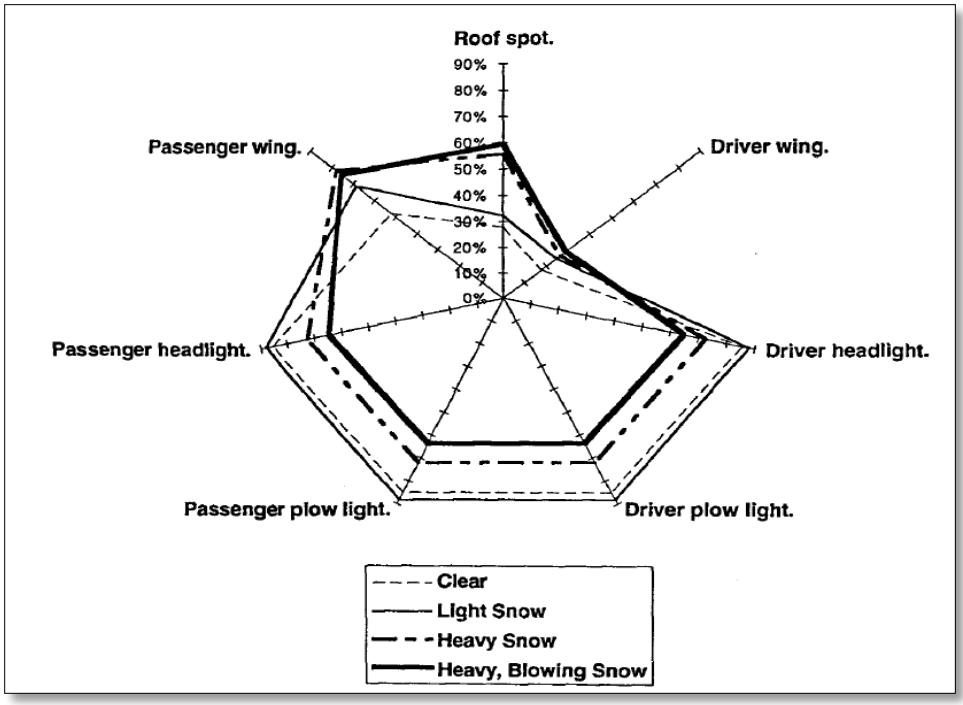
Comparison between Halogen and LEDs lights with high and low beam (www.truckinginfo.com)

Mounting location and Beam width

- Light bounce-back from auxiliary lights during snowy conditions is a major safety issue.
- Mounting locations and beam width play a key role in reducing light bounce-back.
- Auxiliary headlights are primarily located on:
  - Truck body (most common)
  - Cab hood
  - Plow frame
  - Others (front fenders, on the grill, and top of headache rack)

Mounting location

- Previous studies suggest:
  - Mounting auxiliary headlights on the passenger side in snowy conditions
  - Mounting lamps away from the operator's line of sight (passenger side) was preferred over mounting lamps on the operator's line of sight (driver side).

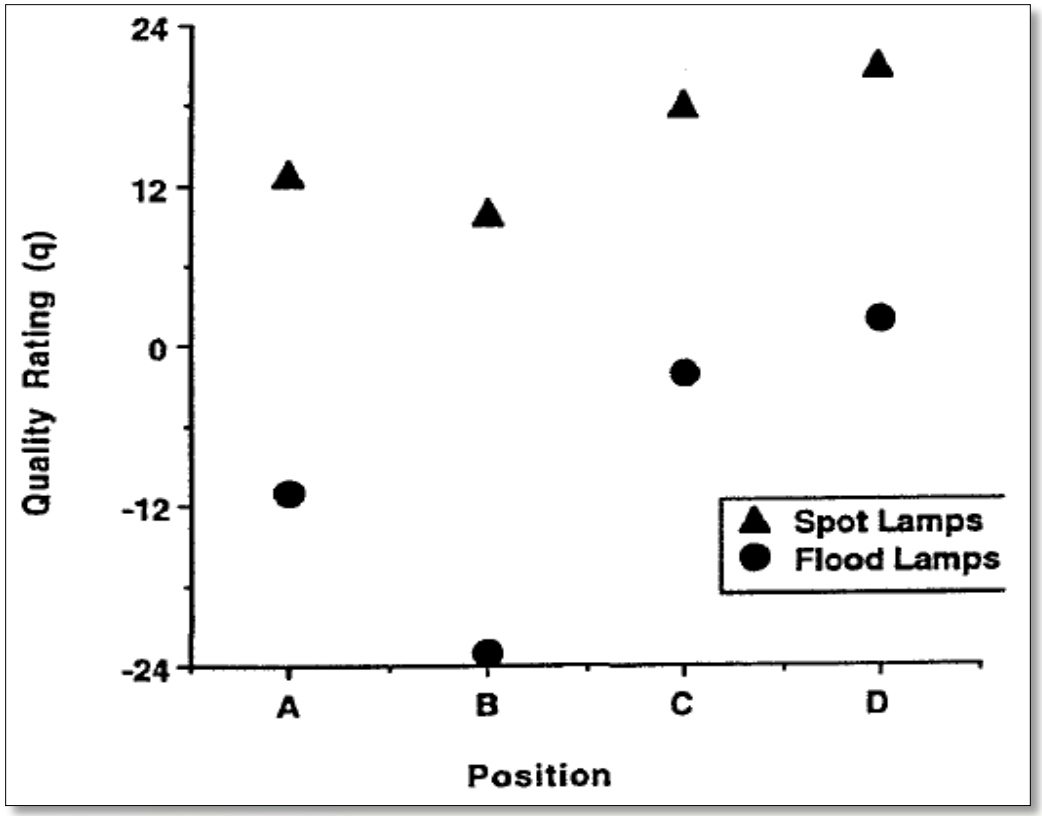


Percentage of operators using light under different weather conditions (Eklund et al., 1997)

Beam width

- Previous studies suggest:
  - Narrower spot lamp was preferred over the wide flood lamp

Subjective quality rating for spot lamps and flood lamps (Bullough and Rea, 1997) .



Mounting location and Beam width

- Survey Respondents indicated:
  - Mounting auxiliary headlights at the lowest possible place (above the plow or fender walls)
    - Con: Potential reflection of light from the back of the plow blade
  - Mounting auxiliary headlights on the top corners of the plow blade
    - Con: Potential of snow sticking on lights
    - Con: Decreased reliability of lights due to plow vibration
    - Con: Installation and wiring difficulties
  - Narrow beam lights preferred over wide beam lights

Mounting location and Beam width

- Identified Best Practices:
  - Mounting the auxiliary headlights away from operator's line of sight with narrow beams (spot light) helps to reduce the light bounce-back during adverse weather conditions.
  - In particular, mounting auxiliary headlights at the lowest possible location (above the plow or fender walls) is recommended.

