



# **Synthesis of Best Practices for Eliminating Fogging and Icing on Winter Maintenance Vehicles**

CTC & Associates LLC



research for winter highway maintenance



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<p>16. Abstract</p> <p>Windows and mirrors on snowplow trucks often become covered with snow, ice, fog and frost during winter storms, obscuring the operators' field of vision and raising safety concerns. The Clear Roads winter maintenance pooled fund research program sought to address these problems through this research project. The objective was to compile the most effective designs, technologies, materials and practices for keeping snowplow glass and mirror surfaces clean of winter precipitation inside and out.</p> <p>To gather information for this synthesis, the researchers completed a literature search of existing research, phone interviews with winter maintenance professionals, and two Web-based surveys. More than 200 winter maintenance professionals from 30 states and five foreign countries responded to the surveys.</p> <p>The study identified a number of strategies that agencies across the country have used to address icing and fogging problems and recommended opportunities for additional research and product testing by state agencies. Successful strategies highlighted in the report include heated mirrors (for addressing icing on mirrors); the improved heating, ventilation and air conditioning systems on newer trucks (for addressing interior fogging and exterior icing); winter-grade wipers (for addressing buildup on wipers); and plow deflectors and plow flaps (for addressing blow-over that leads to windshield icing).</p>			
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# Executive Summary

Snowplow drivers work under challenging conditions. They operate and navigate large vehicles while winter storms are still in progress, dealing with poor visibility and treacherous roadways. They drive for hours at a time, often at night, under stressful conditions physically and mentally. To compound their challenges, windows and mirrors on snowplow trucks often become covered with snow, ice, fog and frost during winter storms, obscuring the operators' field of vision and raising safety concerns. With so many factors impacting the ability of operators to do their jobs safely and effectively, winter maintenance managers nationwide have begun looking for ways to help.

In 2002, the University of Iowa conducted a study of snowplow lane awareness systems. Although snowplow fogging and icing problems were not the focus of the study, the researchers commented on the need for solutions in their findings: "The fact that 80 percent of surveyed drivers reported problems with window icing and fogging indicates a significant safety problem that exacerbates low forward visibility. Vehicles need to have better defrosting capabilities for their front windshield and side windows."<sup>1</sup>

The Clear Roads national pooled fund research program decided to address this icing and fogging problem. Dedicated to real-world research in highway winter maintenance, Clear Roads funded this research project with the goal of compiling the most effective designs, technologies, materials and practices for keeping snowplow glass and mirror surfaces clean of winter precipitation inside and out. The hope was to highlight proven, economical solutions for agencies nationwide, giving them what they needed to improve operator safety and comfort during winter storm events.

To meet the goals of this project, we began by learning more about the problem. We completed a literature search of research and engineering sources, identifying current and completed research related to icing and fogging on snowplows as well as products that have application to the problems, such as exterior glass treatments (brush-on and spray-on) and heat-enhanced equipment (sideview mirror heads, windshield washer fluid systems, and wipers). We also conducted phone interviews with winter maintenance professionals, which helped us identify seven specific types of icing and fogging problems encountered on winter maintenance vehicles: interior fogging on windshields, interior fogging on side windows, ice and snow buildup on windshields, icing on exterior of side windows, blow-over, icing on side mirrors, and ice buildup on windshield wipers.

Using two Web-based surveys, we gathered information related to each of the problem areas about the experiences, solutions, and challenges of more than 200 individuals involved in highway snow removal. We targeted shop managers, maintenance supervisors, fleet managers, and others who had in-the-field experience both with the problems and the solutions. Respondents representing 30 states in the U.S. and Washington, D.C., and five foreign countries answered multiple-choice questions and provided more than 450 written comments.

The results of our surveys overwhelmingly confirmed the problem. At least 82% of the respondents had experienced each problem listed in the main survey and in most cases they considered the problem to be significant. Using a scale of 1 to 5 (with 1 being "not a problem" and 5 being "very big problem"), we asked respondents to indicate the significance of each condition. Below are the percentages of respondents who rated each problem a 4 or 5.

Ice buildup on windshield wipers—85 %  
Icing on exterior surface of windshield—75%  
Fogging on interior surface of side windows—47%

Fogging on interior surface of windshield—54%  
Icing on exterior of side windows—52%  
Icing on exterior (side) mirrors—54%

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<sup>1</sup> Snowplow Lane Awareness System: Operator Interface Design and Evaluation, The University of Iowa, July 2002, page 3: <http://www.dot.state.mn.us/guidestar/pdf/ivihwy19/final%20report.pdf>

Beyond simply confirming the problem, our research also uncovered a number of potential strategies for addressing the icing and fogging problems. Some strategies could be implemented with a relatively small investment, while others would naturally become longer-term goals, such as outfitting a fleet with new, state-of-the-art trucks. Below is a summary of the key solutions identified, along with their reported effectiveness, as indicated by our survey respondents.

Condition	Short-term solutions	Long-term solutions	Emerging strategies
<b>Interior fogging on windshields and side windows</b>	<ul style="list-style-type: none"> <li>▪ Aftermarket accessory fans (fairly effective)</li> <li>▪ Turning off heat in cab (slightly less effective)</li> </ul>	<ul style="list-style-type: none"> <li>▪ Specifying air conditioning on new trucks (fairly effective)</li> </ul>	
<b>Ice and snow buildup on windshields</b>	<ul style="list-style-type: none"> <li>▪ Plow deflectors (most effective)</li> <li>▪ Chemical glass treatments</li> <li>▪ Anti-icing additives for washer fluid (somewhat effective)</li> </ul>	<ul style="list-style-type: none"> <li>▪ Improved heat/defrost systems on new trucks (fairly effective); possibly curved or reverse-slope windshields</li> </ul>	<ul style="list-style-type: none"> <li>▪ Heated windshields</li> <li>▪ Heated washer fluid</li> <li>▪ Vertical wiper systems</li> <li>▪ Double-paned windshields</li> <li>▪ Deluge systems</li> </ul>
<b>Icing on exterior of side windows</b>		<ul style="list-style-type: none"> <li>▪ Specify power window for passenger side on new trucks</li> </ul>	<ul style="list-style-type: none"> <li>▪ Side-window wipers</li> <li>▪ Side-window defrosters</li> </ul>
<b>Blow-over</b>	<ul style="list-style-type: none"> <li>▪ Plow deflectors (fairly effective)</li> <li>▪ Plow flaps</li> <li>▪ Adjust plow angle</li> <li>▪ Hood-mounted wind deflectors</li> <li>▪ Drive slower</li> </ul>	<ul style="list-style-type: none"> <li>▪ Different plow types (larger moldboards, different curvature)</li> </ul>	
<b>Ice buildup on windshield wipers</b>	<ul style="list-style-type: none"> <li>▪ Winter-grade wipers (fairly effective)</li> <li>▪ Heated wiper blades (no consensus on effectiveness)</li> </ul>	<ul style="list-style-type: none"> <li>▪ Specify vertical or top-mounted wipers on new trucks</li> </ul>	<ul style="list-style-type: none"> <li>▪ Slap Wipers</li> <li>▪ Shaker system</li> </ul> <p>(Both above look promising but need testing.)</p>
<b>Icing on side mirrors</b>	<ul style="list-style-type: none"> <li>▪ Heated mirrors--aftermarket (extremely effective)</li> </ul>	<ul style="list-style-type: none"> <li>▪ Heated mirrors (specified on new trucks)</li> </ul>	

Despite an acknowledgement of significant icing and fogging problems, many of the respondents were unfamiliar with several of the solutions presented to them in the survey. In analyzing the responses, it was apparent that two key opportunities exist: 1) to get existing solutions into the hands of plow drivers for trials at individual agencies and 2) to systematically test the most promising solutions and share the results nationally.

# Section 1: Introduction

Windows and mirrors on snowplow trucks often become covered with snow, ice, frost and other precipitation during winter storms, obscuring the operators' field of vision and raising safety concerns. This problem is widespread. In a 2002 study on lane awareness systems by the University of Iowa, "window fogging and icing emerged as another significant safety issue." Drivers participating in the study indicated that they had tried a variety of tactics to address the problem, including turning the cab heat as high as it would go and driving with the side windows down to see the shoulder line, as well as stopping frequently to clear ice from side and front windows, which can be hazardous to approaching vehicles.<sup>2</sup> Although snowplow fogging and icing problems were not the focus of the study, the researchers commented on the need for solutions in their findings: "The fact that 80 percent of surveyed drivers reported problems with window icing and fogging indicates a significant safety problem that exacerbates low forward visibility. Vehicles need to have better defrosting capabilities for their front windshield and side windows."<sup>3</sup>

In response to this need for anti-fogging and anti-icing solutions, Clear Roads, a pooled fund research organization made up of nine state departments of transportation, initiated and funded this research project. The goal was to compile the most effective designs, technologies, materials and practices for keeping snowplow glass and mirror surfaces clean of winter precipitation inside and out while maintaining the comfort and safety of the plow operator.

To accomplish the goals of the project, we completed three information gathering efforts: a literature search to identify research and publications on the topic, phone interviews with winter maintenance professionals to further understand the problem and identify existing solutions, and two Web-based surveys (one aimed at agencies and contractors responsible for snow removal and the other aimed at manufacturers and dealers) to identify new solutions and compile ratings on the effectiveness of known strategies.

The findings of the literature search and phone interviews are included in Section 2: Methodology, with the full reports of these efforts in Appendices A and B. Section 2 also includes a description of the survey design and development process, covering survey goals, topics, distribution lists and format.

Section 3 provides a detailed analysis of the survey responses. We look at who responded, where they're located, and what role they play in highway snow removal. We also provide an in-depth analysis of the survey responses, highlighting solutions to the problems identified.

Section 4 summarizes related research and strategies identified through follow-up research and phone interviews, including efforts in the automotive, glass manufacturing, and aviation fields that may have application to snowplow icing and fogging.

**This project's goal was to compile the most effective designs, technologies, materials and practices for keeping snowplow glass and mirror surfaces clean of winter precipitation inside and out while maintaining the comfort and safety of the plow operator.**

<sup>2</sup> Snowplow Lane Awareness System: Operator Interface Design and Evaluation, The University of Iowa, July 2002, page 21: <http://www.dot.state.mn.us/guidestar/pdf/ivihwy19/final%20report.pdf>

<sup>3</sup> Snowplow Lane Awareness System: Operator Interface Design and Evaluation, The University of Iowa, July 2002, page 3: <http://www.dot.state.mn.us/guidestar/pdf/ivihwy19/final%20report.pdf>

In Section 5, we provide some final observations about our survey findings, including opportunities for plow improvements before next winter, recommendations for further research, opportunities for information sharing, and emerging technology to look for in the future.

## Section 2: Methodology

This research project consisted of three parts: a literature search, phone interviews, and two online surveys. Below we provide a description of each information gathering approach and its results.

### 2.1 Literature Search

In order to take advantage of any research that had already been done on snowplow fogging and icing, we conducted a detailed search of both traditional research and engineering sources, and of manufacturer publications and internal agency reports.

We undertook the following tasks:

- Searched the Transportation Research Board Web site, including the TRIS Online and Research in Progress databases, to identify completed and uncompleted research projects focused on fogging and frosting problems in winter maintenance vehicles.
- Reviewed the Web sites of the following state DOTs for research that may not be included in TRIS or Research in Progress: Illinois, Iowa, Michigan, Minnesota, Montana, North Dakota and Washington.
- Reviewed the Compendium of Papers CDs from recent TRB Annual Meetings for pertinent papers.
- Reviewed the online databases of truck, glass and sideview mirror manufacturer trade associations in the United States, Canada and Britain for pertinent research and products.
- Reviewed Web sites and published information from major truck manufacturers and automotive HVAC equipment manufacturers for pertinent technical reports.

We identified 12 products that have applications to the problems of icing and fogging on winter maintenance vehicles. These products included exterior glass treatments (brush-on and spray-on), heat-enhanced equipment (sideview mirror heads, windshield washer fluid systems and wipers), “slap” windshield wipers that shed snow and ice buildup, and vertical wipers that sweep horizontally and improve visibility.

We also identified three Research and Development reports that have application to the problem:

- A technical paper from Visteon Corporation briefly introduces the key technical requirements for good defrost and demist performance.
- NCHRP research identifies and evaluates in limited field tests several potential features for improving visibility.
- A snowplow Lane Awareness System study performed by the University of Iowa identifies window fogging and icing in snowplow cabs as a significant safety issue, and recommends better defrosting capabilities for windshield and side windows.

The results of our literature search informed the phone interviews that followed and provided us with a broader understanding of the problems and potential solu-

**We identified 12 products that have applications to the problems of icing and fogging on winter maintenance vehicles, including exterior glass treatments; heat-enhanced mirrors, windshield washer fluid systems and wipers; “slap” windshield wipers that shed ice buildup; and vertical wipers.**

**Our goals were to better understand fogging and icing problems on winter maintenance vehicles, to uncover promising solutions at work in the field, and to identify information gaps that could be addressed through our survey questions.**

tions that are available. The lack of any significant research directly related to snowplow fogging and icing reinforced the need for pursuing this research.

## 2.2 Phone Interviews

Prior to developing the survey questions, we conducted phone interviews with about 25 winter maintenance professionals in state departments of transportation, international departments of transportation, the Federal Highway Administration, and truck and aircraft manufacturing and sales. Our goals were to better understand the fogging and icing problems on winter maintenance vehicles, to uncover promising solutions at work in the field, and to identify information gaps that could be addressed through our survey questions. See Appendix B for the full phone interview report, including the list of all individuals contacted.

Virtually everyone called in the U.S. considered fogging and icing on snowplow windshields to be a problem, though to varying degrees. The following additional problems emerged during these conversations, guiding how we structured our survey questions: fogging on interior windows, icing on exterior mirrors, icing on wipers, and blow-over.

Based on our conversations, fogging is a problem on the interior windows of the cab when temperatures are near freezing or in humid conditions. For example, fogging is a significant problem in Missouri, where winter conditions are often close to freezing, but not as much of a problem in Minnesota, where winter conditions are colder. The solution to interior fogging in almost all cases is to combine an increase of airflow over the windshield with drying the air itself in order to eliminate fogging. In general, it seemed that interior fogging is manageable with proper heating, ventilation and air conditioning (HVAC) systems in the trucks. But maintenance costs for air conditioning and the other truck systems they impact can add up, and getting trucks with air conditioning in the first place may not be an option due to cost.

Icing on exterior mirrors has been a problem in the past, but everyone questioned about it used heated mirrors to solve the problem and were pleased with the results. Some mount the heated mirrors as an aftermarket addition and others include them in specifications for new trucks.

We heard about several solutions to the problem of icing on wipers, including winter-grade wipers, the Slap Wiper system, and heated wipers. According to the Monroe Truck Representative we spoke to, the Slap system is regularly re-requested by customers, while heated wipers are not.

Far and away the biggest problem discussed was icing on windshields. The icing tends to be caused by falling snow or plowed snow that is pushed to the outside edges of the windshield by the wipers. This snow then freezes, causing an ice dam that progressively obscures the windshield. There are wide-ranging solutions to this problem, including keeping the inside of the windshield cold so that the snow won't stick, using heated windshield washer fluid, specifying vertical wiper systems, and installing heated windshields. One creative solution we heard about came from the Bon Homme County DOT in Tyndall, South Dakota. They customized several of their older trucks by installing a secondary windshield on the

interior of the main windshield, allowing the outside windshield to be cold and the inside one to be warm. See page 25 for details on this solution.

Our interviews also uncovered relevant solutions outside of the trucking industry, including high-tech heated windshields for aircraft and a unique project in development that uses a low-wattage electrical system to break the adhesion of ice to glass. These solutions are less likely to be implemented in the near future in snow-plow trucks, but they offer a sense of the possibilities of vehicle anti-icing technology. We provide details on these and other efforts in Section 4.

After we compiled the results of our phone interviews, a few key areas stood out as needing further attention. We incorporated the following objectives, among others, into our survey questions:

- Clarify the problems—how they happen, who experiences them, and severity
- Address the challenge of maintenance costs
- Ask about the prevalence and effectiveness of air conditioning to combat fogging
- Ask about the effect of curved windshields on windshield icing
- Determine how much windshield icing is focused along the cowling
- Inquire about current research to evaluate anti-fogging and anti-icing solutions
- Get ratings on the effectiveness of products discussed (Slap Wipers, heated wipers, spray-on treatments, etc.)

## 2.3 Online Surveys

The primary information gathering approach for this research project was two Web-based surveys. The main survey was aimed at agencies and contractors who are responsible for clearing snow from the highways and making truck and parts purchases for their organizations. A second shorter survey went to truck and parts manufacturers and dealers who might be able to identify additional solutions currently available or in development. We distributed both surveys by means of an e-mail containing a link to the surveys online. Recipients had the option of requesting a paper survey if the online format was inconvenient or unfamiliar to them. The vast majority of the questions were multiple choice.

### 2.3.1 Agency/contractor survey

In developing the questions and structure of the agency/contractor survey, we kept in mind the following goals:

- Confirm and clarify the problems
- Document the extent of use of known solutions
- Get ratings on known solutions
- Identify additional solutions
- Document implementation challenges
- Provide respondents with opportunities to share additional information

**The main survey was aimed at agencies and contractors who clear snow from highways and make truck and parts purchases for their organizations. A second shorter survey went to truck and parts manufacturers and dealers.**

To increase the number of respondents, we made follow-up phone calls to international winter professionals and individuals in underrepresented states, and requested assistance from DOT research administrators in reaching the appropriate personnel at their agencies.

Based on the results of our literature search and phone interviews, as well as input from the Clear Roads Technical Advisory Committee, we broke the survey into two parts—the first aimed at those responsible for plowing or overseeing plow efforts, and the second for those involved in truck and parts purchasing decisions for their organization. We grouped the questions based on the best practices we sought to identify as follows:

#### **Part I: Experience with Icing and Fogging**

- Nine questions aimed at establishing the respondent's location and familiarity with icing and fogging severity and causes.
- Fifteen questions asking respondents to indicate use, awareness and effectiveness of known solutions to interior fogging, icing on windshields, icing on wipers, and icing on exterior mirrors. Questions also addressed obstacles to implementing solutions and provided opportunities for listing solutions not already identified.

#### **Part II: Equipment Management**

- Eight questions to identify maintenance issues associated with icing and fogging, including the amount that an organization could potentially spend on effective icing and fogging solutions, and the prevalence of air conditioning and deflector attachments in truck fleets.

We distributed the agency/contractor survey to 470 individuals, as well as the winter-related listserv maintained by the Snow and Ice Pooled Fund Cooperative Program. This listserv has hundreds of participants, a portion of whom received our survey announcement e-mail individually. Below is a breakdown of the groups represented in our distribution lists and the sources of these names.

