New Hampshire DOT

Research

LED Snowplow Lights Evaluation Report

Final Report

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16. Abstract

The NHDOT snowplow fleet currently uses halogen lights mounted on the push frame for night time snowplowing operations. Due to the excessive vibration, frequent bulb replacement is necessary. Light-emitting diodes (LEDs) are less susceptible to vibrations and could reduce long term maintenance cost. Plow drivers have suggested that LED lighting improves their visibility while operating as well as reducing the fatigue experienced during extended hours of plowing. Mechanical Services does not have a firm policy on the use of LED headlamps and needs to determine if the fleet would experience benefits by using LED bulbs. This project compared the use of halogen bulbs to heated LED bulbs. The results indicated that converting the NHDOT snowplow fleet from halogen bulbs to LED bulbs to reduces maintenance requirements, increases service life, and improves operator visibility for safer snowplow operations.

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LED Snowplow Lights Evaluation Report

November 1, 2018 - December 31, 2020

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New Hampshire Department of Transportation
Bureau of Highway Maintenance
Concord, New Hampshire

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EXECUTIVE SUMMARY

The NHDOT snowplow fleet currently uses halogen lights mounted on the push frame for night time and low-light snowplowing operations. Plow truck drivers have suggested that light-emitting diode (LED) lighting may improve their visibility while operating as well as reducing the visibility-related fatigue experienced during extended hours of plowing snow in darkness. In addition, excessive vibration of the equipment makes frequent bulb replacement necessary. LED bulbs are less susceptible to vibrations and could reduce long-term maintenance costs. The Bureau of Mechanical Services does not have a firm policy on the use of LED headlights and needs to determine if the fleet would experience benefits by using LED bulbs.

The project compared the use of heated LED bulbs with halogen bulbs in headlights installed on NHDOT-owned plow trucks. The in-house research project targeted District 1 and District 3 because of available interstate and rural routes. 72 heated LED headlights were purchased and installed on 17 plow trucks per district. Vehicle operators were chosen based on their particular route to assess the variety of weather and traffic conditions. The operators completed surveys relating their driving experience in a variety of weather conditions that include: clear, cloudy, snow, rain, freezing rain, sleet, wind, rain, fog, and blowing materials. Operators also monitored maintenance of equipment. Supervisors completed surveys relating their experience when encountering the plow trucks on the road to assess visibility and if the LED headlights were harmful to oncoming traffic. Feedback from the public was minimal.

The surveys indicated that 98.5% of operator surveys reported better or much better visibility and 97.8% better or much better peripheral visibility. 70.4% of operators reported less eye fatigue. 91.4% of supervisor surveys reported better visibility and 72.4% better peripheral visibility. In addition, 60.3% of supervisors reported less eye fatigue with only three (3) occasions of blinding oncoming traffic. Regarding long-term maintenance cost, no LED headlights required replacement during the duration of the project.

1. INTRODUCTION

Snowplow vehicles and their operators often work in the harshest weather conditions at night with limited visibility. Their visibility is affected by the intensity of the storm, type of precipitation, time of day, and the lighting systems installed on their vehicles. In addition, the severity of the vibration of the equipment during plowing operations necessitates frequent bulb changes, often as many as four (4) bulbs per storm. This maintenance is costly and time consuming. The snowplow vehicle lighting system also affects other users of the highway when the plow truck meets oncoming traffic. Providing better forward visibility for plow truck operators in adverse weather conditions, reduced maintenance costs, and consideration for other users of the highway were the primary focuses of this research project.

Highway Maintenance employees in District 1 and District 3 work an average of 265,000 hours per year with approximately 60% of those hours performing winter maintenance. Extended overtime hours, often weeks at a time, affect the employee's health and ability to do the job. At a District 1 Internal Safety Committee Meeting, an employee proposed replacing the halogen headlights that were standard equipment on fleet vehicles and on the plow frames of the plow trucks. The proposed replacement was LED headlights.

The recommendation was made to reduce driver eye fatigue by improving forward visibility and to reduce maintenance costs. A review of the Clear Roads study, Project 99006/CR14-0 6[1], indicated that many states have been experimenting with LED plow lights for years with overall positive feedback. The light produced by LEDs is closer to that of daylight and LEDs have a significantly longer service life. LEDs are becoming more common in newer vehicles.

The objective of this NHDOT Highway Maintenance research project is to evaluate the performance of the LED lights on plow frames of trucks during winter maintenance. The evaluation will rely primarily on objective data from operators, supervisors, and the public. Based on this data, a recommendation will be made to either continue using the halogen bulbs or convert the NHDOT commercial vehicle fleet to LED headlights.