Color of Auxiliary headlight bulbs

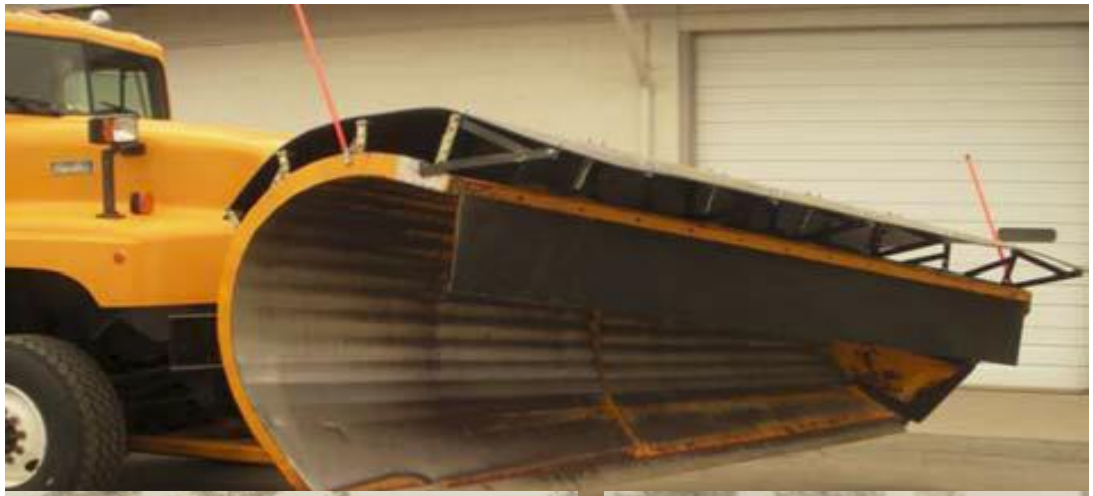
- The amount of light scatter is inversely proportional to the wavelength of light such that;
  - Blue light, with a shorter wavelength, will scatter more light than red light, a with longer wavelength.
- Yellow headlights were mandated rather than white headlights in France until 1990s
- Recent studies did not find any significant advantages of using yellow or any other color lights in reducing the glare during inclement weather conditions.

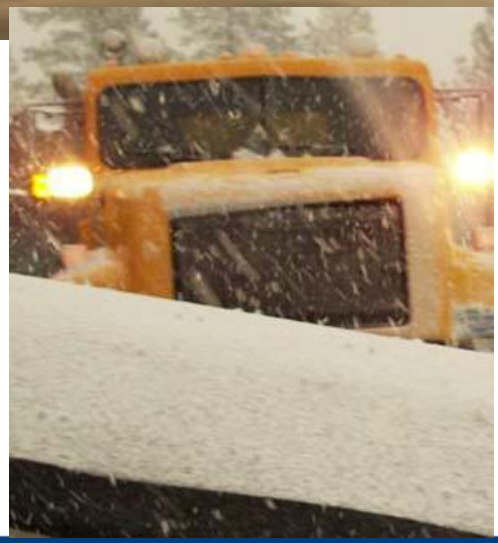
Color of Auxiliary headlight bulbs

- Survey respondents suggested using yellow fog lights to reduce the light bounce back from snow; which is;
  - consistent with older standards,
  - contrast with recent research findings.
- In fact, color of headlights may have little impact on improving visibility when compared to improvements made by changing mounting location and beam width during inclement weather conditions.

Mechanism to Prevent Snow Blowing over the Plow onto the Windshield

- Over plow deflectors
  - With trap angle less than 50°
- Very few respondents have over-plow deflectors on their vehicles
- Other options - air foils, bug shields, and poly plows.





Warning lights

- Warning lights typically provide increased conspicuity of the snowplow vehicle; by indicating the position and direction of travel.
- Forward warning lights
- Rear warning lights
- Side-mount warning lights

Type of Warning light bulbs

- Agencies prefer LEDs
  - reliability, improved efficiency, and reduced maintenance costs
- LEDs lights are brighter in all observed conditions and different light groups
- Minnesota DOT study found that LED lights performed well, or in some cases better when viewed directly from the rear, side, or front of the snowplow vehicle when compared to standard HID strobes.
  - Con: Conspicuity was reduced at off angles

Color of Warning light

- Indiana DOT study found that amber is the color preference for all color configurations followed by bright blue for warning lights
- Snowplow operators preferred white color and amber color warning lights during low visibility (e.g., fog, snow, etc.) conditions
- Lights with red, orange, and yellow color components may have negative impacts during blowing snow and fog conditions (Yonas and Zimmerman, 2006)

Color of Warning light

- NDDOT believes that white color is the most intense light to penetrate during low visibility conditions
- Iowa DOT is also testing flashing blue and white LED lights on 175 snowplow vehicles
- ODOT is using green flashing LED lights placed atop its snowplow vehicles
- NDDOT is currently testing steady burning - green warning lights located outside the box
  - To differentiate DOT vehicles from other trucks (Oil trucks, construction trucks etc.,)

Color of Warning light

The green lights demonstrated in snowy conditions on Nov. 18, 2014 (http://woodtv.com/2014/11/13/kent-co-wants-new-green-lights-for-plow-trucks/)

Intensity of Warning light

- Agencies chose the brightest light bulb type for warning lights, such as LEDs.
- Survey respondents indicated warning lights can never be too bright
  - Brighter lights are better to warn drivers approaching snowplows from the rear
- Very few respondents indicated warning lights can be too bright for those following behind a snowplow vehicles
  - suggest having lower intensity settings especially at night
  - keep a reasonable distance from the back of the snowplow vehicles

Flashing pattern and Interval

- The ability of a driver to detect the presence of a snowplow vehicle is different than the ability of the driver to detect the relative speed of the snowplow vehicles (perceived approach).
- Flashing lights increase conspicuity of snowplow vehicles
  - Con: reduce the ability of drivers to accurately perceive an approaching snowplow vehicle
- Steady-burn (constant burn) lights increase the ability of drivers to accurately perceive an approaching snowplow vehicle

Flashing pattern and Interval

- Previous studies suggest use of steady burning lights if agencies choose only one lighting system
- Flashing lights should not be excessively brighter than steady burning lights
- Survey responses are in contrast with the research findings
  - Operators believe that flashing lights help following drivers estimate the relative speed of the snowplow vehicles
  - Steady burning lights are not commonly used as rear warning lights

Amperage Requirements

- Instantaneous and average power used by all LEDs fixtures are significantly lower than standard strobes (HID)

- LEDs may require heated lens (additional amperage) to stay clear of snow during snowy conditions

Electrical Characteristics of the tested strobes (Vogt and Miller, 2008)

Fixture description	Peak current (Amps)	Peak power (Watts)	Energy/cycle (Joules)	Average power (Watts)	Duty cycle (%)	Cycle time (sec)
Standard strobe	11.3	137.3	49.6	58.2	>0.7	0.82
Whelen LED	3.1	38.1	10.8	13.1	35	0.82
PSE 257 LED	5.9	73.0	37.4	41.9	58	0.89
Federal LED	3.8	46.0	46.0	15.9	25	2.90