##### **Main groups:**

- State DOTs and Canadian provincial DOTs
- U.S. and Canadian contractors
- Overseas transportation agencies
- Local and county highway departments (U.S. and Canada)
- Universities, LTAP centers

##### **Sources of names:**

- County Superintendents and Fleet Managers in Wisconsin, Ohio, Iowa, Missouri, Michigan, Indiana, and Minnesota, as identified by the Clear Roads Technical Advisory Committee
- TRB Winter Maintenance Committee
- American Public Works Association Winter Maintenance Committee
- Pacific Northwest Snowfighters
- Snow and Ice Pooled Fund Cooperative Program Committee
- American Association of State Highway and Transportation Officials Subcommittee on Maintenance
- Winter Maintenance Technical Peer Exchange (2005)
- 2004 International Symposium on Snow Removal and Ice Control Technology
- Canada Public Works Association Board of Directors
- Snow & Ice Management Association

- Maintenance Response Times Transportation Synthesis Report
- Web searches
- Snow and Ice Listserv
- Research Advisory Council Listserv
- Clear Roads Technical Advisory Committee members

In an effort to increase the number of respondents to this survey, we made follow-up phone calls to individuals in Snow Belt states that were underrepresented in our list of respondents at the time of the survey deadline. We used the same approach to successfully encourage participation by more international winter professionals, calling them first to ask for a commitment to complete the survey and resending them the link if they agreed. As a final effort to increase the number of respondents, we also requested assistance from DOT research administrators in underrepresented Snow Belt States in passing on our request for information to the appropriate personnel in their state departments of transportation. Our survey approach was not aimed at achieving a statistically reliable sample but rather an effort to capture representative observations and best practices from as many qualified individuals as possible.

### **2.3.2 Manufacturer survey**

We sent a second, short survey (six questions) to 43 truck manufacturers, glass manufacturers, plow equipment manufacturers and aftermarket accessory manufacturers. Our questions asked respondents to indicate their familiarity with fogging and icing on snowplows and to identify any solutions their organizations currently offer or plan to offer to address these problems. As with the agency/contractor survey, we made some follow-up calls and sent follow-up e-mails in an attempt to encourage participation. As explained in Section 3, these efforts did not yield a great return. We received very few responses to this survey. However, those who did respond provided useful information on available solutions, including photos and contact information. Please see Section 3 for details.



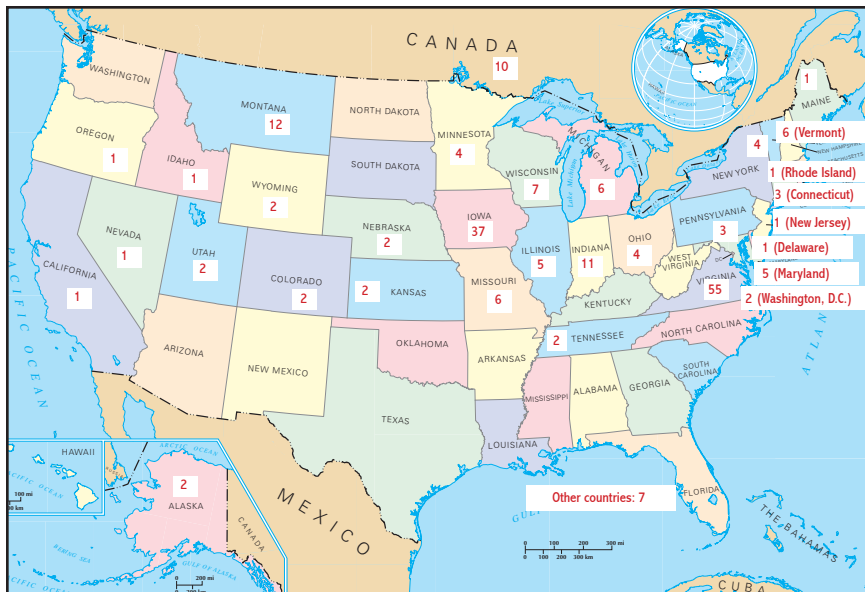
## Section 3: Survey Results and Analysis

### 3.1 Respondents

#### 3.1.1 Agency/Contractor Survey

A total of 209 individuals from 30 states in the U.S. and Washington, D.C., and five foreign countries responded to our primary survey. Many of those who responded were not on our original distribution list, indicating that our contacts followed through with our request that they pass the survey link on to those most qualified to answer the questions. As indicated in the map below, we had especially large numbers of respondents in Iowa and Virginia. We didn't consider this a disadvantage when reviewing the survey results, since we wanted to capture as many individual perspectives as possible; many valuable written comments came from these states. We did, however, make additional efforts (through phone calls and e-mail) to get responses from underrepresented Snow Belt states. Through these efforts, we were able to increase representation in several central and western states. Respondents represented a range of organizations and position titles. However, staff from state departments of transportation made up 75% of the respondents. About 8% of the responses came from international organizations. The remaining responses came from city and county agencies, universities and private contractors

Our goal was to reach those who had firsthand experience with fogging and icing problems, either from driving the plows themselves or from supervising or supporting those who did, and those who might have a hand in developing or implementing solutions.



Distribution of responses to the agency/contractor survey.

Below is a sampling of the titles held by many of the respondents:

- Maintenance Superintendent
- Operations Manager
- Highway Maintenance Supervisor
- Fleet Manager
- Shop Foreman
- Shop Superintendent
- Maintenance Engineer
- Transportation Operations Manager

Our goal was to reach those who had firsthand experience with fogging and icing problems, either from driving the plows themselves or from supervising or supporting those who did. We also wanted to reach those who might have a hand in developing or implementing solutions, whether by leading an innovative shop experiment or purchasing aftermarket wipers for their trucks.

Overall, we were very pleased by the responses we received. The results overwhelmingly confirmed the problems. The percentage of respondents who had experienced each problem listed in the survey (icing on mirrors, windshields, side windows and wipers, blow-over, and interior fogging on windshields and side windows) ranged from 82% to 97%. The majority of respondents also considered most forms of icing and fogging to be a notable problem for plow drivers, as shown in the table of responses below.

4. In your opinion, how big a problem is each of the following conditions for plow drivers?							
	Not a problem 1	2	3	4	Very big problem 5	Don't know/haven't experienced	Response Total
Icing on exterior (side) mirrors	9% (18)	15% (32)	20% (41)	27% (56)	27% (56)	2% (5)	208
Icing on exterior surface of windshield	2% (5)	8% (16)	13% (28)	30% (62)	45% (95)	1% (3)	209
Icing on exterior of side windows	4% (8)	18% (37)	23% (48)	25% (52)	27% (56)	3% (7)	208
Ice buildup on windshield wipers	1% (3)	3% (7)	7% (14)	18% (38)	67% (137)	3% (7)	206
Fogging on interior surface of windshield	8% (16)	17% (35)	26% (54)	22% (46)	23% (48)	4% (8)	207
Fogging on interior surface of side windows	8% (16)	17% (36)	23% (48)	27% (56)	20% (41)	4% (9)	206
Total Respondents							209
(skipped this question)							2

Despite an acknowledgement of significant icing and fogging problems, many of the respondents were unfamiliar with several of the solutions presented to them in the survey. In reviewing the responses, it was apparent that two key opportunities exist: 1) to get existing solutions into the hands of plow drivers for trials at individual agencies and 2) to systematically test the most promising solutions and share the results nationally.

In the pages that follow, we provide a close look at the responses to our questions as they relate to each icing and fogging problem. We describe our respondents' familiarity and experience with the problems as well as their experience with and ratings of known solutions. In analyzing the answers to our multiple-choice questions, we were also able to incorporate more than 450 written comments, which were invaluable for capturing new ideas and highlighting trends. We have included the most illustrative comments in the survey analysis that follows, and all comments are grouped by question in Appendix E.

### 3.1.2 Manufacturer Survey

Only five people responded to our survey of manufacturers and dealers, and one of those respondents checked "don't know" for all questions that he answered, leaving four usable responses: one truck manufacturer

(Mack) and 3 equipment manufacturers (Wiper Shaker, Everblades heated windshield wipers, and Nartron Corp., which manufactures the ClearFast heated washer fluid system). As with the agency/contractor survey, we did some follow-up calling and e-mailing to increase participation but without success. Although we were not able to draw any conclusions from the responses of such a small group, we did summarize the product information the respondents provided, highlighting potential opportunities for further evaluation.

## 3.2 Agency/Contractor Survey Results

### Part 1: Problems and Solutions

We have organized the results of the agency/contractor survey according to the major problem areas discussed:

- fogging on the interior surface of windshields
- fogging on the interior surface of side windows
- ice and snow buildup on windshields
- icing on exterior of side windows
- plow blow-over
- ice buildup on windshield wipers
- icing on exterior (side) mirrors

We summarize the strategies used to address each problem beginning with those that were used most commonly by survey respondents. Where possible, we also indicate the effectiveness of each solution, as reported by the respondents.

#### Notes about presenting the results

Many survey respondents work as regional maintenance managers or in similar positions, but respondents also include central office staff, private contractors, equipment coordinators, and others (see Appendix F for a complete list) who have varying levels of firsthand experience with the problems and solutions discussed. For easier reading, in discussing survey results in this section we often use the convention “50% of respondents reported experiencing the problem” rather than the more precise “50% of respondents reported that drivers at their organization have experienced the problem.”

Several survey questions used a 5-point scale, with “don’t know” or similar text as a sixth choice. In all cases, 1 was the bottom of the scale, with a label such as “Not at all effective,” and 5 was the top of the scale, with a label such as “Extremely effective.” The numerals in between (2, 3 and 4) were not labeled with descriptors. Since all rating scale questions used a 5-point scale, we do not repeat this point throughout the text in this section.

For each problem or strategy, we highlight the most common response or responses and give the percentage of respondents for each. Percentages are based on the number of respondents answering the referenced question, which may be less than the total number of survey respondents. Full details on the responses to each question are given in Appendix C.

Selected comments from respondents are excerpted in this section to provide real-world examples of respondents’ experience addressing icing and fogging. In these comments, we have corrected spelling errors for clarity but have not edited grammar.

Where appropriate, we include Internet hyperlinks to more information on companies’ Web sites. Internet links in this report were active at the time of publication, but changes on the host server can make them obsolete.

For each problem or strategy, we highlight the most common survey responses and give the percentage of respondents for each. Selected comments from respondents are excerpted in this section to provide real-world examples of respondents’ experience addressing icing and fogging.

To enhance readers' understanding of the problems and solutions described in this section, we include images where available. If you are looking at a version of this report that is printed in black and white, you can download a report with full-color images at <http://www.clearroads.org/05-01antifogging.htm>.

### 3.2.1 Fogging on Interior Surface of Windshield

#### PROBLEM

Fogging on the windshield interior is most common when temperatures are near freezing or in humid conditions. Depending on climate conditions in their locations, some agencies may experience fogging more often and more severely than others. In addition to ambient humidity, other moisture in the cab can contribute to fogging, including melted snow from the operator's boots and moisture from his breathing. Fogging is less of a problem at very low temperatures, when the air is too cold to hold enough water vapor to lead to a condensation problem on the windshield—the water is “frozen out” of the air.

In the absence of a better solution, snowplow operators may remove fog from the windshield with a rag, towel or even their sleeves or hands, but this can be a dangerous distraction during plowing, and operators cannot generally reach all interior glass surfaces comfortably from the driver's seat. Removing fog this way can cause streaks and smears on the windshield, and the fog will continue to reappear unless conditions inside the cab change.

Nearly all survey respondents were familiar with interior windshield fogging, and 83% had experienced it on their trucks. Most considered it a fairly serious problem; of those who rated the problem's severity, 27% rated it a 3, 24% rated it a 5 (“very big problem”), and 23% rated it a 4. (See pages C-3 and C-4 of Appendix C for details. Note that these percentages exclude respondents who answered “don't know/haven't experienced,” and will not match the percentages in the Appendix tables.) One respondent mentioned that windshield and side window fogging occurs often when the operator uses the defrost/floor heat setting (so the ventilation system is running the defroster and floor heat at the same time).

#### SOLUTIONS

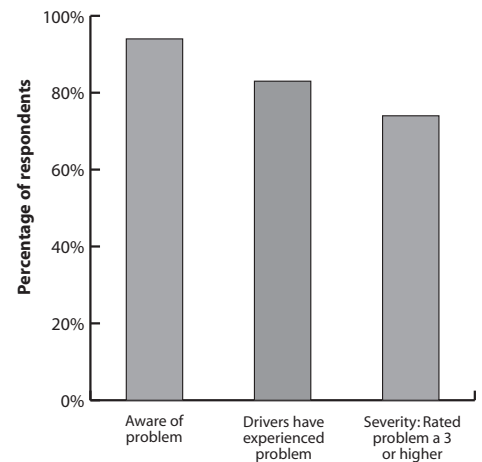
Two approaches found to be fairly effective in combating interior fogging, which may be used simultaneously, are to increase airflow over the windshield and to reduce the moisture content in the air. Some agencies mount small fans inside the cab to direct air over sections of the windshield or windows that do not receive adequate airflow from the truck's ventilation system. To dry the air, agencies may use an air conditioner, alone or as part of the system's defrost setting. In vehicles without air conditioning, the defrost setting circulates warmed air from outside across the windshield.

#### Adding fans to increase airflow over windows

Several companies offer aftermarket automotive fans that can be mounted on the vehicle's dashboard or on the interior roof of the cab near the top of the windshield. They may plug into a 12-volt outlet such as the cigarette lighter, or be wired into the vehicle's electrical system. Operators can position these fans to increase airflow to any areas of the windshield that are not served adequately by the

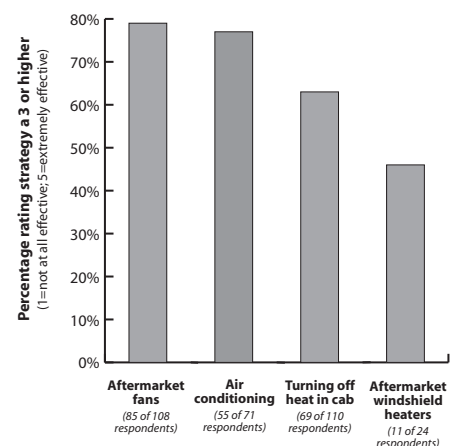
## RESPONDENTS' VIEWS

**Awareness and severity of fogging on windshield interior**



Respondents rated problem severity on a 5-point scale, where 1 = Not a problem and 5 = Very big problem.

**Effectiveness of interior fogging strategies**



## RESPONDENTS' VIEWS

### Comments on fans:

"We started purchasing dump trucks with AC in 2000 and removed the dash-mounted fan. Both Sterling and Macks work well at clearing or prohibiting fogging."

"The newer part of our fleet consists primarily of Sterling models equipped with HVAC. These systems work better than past equipment and we are finding our personnel are not using the auxiliary fans so we have been removing them to the extent of not even putting them in specifications."

### Comments on air conditioning:

"As for the fog on the inside we have noticed that the trucks with AC units don't do it as bad due to the fact that it dehumidifies the air."

"We have added AC to help with the problem and it seems to have made a difference in how much we get on the inside of the truck now."

"Temporarily using the AC does reduce fogging of the windshield."



Vector 12-volt fan  
(photo from amazon.com)

vehicle's ventilation system.

Survey respondents were fairly familiar with the practice of adding fans to increase airflow. Most were aware of it, and 51% reported that their drivers had used this strategy to combat interior fogging. Most respondents found adding fans to be fairly effective; of those who rated its effectiveness, 51% rated it a 3, 24% rated it a 4, and 20% rated it a 2. (See pages C-7 and C-8 of Appendix C for details. Note that these percentages exclude respondents who answered "don't know/haven't used," and will not match the percentages in the Appendix tables.)

Survey respondents reported that improvements in the ventilation systems on newer trucks, including the presence of air conditioning, more powerful blowers, better vent placement and improved overall efficiency, have reduced the need for auxiliary fans. "These systems work better than past equipment and we are finding our personnel are not using the auxiliary fans," said one respondent.

### Using air conditioning to dry the air

Air conditioning compressors remove moisture from the air in the vehicle's cab, thereby minimizing condensation and fogging on the windshield and windows. The compressor may also be engaged during the ventilation system's defrost cycle.

Many respondents were aware that air conditioning can be used to combat interior fogging, but only 23% had used this strategy. Of those who rated its effectiveness, most found air conditioning to be fairly effective at addressing fogging; 42% rated it a 3 and 27% rated it a 4. (See pages C-7 and C-8 of Appendix C for details. Note that these percentages exclude respondents who answered "don't know/haven't used," and will not match the percentages in the Appendix tables.)

Two respondents expressed concerns about the effectiveness of using air conditioning to combat fogging. One said that using air conditioning to move warm air was not effective because not enough air comes through the defroster vents "and you completely lose the windshield."

As mentioned, not all agencies have used air conditioning to combat interior fogging, and many do not have air conditioning on their maintenance trucks; it may not have been available on older trucks, and not all agencies specify it when ordering a new truck. Responses varied widely to the question of how many snowplow trucks at the respondent's location have air conditioning, with 25% and 100% being the most common answers (see page 42 for details).

### Disadvantages of air conditioning

There are several reasons that an agency might choose not to specify air conditioning when purchasing a new truck. Air conditioning adds to a truck's purchase price, which can mean a substantial expense for a state DOT that purchases dozens of trucks each year. It can also increase maintenance costs; one respondent cited "more cab filters, damaged condenser cores and ... having in-house techs certified to work on these units" as maintenance issues associated with air conditioning. Re-

spondents also said the condensers are prone to damage due to corrosion from road salt and leaks from being hit by material during plowing (presumably ice, rocks or other debris).

In addition, air conditioners may cause stress on other systems in the trucks, including radiators, potentially increasing maintenance needs for those systems. “Running air conditioning does take more fuel,” said one respondent, while another commented that “it’s just another item that will down the truck.”

Respondents also mentioned driver comfort as a consideration, since the air conditioning would make the cab colder when the outside temperature is already low. (“It doesn’t help being cold inside the truck in wintry weather,” said one respondent.) Presumably for that reason, one respondent mentioned using air conditioning “temporarily” for defogging. (See page E-6 of Appendix E for details about disadvantages of using air conditioning.)

Our survey asked whether respondents had found the HVAC system on any specific makes or models of trucks to be particularly effective or ineffective at addressing interior fogging. Sterling trucks were mentioned most often as having very effective HVAC systems, and Macks were mentioned a few times as well. Kenworth and Freightliner were each mentioned once as having effective systems. (See page E-5 of Appendix E for details.)

Survey respondents reported that newer models of these trucks have more effective HVAC systems than older models. In an open-ended question about the differences between older and newer trucks, a majority of respondents mentioned HVAC systems as an improvement in newer trucks. More efficient heaters, better vent placement and airflow, more powerful fans, better defrost systems, and better heat controls were among the improvements mentioned. “Newer trucks can control air intake for the cab to help reduce moisture in the cab,” said one respondent; another commented that “the defrosting systems on the newer vehicles are more advanced than the older ones.” (See page E-16 of Appendix E for details.)