2. AUXILIARY HEADLIGHTS

Plowing snow involves a front mount push-frame installation on the front of the plow truck to which a plow is attached. Some plows are fixed for discharge of snow to the right and some have a reversible plow for discharge to either right or left side. The plow is raised and lowered when needed or to clear obstructions in the road such as bridge expansion joints and railroad tracks. Having this additional frame and plow mounted to the front of the plow truck obstructs the truck-mounted headlight making them unusable. This requires auxiliary headlights to be installed on the top of the push frame. These auxiliary headlights become the primary means of forward lighting and directional signals. Visibility for snowplow operators is often reduced due to light reflecting back from blowing snow, fog, freezing rain, and blowing snow over-topping the plow. These conditions make the quality of the forward lighting very important. In addition, the vibrations of the equipment being in contact with the surface of the road shorten the service life of the headlights.

2.1 Halogen Headlight

The Wagner H6054, 5” x 7” Halogen Sealed Beam Headlight is the standard headlight installed and replaced on fleet vehicles within the NHDOT. The halogen light produces heat from the filament in the bulb which prevents snow and ice build-up in all but the harshest conditions. Similar to incandescent bulbs, the heat also makes the bulb more susceptible to the vibration of the equipment and more prone to failure. Halogen bulbs have proven reliable and provide a normal service life when used for routine maintenance activities. Unfortunately, the incandescent and halogen bulbs were not designed to withstand the extreme vibrations encountered when the plow is scraping the snow-covered roadway. Operators often replace four (4) to six (6) halogen bulbs per storm event. The cost per unit is $5.25 each.

Overview:
Wagner® Sealed Beams are the original sealed beam that delivers brighter, whiter light than incandescent lighting. Shining up to 40% farther than incandescent lights, the non-reflective bottom shelf prevents glare in fog, rain and snow. Wagner-certified for long-lasting dependability, they feature an extra strong filament design to withstand greater vibration and coated terminals to prevent corrosion.

Features:
- Brighter, whiter light than incandescent lighting
- Prevents glare in fog, rain and snow
- Shines up to 40% farther than incandescent lighting
- Rugged vibration resistance
- High-grade stainless steel terminals
- Coated terminals to prevent corrosion
- DOT/Society of Automotive Engineers (SAE) compliant

2.2 Light-Emitting Diode (LED) Headlight

The JW Speaker 8910 Evolution 2, 5" x 7" LED Headlight with SmartHeat™ is the light chosen for evaluation in the research project. This model was selected for a number of reasons that include compatibility with existing light housings, service life and warranty, the SmartHeat™ feature, DOT compliance, and cost. A standard LED light generates very little heat thereby allowing snow and ice to quickly accumulate on the lens during snow events. The 8910 model was chosen for evaluation because it offers a SmartHeat™ feature which automatically de-ices the headlight depending on ambient temperature. They have a 2-year warranty with most still in service after five (5) years of use. The cost per unit is $206.04 each.

Overview:
The 8910 Evolution 2 provides a high performance 5" x 7″ LED headlight, available with a SmartHeat™ heated lens and Dual Burn™ technology. The 8910 Evolution 2 heated LED headlights provide a high performance safety solution with improved light output, and glare reduction.

Features:
- Dual Burn™ high beam optics for extra punch of light
- Available with SmartHeat™ Technology that automatically de-ices headlight according to ambient temperature
- Meets proposed National Highway Transportation Safety Administration (NHTSA) guidelines for a 5-Star New Car Assessment Program-compliant low beam headlight
- Drop-in replacement heated LED headlights for typical buckets/panels used in heavy-duty trucks
- Tough, die-cast aluminum housing and polycarbonate lens, with added protection from salt spray for efficient thermal management
- Superior condensation management
- Street legal supporting DOT, Transport Canada Economic Commission for Europe (ECE) and Military standards & requirements
- 5-Star NCAP-compliant Technology: The Model 8910 Evolution 2 will exceed the proposed Federal Motor Vehicle Safety Standards (FMVSS) 108 standard in at least these three criteria, meeting 5-Star compliance:
  1. Light output, measured in lux
  2. Beam pattern, resulting in minimal glare
  3. Light placement, as dictated by mounting locations prescribed for vehicles