Mounting location for warning lights

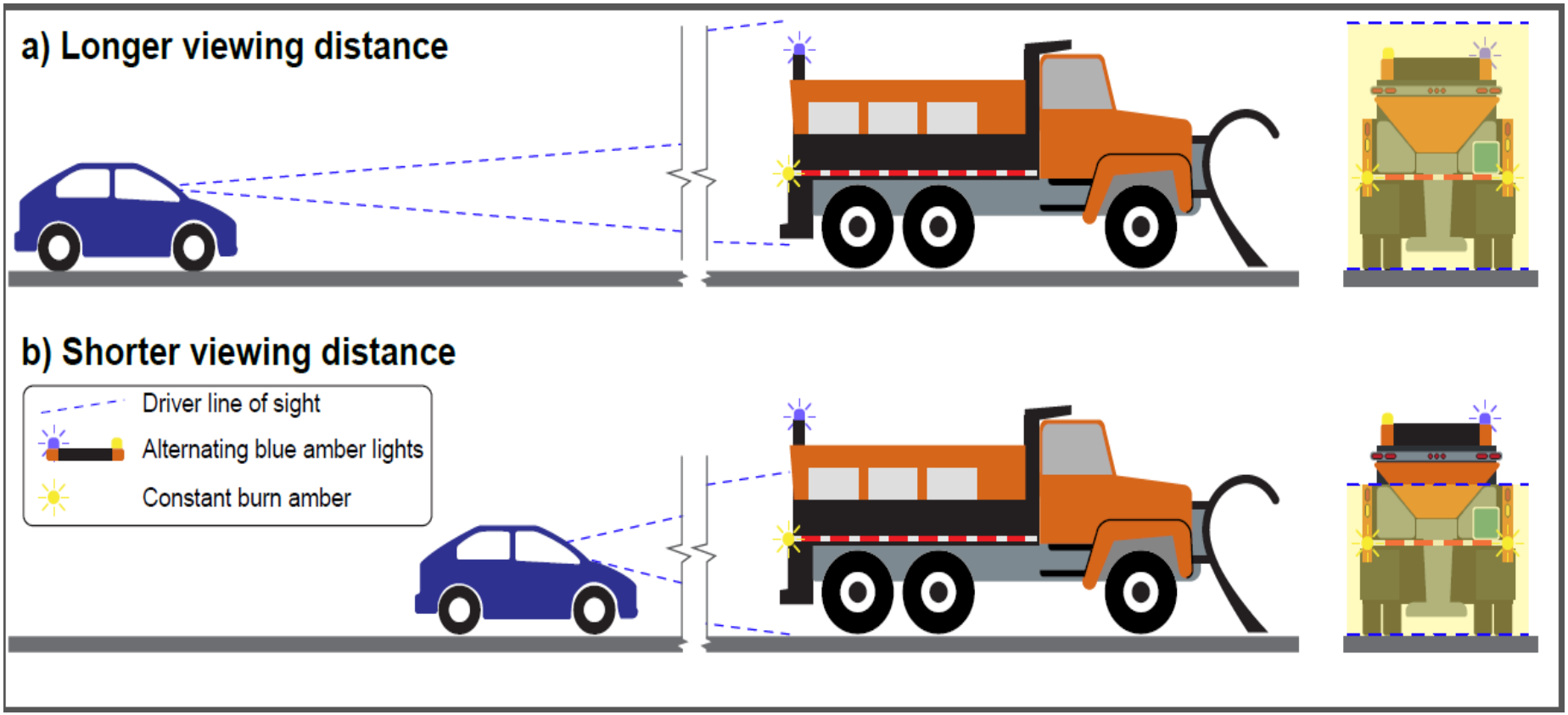
- Agencies are trying to mount the forward warning lights to achieve complete visibility from the rear and sides
- Rear warning lights are commonly flush mounted, followed by pole or telespar mounted lights, single or multiple beacons and surface mounted lights.
- Elevating the rear warning lights (pole mounted or telespar mounted) is becoming more popular with survey respondents.
- Important to have a reasonable distance between lights when using multiple colors for rear warning lights.

Mounting location for warning lights

- NDDOT recommends elevating rear warning lights for increasing air flow around lights and reducing the snow accumulation.
- Must be careful during loading and unloading operations to avoid damaging the elevated lights

Rear warning lights mounted on the telespars, showing snow accumulation (NDDOT).

Proposed Mounting location for steady burn and flashing lights



Work Lights

- Work lights are floodlights or spotlights mounted at various places on the truck exterior for illumination of specific locations such as a wing-plow, under-body plow, top of a truck bed, spreader-spinner, cab-steps, etc.
- Typical mounting locations of work lights identified by survey respondents are the side and rear of the vehicles.
- LEDs and halogen bulbs are the most commonly used light bulb for work lights
- White color is used by the majority of survey respondents
- Operators prefer additional work lights on tow plows, wing plows, top of the cab, under body lights, top of sanders (to keep track of materials), and some additional flood lights on the rear.

Mechanism to Keep Lights Clear of Snow

- LEDs accumulate more snow other light bulbs
- Wind deflectors mounted above the box of the snowplow were recommended to keep the rear warning lights free from snow build-up
- Air foils have been found to be effective in keeping the rear of vehicles clear of snow

Comparison of snow accumulation between standard strobe (left) and Whelen LED (right) after heavy snow conditions (Vogt and Miller, 2008).

Mechanism to Keep Lights Clear of Snow

- Iowa DOT recommended the use of "scoop" tailgate deflectors to decrease the amount of snow on the back of vehicles
- Wind deflectors may not be effective for tail lights and brake lights

Airfoil test run – without airfoil showing more snow accumulation on the rear (left); with airfoil showing less snow accumulation on the rear (right) (Nevada DOT, 2015).

Mechanism to Keep Lights Clear of Snow

- Nevada DOT suggested the feasibility of thin sheet heaters powered by a 12 volt source to be used on snowplow lights

- Heated lenses need a control switch
  - In cold snow events (around 15°F), heated lenses can create a dome of ice over the LED lens

- Alter the mounting locations of lights to enhance air flow around the lights.

Retro-reflective Markings

- Retro-reflective markings increase conspicuity of the vehicle at night and during low-light conditions.
- Retro-reflective materials become completely ineffective if covered by snow and or dirt.
- The biggest issues with retro-reflective markings is keeping them 100% clean
- Most commonly used color combinations for reflective markings are red and white

Day Versus Night Settings

- The combination of more light sources and higher intensities may temporarily blind approaching vehicle drivers especially during nighttime operations

- Studies recommended using different intensity lighting for daytime and nighttime operations

- Day-versus-night time settings are not a commonly available feature in snowplow vehicles

- Very few respondents have manually operated day-versus-night light settings on their vehicles

Conclusions

- Halogen bulbs followed by LED bulbs are the most commonly used bulb types for auxiliary headlights. LEDs are favored for use in new vehicles, retrofits, and replacements due to improved visibility.

- Mounting the auxiliary headlights away from the snowplow operators line of sight with narrow beams (spot light) helps to reduce the light bounce-back during adverse weather conditions. In particular, mounting auxiliary headlights at the lowest possible location (above the plow or fender walls) is recommended.

Conclusions

- With the emergence of LEDs for auxiliary headlights, warning lights, and work lights, it is important to have some mechanism to keep the lights clear of snow because LEDs do not produce enough heat to melt snow and ice off the light surface.

- Over- plow deflectors have been found to be effective in keeping the front grill clear of snow.

Conclusions

- Amber is the color most commonly used for warning lights. However, agencies are using and/or testing blue, white, and green colors. Operators prefer white colored warning lights because of perceived increased conspicuity during low visibility (e.g., fog, storm conditions, etc.) conditions.

- It is important to have both flashing lights and steady burning (constant burn) lights that are spaced apart for rear warning lights. Flashing lights help to identify the presence of a plow and steady burn lights aid in the estimation of the relative speed of plow.