## Turning off heat to keep windshield cold

Another strategy for eliminating fogging is to minimize the temperature difference between the inside of the cab and the outside air, which also minimizes the humidity difference and the opportunity for condensation to form on the windshield.

Respondents were fairly familiar with this strategy; most were aware of it, and 42% reported that their drivers had tried it. This strategy was seen as somewhat less effective than adding fans or using air conditioning; of those who rated its effectiveness, 33% rated it a 3, 25% rated it a 4, and 25% rated it a 2. (See pages C-7 and C-8 of Appendix C for details. Note that these percentages exclude respondents who answered “don’t know/haven’t used,” and will not match the percentages in the Appendix tables.) The primary disadvantage to this strategy is the issue of driver comfort, which is a distraction that may compromise safety and effectiveness.

## Adding aftermarket windshield heaters

Heating the windshield using aftermarket heaters is another strategy for addressing

## RESPONDENTS’ VIEWS

### Comments on air conditioning maintenance issues and costs:

“Although there is additional maintenance required it is not consequential.”

“There is definitely more maintenance costs with trucks with air conditioning. More cab filters, damaged condenser cores and not to mention having in-house techs certified to work on these units.”

“Salt eats up radiators and condensers.”

### Comments on air conditioning putting stress on other systems:

“Running air conditioning does take more fuel.”

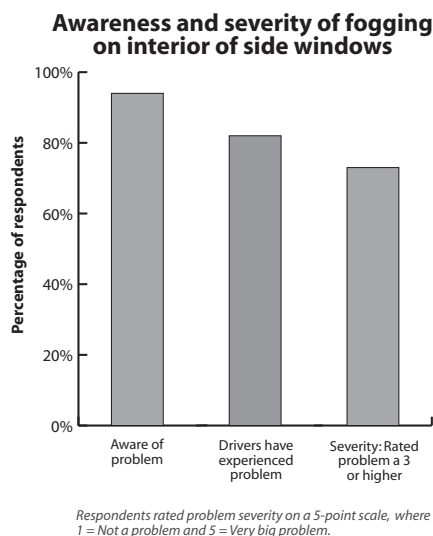
“It’s just another item that will down the truck.”

### Comments on HVAC systems in newer trucks:

“The defrosting systems on the newer vehicles are more advanced than the older ones, which better addresses the fogging issue but not the icing issue.”

“The heating and AC system are much better along with the cab design has better airflow in it.”

## RESPONDENTS' VIEWS



### Comments on fogging on side windows:

"We have included electric windows also, this allows the driver to lower the window if fogged in a backing situation."

"Using electric windows to help with visibility if windows fog up or icy."

fogging that we identified during our pre-survey research. Heating the windshield decreases the temperature differential between the air in the cab and the windshield, which inhibits the formation of condensation on the windshield.

Respondents were less familiar with this strategy, and only 6% reported having tried it. Those who had tried it found it somewhat less effective than other strategies; of the 24 respondents who rated its effectiveness, nine people (38%) rated it a 2, six people (25%) rated it a 4, four people (17%) rated it a 3, and four people (17%) rated it a 1. (See pages C-7 and C-8 of Appendix C for details. Note that these percentages exclude respondents who answered "don't know/haven't used," and will not match the percentages in the Appendix tables.)

### Chemical glass treatments

Several companies make liquid glass treatments that repel moisture. A few respondents reported using sprays or rub-on liquids, and Rain-X makes anti-fog tow-elettes and anti-fog glass cleaner wipes specifically for interior windshields (see <http://www.rainx.com/BB/default.html>; click "Products," then "Windshield Treatments," then "Anti-Fog").

### Other solutions

The double-paned windshield mentioned on page 24 addresses interior fogging as well as exterior icing. By insulating the interior windshield from the cold outside air, the interior glass stays nearer to the same temperature as the air inside the cab, minimizing condensation.

### 3.2.2 Fogging on Interior Surface of Side Windows PROBLEM

Fogging on the interior surface of side windows is caused by similar factors as windshield fogging—humidity in the cab combined with a glass surface that is colder than the air inside the cab. Poor airflow can contribute to this problem; some respondents reported that airflow to the side windows may be inadequate even when the front windshield is kept clear.

Respondents were very familiar with this problem, and 82% reported that their drivers had experienced it. Fogging on side windows was perceived as a fairly serious problem; of those who rated its severity, 28% rated it a 4, 24% rated it a 3, and 21% rated it a 5 ("very big problem"). (See pages C-3 and C-4 of Appendix C for details. Note that these percentages exclude respondents who answered "don't know/haven't experienced," and will not match the percentages in the Appendix tables.)

### SOLUTIONS

Solutions to this problem are similar to those for windshield fogging: install fans to increase airflow, use air conditioning to dry the air, and use chemical glass treatments. Respondents also mentioned using power windows (especially passenger-side windows) to lower the windows when vision is obstructed by fog. This will allow the driver to see out the passenger side while the window is down, and may also help clear condensation from the window if the window seal is tight enough.

## Other solutions

The current specifications sheet for Oshkosh's Municipal Patrol Truck Series (see [http://www.oshkoshttruck.com/pdf/Oshkosh\\_MPT-Series\\_specs.pdf](http://www.oshkoshttruck.com/pdf/Oshkosh_MPT-Series_specs.pdf)) lists side window defrosters as an option for these trucks.

### 3.2.3 Ice and Snow Buildup on Windshields PROBLEM

The accumulation of ice and snow on windshields is a problem that has several sources, and multiple factors influence the problem's severity. Snow may land on the windshield as it is falling from the sky, or may blow over the top of the plow; fallen snow may blow and drift onto the windshield; or passing traffic may kick up slush and snow (or any combination of these sources and situations). Depending on the design of the truck's hood, windshield and wipers, ice and snow may accumulate along the cowl at the base of the windshield, or along the sides, beyond the reach of the wipers.

Survey respondents reported that the severity of the windshield buildup can depend on several factors, including:

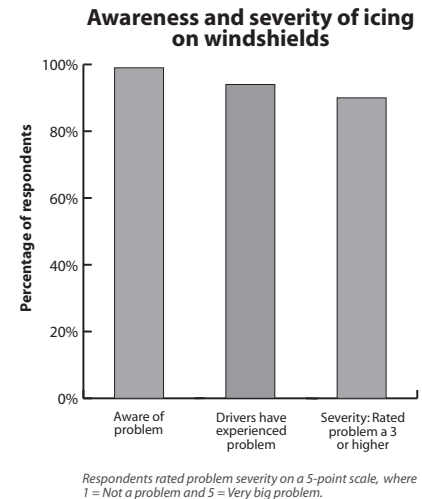
- Temperature outside
- Physical consistency of snow (fine powder, wet snow, etc.)
- Temperature of windshield
- Wind speed and direction
- Amount of snow and ice coming off the plow
- Curvature of windshield
- Design of truck's hood
- Location and design of wipers

Nearly all survey respondents (99%) were aware of the problem of windshield icing, and nearly all (94%) reported experiencing it. Most respondents felt ice buildup on windshields was a serious problem; of those who rated its severity, 46% rated it a 5 ("very big problem") and 30% rated it a 4. (See pages C-3 and C-4 of Appendix C for details. Note that these percentages exclude respondents who answered "don't know/haven't experienced," and will not match the percentages in the Appendix tables.)

Traditionally, snowplow drivers have relied on the truck's windshield wipers to remove most snow and ice, and if the buildup becomes too great for the wipers to handle, a driver may have to stop the truck to clear the windshield with an ice scraper. (During our research, we encountered a mention of one DOT that has specified custom-made steps to allow their drivers to reach the windshield for this purpose.) This creates a dangerous situation, as drivers may have to stop on busy highways at a time when the shoulder may not be clear, increasing their proximity to traffic and creating a hazard for other drivers. This practice also creates down time for the plow.

According to the people we spoke with during our pre-survey interviews, standard defrosting systems (especially on newer trucks) are generally able to keep the center of a truck's windshield fairly warm and free of ice. However, tradition-

## RESPONDENTS' VIEWS



### Comments on ice and snow buildup on windshields:

"Icing on windshields depends on conditions being experienced. Wind direction has a big effect on the severity of the icing and/or fogging problem on any window surfaces. Consistency of snow, temperature both inside the cab and externally also play a big role."

"The problem with ice buildup on the wipers tends to start by piling up on the base of the windshield/hood and builds up from there. The truck/hood design tends to have a greater impact on that than the type of windshield. In extreme cold and falling weather, the wipers will freeze without having a buildup around them, causing them not to clear the windshield."

## RESPONDENTS' VIEWS

### More comments on ice and snow buildup on windshields:

"We have problems with snow buildup on the cowl to the point that the wiper arms can come off of the wiper motor."

"Ice builds up on the cowling which will freeze the wipers lessen the effectiveness of heat/defrost to the windshield."

### Comments on curved windshields:

"With curved windshields, the larger the surface area the worse the ice buildup and the longer the wiper blades, the less effective they are when iced over. Big panoramic and curved windshields are harder to keep clean during snow removal operations and are more sensitive to cracking from the temperature differential of hot defrost air on one side and ice formation on the outside."

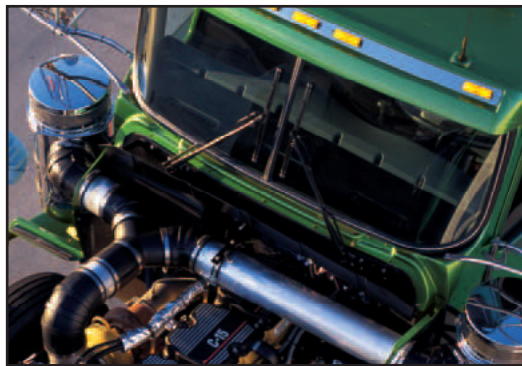
"Even though the ice buildup on wipers seems to be similar in severity, it has a more profound effect on trucks with curved windshields, since it's harder for the wiper to change shape and follow the windshield countour when restricted by ice buildup."

ally designed windshield wipers tend to push snow onto the outside edges and the bottom of the windshield, along the cowling. When the snow is wet, it can tend to melt and then refreeze, building ice dams and progressively obscuring the windshield. These ice dams can impair the function of the windshield wipers, which in turn worsens visibility.

In colder temperatures, ice may form along the outside edges of the windshield, beyond the reach of the windshield wipers, and creep across the windshield toward the center. The truck's heating/defrosting system may not be powerful enough to completely melt the ice in very cold temperatures.

Respondents considered buildup around the edges of a truck's windshield (along the sides and over the cowling) to be a fairly significant factor in contributing to windshield visibility problems. Of those who rated its significance, 30% rated it a 4, 29% rated it a 3, and 24% rated it a 5 ("significantly affects windshield visibility").

A wide variety of windshield styles are available on snowplow trucks. Some are completely flat; others have a slight curvature similar to an automobile wind-



Curved windshield with mullion separating two panes of glass (photo from Kenworth T800 brochure).

shield, and some windshields are designed with dramatic curves in an effort to be more aerodynamic. These curved windshields may be made of a single piece of glass that forms the front windshield and wraps around the sides, or there may be a mullion or post in the center of the windshield separating two panes of glass.

Survey responses were mixed on whether the curvature of the windshield affects snow and ice buildup, and on whether curved or flat windshields are more desirable. Most felt windshield curvature makes no difference, and some mentioned that design of the truck, hood or wipers has the greatest impact on buildup. Of those who had an opinion on curved windshields, 63% said icing is about equal on curved and flat windshields, while 18% said they experience more icing on curved windshields and 19% said they experience less. (See page C-5 of Appendix C for details. Note that these percentages exclude respondents who answered "don't know/don't own trucks with curved windshields," and will not match the percentages in the Appendix tables.)

Most respondents said windshield curvature also does not affect buildup on windshield wipers. Of those who had an opinion, 67% said ice buildup on wipers is about equal with curved and flat windshields, while 21% said they experience more buildup with curved windshields, and slightly fewer respondents (12%) said they experience less. (See page C-5 of Appendix C for details.)

Windshields that curve around the sides of the truck may allow the wipers to clear snow more easily, since the snow can continue to slide as it nears the corner curve,

rather than being stopped by a metal frame that acts as a dam. Related to this point, one respondent said ice buildup is worse with flat windshields because the ice does not slide off the top corners of the windshield, and the buildup then inhibits wiper function. Another respondent said his agency experiences less snow buildup on curved windshields because “the truck fender curves away at the same time as the windshield.”

Respondents mentioned several problems with curved windshields. These included:

- Buildup increases with surface area, and large panoramic curved windshields are harder to keep clean and are more sensitive to cracking from the temperature differential created by hot defrost air and cold outside air. Longer wiper blades needed for large windshields are less effective when iced over.
- Buildup is worse on older split-style curved windshields if wipers do not adequately cover the center of the windshield.
- Wipers may have difficulty conforming to the curved contour of the windshield in very cold conditions or when compromised by ice buildup. Wipers may also freeze in a curved position and then be unable to conform to the flatter parts of the windshield. One respondent mentioned that his agency keeps wipers in the “up” position when the trucks are not in use to prevent the wipers from freezing to the curved contour of the windshield.

## Blow-over

Snow blowing over the top of the plow frequently lands on the windshield, which can contribute to snow and ice buildup. This problem and the solutions designed to prevent it are discussed in detail later in this section on page 28.

## SOLUTIONS

Since many factors contribute to ice and snow buildup on windshields, solutions to the problem take several approaches as well. Some strategies aim to keep the windshield warm in order to melt snow, while others keep the windshield cold in an effort to keep snow from sticking. Chemical glass treatments may be used to repel precipitation, and high concentrations of anti-icing fluid can be applied through the windshield washer fluid system to melt snow and ice and prevent refreezing. Heated washer fluid may also be used to melt accumulated snow. The chart on the following page illustrates respondents' experience with several solutions.

## RESPONDENTS' VIEWS

### More comments on curved windshields:

“Wipers designed with hinges internal tend to freeze to the curved part of windshield then won't touch all of windshield where it is flat.”

“When trucks with curved windshields are turned off, wipers are kept in up position so that they don't freeze to the curved contour of the windshield.”

“Ice collects on both styles of windshields and wipers but for two different reasons. On the flat style the ice does not slide off the top corners so it gathers and then starts lifting the blade and ice then gathers on the blade. The curved style lets the ice slide off but the blade tends not to wipe the top corners and then ice forms there and soon after starts lifting the blade and ice starts there too.”

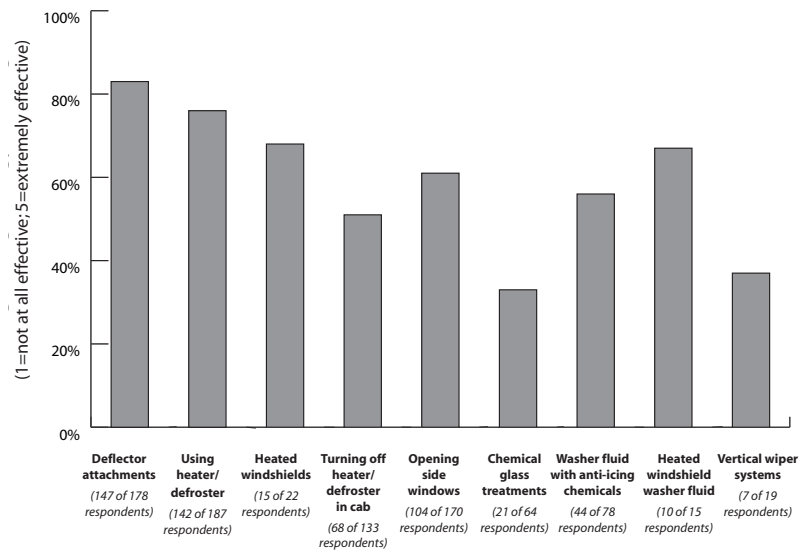
## RESPONDENTS' VIEWS

### Comments on heated windshields:

"We did retrofit one Mack truck with a heated glass windshield. Similar to rear window defoggers. This works exceptionally well and are considering purchasing on all future trucks depending on price."

"We specify a heated windshield in trucks where we can get it. Currently only Mack supplies a heated windshield and it works very well."

## Effectiveness of strategies for addressing icing on windshields



### Using heating/defrosting system to melt snow

This strategy uses a truck's standard heating/defrosting system to keep the windshield warm and melt accumulated ice and snow. Depending on the outside temperature, this may involve running the heat and blower at fairly high settings, and drivers sometimes open the side windows to prevent the cab from getting too hot for comfort.

Nearly all survey respondents (95%) said drivers at their organization had used this strategy, and most respondents found it to be fairly effective; of those who rated its effectiveness, 39% rated it a 3 and 33% rated it a 4; another 22% rated it a 2. (See pages C-9 and C-10 of Appendix C for details. Note that these percentages exclude respondents who answered "don't know/haven't used," and will not match the percentages in the Appendix tables.) As one respondent noted, the effectiveness of this strategy varies from truck to truck, depending on the strength of the defroster. One respondent also mentioned using an auxiliary fan to direct hot air at the windshield.

### Heated windshields

Heated windshields are offered by at least one major truck manufacturer (Mack). Mack's heated windshields use embedded wires around the edges of the windshield, similar to a rear-window defroster.

Respondents were less familiar with heated windshields; only 11% had used this strategy. Of the 22 respondents who rated the effectiveness of heated windshields, there was no consensus about their effectiveness. The most common response (from seven respondents, or 32%) was a 3. (See pages C-9 and C-10 of Appendix C for details. Note that these percentages exclude respondents who answered "don't know/haven't used," and will not match the percentages in the Appendix tables.)



Heated windshield on a Mack truck (photo supplied by Mack).

Respondents were not asked to specify the manufacturer of their windshields, and the ratings may refer to manufacturers other than Mack; see Section 4, page 48 for a discussion of other heated windshield technology.

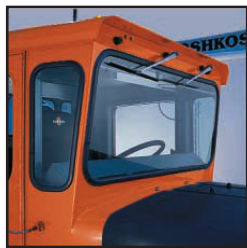
We contacted Dan Wickline, director of government and municipal sales at Mack. He said Mack's heated windshields use a 12-volt heating element around the outside 4 inches of the glass. The windshields are currently available only on Mack's Granite line, but Wickline said they will be offered on other models in 2007. More information on the Granite line is available at <http://www.macktrucks.com/default.aspx?pageid=64> and <http://www.macktrucks.com/default.aspx?pageid=361>. A Granite brochure is available at [http://www.macktrucks.com/assets/mack/product\\_specs/granite\\_series\\_snow.pdf](http://www.macktrucks.com/assets/mack/product_specs/granite_series_snow.pdf).



Oshkosh H-Series snowplow with heated windshield—note defroster lines on top and right side of windshield. (photo from Oshkosh brochure)

Oshkosh Truck Corp., which specializes in snow removal equipment for airports, also offers heated windshields on some trucks, including their H-Series. The H-Series is specifically for airport snow removal (see <http://www.oshkoshtruck.com/airportmunicipal/sproducts~hseries~home.cfm> for more information).