- Dual Burn™ Technology: Dual Burn™ technology goes beyond the average high beam pattern with a three-part beam pattern designed to help people see better and stay safe.
- SmartHeat™ Heating System: The heated LED headlight, Model 8910 Evolution 2, features a thermally conductive grid system that will de-ice the lens up to twice as fast as other lights. This intelligent system reacts to temperature changes on a real-time basis with no action required by the driver.
- Street legal supporting DOT, ECE and Military standards: DOT versions are for use in the U.S. DOT-compliant guarantees that the lights are legal on the road, meeting section 108 requirements of the Federal Motor Safety Standards. The DOT-compliance is clearly etched on the lens of the light.
- Also available in a non-heated version (Model 8900 Evolution 2)

2.3 Installation of Lights

The compatibility of the JW Speaker LED model to the existing vehicle light housings made the installation of the lights very simple. The halogen bulbs were removed and the LEDs were plugged into the 3-prong wiring harness. The lights were then adjusted properly according to the State of New Hampshire inspections rules. Installation was performed by the NHDOT Bureau of Mechanical Services heavy equipment mechanics at the service garages in Lancaster, Twin Mountain, Ossipee, and Concord.

The headlights were installed to meet New Hampshire's requirements of Chapter Saf-C 3200 Official Motor Vehicle Inspection Requirements, Part Saf-C 3216, Headlight Aim (http://www.gencourt.state.nh.us/rules/state_agencies/saf-c3200.html). The requirements are outlined as follows:

PART Saf-C 3216 HEADLAMP AIM

Saf-C 3216.01 Headlight Aim.

(a) A vehicle shall be rejected if:

(1) A commercially manufactured aimer shows the headlight beam is not straight ahead and 2 degrees down; or

(2) A headlight board shows the headlight beam is not straight ahead and less than 2 inches lower than the horizontal center line of the board, measured 25 feet from the headlamps; or

(3) Headlight aim is unachievable due to fogging or glazing of the lens or reflector.

3. TEST SITES

The Technical Advisory Group (TAG) selected plow route test locations within Districts 1 and 3 with consideration based on assessment of the LED headlight performance on remote, lower traffic volume roadways like Route 3 in Pittsburg, NH, north to the border of Canada. Also chosen were high traffic volume sections of Interstate 93 in Franconia Notch and Littleton. District 3 locations were likewise selected including remote, low volume Route 3 in Ellsworth and high volume Interstate 93 north from Exit 27 to 32 and south from Exit 23 to Exit 20. The intention was to

encounter a variety of winter conditions and traffic. The trucks and operators responsible for the winter maintenance of these roadways were chosen to participate in the research.

LED Lights - District One					
Driver Name	**Section**	**Truck No.**	**Truck Type**	**Route /Road**	**Plow Route**
Lorne LeClaire	101	H438	10 Wheeler	Rte 3 North/South	Pittsburg, Upper shed to Canadian border
Mike Hughes	101	H643	3-5 Ton	Rte 3 North/South	Pittsburg, Lower shed to Stewartstown
Sherman Coderre	103	H531	3-5 Ton	Rte 16	Thirteen Mile Woods, Errol
John Rooney	104	H514	3-5 Ton	Rte 3 North/South	Groveton to North Stratford
Keith Grenier	105	H567	3-5 Ton	Rte 110	West Milan East to Groveton
Dana Flynn	107	H638	3-5 Ton	Lost Nation Rd.	North Road to Lost Nation Road
Michael Pickett	108	H430	10 Wheeler	Rte 2	Rte 2 Jefferson to Gorham Hill/ Rte 115
Todd Webster	125	H1654	3-5 Ton	Rt.135	Harvey View Drive, Monroe to Rte 18, Littleton
Jason Marro	112	H441	10 Wheeler	Rte 302	Crawford Notch to Fourth Iron Bridge
Marc Brodeur	112	H487	3-5 Ton	Rte 3	Twin Mountain to Whitefield & Rte 115 to Jefferson
Travis Spencer	113	H540	3-5 Ton	Rte 16	Glen intersection North/South to mile marker 94.6
Shawn Woods	115	H613	3-5 Ton	Rte 112	Route 112, Lost River, Route 3 to Route 116, Easton
Corey St. Cyr	111	H662	3-5 Ton	Rte.135	Littleton village to Bridge Hill Road in Dalton
Tyler Spaulding	124	H413	10 Wheeler	I-93 North/South	Franconia Notch/Tandem with Kyle Bryant
Kyle Bryant	124	H423	10 Wheeler	I-93 North/South	Franconia Notch/Tandem with Tyler Spaulding
Todd Ferland	125	H604	3-5 Ton	I-93	Littleton, I-93 north to exit 40 (VT border)
William Nast	125	H1623	3-5 Ton	I-93	Littleton, I-93 north to exit 40 (VT border)