Conclusions

- Retro-reflective tape markings are very effective and provide an additional level of warning for approaching vehicles. However, keeping retro-reflective markings clear of snow and visible at all times is an issue during snow plowing operations.

- A combination of wind deflectors and heated lens can be used to keep the warning lights and retro-reflective tape clear of snow. However, it is important to have a control switch that can turn on and off the heated lenses based on the conditions.

Conclusions

- The issue of increased brightness introduced by warning lights can be resolved by using day-versus-night settings for lights on snowplow vehicles, but this feature is not commonly available.

Acknowledgements

- Clear Roads Technical Advisory Committee
- Colleen Boss and Greg Waidley, project coordinators from CTC & Associates
- WTI Colleagues: Carla Little and Neil Hetherington.
- Survey participants

QUESTIONS !!!

Questions?

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Appendix B Agency and Operator Survey Questionnaires

Use of Equipment Lighting During Snowplow Operations - Agency Survey

Introduction

The Western Transportation Institute (WTI) at Montana State University is conducting this survey for a research project for Clear Roads and the Minnesota Department of Transportation.

The purpose of this survey is to gather information from winter maintenance supervisors and managers on their experience with lighting and specifications for auxiliary headlights, warning lights and working lights used for snowplow operations.

This survey is estimated to take about 20 - 25 minutes to complete.

- Participation is voluntary.
- You can choose to not answer any question, and you can stop at any time.
- Your contact information will only be used by the researchers for the purposes of this study.
- We may try to contact you for clarification or additional information.
- Your participation in any follow up phone calls or emails is also voluntary.

If you have any questions about the survey, please contact Anburaj Muthumani at anburaj.muthumani@coe.montana.edu or call (406) 994-6782. For questions regarding your personal rights to voluntarily participate in this survey contact Mark Quinn the Institutional Review Board Chair at Montana State University at 406-994-4707 or mquinn@montana.edu.

Your knowledge and experience are key, so we really appreciate your participation!

Use of Equipment Lighting During Snowplow Operations - Agency Survey

Background Information

1. Survey Respondent Information

Name

Title

Agency Name

E-mail

Phone

2. Agency Type

- [ ] State/Province DOT
- [ ] County Public Works/DOT
- [ ] Municipal Public Works
- [ ] Federal
- [ ] Toll Authority
- [ ] Tribal

Other (please specify)

Use of Equipment Lighting During Snowplow Operations - Agency Survey

Fleet Information

3. Please provide your typical plow configuration? (Please indicate all that apply. : *"F"*= front; *"WR"*=right wing; *"WL"*=left wing; *"U"*=underbody; *"T"*=tow plow, *"V"*= V-plow, *"B"*=blower attachment, *"S"*= sweeper) For example, a tandem axle truck with front plow and right wing plow (see picture below) would be indicated as: *Tandem axle trucks: "F, WR"*

Single-axle trucks	
Tandem axle trucks	
Triple-axle trucks	
Grader	
Front-loader	
Backhoe loader	
Skid-steer	
Tractor	
Other (Please specify)	

Use of Equipment Lighting During Snowplow Operations - Agency Survey

Fleet Information

4. What is your Fleet Size? (please indicate the number used for roadway snow plowing and/or material applications)

Single-axle dump trucks	
Tandem axle dump trucks	
Tri-axle dump trucks	
One-ton dump trucks	
½ and ¾ ton pickups	
Flat-bed trucks	
Graders	
Front-end loaders	
Back-hoe loaders	
Skid-steers	
Snow blowers	
Other (Please specify and the number)	

Use of Equipment Lighting During Snowplow Operations - Agency Survey

Auxiliary Headlights

Auxiliary Headlights are typically used on the front of plows and provide supplemental illumination of the road surface during plowing. They also provide forward-lighting and directional signals when a raised plow obscures standard truck headlights. Auxiliary headlights increase visibility for on-coming traffic during the day and are typically mounted on the plow frame or truck body. (*see picture below*)

5. What '*bulb type*' does your agency use for Auxiliary Head lamps? (More than one answer can be provided)

- [ ] Halogen
- [ ] Incandescent
- [ ] Xenon
- [ ] LED
- [ ] Please provide make and model for the selected bulb type.

Use of Equipment Lighting During Snowplow Operations - Agency Survey

Auxiliary Headlights

6. What is your agency's typical auxiliary headlight with turn signal - parking light configuration?

☐ Twin single

☐ Twin dual

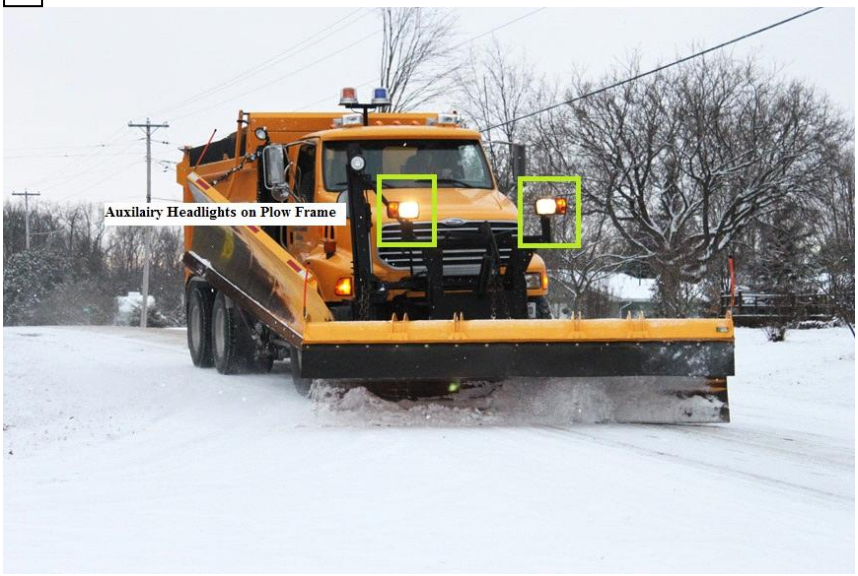
☐ Other (please specify)

Use of Equipment Lighting During Snowplow Operations - Agency Survey

Auxiliary Headlights

7. What is your typical mounting position of Auxiliary Headlights?

☐ **Plow frame**



☐ **Truck Body**

☐ Other (please specify)

Use of Equipment Lighting During Snowplow Operations - Agency Survey

Auxiliary Headlights

8. How does your agency deal with the light bounce-back from auxiliary headlights during snowy conditions? Please explain. (see picture below)

(e.g., yellow auxiliary headlights, Cab roof spot light, altering the mounting positions of auxiliary headlights, turning off the auxiliary headlamps that is in driver's line of sight)

9. Does your agency use any mechanism to keep the snow from blowing onto the windshield (other than windshield wipers)?

- ◯ Yes
- ◯ No
- ◯ If yes, what kind of mechanism is used? Describe its effectiveness? (e.g., over plow deflectors)

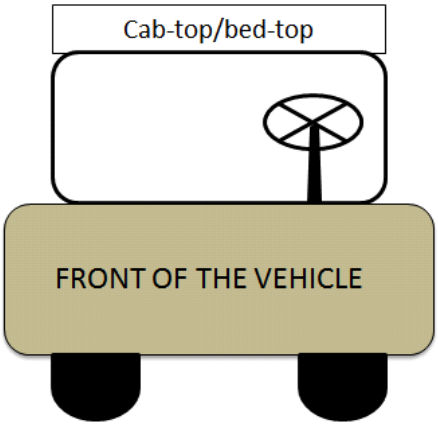
Use of Equipment Lighting During Snowplow Operations - Agency Survey

Forward Warning Lights

Warning lights typically provide increased visibility for the driving public; aiding in indication of position and direction of travel of the plow vehicle. These lights also supplement a vehicle's regular headlights, tail lights, and side marker lights. Forward warning lights are typically located on the front of a vehicle such as cab-top/bed-top (See picture).