Oshkosh also offers a Municipal Patrol Truck Series, which doesn't appear to include heated windshields but does offer other features that address ice buildup, including a reverse-slope windshield, top-mounted windshield wipers, and optional side-window wipers.



Oshkosh MPT-Series snowplow with reverse-slope windshield and top-mounted wipers (photo from Oshkosh brochure).

See <http://www.oshkoshtruck.com/airportmunicipal/sproducts~mptseries~home.cfm> for more information, including a brochure at [http://www.oshkoshtruck.com/pdf/Oshkosh\\_MPT-Series\\_brochure.pdf](http://www.oshkoshtruck.com/pdf/Oshkosh_MPT-Series_brochure.pdf).

One survey respondent mentioned a problem with drivers leaving heated windshields and heated wipers on while the truck is idling. In this respondent's experience, this leads to the hot wiper blade transferring a skim of rubber onto the windshield glass. He suggests that the heating elements for the windshields or wiper blades should be controlled by a timer, and that heated wipers should be disabled when the parking brake is applied.

## Keeping the windshield exterior cold

Another approach to preventing ice buildup is to keep the outside of the windshield cold to prevent snow from sticking. This can include turning off the heating system in the cab, or driving with the side windows open. Respondents were somewhat less aware of these strategies; 44% reported that their drivers had turned off the heating system in the cab, while 72% had driven with the truck windows open. (Respondents also mentioned opening windows when visibility is obstructed, or when the cab becomes too warm for comfort because of hot air used to heat the windshield.)

## RESPONDENTS' VIEWS

### Comments on keeping the windshield exterior cold:

"The way we stop a lot of snow buildup on the windshield is to open the side window wing, turn the defroster off. This lets the windshield cool so the snow does not stick to it as much."

"We have had a certain amount of good from reducing the heat to the inside of the glass, not causing a melting wet surface for more snow to collect on."

## RESPONDENTS' VIEWS

Of those who rated the effectiveness of turning off the heat, 35% rated this strategy a 3 and 29% rated it a 2. Of those who rated the effectiveness of opening side windows, 44% rated this strategy a 3 and 26% rated it a 2. (See pages C-9 and C-10 of Appendix C for details. Note that these percentages exclude respondents who answered “don’t know/haven’t used,” and will not match the percentages in the Appendix tables.)

### Double-paned windshields

Another method of keeping the windshield cold is to create a double-paned windshield—two parallel panes of glass with a small gap between them, similar to a thermal-pane window on a house. Our pre-survey research found this solution in



Double-paned windshield developed by Bon Homme County (South Dakota) DOT (photo from LTAP award Web site).

Bon Homme County, South Dakota, where the county highway department custom-built these windshields by adding a pane of glass to the inside of a truck’s existing windshield. This secondary windshield was cut from regular safety glass that was ordered to specification from a local glass dealer. The highway department attached the secondary windshield with a gasket between the two layers in order to maintain an air gap.

This strategy allows the outside windshield to remain cold and clear of snow, while the interior windshield is warmed by the cab’s heaters. According to a representative of Bon Homme County DOT, the windshield stays clear of snow and ice. They do experience some ice buildup on the outside edges of the outer windshield, but they don’t consider it problematic. The department has installed secondary windshields on trucks with curved windshields, but can only apply the glass to the section of the windshield that is relatively flat. The department says they haven’t had to replace the windshields once installed and have never had one fall out. The department received a regional Local Technical Assistance Program award in 1996 for developing this solution.

During discussion of this solution prior to the survey, the issue of its safety was raised. This issue did not come up during our discussions with Bon Homme County DOT, but it should be noted that we did not attempt to identify any research or specifications on how the secondary windshield would perform in a crash situation or if the primary windshield were broken by a foreign object, or whether installing a secondary windshield conforms to vehicle safety regulations.

Seven survey respondents from states besides South Dakota reported that their drivers had used double-paned windshields. We believe it is possible that some respondents interpreted “double-paned windshields” to mean a windshield such as the one shown on page 20, which uses two adjacent panes of glass for the driver and passenger sides of the windshield. Because of this concern and the small sample size, we chose not to draw any conclusions from respondents’ ratings of the windshields’ effectiveness. (See pages C-9 and C-10 of Appendix C for details on respondents’ ratings of this strategy.)

### Chemical glass treatments

Chemical glass treatments are periodically sprayed or brushed on the exterior surface of the windshield to repel precipitation and minimize ice and snow buildup.

Respondents were fairly aware of these treatments, but only 26% of respondents reported that their drivers had used them. Of those who rated the treatments' effectiveness, 52% rated them a 2 and 23% rated them a 3. (See pages C-9 and C-10 of Appendix C for details. Note that these percentages exclude respondents who answered "don't know/haven't used," and will not match the percentages in the Appendix tables.)

Most respondents seemed to regard this as an auxiliary strategy that may limit the amount of buildup or make removal easier in conjunction with other methods, but does not completely prevent or alleviate the problem on its own. In respondents' comments, Rain-X was the only brand of glass treatment mentioned; two others are listed below.

One respondent mentioned that his agency had had good results with chemical glass treatments until salt and chloride spray from the roads began hitting the windshield. This created a condition that he said was "like looking through a fluorescent bulb," and he said the film was very difficult to remove from the glass.

### Chemical glass treatment products

As mentioned, Rain-X was the only brand of glass treatment mentioned by respondents, but other products are available; we identified two in our literature search. Here are brief descriptions of each product:

**Rain-X:** Rain-X is "formulated with a transparent polymer that fills the microscopic pores of glass with hydrophobic molecules that force rain, sleet and snow to bead up and roll off." It is available as a spray, a liquid, and as wipes and towelettes. See the product Web site at <http://www.rainx.com/>; click "Products" in the yellow bar and then "Windshield Treatments." Also see the product description on Amazon.com at <http://www.amazon.com/gp/product/B0002JN26S/002-2095541-8951204?v=glance&n=15684181>.

**Clarity Defender:** This brush-on liquid treatment for exterior vehicle glass repels rain, snow, ice and most other liquids. This "nanofilm" treatment is claimed to remain effective for nearly a year following application, longer than other less expensive products. See the product Web site at [http://www.nanofilmtechnology.com/products\\_name/clarity-auto-windshield.htm](http://www.nanofilmtechnology.com/products_name/clarity-auto-windshield.htm).

**Ice-MC spray:** Alcohol-based Ice-MC spray is designed to prevent ice and frost from forming on windshields, and is said to dissolve ice and frost that has already formed. It can also be used on windows, headlights and taillights. Applications include stopping misting and fogging on windows and thawing frozen locks. Contact SHH (see <http://www.shh-chem.com/>) for more information about the product and availability.

### Anti-icing fluid applied through windshield washer system

In addition to chemical glass treatments that are applied manually, anti-icing additives are available for windshield washer fluid, and some washer fluids are formulated to include these additives. Most survey respondents were familiar with this strategy, and 39% reported using high concentrations of anti-icing fluid with their wiper system. Of those who rated this strategy's effectiveness, 36% rated it a 3

### Comments on chemical glass treatments:

"I know that if I put an application of 'Rain-X' on the windshield it helps with not as much accumulation of ice/snow."

"We have noticed that when you wipe on a product such as 'Rain-X' it does help in the removal in the corners and center of the windshield."

"Having the hood waxed, and the windshield Rain-X'd is helpful sometimes with drier snow."

"We have used deicing sprays in aerosol cans that seemed to help somewhat."

[From the UK] "In particularly bad conditions windscreens are treated with an external water dispersal polish/treatment."

and 35% rated it a 2. (See pages C-9 and C-10 of Appendix C for details. Note that these percentages exclude respondents who answered “don’t know/haven’t used,” and will not match the percentages in the Appendix tables.)

No brands of anti-icing fluid were mentioned in respondents’ comments, but several brands are available at auto supply stores. They include:

**Rain-X De-Icer Windshield Washer Fluid:** This washer fluid is designed to remove frost, light snow, ice and salt; reduce ice buildup on windshields; and provide freeze protection to –25° F. See <http://www.rainx.com/> (click “Products” in the yellow bar, then “Windshield Washer Fluids,” then “De-icer Washer Fluid” in the gray bar).

**Prestone De-Icer Additive and De-Icer Washer Fluid:** These products are designed to remove light ice and frost and prevent refreezing. See <http://www.prestone.com/products/windshieldWasherFluids.php>.

### Heated windshield washer fluid

Heated washer fluid aims to melt accumulated snow and ice and prevent buildup on the windshield and wipers. Slightly less than half of respondents were aware of this strategy, and just 6% of respondents had used heated washer fluid. Only 15 respondents rated the effectiveness of this solution; six of those (40%) rated it a 3, while four (27%) rated it a 4 and four (27%) rated it a 2. (See pages C-9 and C-10 of Appendix C for details. Note that these percentages exclude respondents who answered “don’t know/haven’t used,” and will not match the percentages in the Appendix tables.)

No survey respondents provided written comments on the systems’ effectiveness in the survey, and no brands were named. Our literature search identified two systems: the HotShot system from Microheat Inc. and the SmartWash system from Valeo. In addition, during our research we identified the ClearFast system, and a ClearFast representative responded to the manufacturer survey. These three systems are described below.

**HotShot:** This system produces heated washer fluid in about 30 seconds and automatically sprays it onto the windshield. A compact unit weighing just over one pound, HotShot is installed in the vehicle’s engine bay and then connected to the existing washer reservoir tubes and the battery. The device is controlled from a separate fluid heater on/off switch placed on the dashboard or integrated into existing switches. See the product Web site at [http://www.microheat.com/Products\\_Windshield.asp](http://www.microheat.com/Products_Windshield.asp).



HotShot heated washer fluid system (photo from [www.microheat.com](http://www.microheat.com)).

**SmartWash:** This autonomous, automatic washer fluid heating system heats a controlled amount of fluid in a heating chamber to about 149° F. Hot fluid is available within one minute after vehicle ignition. The system features integrated low-voltage protection that is compatible with 12-volt systems. See a product fact sheet at [http://www.valeo.com/automotive-supplier/webdav/site/valeo/shared/en/pdf/4presse/evenements/mondial-auto-2004/technologies/driving/smartwash\\_uk.pdf](http://www.valeo.com/automotive-supplier/webdav/site/valeo/shared/en/pdf/4presse/evenements/mondial-auto-2004/technologies/driving/smartwash_uk.pdf).

**ClearFast:** This washer fluid heating system provides 5.1 ounces of heated fluid for effective cleaning of large truck and bus windshields. Hot fluid is available 18 seconds from a cold start, and this temperature is automatically maintained by a microprocessor and thermistors. ClearFast heats washer fluid to 120° F; the company says this temperature is critical because the alcohol in washer fluid begins to evaporate between 140° F and 150° F. ClearFast uses the existing vehicle washer fluid button and pump system, so no other switches are required, and the driver has total control of how much fluid is dispensed to the windshield. Several safety features are incorporated to prevent the unit from overheating and causing damage to the unit or the vehicle. If the vehicle system voltage drops below 12.8 volts, ClearFast automatically shuts off, preventing excess current draw and electrical system overload. See additional product information in Appendix E.



ClearFast heated washer fluid system (photo supplied by ClearFast).

## Other solutions

Survey respondents mentioned two other solutions to ice and snow buildup on windshields. One respondent said that waxing the truck's hood is sometimes helpful in repelling drier snow. This may help reduce buildup along the cowl, where the hood meets the windshield. Another respondent mentioned deluge systems, which use water from an onboard tank to flood the mirrors, windshield and side windows. In our research, we found one 2002 reference to these systems being available on Oshkosh H and HB Series trucks, and a 1997 reference to the systems on Oshkosh cement mixers.

Also, as mentioned previously, Oshkosh's Municipal Patrol Truck Series has reverse-slope windshields that are designed to minimize ice and snow buildup and wiper problems.

### 3.2.4 Icing on Exterior of Side Windows

#### PROBLEM

Snow and ice buildup on side windows is another problem that can affect driver visibility. This problem can have several sources, including falling or blowing snow, snow discharged from the wing plow, and passing traffic. Windy conditions can exacerbate this problem.

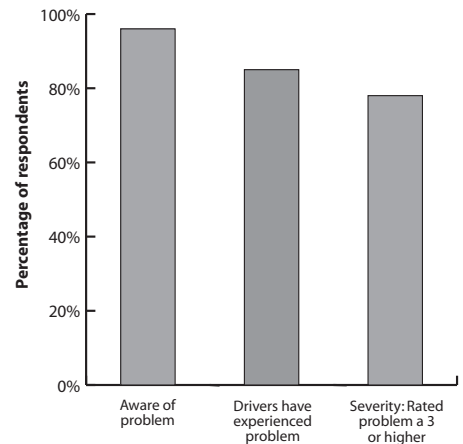
Nearly all survey respondents were familiar with icing on side windows, with 85% reporting that they had experienced the problem. Most considered it to be a fairly serious problem; of those who rated its severity, 28% rated it a 5 ("very big problem") and 26% rated it a 4; another 24% rated it a 3. (See pages C-3 and C-4 of Appendix C for details. Note that these percentages exclude respondents who answered "don't know/haven't experienced," and will not match the percentages in the Appendix tables.)

#### SOLUTIONS

Our pre-survey interviews did not uncover any specific strategies for addressing ice buildup on side windows, so the survey did not include a multiple-choice sec-

## RESPONDENTS' VIEWS

### Awareness and severity of icing on side windows



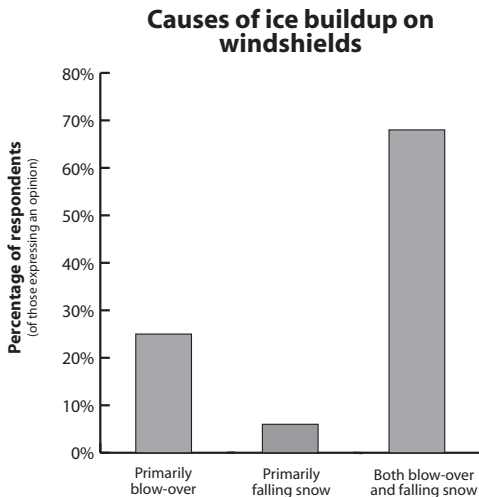
Respondents rated problem severity on a 5-point scale, where 1 = Not a problem and 5 = Very big problem.

### Comments on side window icing:

"Traffic passing will throw the slush and snow onto side windows and mirrors as well as the windshield."

"Side windows also cause us problems when turning into the wind, the snow when coming off the wing really loads the window, we cannot keep the side glass hot enough to melt this kind of buildup."

## RESPONDENTS' VIEWS



### Comments on plow flaps:

"We are currently working with a vendor on a flap system where the flap comes out at an angle away from the plow."

"Ribbing to stiffen rubber flap."

"A stiff flap mounted on the front of the plow curl helps (stiff so it doesn't 'sail' or cave into the curl)."

tion on this problem. However, several respondents mentioned one solution in their comments: lowering the windows to clear snow and ice, and specifically installing a power-operated window on the passenger side to allow the driver to lower that window without stopping the truck.

During our research, we discovered that the Oshkosh MPT-Series trucks offer optional side-window wipers. They are mentioned (but not pictured) in a brochure at [http://www.oshkoshtruck.com/pdf/Oshkosh\\_MPT-Series\\_brochure.pdf](http://www.oshkoshtruck.com/pdf/Oshkosh_MPT-Series_brochure.pdf). In addition, the current specifications sheet for Oshkosh's MPT-Series (see [http://www.oshkoshtruck.com/pdf/Oshkosh\\_MPT-Series\\_specs.pdf](http://www.oshkoshtruck.com/pdf/Oshkosh_MPT-Series_specs.pdf)) lists side-window defrosters as an option for this truck.

### 3.2.5 Blow-over PROBLEM

Plowed snow blowing over the top of the plow contributes to the problem of ice and snow buildup on windshields, as well as on wipers and mirrors. Blow-over may be more severe in colder temperatures when the snow is fine and powdery, on windy days, and at higher plowing speeds.

Of those who had an opinion, nearly all respondents (93%) reported that blow-over contributes to icing on windshields, with 25% saying blow-over was the primary source of windshield icing (68% said both blow-over and falling snow contributed to icing). (See page C-4 of Appendix C for details. Note that these percentages exclude respondents who answered "not sure" or "have not experienced icing on exterior windshields," and will not match the percentages in the Appendix tables.)

Survey respondents identified a range of solutions to the problem, including plow attachments (deflectors and flaps), plow design solutions, hood deflectors and shields, underbody plows, and driving slower.

## SOLUTIONS

### Plow deflectors

A deflector attachment is a strip of stiff rubber, metal, plastic or other material that is bolted to the top of the plow to prevent plowed snow from blowing over the top of the plow and obscuring the driver's vision. Nearly all respondents were familiar with deflector attachments, and 88% reported that their drivers had used them. Respondents generally felt deflectors were fairly effective; of those who rated their effectiveness, 37% rated them a 3, 31% a 4 and 15% a 5 ("extremely effective").

(See pages C-9 and C-10 of Appendix C for details. Note that these percentages exclude respondents who answered "don't know/haven't used," and will not match the percentages in the Appendix tables.)



Plow deflector (photo from Wisconsin DOT concept vehicle report).

A few respondents mentioned problems with deflector attachments—that they may block the operator's field of vision, especially when the plow is in the raised position, and that they can be torn off by wind turbulence.

Plow deflectors were the only solution of this type identified in our pre-survey interviews, so we included a question in the agency/contractor survey that asked respondents to list other strategies for addressing blow-over. Respondents identified several solutions, including plow flaps and hood-mounted wind deflectors, adjusting plow design and settings, using underbody plows, and reducing plowing speeds. These solutions are described below.

## Plow flaps

Like deflectors, plow flaps work to trap the plowed snow and prevent it from moving upward and over the plow. The flaps are typically attached to the underside of the top edge of the plow and hang down the front. Respondents reported different designs among the flaps on their plows; flaps are often made of stiff rubber or belting material, and some mentioned that the belts were ribbed. Belt widths of 12 inches and 30 inches were reported, with one respondent mentioning that his agency is trying wider flaps than they had previously used. One respondent men-

tioned the flap coming out from the plow at an angle.



Plow flap (photo from Oshkosh snowplow brochure).

## Plow design and settings

Respondents also mentioned the importance of choosing an appropriate plow design, including using a plow that is large enough for the job, and using the right attack angle on the plow. In terms of plow design, several respondents said plows with a greater curvature

or deeper funnel were more effective, and some cited the height of the moldboard as a factor. One respondent mentioned using variable-shape plow moldboards that can be adjusted as conditions change.



Plow with curved moldboard (photo from Oshkosh snowplow brochure).

Several respondents mentioned that adjusting the plow angle so that the blade is turned as far forward as it will go can help reduce blow-over.

Our research found two references to deflectors and deflector or plow trap angles in a scholarly journal and an NCHRP project. Researcher Brian Thompson (first of Rensselaer Polytechnic Institute, then of the University of Western Ontario) was involved in both projects, so there may be some overlap in the tests or methodology in the two projects.