LED Lights - District Three					
Driver Name	**Section**	**Truck No.**	**Truck Type**	**Route /Road**	**Plow Route**
Kyle Bilodeau	313	H641	3-5 Ton	Rte 3 from Rte 140 to Belknap Mall	Rte 3, Rte 140 to Belknap - Tilton/Belmont
Bill Laflam	314	H457	3-5 Ton	Rte 140	Rte 140, 106, 107 - Belmont/Gilmanton/Laconia
Dana Decormia	314	H635	3-5 Ton	Rte 107	Rte 107, Rte 140, Rte 129 - Gilmanton
Warren Merrill	316	H585	3-5 Ton	Rte 106	Rte 106, Rte 140 - Concord/Loudon/Canterbury
James Eckert	324	H440	10 Wheeler	I-93	I-93 – New Hampton/Meredith/ Sanbornton/Tilton
Arthur Desroisiers	324	H463	10 Wheeler	I-93	I-93 - New Hampton/Ashland/ Holderness/Plymouth/Campton
Paul Lebreck	325	H479	10 Wheeler	I-93	I-93 - Campton/Thornton/ Woodstock/Lincoln
Dillon Trott	325	H548	3-5 Ton	Rte 49	Ellsworth Hill Road, Campton/Ellsworth
Chris Plancon	309	H1645	3-5 Ton	Rte 3 & Rte 25	Rte 3 - Meredith
William Chick	301	H404	10 Wheeler	Rte 16	Rte 16 - Albany/Conway
Blair Eastmans	301	-606	3-5 Ton	Rte 113	Rte 302 - Conway/Chatham
Keith Ross	302	H624	3-5 Ton	Rte 16	Rte 16, Rte 25 - Ossipee/Tamworth
George Boewe	303	H498	3-5 Ton	Rte 153	Rte 153, Rte 25 - Freedom/Madison/Eaton
Richard Atwood	305	H1649	3-5 Ton	Rte 113	Rte 113, Rte 3 - Tamworth/Sandwich/Holderness
Richard Maloney	311	H583	3-5 Ton	Rte 109	Rte 109, Rte 109A Jct. - Tuftonboro/Wolfeboro
Gene Doe	312	H1500	3-5 Ton	Rte 16	Rte 16, Rte 28 - Ossipee/Wakefield
Currie DeBow	312	H679	3-5 Ton	Rte 16	Rte 16 - Wakefield
Donald White	315	H673	3-5 Ton	Rte 11	Rte 11 - Alton/New Durham

4. DATA COLLECTION

The Technical Advisory Group (TAG) prepared surveys relevant to the operators, the supervisors, and the public. The surveys were distributed as appropriate and requested to be completed during weather events. The surveys were returned to the district offices on a biweekly schedule. The data was then compiled on a spreadsheet for review. 135 operator surveys, 58 supervisor surveys, and 4 public surveys were completed during the research period.

4.1 Operator Survey

LED Plow Light Work Plan

Operator Survey

Truck # _____ District_____ __ Date_____ ____Time_____

Driver Name_____ Patrol Section_____

Location/Rte#_____ or Road Name(s)_____

Weather Conditions (Check all that apply)

Clear____ Cloudy_____ Snow _____ Rain_____ Freezing Rain ____ Sleet_____ Wind_____ Fog____ Rain & Fog____ Blowing Materials_____

Road Conditions (Check all that apply)

Dry_____ Wet_____ Snow_____ Slush_____ Ice _____ Debris_____ Sand /dust /Oil_____ Other_____ (Please specify)

Road Type: (Check all that apply)

Interstate____ Ramps____ Two Lane Road_____ Two Lane Road (High speed)_____Parking Areas_____

---

1) How is the visibility with the LED lights? As compared to Halogen lights **(Check one)**
   - ____Much Better
   - ____Better
   - ____About the same
   - ____Not as good

2) Visibility enhanced to each side of the truck? As compared to Halogen lights **(Check one)**
   - ____Much Better
   - ____Better
   - ____About the same
   - ____Not as good

3) Eye Fatigue from headlights reflecting off falling Snow, Sleet , fog, etc...? As compared to Halogen lights **(Check one)**
   - ____ Worse
   - ____About the same
   - ____ Better

4) Are oncoming drivers flashing their headlights at you? Yes _____No _____Sometimes _____

Comments:

_____
_____
_____
_____

4.2 Supervisor Survey

LED Plow Lights Work Plan

Supervisor Survey

Truck #_____ District_____ Date_____ ____Time_____

Supervisor Name_____ _____ Supervisor Call #_____

Location/Rte#_____ or Road Name(s)_____

Weather Conditions (Check all that apply)

Clear____ Cloudy___ Snow _____ Rain___ Freezing Rain ____ Sleet_____ Wind_____ Fog____

Rain & Fog____ Blowing Materials_____

Road Conditions (Check all that apply)
Dry_____ Wet_____ Snow_____ Slush_____ Ice _____ Debris_____ Sand /dust /Oil_____

Other_____ (Please specify)

Road Type: (Check all that apply)

Interstate____ Ramps____ Two Lane Road____ Two Lane Road (High speed)____Parking Areas

---

1) Are you blinded by the oncoming plow lights? Yes_____ No_____ Sometimes_____
2) Are other oncoming drivers flashing their headlights at the plow truck? Yes ___No___ Sometimes____
3) In speaking with the Drivers, do they feel that the LED lights provide: (Check all that Apply)

- Better visibility_____
- Less Visibility____
- Better peripheral visibility _____
- Less peripheral visibility_____
- More Eye Fatigue____
- Less Eye fatigue____
- Blinding oncoming traffic_____

Comments:

_____
_____
_____
_____

4.3 Public Survey

LED Plow Light Work Plan

Public Survey

Date_____ ____Time_____

Name(Optional)_____

Location/Town_____ Route or Road Name(s)_____

Weather Conditions (Please check all that apply)

Clear____ Cloudy_____ Snow _____ Rain_____ Freezing Rain ____ Sleet_____ Wind_____ Fog____ Rain & Fog____ Blowing Materials_____

Road Conditions (Please check all that apply)

Dry_____ Wet_____ Snow_____ Slush_____ Ice _____ Debris_____ Sand /dust /Oil_____ Other_____ (Please specify)

Road Type: (Please check all that apply)

Interstate____ Ramps____ Two Lane Road_____ Two Lane Road (High speed)_____Parking Areas_____

_____

Comments: Please provide comments regarding your experience when encountering a NHDOT Plow Truck with LED Plow Lights.

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Pease Return Surveys to:

NHDOT, District One
641 Main Street
Lancaster, NH 03584

NHDOT, District Three
2 Sawmill Road
Gilford, NH 03249

5. SUMMARY AND CONCLUSION

The research project began at an Internal Safety Committee meeting in District 1 in February 2018. Highway Maintainer II, James K. Flanders, from the M-104 Patrol Crew in Groveton, New Hampshire, requested permission to replace the halogen auxiliary headlights with LED headlights to improve the forward illumination of his 3/5-ton plow truck and reduce the fatigue experienced when plowing snow particularly at night. Flanders request was denied because LEDs are not standard issue for that truck model and NHDOT does not have a firm policy on their use.

The topic was then discussed in May 2018 at the NHDOT Unit Safety Committee and a task force was created to examine the merits of LED headlights versus halogen. The task force recommended further research on the subject and a problem statement was presented to the NHDOT Research Advisory Council with request for funding. The research project was approved and funding of $15,000.00 was authorized. 72 LED headlights were purchased to retrofit 17 trucks in both Districts 1 and 3. Because of the late start in the 2018-2019 winter season, the research portion of the project was postponed until the winter of 2019-2020. Surveys were completed and research was terminated in May 2020.

Data from the surveys has been consolidated in the spreadsheet included in Section 6 Survey Data. The data is objective and based on the opinions of operators, supervisors, and limited public feedback. However, it is very clear from the collective data that the LED lights were an overwhelming improvement over the standard issue halogen lights installed on the fleet vehicles. The research supports the original proposal that LED light conversion from halogen lights will reduce maintenance requirements, increase service life, improve operator visibility for safer snowplow operations, lessen eye fatigue, and has the potential to improve employee morale and public safety.