Use of Equipment Lighting During Snowplow Operations - Agency Survey

10. What type of '*warning light*' do you use on the '*front of the vehicle*' such as cab-top/bed-top warning lights? (See picture below)



	Rotating	Strobe	Flashing	Steady-burn
Single Beacon 	☐	☐	☐	☐
Twin Beacon (L/R) 	☐	☐	☐	☐
Single light bar, mid-full size 	☐	☐	☐	☐
Twin mini-light bars (L/R) 	☐	☐	☐	☐

Please specify - if you use any other warning light type or different mounting position for the front of vehicle.

Use of Equipment Lighting During Snowplow Operations - Agency Survey

Forward Warning Lights

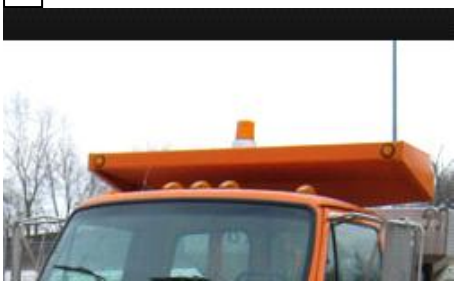
11. What is your agency's typical configuration (mounting location and grouping) of warning lights for 'forward lighting' to clearly illuminate the snow plows?

☐ top of cab, single beacon (not visible from rear)

☐ top of cab, light bar with multiple lamps (not visible from rear)

☐ top of cab, pair of beacons placed outboard (partially visible from rear)

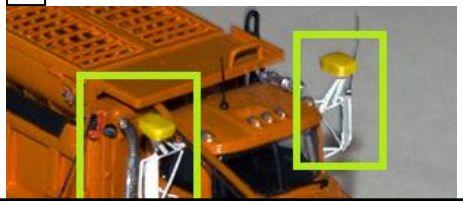
☐ extended above cab and truck bed; single beacon 360 visibility



☐ extended above cab and truck bed; light bar with multiple lamps 360 degree visibility

☐ extended above cab and truck bed

☐ mounted above side rear-view mirrors



☐ Other (please specify)

Use of Equipment Lighting During Snowplow Operations - Agency Survey

Forward Warning Lights

12. What '*bulb type*' do you use in '*front of the vehicle*' such as cab-top/bed-top warning lights? Please check all that apply.

	Halogen	Incandescent	HID	LED
Single Beacon (center) 	☐	☐	☐	☐
Twin Beacon (Left/Right) 	☐	☐	☐	☐
Single light bar, mid-full size (center) 	☐	☐	☐	☐
Twin mini-light bars (Left/Right) 	☐	☐	☐	☐

Please provide make and model for the selected bulb type.

Use of Equipment Lighting During Snowplow Operations - Agency Survey

Forward Warning lights

13. Please indicate all the colors your agency use for forward warning lights?

- ☐ All-amber
- ☐ Amber-'white'
- ☐ Amber-blue
- ☐ Amber-red
- ☐ Amber-green
- ☐ All-Blue
- ☐ Blue-'white'
- ☐ Blue-red
- ☐ Blue-green
- ☐ 'All-white'
- ☐ 'White'-red
- ☐ 'White'-green
- ☐ All-red
- ☐ Red-green
- ☐ All-green
- ☐ Other (please specify)

Rear Warning lights

Rear warning lights are typically mounted on vertical rear surfaces of truck bodies. Types include surface, flush-mount, and beacons; which provide better visibility to following traffic. Side-mount warning lights are typically surface or flush–mounted and increase visibility of the truck to cross-traffic and to vehicles in adjacent lanes.

Use of Equipment Lighting During Snowplow Operations - Agency Survey

14. What type of 'warning light' do you use in the 'Rear of the vehicle'. Rear warning lights are typically mounted on vertical rear facing surfaces of the truck body. Common types include surface, flush-mount, and beacons; which increase visibility for following traffic.

	Rotating	Strobe	Flashing	Steady-burn
Single or multiple beacons 	☐	☐	☐	☐
Flush mounted lights (L/R) 	☐	☐	☐	☐
Surface mounted lights 	☐	☐	☐	☐
Pole mounted lights 	☐	☐	☐	☐
Light bar with multiple lights on top 	☐	☐	☐	☐

Please specify if you use any other types of warning lights in the rear of the vehicle.

Use of Equipment Lighting During Snowplow Operations - Agency Survey

Rear Warning lights

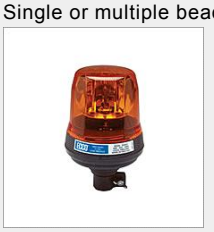
15. Please indicate all the colors your agency use for rear-mounted warning lights?

- [ ] All-amber
- [ ] All-Blue
- [ ] 'White'-red
- [ ] Amber-'white'
- [ ] Blue-'white'
- [ ] 'White'-green
- [ ] Amber-blue
- [ ] Blue-red
- [ ] All-red
- [ ] Amber-red
- [ ] Blue-green
- [ ] Red-green
- [ ] Amber-green
- [ ] 'All-white'
- [ ] All-green
- [ ] Other (please specify)

Use of Equipment Lighting During Snowplow Operations - Agency Survey

Rear Warning lights

16. What type of 'warning light bulb' do you use in the 'Rear of the vehicle'. Rear warning lights are typically mounted on vertical rear facing surfaces of the truck body. Common types may be surface, flush-mounted, or beacons; which improve visibility for following traffic.

	Halogen	Incandescent	HID	LED
Single or multiple beacons 	☐	☐	☐	☐
Flush mounted lights (L/R) 	☐	☐	☐	☐
Surface mounted lights 	☐	☐	☐	☐
Pole mounted lights 	☐	☐	☐	☐

Use of Equipment Lighting During Snowplow Operations - Agency Survey

Light bar with multiple lights on top 	☐	☐	☐	☐

Please specify if you use any other types of bulbs in the warning lights in the rear of the vehicle.

Use of Equipment Lighting During Snowplow Operations - Agency Survey

Rear Warning lights

17. Have you found any one type of rear warning light that is better for estimating the relative speed of the snowplow, especially for plow truck drivers following behind another truck during snow removal operations?

- ◯ Flashing; all at same time (such as hazard flashers)
- ◯ Flashing; alternating (i.e. “wig-wag”)
- ◯ Flashing; random sequences
- ◯ Steady Burning
- ◯ Other (additional comments,Please explain)

18. How does your agency accommodate "*increased brightness introduced by warning lights*", especially for plow truck drivers following behind another truck during snow removal operations?

19. Does your vehicle have day versus night lighting settings to accommodate the increase in brightness caused by warning lights especially during night time?