- A 2002 paper published in the Journal of Cold Regions Engineering, “Visibility Improvements with Overflow Deflectors During High-Speed Snowplowing,” used wind tunnel and field experiments to quantify visibility improvements for plow drivers and following traffic with deflectors mounted to the top of plow blades. Researchers found that blow-over was eliminated with deflector trap angles less than 50 degrees. See the abstract at <http://scitation.aip.org/getabs/servlet/GetabsS>

## RESPONDENTS' VIEWS

### Comments on plow design:

“The barrel-type plows are the most effective.”

“The shape of the plow curl affects the amount of snow that comes over it as does the angle of the plow in relationship to the road.”

“Change the geometry of the plow. Some manufacturers increase the roll of the plow.”

### Comments on plow settings:

“With the problem of plowed snow blowing over the top of the plow, we usually modify the plow so that the top of the curl extends out further away from the truck. This usually prevents this.”

“MoDOT has went with a higher angle on the moldboard to eliminate ‘bulldozing.’ With the higher angle we are turning the snow over fewer times which helps eliminate the wind getting under it and blowing it up on the truck.”

“Keeping the blade turned as far as it will go helps sometimes it also depends on what type of snow you are pushing—wet, dry, etc.”

## RESPONDENTS' VIEWS

### Comments on wind deflectors:

"Some of our operators have stated that in combination with a plow deflector, a simple bug shield has helped to prevent some snow hitting the windshield. This still seems inconclusive yet."

### Comments on reducing plowing speed:

"Most of the time snow blowing over the plow means you're driving too fast unless you're pushing more of a powdery snow."

"Speed of plowing can be adjusted to snow conditions, where practical. Wet snow does not blow back as bad as dry, cold snow."

[ervlet?prog=normal&id=JCRGEI000016000003000102000001&idtype=cvips&gif=yes](http://www.fhwa.dot.gov/ohp/ervlet?prog=normal&id=JCRGEI000016000003000102000001&idtype=cvips&gif=yes).

- NCHRP Project 6-12, "Improved Visibility for Snowplowing Operations," produced a report in 2000. The NCHRP Research Results Digest on the project stated that "Front plows, or front plows used with plow-mounted deflectors, with a trap angle of about 50 degrees will reduce the amount of material blown over the plow and onto the windshield." See [http://gulliver.trb.org/publications/nchrp/nchrp\\_rrd\\_250.pdf](http://gulliver.trb.org/publications/nchrp/nchrp_rrd_250.pdf).

### Hood-mounted wind deflectors/bug shields

Some respondents mentioned that bug shields or wind deflectors attached to the hood of the truck provided some protection against blow-over as well, especially in combination with other strategies such as plow deflectors.



Hood-mounted wind deflector (photo from Wisconsin DOT concept vehicle report).

### Reducing plowing speed

A traditional, simple method of addressing blow-over has been to drive more slowly, especially when the snow is dry and powdery and more likely to create a cloud. Several respondents mentioned this solution.

### Other solutions

One respondent commented that truck design could decrease blow-over, because "taller trucks with higher hoods block more snow from hitting the windshield."

Another respondent mentioned that using underbody plows instead of front plows when practical diminishes blow-over, since snow coming off the underbody plow does not enter the driver's field of vision:

"We have moved to quite a few high-speed under truck mounted plows in addition to the front mounts and when the snow is blowing or very light and dry the front plow isn't used and no visibility is lost from the snow coming off the underbody plow."

One respondent reported at least some evidence that using double blades can increase blow-over, but thought the mild winter his area experienced this year could also be a factor:

"... We have set up 12 out of our 19 route trucks with a Joma blade (a carbide encased in rubber single blade). The reports back from our personnel is that they are extremely happy with the way the blade cuts to the pavement but they are getting more than usual snow and ice buildup back on the windshield and wipers. ... With the mild winter we have experienced we feel this is part of the cause. We tried the blades for the first time in January of 2005 and ran them the rest of the season and didn't have the complaints from the operators like we experienced this year. We talked to other municipalities in northern Wisconsin where the snow is generally more fluffy we think and they reported no problems with the blades. We have recently been experimenting with lon-

ger flaps on the plow but haven't had enough feedback on how that works and with the season coming to an end we will have to wait until next year."

### 3.2.6 Ice Buildup on Windshield Wipers

#### PROBLEM

Ice buildup on wipers can take several forms. When temperatures are near freezing, wet snow sticks to the windshield and the hood and can build up quickly. Falling and blowing snow as well as blow-over from the plow can contribute to this problem, as can slush kicked up by passing traffic. Respondents reported that snow and ice tend to build up along the cowl or the bottom edge of the windshield, and then are packed down by the moving wipers. At times, this can put strain on the wiper motor, eventually causing it to fail, or causing the wiper arm to break or detach from the motor. Respondents also mentioned that this buildup can block air intakes, which can lessen the effectiveness of the truck's heat and defrost systems.

Ice and snow may also build up on the wipers themselves, lifting parts of the wipers off the windshield and causing streaks



Ice buildup on windshield wipers (photo from Wiper Shaker Web site).

and smears that obscure the driver's vision. Using washer fluid can increase the visibility problem, since wipers obstructed by ice cannot adequately clear the fluid from the windshield, and the fluid may freeze on the glass. One survey respondent also mentioned that the longer wiper blades needed for large windshields are less effective when iced over.

In colder temperatures, or when temperatures start out warmer and drop below freezing during a plow run, the wiper blades may freeze and fail to conform adequately to the curved and flat portions of the windshield, again causing streaks and smears as the wipers skip over some parts of the glass.

In the absence of a better solution, drivers may resort to clearing wiper blade buildup manually, either by stopping the truck or by reaching out the side window while driving and attempting to slap the wiper against the glass. Clearing the wiper blade while driving is a dangerous distraction, while stopping to clear the blade creates downtime and can be a safety hazard for both the plow operator and other drivers.

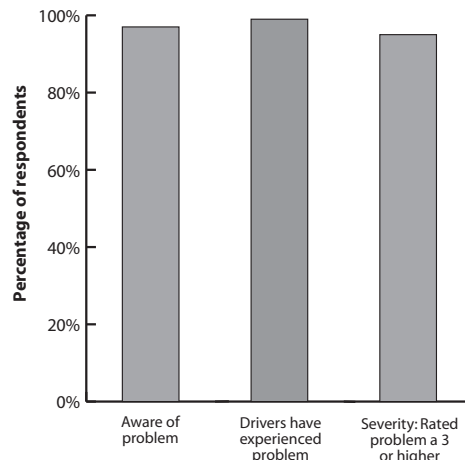
Of the problems discussed in the survey, respondents reported that ice buildup on windshield wipers was the most severe problem, with 69% rating it a 5 ("very big problem") and another 19% rating it a 4. Virtually all respondents (99%) were aware of the problem, and nearly all (97%) reported that their drivers had experienced it. (See pages C-3 and C-4 of Appendix C for details. Note that these percentages exclude respondents who answered "don't know/haven't experienced," and will not match the percentages in the Appendix tables.)

#### Curved windshields

As mentioned on page 20, most survey respondents reported that the curvature of

## RESPONDENTS' VIEWS

### Awareness and severity of ice buildup on wipers



Respondents rated problem severity on a 5-point scale, where 1 = Not a problem and 5 = Very big problem.

### Comments on causes of ice buildup on wipers:

"One major problem is the left and right wipers tend to feed snow and ice down under the left windshield wiper, piling up, pounding and eventually failing the wiper arm or motor."

"Ice and snow buildup on wipers not only causes problems seeing but also causes mechanical failures during emergency winter operations."

"We have problems with snow buildup on the cowl to the point that the wiper arms can come off of the wiper motor."

"Wipers pushing snow leads to motor failures and wiper transmission arms failing."

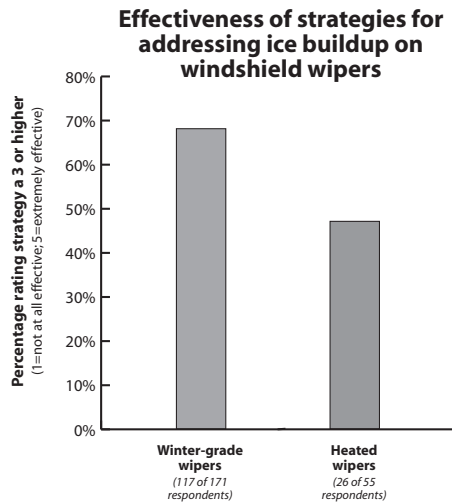
"Ice builds up on the cowl which will freeze the wipers lessen the effectiveness of heat/defrost to the windshield."

## RESPONDENTS' VIEWS

### Comments on curved windshields:

"Wipers designed with hinges internal tend to freeze to the curved part of windshield then won't touch all of windshield where it is flat."

"When trucks with curved windshields are turned off, wipers are kept in up position so that they don't freeze to the curved contour of the windshield."



### Comments on winter-grade wipers:

"Ice-resistant wiper blades do help, but do not always prevent the problem."

"Use of heated mirrors and freeze-proof wipers has helped a little with these problems. ... But all of the technologies also have maintenance problems associated with them."

the windshield does not markedly affect the buildup of ice on windshield wipers. Of respondents expressing an opinion, two-thirds (67%) said buildup was about equal on wipers used with curved and flat windshields, with 21% stating that buildup was greater on curved windshields and 12% stating it was greater on flat windshields. (See page C-5 of Appendix C for details. Note that these percentages exclude respondents who answered "don't know/don't own trucks with curved windshields," and will not match the percentages in the Appendix tables.)

One problem noted with curved windshields was that wipers may freeze to the curved contour of the windshield; one respondent mentioned that drivers at his organization prevent this by putting the wipers in the "up" position when they turn off the trucks.

## SOLUTIONS

Solutions to ice buildup on wipers take several forms. Winter-grade wipers protect the blades from buildup, while heated wipers melt snow and ice. Vertical and top-mounted wipers use gravity to help keep the blades clear. In addition, two types of aftermarket wiper attachments remove buildup mechanically by vibrating or slapping the wiper blades.

### Winter-grade wipers

The solution used most commonly by survey respondents was winter-grade wipers, which have covers over the wiper blades to prevent ice buildup. Often made of rubber, these sleeves or "boots" encase the brackets and joints of the wiper assembly where snow can become trapped. Many wiper blade manufacturers offer these blades. Bosch also offers blades that use an enclosed metal tension spring rather than exposed external tension strips, which the company says helps keep the blades flexible in wintry weather.

Survey respondents were very familiar with winter wipers (sometimes called "ice-resistant" or "freeze-proof" in respondents' comments), and 87% of respondents reported that their drivers had used these wipers. Of those who rated their effectiveness, 40% rated them a 3, with an additional 25% rating them a 2 and 23% rating them a 4. (See pages C-11 and C-12 of Appendix C for details. Note that these percentages exclude respondents who answered "don't know/haven't used," and will not match the percentages in the Appendix tables.)



Trico winter wiper blade (photo from Trico Web site).

Traditional wiper blades are made of rubber, but manufacturers offer blades made of other materials, often advertised as longer-lasting and providing a smoother wiping surface. One survey respondent mentioned getting good performance from Teflon blades, and wiper blades made of silicone are also available. A few sources of these blades include:

#### Teflon wiper blades

Trico winter Teflon blade: [http://www.tricoproducts.com/brochure.cfm?brochure=1433&location\\_id=65](http://www.tricoproducts.com/brochure.cfm?brochure=1433&location_id=65)

## Silicone wiper blades

TriplEdge wiper blades: <http://www.tripledge.com/index.php>

SilBlade wiper blades: <http://www.silblade.com/>

PIAA wiper blades, including a curved blade: <http://www.piaa.com/WiperBlades/silicone.html>

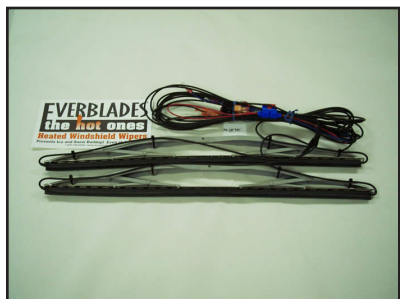
One respondent also mentioned getting good performance from DuraKlear wiper blades (made by Anco), which have a “no wax rubber formula” that “protects against hardening and ‘park set’ rubber,” according to the product description (see <http://www.autobarn.net/anwipblad.html>).



PIAA silicone wiper blades (photo from PIAA Web site).

## Heated wipers

Heated wipers are another solution to ice and snow buildup. Most heated wipers we encountered work by heating the wiper blades to melt snow and ice and keep the blades' rubber flexible. The Web site of one brand, Everblades (<http://www.everblades.com/>), says the blades contain calibrated heating elements that radiate heat through the rubber blades, which reach temperatures of 150° F to 190° F. They are controlled by a dashboard-mounted on/off switch. Heated wiper frames are also available.



Bolt-on Everblades heated wipers (photo from Everblades Web site).

Everblades' Web site includes a list of design improvements to their product for the 2005-2006 season (see <http://www.everblades.com/pages/4/productimprovements.htm>), including updates to the blades, wiper housing, and wiring. The company is also working on a blade suitable for highly curved windshields. Everblades' owner responded to our manufacturers' survey; see the full text of his description of the product in Appendix C.

Another brand of heated wipers is the Safety HotBlade (see <http://www.motorists.com/secure/store/hotblade/hotblade.html>), although some Web pages for this product are outdated, and it may have been discontinued. The HotBlade uses a thermostatically controlled silicone wiper blade.



Safety HotBlade heated wipers kit (photo from [www.motorists.com](http://www.motorists.com)).

In addition to aftermarket products, heated wipers may be available as part of OEM specifications from some truck manufacturers; Dan Wickline of Mack mentioned in the manufacturer survey that Mack offers heated wiper blades on its trucks.

One survey respondent also mentioned heated wiper arms, and heated wipers (as

## RESPONDENTS' VIEWS

### Comments on heated wipers:

“We did try a set of heated wipers a few years ago. They didn't work because for one they weren't a winter blade and they were too fragile to keep up with the amount of snow and ice coming at them.”

“Heated wipers were not able to hold up to weather conditions.”

“Heated wiper arms are another advance which has provided some help but all of the technologies also have maintenance problems associated with them.”

“We've tried heated wipers and found them to be very high-maintenance.”

“We have looked at heated wipers, but we are concerned that adding more electrical draw on a system that is already maxed will create problems down the road.”

## RESPONDENTS' VIEWS

### Comments on vertical and top-mounted wipers:

"I have always thought that all of our fleet should have vertical wipers. First it keeps the wipers from getting frozen down by packed snow that falls between the hood and the cowl and would stop the windshield wiper fluid from freezing."

"We have one truck with top-mounted wipers; we do not see any significant difference."

opposed to heated wiper blades) on a brand that is no longer produced (Northern Blades) were mentioned by one person we interviewed during our research.

Survey respondents were somewhat familiar with heated wiper blades; 61% of respondents said they were aware of the blades, but only 23% of respondents had used them. Respondents varied in their assessments of heated wiper blades' effectiveness; 27% rated them a 1 ("not at all effective"), while 25% rated them a 2, 24% rated them a 3, and 20% rated them a 4. No brand names were mentioned in respondents' comments, and respondents may be using different brands and/or ages of heated wipers. (See pages C-11 and C-12 of Appendix C for details. Note that these percentages exclude respondents who answered "don't know/haven't used," and will not match the percentages in the Appendix tables.)

Respondents mentioned several problems and concerns with heated wiper blades. Two respondents said the blades were too fragile to hold up to winter conditions, and two mentioned maintenance issues. One said the blades left streaks in the areas that the blades were not heated, one was concerned about the wipers adding additional stress on the truck's electrical system, and one mentioned cost as an obstacle to installing them throughout the state's fleet.

In addition, one survey respondent mentioned a problem with drivers leaving heated windshields and heated wipers on while the truck is idling. In this respondent's experience, this leads to the hot wiper blade transferring a skim of rubber onto the windshield glass. He suggests that the heating elements for the windshields or wiper blades should be controlled by a timer, and that heated wipers should be disabled when the parking brake is applied.

### Vertical and top-mounted wipers

The term "vertical wipers" may be used to describe wipers that rest in an upright, vertical position and sweep horizontally across the windshield. The upright design provides less surface for snow to collect on, and the arc of the wipers minimizes packing of snow and ice at the base of the windshield. At least one manufacturer, Kenworth (see [http://www.kenworth.com/2100\\_vir\\_t800.asp](http://www.kenworth.com/2100_vir_t800.asp)), offers this wiper design.

"Vertical" may also be used to describe some top-mounted wipers that hang vertically when at rest and sweep horizontally across the windshield. In addition, some top-mounted wipers give the appearance of traditional wipers mounted



Vertical wipers (photo from Kenworth T800 brochure).

upside down at the top of the windshield (see photo at the top of page 35). A benefit of top-mounted wipers is that they do not pack snow and ice along the cowl and cause a buildup that strains the wiper motors. In addition, gravity helps dislodge any snow that does collect on the top-mounted blades. Most major heavy truck manufacturers do not appear to offer top-mounted wipers, but they are available from at least one manufacturer, Oshkosh (see <http://www.oshkoshtruck.com/airportmunicipal/sproducts~mptseries~home.cfm>).



Top-mounted wipers on Oshkosh MPT-Series (photo from MPT-Series brochure).

Survey respondents were not very familiar with vertical windshield wipers; 31% of respondents were aware of them, but only 7% had used them on their agency's trucks. Based on information from our initial interviews, we listed "vertical wiper systems" in the survey as a strategy to address icing on windshields, rather than on windshield wipers, so respondents' assessments of their effectiveness cannot be compared directly with the effectiveness ratings of the other solutions to wiper buildup. Only 19 respondents rated the systems' effectiveness, and their responses were mixed: six (32%) rated them a 1 ("not at all effective"), six (32%) rated them a 2, and five (26%) rated them a 3. (See pages C-11 and C-12 of Appendix C for details. Note that these percentages exclude respondents who answered "don't know/haven't used," and will not match the percentages in the Appendix tables.)

## Aftermarket wiper attachments

At least two companies provide products that mechanically remove snow and ice from wipers. Slap Wipers from the Slap Me Company use air pressure to raise the wipers about 8 inches off the windshield and "slap" them back in place, causing accumulated snow and ice on the wiper to break off. Slap Wipers are controlled by a button inside the cab, and the company says the slapping does not cause damage to windshields. See Appendix A: Literature Search, for contact information.



Shaker system installed on Nova Scotia DOT truck (photo from Wiper Shaker Web site).

A second product is the Shaker from Wiper Shaker Technologies, an attachment that clamps onto an existing wiper arm and blade assembly and vibrates the wiper arm to clear trapped snow, ice and debris. The Shaker uses a "specially designed eccentric motor/weight combination" to lift the blade about 1/16" off the windshield, "skipping" the blade across the glass in increments of about 1/2" to 1". It is controlled by a button inside the cab. See the product Web site at <http://www.wipershaker.com/>. Wiper Shaker's

president also completed our manufacturers' survey; product information he provided is available in Appendix E.