6. SURVEY DATA

2019-2020 LED Plow Light Program Survey Data

	District 1	District 3
Public Surveys Received:	1	3
Operator Surveys Received:	64	71
Supervisor Surveys Received:	27	31
Total Surveys Received:	**92**	**105**

	Clear	Cloudy	Snow	Rain	Freezing Rain	Sleet	Wind	Fog	Rain & Fog	Blowing Materials
District 1 Weather Conditions Operator Surveys:	14	19	51	24	18	15	21	10	7	16
District 1 Weather Conditions Supervisor Surveys:	2	3	19	6	4	2	1	0	0	3
District 1 Weather Conditions Public Surveys:	1	0	0	0	0	0	0	0	0	0
District 3 Weather Conditions Operator Surveys:	4	11	45	19	23	14	11	7	6	6
District 3 Weather Conditions Supervisor Surveys:	0	3	20	9	11	7	5	4	2	3
District 3 Weather Conditions Public Surveys:	0	0	3	0	0	0	0	0	0	0
Total Surveys Received During Weather Condition:	**21**	**36**	**138**	**58**	**56**	**38**	**38**	**21**	**15**	**28**

	Better Visability	Less Visability	Better Peripheral Visibility	Less Peripheral Visibility	More Eye Fatigue	Less Eye Fatigue	Blinding Oncoming Traffic	Blinded by Oncoming Plow
District 1 Supervisor Surveys:	26	0	22	0	0	17	0	1
District 3 Supervisor Surveys:	27	0	20	1	0	18	1	1
Totals:	**53**	**0**	**42**	**1**	**0**	**35**	**1**	**2**

	Much Better Visability	Better Visability	Same Visability	Less Visability	Much Better Peripheral Visibility	Better Peripheral Visibility	Same Peripheral Visibility	Less Peripheral Visibility	Worse Eye Fatigue	Same Eye Fatigue	Less Eye Fatigue
District 1 Operator Surveys:	49	13	0	0	50	12	0	0	0	22	40
District 3 Operator Surveys:	48	23	0	0	43	27	0	1	0	15	55
Totals:	**97**	**36**	**0**	**0**	**93**	**39**	**0**	**1**	**0**	**37**	**95**

District 1 Operators Flashed by Oncoming Vehicles:	**3**
District 3 Operators Flashed by Oncoming Vehicles:	**9**

7. COST BENEFIT ANALYSIS

Although the Department has not tracked the supply and maintenance costs of using halogen headlights, a comparison between this practice and the use of LED headlights was analyzed. On average, the maintenance sheds involved with this study are out plowing for 40 to 50 storm events per season. Most of these storms require the use of the plow headlights due to darkness or overcast skies causing low sunlight, therefore the comparison was based on 40 events. During each storm, a halogen bulb may need to be replaced one to two times because of the heat generated by the bulb or excess vibration from roadway condition such as frost heaves or poor pavement surface. The time allotted for the plow truck operator to return to the shed and replace the blown bulb is one hour. The average pay for highway maintainers during storm events is $24.52/hour. Based on this data, the current practice costs the Department $1,295.80 per truck per season. In comparison, none of the LED headlamps required replacement during the test period resulting in a total cost of $206.04 per truck per season. One additional cost benefit not reflected in the table is that the LED headlamps have a two-year warranty and may last up to five (5) years.

Bulb	Cost	# Replaced per storm	Average # of storms	Operator time to replace (hr.)	Pay rate (per hr.)	Material cost	Labor cost	Total cost/truck/ season
Halogen	$5.25	1.5	40	1	$24.52	$315.00	$980.80	$1,295.80
LED	$206.04	0	40	NA	$24.52	$206.04	$0.00	$206.04

8. ADDITIONAL INFORMATION

One of the main concerns of snowplow operators is the light bounce-back from the auxiliary headlights during some adverse weather conditions particularly at night. During hours of darkness, operators often experience reflected light from falling snow and ice that contributes to eye discomfort and fatigue. An observation made by several operators was the need to consider altering the mounting locations of the auxiliary headlights such that it is away from the driver's line of sight. It should be noted that the LED mounting location for this research project was in the previous location of the halogen light housings.

9. RECOMMENDATION

Winter maintenance operators report feeling fatigued at some point while operating a snowplow during a storm. In addition to limited visibility, particularly at night and in the worst weather conditions, these operators are not restricted by hours-of-service rules and frequently work extended hours. These long stressful hours potentially contribute to increased accident rates, health issues, lower morale, and reduced productivity. Clear Roads Research Project 99006/CR14-06[1] and Project 1001325/CR15-02[2] suggest that LED lighting has been found to greatly improve nighttime visibility and reduce operator fatigue. Project 10011325/CR15-02[2] further recommends that winter maintenance agencies should replace headlights, plow lights, and other auxiliary light bulbs with LEDs.

Based on the feedback in the operator surveys and observations by the supervisors in this research project, conversion from halogen headlights to LEDs is recommended. In addition, new equipment specifications should include LED headlights when new vehicles are purchased.

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