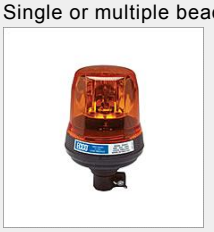
- ◯ Yes
- ◯ No
- ◯ No - planned for future installations?
- ◯ Don't know
- ◯ If yes, please note whether this is automatic or manual.

Use of Equipment Lighting During Snowplow Operations - Agency Survey

Side-mounted warning lights

Side-mount warning lights are typically surface or flush–mounted and increase visibility of the truck to cross-traffic and to vehicles in adjacent lanes.

20. What type of 'warning light' do you use on the '*side of the vehicle*'?

	Rotating	Strobe	Flashing	Steady-burn
Single or multiple beacons 	☐	☐	☐	☐
Flush mounted lights (L/R) 	☐	☐	☐	☐
Surface mounted lights (L/R) 	☐	☐	☐	☐

Please specify if you use any other type of side warning light.

21. Please indicate all the colors your agency use for side-mounted warning lights?

☐ **All-amber**	☐ **All-Blue**	☐ 'White'-red
☐ Amber-'white'	☐ Blue-'white'	☐ 'White'-green
☐ Amber-blue	☐ Blue-red	☐ **All-red**
☐ Amber-red	☐ Blue-green	☐ Red-green
☐ Amber-green	☐ '**All-white**'	☐ **All-green**

☐ Other (please specify)

22. What 'bulb type' do you use on the 'side of the vehicle'? Please check all that apply.

	Halogen	Incandescent	HID	LED
Beacons 	☐	☐	☐	☐
Flush mounted lights 	☐	☐	☐	☐
Surface mounted lights 	☐	☐	☐	☐

Please provide make and model for each bulb type.

Use of Equipment Lighting During Snowplow Operations - Agency Survey

Work Lights

Work lights are floodlights or spotlights mounted at various places on the truck exterior for illumination of specific locations such as a wing-plow, under-body plow, top of truck bed, spreader-spinner, cab-steps, etc. They enhance safety and convenience for the truck operator. (See pictures below)

23. What is the typical location and type of light used for work lights?

	Flood light	Spot light
Front	☐	☐
Side	☐	☐
Rear	☐	☐

Other (please specify)

24. Please provide the bulb type you use for work light?

- ☐ Incandescent
- ☐ Halogen
- ☐ HID
- ☐ LED
- ☐ Please provide make and model for each type.

Use of Equipment Lighting During Snowplow Operations - Agency Survey

25. Please indicate all the colors your agency use for work lights?

- ☐ **All-amber**
- ☐ Amber-'white'
- ☐ Amber-blue
- ☐ Amber-red
- ☐ Amber-green
- ☐ **All-Blue**
- ☐ Blue-'white'
- ☐ Blue-red
- ☐ Blue-green
- ☐ '**All-white**'
- ☐ 'White'-red
- ☐ 'White'-green
- ☐ **All-red**
- ☐ Red-green
- ☐ **All-green**
- ☐ Other (please specify)

Use of Equipment Lighting During Snowplow Operations - Agency Survey

Reflective markings

Highly retro-reflective markings are typically added on the rear of the vehicle and side of trucks. It increases visibility of the vehicle at night and during low-light conditions.

26. Do you use retro-reflective markings on your agency vehicle?

- ◯ Yes
- ◯ No
- ◯ Don't Know

27. Please provide the colors combinations your agency typically use for reflective markings.

28. Please provide the typical patterns your agency use for reflective markings?

- ☐ Body outline (rectangle)
- ☐ Horizontal stripes only
- ☐ Vertical stripes only
- ☐ Chevrons
- ☐ Other (please specify)

29. How does your agency deal with snow sticking on the reflective markings?

Use of Equipment Lighting During Snowplow Operations - Agency Survey

Thank you - Survey Complete

Thank you for participating in this survey. If you like to provide follow up information or if you are interested in receiving notification once the final report is completed, please contact Anburaj Muthumani at anburaj.muthumani@coe.montana.edu or call (406) 994-6782.

Use of Equipment Lighting During Snowplow Operations - Operator Survey

Introduction

The Western Transportation Institute (WTI) at Montana State University is conducting this survey for a research project for Clear Roads and the Minnesota Department of Transportation.

The purpose of this survey is to gather information from snow plow operators on their experience with lighting and specifications for auxiliary headlights, warning lights and working lights used for snowplow operations.

This survey is estimated to take about 20 - 25 minutes to complete.

- **Participation is voluntary.**
- **You can choose to not answer any question, and you can stop at any time.**
- **Your contact information will only be used by the researchers for the purposes of this study.**
- **We may try to contact you for clarification or additional information.**
- **Your participation in any follow up phone calls or emails is also voluntary.**

If you have any questions about the survey, please contact Anburaj Muthumani at anburaj.muthumani@coe.montana.edu or call (406) 994-6782. For questions regarding your personal rights to voluntarily participate in this survey contact Mark Quinn the Institutional Review Board Chair at Montana State University at 406-994-4707 or mquinn@montana.edu.

Your knowledge and experience are key, so we really appreciate your participation!

1 / 19 5%

Next

Use of Equipment Lighting During Snowplow Operations - Operator Survey

Background Information

1. Survey Respondent Information

Name

Title

Agency Name

E-mail

Phone

2. Agency Type

- [ ] State/Province DOT
- [ ] County Public Works/DOT
- [ ] Municipal Public Works
- [ ] Federal
- [ ] Toll Authority
- [ ] Tribal

Other (please specify)

2 / 19 11%

Prev Next

Use of Equipment Lighting During Snowplow Operations - Operator Survey

Fleet Information

3. What is the plow configuration of the vehicle you currently operate? (Please select all that apply). For example, the equipment type as shown in picture below - Respondent would select both '***front plow***' and '***right wing plow***' for a tandem axle truck.

	Front plow	Right wing plow	Left wing plow	Underbody plow	Tow plow	V-plow	Blower attachment	sweeper
Single-axle trucks	☐	☐	☐	☐	☐	☐	☐	☐
Tandem axle trucks	☐	☐	☐	☐	☐	☐	☐	☐
Triple-axle trucks	☐	☐	☐	☐	☐	☐	☐	☐
1 ton trucks	☐	☐	☐	☐	☐	☐	☐	☐
1/2 and 3/4 ton trucks	☐	☐	☐	☐	☐	☐	☐	☐
Flatbed trucks	☐	☐	☐	☐	☐	☐	☐	☐
Graders	☐	☐	☐	☐	☐	☐	☐	☐
Front-end loaders	☐	☐	☐	☐	☐	☐	☐	☐
Back-hoe loaders	☐	☐	☐	☐	☐	☐	☐	☐
Skid-steers	☐	☐	☐	☐	☐	☐	☐	☐
Tractor	☐	☐	☐	☐	☐	☐	☐	☐

Other (please specify)

3 / 19 16%

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Use of Equipment Lighting During Snowplow Operations - Operator Survey

Auxiliary Headlights

Auxiliary Headlights are typically used on the front of plow trucks and provide supplemental illumination of the road surface during plowing. They also provide forward-lighting and directional signals when a raised plow obscures standard truck headlights. Auxiliary headlights increase visibility for on-coming traffic during the day and are typically mounted on the plow frame or truck body. (*see picture below*)