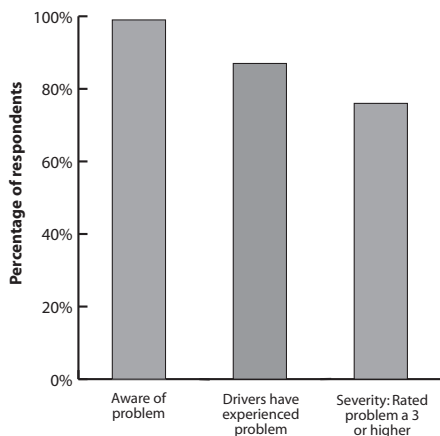
Close-up view of Shaker attachment (photo from Wiper Shaker Web site).

Most survey respondents were not familiar with these aftermarket attachments; 20% were aware of Slap Wipers, while 4% had used them, and 16% were aware of the Shaker, while 2% had used it. There were not enough responses about the product's effectiveness to constitute a valid sample. (See pages C-11 and C-12 of Appendix C for details.)

During our literature search, we interviewed Alan Lightfoot, a transportation operations supervisor with Minnesota

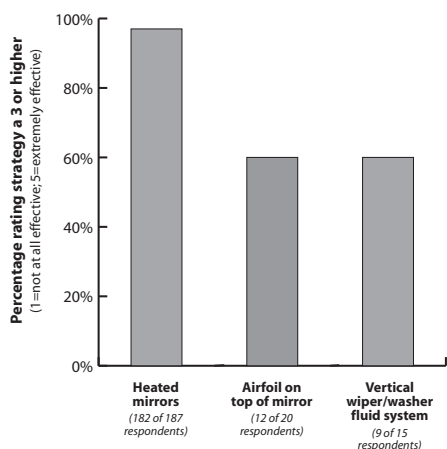
## RESPONDENTS' VIEWS

### Awareness and severity of icing on mirrors



Respondents rated problem severity on a 5-point scale, where 1 = Not a problem and 5 = Very big problem.

### Effectiveness of strategies for addressing side mirror icing



### Comments on heated mirrors:

"Icing on mirrors is not as big a problem as it once was. All of my snowplow trucks have heated mirrors. The snowplow trucks either came with them, or I had them added."

"All plow trucks have heated mirrors, so icing on the mirror is not the problem that it would be without the heating option."

DOT, which tested eight sets of the Slap Wipers during the 2004-2005 winter. He reported that the wipers worked well to clear ice and snow from the blades. His comments included:

"The operators who got an opportunity to use them thought they were great. We get a very heavy snow buildup on our windshields when in a plowing operation, and we used to have to reach out through the side window and slap the wiper to get ice and snow off. Now, you just push an air button and the wiper lifts off the windshield and slaps back down, clearing the blade."

One survey respondent said that the Shaker had been effective on his agency's trucks. His comments included:

"With snow/ice sticking to wipers, we tried installing a vibrator to the wiper arm. With the press of a button in the cab of the truck, the vibrator is activated, and the snow/ice usually comes off."

### 3.2.7 Icing on Exterior (Side) Mirrors PROBLEM

Snow and ice may build up on exterior mirrors from similar sources as those that affect side windows (falling or blowing snow, discharge from the wing plow, and traffic). Virtually all respondents (99%) were aware of this problem, and 87% reported experiencing it. Most respondents felt it was a fairly serious problem; of those who rated its severity, 28% rated it a 5 and 28% rated it a 4; another 20% rated it a 3. (See pages C-3 and C-4 of Appendix C for details. Note that these percentages exclude respondents who answered "don't know/haven't experienced," and will not match the percentages in the Appendix tables.)

### SOLUTIONS

Heated mirrors are by far the most prevalent solution to icing on exterior mirrors. Heated mirrors melt snow and ice that accumulate on the mirror, a strategy that works so well that several respondents and people we interviewed said they consider the problem virtually solved. Nearly all survey respondents were aware of heated mirrors, and 95% reported that they had used them on their trucks. Respondents identified heated mirrors as by far the most effective strategy of any in this survey; of those who rated their effectiveness, 61% rated them a 5 ("extremely effective") and 27% rated them a 4. (See pages C-12 and C-13 of Appendix C for details. Note that these percentages exclude respondents who answered "don't know/haven't used," and will not match the percentages in the Appendix tables.)

Heated mirrors are now offered by many truck manufacturers as part of OEM specifications, and may also be added as aftermarket solutions. They may be more expensive to add as an aftermarket feature than standard mirrors, and since they extend beyond the body of the truck, they run the risk of being damaged in collisions (for this reason, truck mirrors may have a breakaway design that prevents further damage to the truck if a mirror is hit). One survey respondent also mentioned heated mirrors being destroyed by plow wings.

Survey respondents had few negative comments concerning heated mirrors. Two

mentioned cost as a concern, and one said they were affordable. Two respondents pointed out that if the side windows are obstructed with snow and ice, the driver cannot see the mirrors. One respondent also included heated mirrors in a list of strategies that have maintenance issues.

Our literature search identified one manufacturer of heated mirrors for both OEM and aftermarket applications, Sure Plus Manufacturing Co. (see <http://www.sureplus.com/products/westcoast.htm>). Their West Coast series features several models with sealed heating units to withstand moisture.

Our pre-survey interviews identified two other strategies for addressing icing on mirrors, which were less familiar to survey respondents. The first is attaching an airfoil to the top of the mirror to keep snow from landing on the mirror; 6% of respondents had used this strategy. Only 20 respondents rated the airfoil's effectiveness; of those, seven (35%) rated it a 4, four (20%) rated it a 3, four (20%) rated it a 2, and four (20%) rated it a 1. (See pages C-12 and C-13 of Appendix C for details. Note that these percentages exclude respondents who answered "don't know/haven't used," and will not match the percentages in the Appendix tables.)



Integrated wiper/washer fluid system for mirrors (photo supplied by Iowa DOT).

The second strategy is a wiper that moves vertically along the mirror and is integrated with an anti-icing fluid dispenser; only 3% of respondents had used this strategy. Only 15 respondents rated this strategy's effectiveness; of those, five (33%) rated it a 3, three (20%) rated it a 4, three (20%) rated it a 2, and three (20%) rated it a 1. (See pages C-12 and C-13 of Appendix C for details. Note that these percentages exclude

respondents who answered "don't know/haven't used," and will not match the percentages in the Appendix tables.)

One survey respondent also mentioned using Rain-X on nonheated mirrors to help repel precipitation.

Two respondents had other comments about mirrors that did not relate to icing. One mentioned adding convex mirrors to the front of the trucks, presumably for greater visibility. Another respondent said power-adjustable mirrors would be a helpful feature. In our research, we noted that Sure Plus (mentioned above) also supplies power mirrors; see the Power Swing mirrors near the bottom of the page at <http://www.sureplus.com/products/westcoast.htm>.

### 3.2.8 Other Problems

In answering the survey's open-ended questions, respondents mentioned several other problems that were outside the scope of this research project. We list them here so they may inform future research efforts.

## RESPONDENTS' VIEWS

### More comments on heated mirrors:

"Heated mirrors have solved most of the problems with exterior mirror icing."

"We've utilized heated mirrors for years and they work very well!"

"We do have heated mirrors on all our trucks and that does help only if the side windows don't build up with snow and ice."

"Heated mirrors work great only if you can see out the side windows."

### Comments on lighting problems:

"Ice buildup on headlights is a big problem that affects a driver's vision."

"Visibility is decreased by the plow lights being obscured by blowing snow from the plow."

"Backup lights affect your vision a lot because they do not put out enough light. The trucks come with the new LED bulbs in them but they don't do very well. They're bright to look at but when you're on a rural route with limited space to turn they don't light up the area enough."

### Comments on lighting solutions:

"Our plow trucks need a better head lighting system and the lights need put on the fenders of the trucks instead of on the hood. We have tried this and it helps dramatically."

"Some of our operators use Rain-X or other similar product, on nonheated mirrors or LED lights that don't generate a lot of heat."

## RESPONDENTS' VIEWS

### Comments on cost:

"The primary obstacle is cost/calculated benefit."

"The cost of heated wiper blades has been prohibitive for the number of trucks statewide."

"Heated mirrors have been an added expense. Many have been smashed by plow wings and other similar damages. Heated mirrors are expensive to replace."

"Retrofits of heated/power mirrors are not cost-effective for us, but all new equipment gets this for last ten years."

### Comments on lack of familiarity with strategies:

"Some of the solutions that you have noted are not familiar to our organization."

"I am not aware of some of these systems being available. Our fleet is several years old, and has not been replaced."

"Some features may be unavailable on certain makes of truck."

### Comments on process issues:

"Cost and red tape of installation."

"Cost and getting the OK to do the project."

The problem mentioned most frequently related to lighting, specifically the effectiveness of headlights, backup lights and plow lights, and difficulties with ice and snow buildup on these lights. Buildup on these lights can diminish the amount of light cast on the road, limiting the snowplow operator's field of vision during nighttime plowing.

Respondents mentioned two solutions to lighting problems—putting lights on the truck's fenders instead of the hood, and using chemical glass treatments on LED lights. In addition, during our pre-survey interviews, we identified a system developed by Iowa DOT that uses compressed air from the truck's air brake supply tanks to blow snow off signal and taillights. It is possible that a similar system could be developed for headlights and other plow lights.

Respondents also mentioned several problems related to snow blowing over the plow. Windshields may be scratched by chemicals, sand or other abrasives in the snow. In addition, snow blowing over the plow can freeze on the truck's grille, engine air intakes, and other areas. Snow blow-back onto radiators can cause the truck to overheat, and road salt can corrode radiators and air conditioning condensers. Condensers may also be damaged by flying material from the plow and develop leaks.

Other problems mentioned by survey respondents included white-out conditions, high winds, freezing rain, and driver fatigue.

### 3.2.9 Obstacles to Implementing Icing and Fogging Solutions

Agencies face several potential hurdles to implementing strategies to address icing and fogging, including the solutions' cost and potential maintenance requirements, bureaucracy and process issues, lack of familiarity with available solutions, and time to install the equipment. To determine if an equipment investment is worthwhile, many agencies test new strategies on a small number of trucks before implementing them across an entire fleet.

Cost of the solutions was by far the most frequent challenge mentioned by survey respondents; of those who cited one or more obstacles, 77% mentioned cost. Some mentioned the difficulty of justifying the costs of the solutions in relation to their benefits or effectiveness, and one mentioned the high cost of adding equipment to all trucks in a state's fleet.

Some respondents (23%) also mentioned being unfamiliar with the strategies listed in the survey, or that these solutions were unavailable to them. One respondent mentioned that his agency has not ordered new trucks in several years, and another mentioned that certain features are not available on all trucks.

Several respondents (16%) mentioned bureaucracy and process issues within their agencies, with several respondents stating that they have limited input into their agency's equipment specifications.

Several respondents (16%) also said that the maintenance required for added equipment was an obstacle. No specific maintenance concerns were listed in this

section, but maintenance associated with air conditioning was discussed in other parts of the survey (see page 16), and two respondents mentioned maintenance concerns with heated wipers.

Other concerns mentioned were the time required to install the equipment, providing training on new systems, and vendors going out of business after new products have been purchased.

### 3.3 Agency/Contractor Survey Results

## Part 2: Equipment Management

Part 2 of the agency/contractor survey was directed at respondents whose jobs involve truck and equipment management or purchasing. It gathered information about types of vehicles used for snowplowing, maintenance issues, truck characteristics (including percentage with air conditioning and deflector attachments), and probable levels of spending on solutions.

About half of the survey respondents (100, or 48%) completed this section. We summarize their responses in this section according to question topic.

### Vehicles used for snowplowing

**Question text: 1. What types of vehicles does your organization use for snowplowing? Select all that apply.**

Depending on their size and their other maintenance needs, agencies may use many different kinds of trucks and other equipment for snowplowing. Most state DOTs use dump trucks or other heavy trucks to plow state-owned highways, so we were most interested in survey responses from agencies that use those types of trucks. Because respondents might answer some questions differently depending on their equipment, we included this question to allow us to filter out any respondents who only used pickup trucks, tractors, or similar vehicles for plowing, if necessary based on the number of respondents with these vehicles. Nearly all respondents (98%) reported using heavy trucks or dump trucks for plowing, which confirmed that our survey was sent to agencies with appropriate equipment.

### Maintenance costs

**Question text: 2. To what extent does icing and fogging contribute to vehicle maintenance costs at your organization? (1 = Does not contribute to vehicle maintenance costs; 5 = Significantly contributes to vehicle maintenance costs.)**

Most respondents felt icing and fogging did not contribute significantly to vehicle maintenance costs. Of those who rated their contribution's significance, 56% rated it a 2 and 27% rated it a 3.

Some strategies used to address icing and fogging may lead to increased vehicle maintenance costs. As mentioned on page 16, air conditioning systems require additional maintenance. In their responses to Question 13 on Page 2 of the survey ("Do you face any obstacles to implementing any of the strategies above...?"), several respondents mentioned maintenance as a factor, but respondents did not

## RESPONDENTS' VIEWS

### More comments on process issues:

"For VDOT it would have to be approved by the equipment division to be added to our fleet for any such 'add on' or upgrade to be made to modify equipment. Solvents or fluids would have to be added to our inventory systems."

"VDOT Specifications limit our input."

"Any additions have to be approved by the Equipment and Safety divisions."

"MoDOT General Service set the specs for our fleet and we have never been offered the option to get vertical wipers but I think they would be an asset."

specify which strategies were affected. (See Appendix E for details.)

## Windshield replacement

**Question text: 3. During the time your organization owns a typical truck used for snowplowing, about how often do you replace the truck's windshield?**

Maintenance trucks often work under rough conditions—depending on the agency, a snowplow truck may also be used in construction and maintenance areas during warmer months, and during winter a plow may encounter ice chunks, rocks and other debris that can be thrown into the windshield, leading to cracks, pitting and breakage. Windshields can also be scratched by abrasives such as sand.

Respondents were divided in how often truck windshields are replaced at their agencies. Of those who gave a response other than “don’t know,” 27% said every 1-2 years and 27% said every 3-4 years. In addition, 18 people (20%) checked “other” and gave an answer similar to “whenever it is damaged,” sometimes also indicating that this occurs fairly rarely, and 17% said every 5 years or more.

We asked respondents about the frequency of truck windshield replacement at their organization in order to help us understand which windshield solutions would be practical for most agencies to implement. (The more often windshields are replaced, the less cost-effective it would be to purchase a more expensive windshield designed specifically to address fogging or icing.)

## Spending on effective solutions

**Question text: 4. About how much per truck would your organization consider spending on a product that effectively addressed icing or fogging (either as an aftermarket purchase or added to the price of a new truck)?**

Agencies have limited resources, and many competing needs within maintenance budgets. The amount of money an agency spends on strategies to address icing and fogging may depend on overall funds available, the severity of the problems at that agency, and other factors.

Most survey respondents reported that their organization would consider spending less than \$500 on a product that effectively addressed icing or fogging, and nearly all respondents put their spending levels at less than \$1,000. Of those who specified an amount, 36% said their organization would spend \$250 to \$499, and 34% put the amount at under \$250. Another 23% said their organization would spend \$500 to \$999.

Similar to the previous question, we asked this question to help us understand which solutions would be practical for most agencies to implement.

## Effectiveness of newer vs. older trucks

**Question text: 5. In your experience, are newer trucks more effective than older trucks at addressing icing or fogging?**

Truck design and available options have improved steadily over the years, and

some improvements directly address icing and fogging. Some options have been added over the past few decades, such as heated mirrors and heated windshields, and manufacturers have improved existing features, such as ventilation systems. Many agencies have a mix of older and newer trucks in their fleets, and replace older trucks as needed and as their budgets allow.

Most respondents felt that newer trucks more effectively address icing and fogging problems. Of those who gave a response other than “don’t know,” 76% said newer trucks were better. The most commonly cited improvements available on newer trucks were enhanced HVAC systems, including better heaters, defrosters and air conditioning, with 65% of those who said newer trucks were better mentioning those systems. Heated mirrors were the next most common improvement mentioned (cited by 33%). Respondents also mentioned windshields (heated and curved), wipers (heated, vertical and providing better coverage), truck design (more aerodynamic and with cowlings that allow more runoff), and power windows.

Respondents’ answers to this question helped us understand which problems had been substantially addressed by recent improvements to trucks’ design, and which are still in need of solutions.

## **Deflector attachments**

**Question text: 6. About what percentage of your organization’s snowplows have a deflector attachment at the top of the plow to keep snow from blowing over the plow and landing on the truck?**

As explained in Section 3.2.5, a deflector attachment is a strip of stiff rubber, metal, plastic or other material that is bolted to the top of the plow to prevent plowed snow from blowing over the top of the plow and obscuring the driver’s vision. Most respondents reported that a large percentage of the trucks at their location had deflector attachments. Of those who gave a percentage, 58% said that 100% of the trucks at their location had the attachments, and 13% said that 75% did. Another 11% said that only 25% of their trucks had deflectors. Three respondents mentioned that their agencies use plow flaps that hang down the front of the plow rather than deflectors.

## **Air conditioning**

**Question text: 7. About what percentage of the trucks that your organization uses for snowplowing have air conditioning?**

As described in Section 3.2.1, using air conditioning can be a fairly effective method of addressing interior fogging, but many agencies have not used this strategy, and the use of air conditioning has disadvantages as well, which may outweigh its benefits for some agencies.

Survey respondents gave a range of answers to the question of what percentage of their agency’s snowplow trucks have air conditioning. The most common responses were 25% and 100%, but all answers got a fairly similar number of replies. Two respondents mentioned that their agency had air conditioning on its newer trucks.

**Question text: 8. Is air conditioning offered as a standard feature on the make and model of heavy truck that your organization purchases most often?**

Nearly all respondents (96%) said air conditioning was available on the truck their agency purchases most often, either as a standard feature (59%) or through special order (36%).

Respondents' answers to this question helped us understand the viability of air conditioning as a solution to interior fogging. Air conditioning appears to be widely available, so this should not be an obstacle to agencies that wish to try this solution. One respondent mentioned that air conditioning has been available on trucks purchased by his agency only in the last few years.

### **Other comments**

**Question text: 9. Please use this space to provide details on any of the answers you gave above, or to provide any other comments about truck features that affect icing and fogging.**

Respondents identified a variety of issues in their answers to this question, including a few who reiterated their use of air conditioning and its effectiveness. One respondent mentioned that his agency continually looks for ways to improve truck design, emphasizing safety in these improvements. Other comments addressed heated mirrors; age of fleet ("All trucks ordered after 2000 have air conditioning. We have trucks in our fleet that are 22 years old."); effectiveness of newer trucks; new product testing; windshield replacement (the respondent said they are no longer used "as often because sand is not used in the operation anymore"); and deflector attachments ("still need to be enhanced").

## **3.4 Manufacturer Survey Results**

As mentioned in Section 2.3.2, we had very little participation in the manufacturers' survey—only 5 people responded, and one of those respondents checked "don't know" for all questions that he answered, which leaves 4 usable responses. This sample size is too small to yield meaningful survey results, but we provide a summary of the responses below, citing raw numbers rather than percentages.

One of the 4 respondents works for a truck manufacturer (Mack), while the other 3 respondents work for equipment manufacturers (Wiper Shaker, Everblades heated windshield wipers, and Nartron Corp., which manufactures the ClearFast heated washer fluid system). The full text of their responses to the open-ended questions is given in Appendix E.

### **Severity of problems**

In general, respondents felt the problems addressed in the survey were fairly significant for snowplow drivers, especially windshield icing and ice buildup on windshield wipers. Excluding "don't know" answers, the four respondents gave the following answers in rating the significance of each of the problems:

- **Icing on exterior (side) mirrors:** two respondents rated this a 5 ("extremely significant")

- **Icing on exterior surface of windshield:** four respondents rated this a 5 (“extremely significant”)
- **Icing on exterior of side windows:** one respondent rated this a 3, one rated it a 5
- **Ice buildup on windshield wipers:** four respondents rated this a 5 (“extremely significant”)
- **Fogging on interior surface of windshield:** one respondent rated this a 3, one a 4, one a 5
- **Fogging on interior surface of side windows:** one respondent rated this a 3, one a 5

## Current solutions

The equipment manufacturers who responded described their products (the Shaker system, Everblades, and ClearFast), and the Mack representative listed heated windshields and heated wiper blades as solutions available on Mack trucks. See Appendix E for more information.

University of Nevada-Reno investigators are studying the feasibility of using a high-speed air blower to blow falling snow off and away from snowplow windshields.

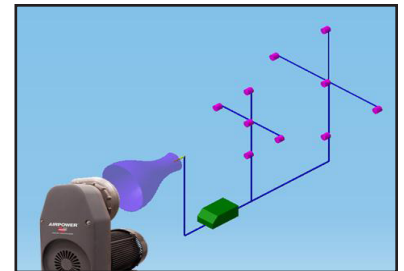
## Section 4: Related Research and Solutions

During our research, we identified several projects that address topics related to improving visibility for snowplow operators and minimizing blow-over. Among the most relevant is a project in progress at Nevada DOT, which is exploring the use of a high-speed air blower to keep snow off windshields.

### 4.1 Research in Progress

Nevada DOT/University of Nevada-Reno, “Winter Maintenance Improvements,” expected completion in late spring 2007.

Nevada DOT is sponsoring a research project that has two objectives: to improve the field of vision of snowplow operators and to improve the visibility of snowplow trucks to other drivers. A team of University of Nevada-Reno investigators is pursuing several avenues to address these problems, including studying the feasibility of using a high-speed air blower to blow falling snow off and away from the windshield. Tests and numerical modeling will determine the power necessary and the proper nozzle design for a cost-effective system. (See <http://www.energy.unr.edu/Blowers.htm>.)



Concept drawing of high-speed air blower (photo from University of Nevada-Reno Web site).

This project is also exploring options for improving visibility through lighting. To address snow buildup on taillights and decrease the size of the snow cloud in the plow's wake, researchers are using Computational Fluid Dynamics modeling to identify the most efficient rear airfoil design for NDOT trucks. The design selected will be considered by NDOT for field testing. The research team is also investigating a collision warning system that uses radar to detect obstacles and vehicles in the snowplow's path in low-visibility conditions such as snowstorms.

A summary of this research project is available at <http://www.energy.unr.edu/>.

**Iowa State University** (Center for Transportation Research and Education), Concept Highway Maintenance Vehicle project  
<http://www.ctre.iastate.edu/research/conceptv/phase5/>

Initiated in 1995, this multiphase research project creates prototype snowplow vehicles with state-of-the-art equipment for field testing. Clear Roads is sponsoring Phase V of the project, which focuses on identifying and testing snowplow features that would help plows clear the roadway in one pass at speeds within 10 mph of traffic speed, reduce the amount of snow residue left behind the plow, and minimize blow-over.

The Clear Roads project team recently held a charette with CTRE researchers to

determine the desired capabilities for a concept highway maintenance vehicle and predict the feasibility of assembling prototype vehicles. Charette observations included:

- It is difficult to avoid a cloud when plowing dry snow. Attendees mentioned a curved underbody plow with a cover; and noted that light, fluffy snow will pack under a truck with an underbody blade, and that wet snow will come off in a “rooster tail” shape.
- Attendees felt there was a need for more work on aerodynamics in front of the plow to address blow-over. They noted that snow pack can plug radiators and air intakes, which will slow trucks down, and that trucks will run out of horsepower above 45 mph.
- Attendees mentioned that rotating the plow blade forward allows for plowing at higher speeds (50 mph in Bedford, Iowa).

New ideas to reduce blow-over included injecting brine up front to hold down the plume, spraying the cloud, and spraying the roadway in front. Brine injection is expected to be part of both concept vehicles, to be tested this winter in Indiana and Iowa (the Iowa vehicle will use an underbody plow).

## 4.2 Completed Research

### 4.2.1 National Research

**NCHRP Project 6-12**, “Improved Visibility for Snow Plowing Operations,” November 2000, Research Results Digest 250.

[http://gulliver.trb.org/publications/nchrp/nchrp\\_rrd\\_250.pdf](http://gulliver.trb.org/publications/nchrp/nchrp_rrd_250.pdf)

This research identified and evaluated several snowplow features that have the potential to improve visibility. Conclusions included:

- Front plows, or front plows used with plow-mounted deflectors, with a trap angle of about 50 degrees will reduce the amount of material blown over the plow and onto the windshield.
- Front plows equipped with packing flaps at the discharge ends of the plow reduce the size of the snow cloud around and behind the snowplow vehicle.
- When wing plows are used, closing the gap between the front plow’s discharge end and the intake end of the wing plow will reduce the size of the snow cloud around and behind the snowplow vehicle.

**SHRP-H-673**, “An Improved Displacement Snowplow,” University of Wyoming, May 1994.

<http://trb.org/publications/shrp/SHRP-H-673.pdf>

This SHRP project focused on improving snowplow design to reduce energy consumption during plowing. One page references that a “large-radius upper mold-board” tends to decrease blow-over (see page 59 of the PDF).

**Other state and federal research projects have evaluated the best trap angles to reduce blow-over, and the effectiveness of plow deflectors.**

## 4.2.2 State Research

**Wisconsin DOT**, Wisconsin Winter Concept Vehicle, November 2002

During the 1999-2000, 2000-2001 and 2001-2002 winters, eight counties in Wisconsin were involved in a concept vehicle testing project that evaluated new equipment and technology for snowplow vehicles under actual winter conditions. A front plow snow shield (plow deflector) to reduce blow-over was among the technologies tested during this project. All but one of the counties that tested this strategy gave it an A or B (based on an A through F rating scale, where A indicates most effective); see page 19 of the PDF at [https://trust.dot.state.wi.us/extntgtwy/dtid\\_bho/extranet/winter/reports/pdf/conceptvehicleiiifinalreport1102.pdf](https://trust.dot.state.wi.us/extntgtwy/dtid_bho/extranet/winter/reports/pdf/conceptvehicleiiifinalreport1102.pdf) (this strategy is referred to as “front snow plow foil” in the chart). (Access to this page requires a State of Wisconsin user ID; you may obtain a free account at <https://trust.dot.state.wi.us/WAMS/SelfRegistration>.)

## 4.2.3 Automobile Industry Research

**Visteon Corp.**, “Combining CAE and Experimental Techniques to Develop Optimal Defrost/Demist Performance in a Vehicle,” SAE Technical Paper Series, 2004.

[http://www.visteon.com/utis/whitepapers/2004\\_01\\_1506.pdf](http://www.visteon.com/utis/whitepapers/2004_01_1506.pdf)

This paper briefly introduces the key technical requirements for good defrost and demist performance in automobiles, highlighting the importance of optimizing the airflow over the windshield and other glass surfaces. The paper describes a laser-based methodology for rapidly and accurately measuring the velocity of air flowing up the windshield or across the front side windows.

## 4.3 Other solutions

In addition to researching solutions to icing and fogging that are currently available for snowplow vehicles, we investigated strategies used by other industries to address these problems and similar visibility issues. Our goal was to determine if any of these strategies could be applied to trucks used for snowplowing, either directly or with modifications as part of future research. We researched solutions in the automotive, aviation and farm industries.

We also identified a new technology in development by a Dartmouth College professor that changes the adhesion properties of ice to surfaces such as windshields, allowing it to be removed instantaneously with an electric pulse. Several companies are developing the technology for use in vehicles and other applications.

### 4.3.1 Automotive

Since cars face many of the same challenges from snow and ice buildup that snowplows do, several automobile manufacturers have implemented technologies designed to address these problems. We identified heated windshields and improved wiper systems from several manufacturers. Some systems are available as part of OEM specifications for certain vehicles, and the Heated Windshields section below describes several automotive glass manufacturers' offerings in this category.

### Heated windshields

#### Glass manufacturers

**PPG Industries:** PPG's Sungate WeatherMaster windshield uses a proprietary transparent coating that can be heated to melt ice and snow, and provides fast clearing of mist and fog. PPG says the heated windshield melts ice in about one-quarter of the time of a hot-air defroster system. The windshield temperature can be set just above freezing to eliminate ice buildup, or just above the dew point to prevent interior fogging.

The Sungate WeatherMaster windshield has a transparent multilayer metallic coating applied to one of the glass plies in the laminate. Current flows through the coating via electrical connectors attached to the upper and lower glass edges. The coating acts as a transparent resistor, heating up the glass surface.



Sungate WeatherMaster heated windshield from PPG (photo from PPG Web site).

The windshield requires a 42-volt electrical system, higher than is typically found on snowplow trucks; PPG says this can be provided by a voltage converter. See [http://corporateportal.ppg.com/na/oemglass/Information/ProductsandServices/SungateWindshield/sungate\\_weather.htm](http://corporateportal.ppg.com/na/oemglass/Information/ProductsandServices/SungateWindshield/sungate_weather.htm).

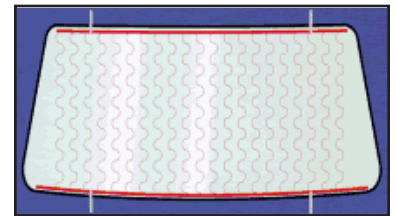
**Pilkington PLC:** Pilkington's Hotscreen incorporates fine wires that the company says can deice a frozen windshield at  $-5^{\circ}\text{C}$  within two minutes.

Several automobile manufacturers have implemented technologies designed to address icing and fogging on windshields, including heated windshields and improved wiper systems.

Pilkington is also developing a coated heated windshield that provides both deicing and anti-fogging properties. See <http://www.pilkington.com/Automotive+International/products/visual+comfort.htm>, or e-mail [pilkauto@pilkington.com](mailto:pilkauto@pilkington.com).

**Asahi Glass Co.:** Asahi offers an electrically heated windshield for 42-volt systems that uses a transparent conductive coating on the inside of laminated windshield glass for deicing and defogging. As in PPG's windshield, the coating is heated as an electric current passes through it. See <http://www.agc-automotive.com/english/global/technology10.html>, e-mail [sales@us.agc-automotive.com](mailto:sales@us.agc-automotive.com), or call (248) 324-1042.

**Saint-Gobain:** Specifically for trucks, the SGS Icecontrol heated windshield is constructed of safety glass laminated with a film containing invisible heating filaments, either throughout the surface of the windshield or on the bottom few inches, near the wipers. The system combats both icing and fogging. See <http://www.saint-gobain-sekurit-transport.com/camion/safety/#2>, or e-mail [SGSekuritTransport@saint-gobain.com](mailto:SGSekuritTransport@saint-gobain.com).



SGS Icecontrol heated windshield from Saint-Gobain (image from Saint-Gobain Web site).

### Automobile manufacturers

**Land Rover:** The LR3 offers optional heated front windshields and washer jets as part of the Cold Climate Package. See <http://www.landroverusa.com/us/en/Vehicles/LR3/Vehicle%20Features/Exterior%20Features.htm> (scroll to the bottom of the page to the "Heated Windshields and Mirrors" heading).



Heated windshield on the Land Rover LR3 (photo from Land Rover Web site).

**Ford/GM:** During the 1990s and possibly earlier, Ford made a heated windshield called InstaClear, and GM offered one called ElectriClear. We couldn't find any current references to these windshields online, but one undated article from a Libbey Owens Ford employee newsletter describes the development of the ElectriClear: <http://www.netw.com/~dilworth/news3.htm>. According to the article, the windshields contained a conductive metallic film a millionth of an inch thick that drew power from the car's electrical system.

### Windshield Wipers

**Mercedes-Benz:** The 2004 Mercedes-Benz C-Class introduced the aero windscreen wiper, which uses a new design to prevent icing. The wiper is made from a single-section rubber strip with an integral spoiler and sprung rails positioned on the outside, allowing the wiper to adjust to the curvature of the windshield. The sprung rails distribute even contact pressure over



New wiper design on the Mercedes-Benz C-Class (photo from [www.auto-innovations.com](http://www.auto-innovations.com)).

the length of the wiper blade, maximizing the contact force at all points on the blade. The new design eliminates the conventional holder system, which can trap ice. See <http://www.conceptcarz.com/vehicle/z7731/default.aspx>.

**Acura:** The 2006 Acura MDX features a Touring Package that includes rain-sensing front windshield wipers. A sensor located on the windshield behind the rearview mirror monitors the amount of rain on the windshield and adjusts wiper speed accordingly. The wiper system also uses single-piece wiper arms, and fluidic nozzles with a large orifice that dispenses washer fluid over greater surface area and are less likely to clog than a conventional nozzle. See <http://www.hondanews.com/CatID3028?mid=2005090149601&mime=asc>.

### 4.3.2 Aviation

Keeping windshields clear of ice and fog is extremely critical on an aircraft, so we investigated the aviation industry's solutions to these problems. We concluded that solutions exist for aircraft that are quite effective, but generally would not be cost-effective for snowplow trucks, especially given the likelihood that a snowplow windshield would need to be replaced during the life of the truck. Two systems commonly used for deicing aircraft windshields are heated windshields and deicing fluid spray bars.

**Heated windshields:** Perkins Aircraft Services makes heated windshields for aircraft. We spoke with a company representative, who said the industry standard is to use heated windshields constructed either with very fine embedded wires or coated with gold. These heated windshields are very effective at maintaining visibility and keeping snow and ice off, but they are expensive—\$10,000 to \$15,000 for embedded wire windshields and more for gold-coated ones. The representative knew of no one doing research or development toward new solutions in this area. See <http://www.perkinsaircraft.com/>.

PPG Aircraft Products also offers four types of heated windshields—three using tin oxide coatings and one using embedded wires. See [http://www.ppg.com/gls\\_ppglass/aircraft/heating.htm](http://www.ppg.com/gls_ppglass/aircraft/heating.htm).

**Heated windshield strips:** Maine Aviation Sales offers a heated windshield strip as an aftermarket accessory for Cessna planes that covers a portion of the plane's windshield. The company's Web site doesn't explain how it works, or whether it heats the entire windshield or if the pilot just looks through the strip. See <http://www.maineaviationsales.com/windshield/>.



Heated windshield strips for Cessna planes from Maine Aviation Sales (photo from company Web site).

**Deicing fluid applications:** Weeping Wings produces the TKS system for deicing aircraft windshields, wings and other equipment. On propeller-driven planes, the propeller "flings" deicing fluid onto the windshield. The system also applies deicing fluid to the leading edges of the aircraft through small holes in titanium pipes, allowing the airflow to distribute the fluid over the wings and other parts. See <http://www.weepingwings.com/>.

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## RESPONDENTS' VIEWS

Given the use of the propeller to apply fluid to the aircraft windshield, it seems impractical to adapt this product to snowplow trucks. However, some type of uniform application of deicing fluid to snowplow windshields (as opposed to through the washer fluid system) might be effective.

### 4.3.3 Farm

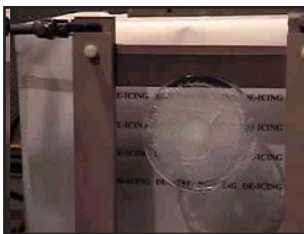
At the suggestion of Iowa DOT's winter equipment committee, we researched combine vacuums used by the farm industry to remove dust and debris before it reaches the equipment's windshield. Our objective was to investigate how a combine vacuum works to see if a similar principle could be used to prevent snow from reaching the windshield of a plow truck.

We found a few references online to an aftermarket product made for John Deere combines, the E-Z View Dust Eliminator, which attaches to the combine's feeder housing. We were unable to find pictures of this device, and from the description it is difficult to tell whether this would be applicable to snowplows. It appears to be designed to deal with dry dust and debris, whereas the consistency of snow is quite variable. (See <http://www.patentstorm.us/patents/6036600-fulltext.html>.) We were unsuccessful in reaching the inventor.

### 4.3.4 Other Systems in Development

#### ICE Technology

An intriguing system in development uses low-wattage electrical systems to mod-



Demonstration of ICE Technology (photo from Torvec Web site).

ify the adhesion properties of ice to surfaces such as windshields. A thin, electrically conductive film applied to the windshield's surface is heated with a milliseconds-long pulse of electricity. With this method, only a micrometer-thin layer of ice directly at the ice/material interface is heated, without having to heat the entire windshield or melt the full thickness of the ice. Depending upon the system, ice can be intermittently removed, kept continuously at bay, or merely loosened in preparation for mechanical removal.

This technology was invented by Dartmouth College physicist Victor Petrenko. Several applications of the technology are in development through Petrenko's company, Ice Engineering, and several other companies. Automotive windshield applications are being developed through Torvec Inc. More information is available at the following links:

- Dartmouth Web page: <http://engineering.dartmouth.edu/thayer/research/ice-engg.html> (scroll to "De-icing the world" heading)
- Ice Engineering Web site, Technology section: <http://www.iceengineering.com/technology.html> (see video of windshield de-icing at bottom of page, right column)
- Torvec Web site, ICE Technology page: [http://www.torvec.com/products\\_ice.html](http://www.torvec.com/products_ice.html) Also see Appendix B for more information.

## Section 5: Observations and Recommendations

This research project successfully identified a range of solutions to each fogging and icing problem, including both aftermarket solutions that can be implemented quickly and longer-term solutions, such as features agencies can specify in future truck purchases. Several aftermarket solutions were rated highly by survey respondents; interested agencies can begin testing these solutions next winter as their budgets allow.

Although few solutions work perfectly under all conditions, our research results were encouraging in that there are several strategies for addressing each problem, and plow drivers and maintenance managers continue to search for better solutions. During our research, we never encountered a maintenance professional who said “There’s no way to fix that.”