4. What bulb type is used in your vehicle for auxiliary headlights?

- ○ Halogen
- ○ Incandescent
- ○ HID
- ○ LED

Please specify

4 / 19 21%

Prev Next

Use of Equipment Lighting During Snowplow Operations - Operator Survey

Auxiliary Headlights

5. What type of auxiliary headlight with turn signal is installed in your vehicle ?

- [ ] Twin single

- [ ] Twin dual

- [ ] Twin single (no turn signal)

- [ ] Other (please specify)

6. Please indicate the effectiveness of the auxiliary headlight you use.

- ○ Excellent
- ○ Very good
- ○ Good
- ○ Fair
- ○ Poor
- ○ No opinion

5 / 19		26%

Prev Next

CLEAR ROADS

Use of Equipment Lighting During Snowplow Operations - Operator Survey

Auxiliary Headlights

7. Please indicate the mounting position of your primary vehicle's auxiliary headlights

- ☐ **Plow frame**

☐ **Truck Body**

☐ **Cab hood**

☐ Other (please specify)

8. Are you satisfied with the mounting location of the auxiliary headlights?

- ○ Yes
- ○ No
- ○ No opinion

Other (please specify)

6 / 19		32%

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Use of Equipment Lighting During Snowplow Operations - Operator Survey

Auxiliary Headlights

9. Do you experience the problem of light bounce- back (back-scattered light) from auxiliary headlights during plowing operations?

- ☐ Yes
- ☐ No
- ☐ Sometimes

Additional comments

10. Would you suggest any change in auxiliary headlight mounting locations to reduce back-scattered light and/or improve visibility?

- ○ Yes
- ○ No

If yes, please explain

11. Does your vehicle use any mechanism to keep the snow from blowing onto the windshield (other than windshield wipers)?

- ○ Yes
- ○ No

If yes, what kind of mechanism is used? Describe its effectiveness? (e.g., over plow deflectors)

Prev Next

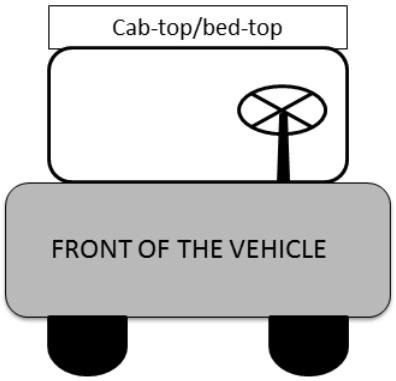
Use of Equipment Lighting During Snowplow Operations - Operator Survey

Forward Warning Lights

Warning lights typically provide increased conspicuity of the plow vehicle; aiding in indication of position and direction of travel of the plow vehicle. These lights augment the identification of the plow vehicle provided by the regular headlights, tail lights, and side marker lights. Forward warning lights are typically located on the front of a vehicle such as cab-top/bed-top (See picture).


Warning Mounted on the Cab-top

12. What type of warning light do you use for forward warning light such as cab-top/bed-top warning lights? (See picture below) Note: **Strobe light:** A lamp that produces very short, intense flashes of light in rapid succession. **Flashing light:** Exhibits only single flashes which are repeated at regular intervals.



	Rotating	Strobe	Flashing	Steady-burn
Single Beacon 	☐	☐	☐	☐
Twin Beacon (L/R) 	☐	☐	☐	☐
Single light bar, mid-full size 	☐	☐	☐	☐
Light head (mounted in multiple locations above the cab shield) 	☐	☐	☐	☐

Please specify - if you use any other warning light type

8 / 19 42%

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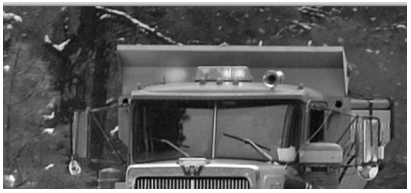
Forward Warning Lights

13. What is the configuration (mounting location and grouping) of forward warning lights on your plow vehicle to provide conspicuity (or visibility) ?

- [ ] top of cab, single beacon (not visible from rear)

- [ ] top of cab, light bar with multiple lamps (not visible from rear)



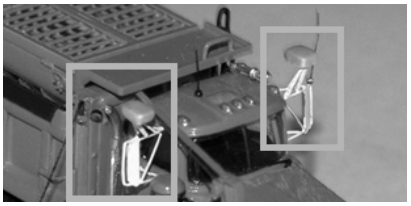
- [ ] top of cab, pair of beacons placed outboard (partially visible from rear)

- [ ] extended above cab and truck bed; single beacon 360 visibility

- [ ] extended above cab and truck bed; light bar with multiple lamps 360 degree visibility

- [ ] extended above cab and truck bed

- [ ] mounted above side rear-view mirrors



- [ ] Please specify - if you use different mounting position for forward warning lights.

9 / 19		47%

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Use of Equipment Lighting During Snowplow Operations - Operator Survey

Forward Warning Lights

14. What bulb type do you have in your plow truck for forward warning light such as cab-top/bed-top warning lights.

	Halogen	Incandescent	HID	LED
Single Beacon (center) 	☐	☐	☐	☐
Twin Beacon (Left/Right) 	☐	☐	☐	☐
Single light bar, mid-full size (center) 	☐	☐	☐	☐
Light head (mounted in multiple locations above the cab shield) 	☐	☐	☐	☐

Others, please specify

10 / 19 53%

Prev Next

Use of Equipment Lighting During Snowplow Operations - Operator Survey

Forward Warning lights

15. Please indicate the color of the forward warning lights for the plow truck you currently use.

- [ ] All-amber
- [ ] Amber-'white'
- [ ] Amber-blue
- [ ] Amber-red
- [ ] Amber-green
- [ ] All-Blue
- [ ] Blue-'white'
- [ ] Blue-red
- [ ] Blue-green
- [ ] 'All-white'
- [ ] 'White'-red
- [ ] 'White'-green
- [ ] All-red
- [ ] Red-green
- [ ] All-green
- [ ] Other (please specify)

11 / 19 58%

Prev Next

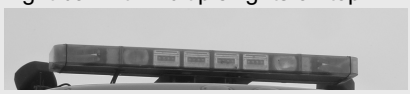
Use of Equipment Lighting During Snowplow Operations - Operator Survey

Rear Warning lights

Rear warning lights are typically mounted on vertical rear surfaces of truck bodies. Types include surface, flush-mount, and beacons; which provide better visibility to following traffic.

16. What type of warning light (secondary) do you use in the rear of the vehicle? NoteStrobe light: A lamp that produces very short, intense flashes of light in rapid succession. Flashing light: Exhibits only single flashes which are repeated at regular intervals.

	Rotating	Strobe	Flashing	Steady-burn
Single or multiple beacons 	☐	☐	☐	☐
Flush mounted lights (L/R) 	☐	☐	☐	☐
Surface mounted lights 	☐	☐	☐	☐

	Rotating	Strobe	Flashing	Steady-burn
Pole mounted lights 	☐	☐	☐	☐
Light bar with multiple lights on top 	☐	☐	☐	☐
Swivel mount 	☐	☐	☐	☐

Please specify if you use any other types of warning lights in the rear of the vehicle.

12 / 19 63%

Prev Next

CLEAR ROADS

Use of Equipment Lighting During Snowplow Operations - Operator Survey

Rear Warning lights

17. Please indicate the color of the rear warning lights for the plow truck you currently use.

- [ ] All-amber
- [ ] Amber-'white'
- [ ] Amber-blue
- [ ] Amber-red
- [ ] Amber-green
- [ ] **All-Blue**
- [ ] Blue-'white'
- [ ] Blue-red
- [ ] Blue-green
- [ ] **'All-white'**
- [ ] 'White'-red
- [ ] 'White'-green
- [ ] **All-red**
- [ ] Red-green
- [ ] **All-green**
- [ ] Other (please specify)

13 / 19 68%

Prev Next

CLEAR ROADS

Use of Equipment Lighting During Snowplow Operations - Operator Survey

Rear Warning lights

18. What bulb type do you have in your plow truck for rear warning light?

	Halogen	Incandescent	HID	LED
Single or multiple beacons 	☐	☐	☐	☐
Flush mounted lights (L/R) 	☐	☐	☐	☐

	Halogen	Incandescent	HID	LED
Surface mounted lights 	☐	☐	☐	☐
Pole mounted lights 	☐	☐	☐	☐
Light bar with multiple lights on top 	☐	☐	☐	☐

Please provide information on the bulb type that is currently specified or has most recently been purchased.

14 / 19 74%

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CLEAR ROADS

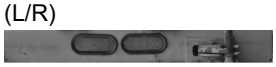
Use of Equipment Lighting During Snowplow Operations - Operator Survey

Side-mounted warning lights

Side-mount warning lights are typically surface or flush–mounted and increase visibility of the truck to cross-traffic and to vehicles in adjacent lanes. Note: Strobe light: A lamp that produces very short,

intense flashes of light in rapid succession. Flashing light: Exhibits only single flashes which are repeated at regular intervals.

19. What type of warning light do you use on the side of the vehicle?

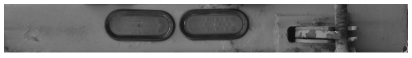
	Rotating	Strobe	Flashing	Steady-burn
Single or multiple beacons 	☐	☐	☐	☐
Flush mounted lights (L/R) 	☐	☐	☐	☐
Surface mounted lights (L/R) 	☐	☐	☐	☐

Please specify if you use any other type of side warning light.

20. Please indicate the color of the side-mounted warning lights for the plow vehicle you currently use.

- ☐ All-amber
- ☐ Amber-'white'
- ☐ Amber-blue
- ☐ Amber-red
- ☐ Amber-green
- ☐ **All-Blue**
- ☐ Blue-'white'
- ☐ Blue-red
- ☐ Blue-green
- ☐ '**All-white**'
- ☐ 'White'-red
- ☐ 'White'-green
- ☐ **All-red**
- ☐ Red-green
- ☐ **All-green**
- ☐ Other (please specify)

21. What type of bulb is used in side warning lights? Please check all that apply.

	Halogen	Incandescent	HID	LED
Beacons 	☐	☐	☐	☐
Flush mounted lights 	☐	☐	☐	☐
Surface mounted lights 	☐	☐	☐	☐

Others (please specify)

15 / 19 79%

Prev Next

CLEAR ROADS

Use of Equipment Lighting During Snowplow Operations - Operator Survey

Effectiveness of Warning lights

22. What is your preferred warning light color for daytime, nighttime, and operations during low visibility (e.g., fog, storm conditions, etc.) operations for improved visibility?

	Daytime	Nighttime	Low visibility (e.g., fog, storm conditions, etc.)
Amber	☐	☐	☐
Blue	☐	☐	☐
Green	☐	☐	☐
Red	☐	☐	☐
White	☐	☐	☐

Combinations (please specify)

23. From your experience, what type of warning lights clearly identify the presence of the snowplow vehicle from the rear?

- ○ Flashing Strobe warning light
- ○ Flashing LED warning lights
- ○ Rotating halogen or HID bulb warning light
- ○ Steady -burn warning light
- ○ Other (please specify)

24. Is one type of lighting pattern better for indicating the relative speed of the snowplow to following vehicles?

- ○ Flashing; all at same time (such as hazard flashers)
- ○ Flashing; alternating (i.e. “wig-wag”)
- ○ Flashing; random sequences
- ○ Steady Burning
- ○ Other (additional comments,Please explain)

25. Do you think warning lights are too bright or intense (excessive flashing) especially for other plow truck drivers following behind during snow removal operations?

- Yes
- No

Additional comments (Suggestions)

26. Does your vehicle have day versus night lighting settings to accommodate the increase in brightness caused by warning lights especially during night time?

- Yes
- No
- No - planned for future installations?
- Don't know
- If yes, please note whether this is automatic or manual.

27. Does your vehicle have any devices/mechanism to keep lights clear of the snow?

- Yes
- No
- If yes, what kind of mechanism/device is used? Describe its effectiveness?

16 / 19 84%

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Use of Equipment Lighting During Snowplow Operations - Operator Survey

Work Lights

Work lights are floodlights or spotlights mounted at various places on the truck exterior for illumination of specific locations such as a wing-plow, under-body plow, top of truck bed, spreader-

spinner, cab-steps, etc. They enhance safety and convenience for the truck operator. (See pictures below)

28. What is the typical location and type of light used for work lights? Below is a picture of beam spread for spot and flood light.

	Flood light	Spot light
Front	☐	☐
Side	☐	☐
Rear	☐	☐

Other (please specify)

29. Please provide the bulb type you use for work light?

- ☐ Incandescent
- ☐ Halogen
- ☐ HID
- ☐ LED
- ☐ Please provide information on the bulb type that is currently specified or has most recently been purchased.

30. Please indicate the colors your agency use for work lights?

- [ ] '**All-white**'
- [ ] Other (please specify)

31. What additional work lights would you recommend, what type, where placed and why?

17 / 19 89%

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Use of Equipment Lighting During Snowplow Operations - Operator Survey

Reflective markings

Highly retro-reflective markings are typically added on the rear of the vehicle and side of trucks. It increases visibility of the vehicle at night and during low-light conditions. Retro-reflective markings are addition to standard USDOT red/white markings; these are usually larger than standard and may be of different colors or combinations.

32. Do you use retro-reflective markings on your agency vehicle?

- ○ Yes
- ○ No
- ○ Don't Know

33. Please indicate the location and pattern of the retro-reflective markings are on your primary vehicle.

	Body outline (rectangle)	Horizontal stripes only	Vertical stripes only	Chevrons
Side	○	○	○	○
Rear	○	○	○	○
Plow (back or edges)	○	○	○	○

Other (please specify)

34. Please provide the colors combinations of reflective markings on your vehicle.

35. What is your opinion of the effectiveness of the retro-reflective marking?

- ○ Increase visibility to other drivers/vehicles on the road
- ○ Effective if kept clean
- ○ Do nothing
- ○ No opinion
- ○ Other (please specify)

36. Would you recommend the use of more retro-reflective markings on snow trucks?

- ○ Yes
- ○ No
- ○ If yes, where on the truck and what color?

18 / 19 95%

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Use of Equipment Lighting During Snowplow Operations - Operator Survey

Thank you - Survey Complete

Thank you for participating in this survey. If you like to provide follow up information or if you are interested in receiving notification once the final report is completed, please contact Anburaj Muthumani at anburaj.muthumani@coe.montana.edu or call (406) 994-6782.

Prev Done

research for winter highway maintenance

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