Some of the strategies that those we interviewed and surveyed have had success with included:

- **Interior fogging:** Air conditioning to dry the air; aftermarket accessory fans to increase airflow
- **Ice and snow on windshields:** Plow deflectors and other modifications, standard heating/defrosting system to melt buildup, chemical glass treatments, washer fluid solutions, heated windshields
- **Ice and snow on side windows:** Power windows (especially for passenger side) to clear buildup
- **Blow-over:** Plow deflectors, plow flaps, hood-mounted wind deflectors, larger plows with appropriate curvature, adjusting plow angle
- **Ice buildup on windshield wipers:** Winter-grade wipers, heated wiper blades, vertical or top-mounted wipers, aftermarket accessories that mechanically remove buildup
- **Icing on side mirrors:** Heated mirrors

As agencies replace their existing maintenance trucks over the coming years, some icing and fogging problems may begin to diminish. Survey responses indicate that newer trucks are better than older trucks at addressing several problems—better ventilation systems decrease both icing and fogging, and the heated mirrors that are standard equipment on many new trucks have been extremely effective at addressing ice buildup on mirrors. Agencies and manufacturers continue to develop new solutions to icing and fogging problems, from small tweaks made to existing equipment to fundamental technology changes like the ICE Technology in development by a Dartmouth College professor.

The strategies identified in this research can become more widespread if maintenance managers who are ordering new trucks are vocal about requesting icing and fogging solutions from truck and equipment manufacturers. We hope this research project will help raise the visibility of icing and fogging issues in the winter maintenance community, and convey to manufacturers that there is a substantial market for solutions to these problems.

In addition, we recommend that those who set specifications for winter maintenance

Although few solutions work perfectly under all conditions, there are several strategies for addressing each problem, and plow drivers and maintenance managers continue to search for better solutions.

nance equipment at state agencies regularly solicit input from plow drivers and regional maintenance managers about the types of problems they encounter and their ideas for solutions. Survey responses indicated that gaining approval to test new technologies is easier at some agencies than others.

The results of this project demonstrate a clear need for additional research involving controlled field tests of the most promising strategies for addressing icing and fogging problems. The research results should be shared nationally with all interested winter maintenance professionals. The Clear Roads pooled fund, which sponsored this project, maintains a Web site at [www.clearroads.org](http://www.clearroads.org) that could act as a clearinghouse for such test results.

# Appendix A

## Literature Search

CTC & Associates was asked to conduct a detailed literature search to identify current and existing research related to designs, technologies, materials and practices for keeping snowplow windshields, side and rear windows, and mirrors clean of winter precipitation such as frost, ice and fog. We conducted a detailed literature search of both traditional research and engineering sources, and of manufacturer publications and internal agency reports, to locate items that may not be immediately identifiable through online searches. We undertook the following tasks:

- Searched the Transportation Research Board Web site, including the TRIS Online and Research in Progress databases, to identify completed and uncompleted research projects focused on the fogging and frosting problem in winter maintenance vehicles.
- Reviewed the Web sites of the following state DOTs for research that may not be included in TRIS or Research in Progress: Illinois, Iowa, Michigan, Minnesota, Montana, North Dakota and Washington.
- Reviewed the CD Compendium of Papers from recent TRB Annual Meetings for pertinent papers.
- Reviewed the online databases of truck, glass and side view mirror manufacturer trade associations in the United States, Canada and Britain for pertinent research and products.
- Reviewed Web sites and published information from major truck manufacturers and automotive HVAC equipment manufacturers for pertinent technical reports.

We identified 12 **Products** having application to the problem, including exterior glass treatments (brush-on and spray-on), heat-enhanced items (side view mirror heads, windshield washer fluid systems and wipers), “slap” windshield wipers that shed snow and ice buildup, and vertical wipers that sweep horizontally and improve visibility. We also identified four **Research and Development** reports that have application to the problem:

- A technical paper from Visteon Corporation briefly introduces the key technical requirements for good defrost and demist performance.
- NCHRP research identifies and evaluates in limited field tests several potential features for improving visibility.
- A snowplow Lane Awareness System study performed by the University of Iowa identifies window fogging and icing in snowplow cabs as a significant safety issue, and recommends better defrosting capabilities for windshield and side windows.
- An article from the Jacobs Sverdrup company describes efforts to design and develop a full function, windshield defrost area measurement system using vision hardware and LabVIEW application software.

## PRODUCTS

### Defog/Demist System

#### **Auto Defog/Demist System - Visteon Corporation**

[http://www.visteon.com/products/automotive/auto\\_defog.shtml](http://www.visteon.com/products/automotive/auto_defog.shtml).

This system enhances windshield visibility by alleviating the occurrence of window fogging. It monitors interior humidity, predicts misting conditions, and takes preventive action before mist is visible. Input from the humidity sensor is used to automatically adjust interior temperature with use of "closed loop feedback." We contacted Visteon to learn whether this system could serve to reduce interior window fogging and frosting in snowplow cabs under very cold conditions. Visteon told us that the Defog/Demist was designed for an automatic climate control unit and not as a stand-alone system. “Additionally, with the exception of those products offered through our aftermarket portfolio ([www.evisteon.com](http://www.evisteon.com)), Visteon's products are offered exclusively to vehicle manufacturers for high volume applications. However, it is the understanding of the technical community that there are fuel-fired heater aftermarket installation kits for heavy trucks that provide this level of functionality, but these are not supplied by Visteon.”

## **Glass Treatments**

### **Clarity Defender auto glass treatment - Nanofilm Ltd.**

<http://www.nanofilm.cc/>

Click on: VIDEOS – Clarity Defender – your connection speed.

Nanofilm Ltd., Ohio, was founded in 1985 to develop and commercialize ultra-thin films, or “nanofilms,” to enhance the durability, clarity, ease of use and performance of transparent materials. The company has developed a brush-on, liquid treatment for exterior vehicle glass – Clarity Defender – to repel rain, snow, ice and most other liquids. While the product enters a market already occupied by similar products selling for less, Clarity Defender was formulated to remain effective for nearly a year following application, compared to about three months for similar products.

### **Ice-MC spray - SHH Company, LTD.**

Alcohol-based Ice-MC spray is designed to prevent ice and frost from forming on windshields, and will dissolve ice and frost that has already formed. Can also be used on windows, headlights and taillights. Applications include stopping misting and fogging on windows and thawing frozen locks. Contact SHH (<http://www.shh-chem.com/>) for more information about the product and availability.

### **Rain-X - SOPUS Products**

<http://www.rainx.com/BB/default.htm>

Click on: Products.

- Original Glass Treatment is formulated with a transparent polymer that fills the microscopic pores of glass with hydrophobic molecules. Reduces the adhesion of sleet and snow to vehicle exterior glass surfaces. Easily applied.
- Windshield Wax reduces the adhesion of sleet and snow.
- Anti-fog prevents fogging of interior glass and mirrors.
- Deicer Windshield Washer Fluid removes frost, light snow, ice and salt. Reduces ice buildup on windshields, provides freeze protection to minus 25 degrees Fahrenheit.

## **Heated Side View Mirrors**

### **Heated West Coast-style mirror heads - Sure Plus Manufacturing Company**

<http://www.sureplus.com/products/westcoast.htm>

This company has been producing truck mirrors since 1963. Their West Coast series features several models with sealed heating units to withstand moisture. The heating unit electric draw for the 7430, 7440 and 7500 models is 3.2 amps at 12 Volts, 38 watts at minus 20 degrees Fahrenheit, and 26.5 watts at 75 degrees Fahrenheit.

## **Heated Washer Fluid**

### **HotShot glass cleaning systems - Microheat**

Microheat, headquartered in Michigan, develops, manufactures and supplies intelligent hot fluid systems for vehicle manufacturers and the aftermarket. The company’s HotShot systems rapidly heat washer fluid to clear and deice windshields, windows, headlights and radar sensors. The HotShot product line includes:

- HotShot for windshields ([http://www.microheat.com/Products\\_Windshield.asp](http://www.microheat.com/Products_Windshield.asp)). Produces heated washer fluid in about 30 seconds and automatically sprays it onto the windshield. Removes ice, snow and frost, unblocks frozen nozzles and releases stuck wipers. A compact unit weighing just over one pound, HotShot is installed in the vehicle’s engine bay and then connected to the existing washer reservoir tubes and the battery. The device is controlled from a separate fluid heater on/off switch placed on the dashboard or integrated into existing switches.
- HotShot for rear windows ([http://www.microheat.com/Products\\_rear.asp](http://www.microheat.com/Products_rear.asp)). Factory installed. Hot fluid on the rear windshield defogs and removes frost, ice or snow.
- HotShot for headlights ([http://www.microheat.com/products\\_Headlights.asp](http://www.microheat.com/products_Headlights.asp)). Today’s headlight systems stay cool -- snow and sleet just stay put on the lights. This factory-installed system clears and cleans headlights.
- HotShot for radar ([http://www.microheat.com/products\\_Radar.asp](http://www.microheat.com/products_Radar.asp)). The HotShot Radar unit automatically cleans and deices adaptive cruise control sensors for optimal functioning.

### **SmartWash™ windshield washer system - Valeo**

<http://www.valeo.com/automotive-supplier/Jahia/lang/en/pid/53>.

Valeo claims that this autonomous and automatic washer fluid heating system fits all vehicle types and is easily installed between the pump and washer nozzles. Fluid is hot and ready for use one minute after vehicle ignition and reaches the jets at about 149 degrees Fahrenheit. SmartWash™ defrosts the windshield and eases ice removal.

### **Heated Windshields**

#### **Fine Wire Heated Windshield - Visteon Corporation**

[http://www.visteon.com/products/automotive/heated\\_windshield.shtml](http://www.visteon.com/products/automotive/heated_windshield.shtml).

Fine Tungsten wire components embedded in the windshield are energized by the vehicle's electrical system and conduct heat to the glass, clearing windshield of ice, frost, snow and other moisture. Produces an even defrost pattern, and offers a 50 percent reduction in defrost time compared to conventional forced air windshield defrosters – approximately 13 minutes vs. 30 minutes (test conditions: 0 degrees Fahrenheit and .02 inches of ice at 12.2 volts). Operates within normal 12-volt electrical system and capable of higher voltage architectures. Ford Motor Company and Visteon are partnering to offer the Fine Wire Heated Windshield as optional equipment for the 2007 Explorer, Explorer Sport Trac and Mountaineer SUVs, and Ford truck programs have shown an interest in the windshield. For more information about the windshield contact Jeff Bourque, Visteon Glass Operations, at [JBOURQU1@visteon.com](mailto:JBOURQU1@visteon.com).

### **Strip Heaters**

#### **Staying Safe and Warm All Winter Long**

Metro, Vol. 99, Issue 7, September 2003

[http://www.metro-magazine.com/t\\_featpick.cfm?id=90506244](http://www.metro-magazine.com/t_featpick.cfm?id=90506244).

This article reviews some heat-using devices that can help bus operators maintain smooth operations under cold, snowy and icy conditions. Among the items profiled are Caloritech strip heaters, manufactured by CCI Thermal Technologies Inc. of Alberta, Canada. The heaters are versatile, fitting many applications, including process air heating, frost protection and surface heating.

### **Windshield Wipers**

#### **Heated windshield wiper blades - Everblades®**

<http://www.everblades.com/>.

Everblades® heated wipers have been marketed since 1986, and complement existing vehicle defroster systems to provide clearer windshield visibility during adverse weather conditions. Everblades® are claimed to reach temperatures of 150 to 190 degrees Fahrenheit, and remain free of ice buildup to outside temperatures of minus 40 degrees. The blades work on both flat and curved windshields for most vehicles including heavy-duty trucks, and are available for every wiper arm style including bayonet, saddle mount, side pin and hook. Everblades® are controlled by an illuminated, dash mounted on/off switch supplied with the installation kit, and carry a 12-month guarantee.

#### **Slap Wipers - Slap Me Company**

Contacts: Brad Thielson, product designer, 320-583-3881 (Dassel, MN); Steve Nelson, president, 507-825-5704 (Pipestone, MN).

Slap Me Wipers use air pressure to raise the wipers about eight inches away from the windshield and "slap" them back in place, causing accumulated snow and ice on the wiper to break off - without causing damage to the windshield. Minnesota DOT purchased eight sets of the wipers for its snowplow trucks at North Branch, MN for the 2004 - 2005 winter season. "The operators who got an opportunity to use them thought they were great," says Alan Lightfoot, Transportation Operations Supervisor in North Branch. "We get a very heavy snow buildup on our windshields when in a plowing operation, and we used to have to reach out through the side window and slap the wiper to get ice and snow off. Now, you just push an air button and the wiper lifts off the windshield and slaps back down, clearing the blade."

### **Vertical Wipers**

Let It Snow – Dulles Airport is Ready

Public Works, Vol. 134, Issue 10, September 2003

Article is attached to this report.

This article focuses on snowplows and relates how the Washington Dulles International Airport stayed open during a winter season that saw more than 50 inches of snowfall. The dump trucks were designed with features including vertical wipers that sweep horizontally and improve visibility, and an aluminum and fiberglass cab containing extra insulation for heat and humidity control. See pdf Page 4 of the article.

## **RESEARCH AND DEVELOPMENT**

### **Combining CAE [Computer Aided Engineering] and Experimental Techniques to Develop Optimal Defrost / Demist Performance in a Vehicle**

Visteon Corporation: C. Swales, C. Capellmann, M. Crompton, M. Matthes

SAE Technical Paper Series -- 2004-01-1506, 2004

[http://www.visteon.com/utis/whitepapers/2004\\_01\\_1506.pdf](http://www.visteon.com/utis/whitepapers/2004_01_1506.pdf).

This paper briefly introduces the key technical requirements for good defrost and demist performance, highlighting the importance of optimizing the airflow up the windshield or indeed adjacent to any other glass surface. Emphasis is placed on the description of a laser-based methodology to measure, rapidly and accurately, the velocity of the air flowing up the windshield or across the front side windows. This technique, developed and extensively employed by Visteon, is employed at all stages of the development cycle from target setting to final product verification. The authors' reference documents are cited at the close of the paper for further reading on related topics.

### **Improved Visibility for Snowplowing Operations**

NCHRP Research Results Digest 250; November 2000

[http://gulliver.trb.org/publications/nchrp/nchrp\\_rrd\\_250.pdf](http://gulliver.trb.org/publications/nchrp/nchrp_rrd_250.pdf)

pdf Page 3.

This research identified and evaluated in limited field tests several potential features for improving visibility. The features include: front plows, or front plows used with plow-mounted deflectors, with a trap angle of about 50 degrees will reduce the amount of material blown over the plow and onto the windshield.

### **Snowplow Lane Awareness System: Operator Interface Design and Evaluation**

Human Factors and Vehicle Safety Research Program, The University of Iowa, July 2002

<http://www.dot.state.mn.us/guidestar/pdf/ivihwy19/final%20report.pdf>.

This report describes the design and evaluation of a Lane Awareness System (LAS) operator interface to support 3M™ Magnetic Tape Series 2000.

Pdf Page 21: Although seemingly unrelated to the lane-monitoring task, window fogging and icing emerged as another significant safety issue. The ride-along drives clearly demonstrated how windows lacking defrosters -- or equipped with inadequate ones -- can ice up very quickly, thereby exacerbating low-visibility conditions. Window icing appeared worse in conditions where there was a crosswind and the operator was using a wing plow located on the crosswind side. Under such conditions, several drivers chose to turn the cab heat as high as it would go and to drive with their side windows down in order to see the shoulder line and/or their freshly plowed tracks. Other tactics included frequent stops to clear ice from side and front windows, a practice that can be hazardous for approaching vehicles.

Pdf Page 31: Interface design recommendations were developed based on the ride-along drives, interviews and surveys and include: (8) Provide better defrosting capabilities. "Although this recommendation does not pertain to the design of the operator interface, we consider it to be critical to snow removal operations and thought it important that we call attention to it. The fact that 80 percent of surveyed drivers reported problems with window icing and fogging indicates a significant safety problem that exacerbates low forward visibility. Vehicles need to have better defrosting capabilities for their front windshield and side windows."

See also:

Appendix C (Summary of Answers to Item #48 of Survey)

<http://www.dot.state.mn.us/guidestar/pdf/ivihwy19/append%20c.pdf>

Pdf Page 3- Improve windshield design and heating and defrosting systems.

Appendix D (Summary of Comments Made by Respondents in the Margins of the Survey)

<http://www.dot.state.mn.us/guidestar/pdf/ivihwy19/append%20d.pdf>

Pdf Page 3, Item 14- During the current winter season, did the side windows of your snowplow vehicle ice up and reduce your visibility?



## Appendix B

### Phone Interview Results

We telephoned professionals working in transportation departments, winter vehicle maintenance, truck manufacturing and sales, among others regarding the current best practices for minimizing and eliminating fogging and icing problems that compromise visibility in snowplow cabs. Everyone called in the US, save one, considers fogging and icing of the windshield of snowplows to be a problem, though to varying degrees. There are a variety of methods of combating it, though only one was considered by the user to be a solution. Several factors were identified as contributing to the problem.

#### **Statement of the problem**

Simply stated, good, clear visibility of the road, traffic, and environment outside of the snowplow cab is compromised by the presence of fog on the interior side of the windows and ice on the exterior side of the windows. Concern regarding the problem varied between being a significant annoyance that takes the backseat to other problems to “a real safety hazard.” The predominant sentiment was one of frustration. The problem is bothersome and, at times, dangerous, but obvious solutions seem missing.

The difficulties encountered, their severity and solutions, vary with the weather conditions. The causes and sources of the problems outlined in this report are intended to be a summary gleaned from the phone discussions, amounting to a summary of the understanding of the problems “from the street,” so to speak, and are not intended to be a detailed, scientific explication of the problem.

#### **I. Interior Fogging**

Fogging is a problem only on the interior windows of the cab and is most often a problem when temperatures are near freezing or in humid conditions. For instance, in Norway, interior fogging is a problem near the coasts where the air is more humid, but less of a problem in the mountains. It is also a significant problem in Missouri, where winter conditions are often close to freezing, whereas it is not as significant a problem in Minnesota where the winter conditions are colder. In addition to ambient humidity, moisture gets inside the cabs from boots and breathing of the operator, increasing the humidity in the cabs themselves, particularly with respect to the outside air. The temperature is high enough to keep sufficient water in the air to condense on the windows, which are generally colder than the average cab temperature, but warmer than the outside air. At very low temperatures, the air is too cold to hold enough water vapor to lead to a condensation problem on the windshield – the water is “frozen out” of the air. It seems to be the case that even melted snow brought into the cab from boots or the opening and closing doors is not a significant problem if the temperatures are low enough.

The solution to interior fogging in almost all cases is to combine an increase of the airflow over the windshield with drying the air itself in order to eliminate the fogging. This is sometimes managed by mounting small fans inside the cab to direct increased airflow over the problematic section of the windows. In some cases, the solution is to drive without heat, keeping the cab cold. By eliminating the temperature difference between the inside and outside of the cab, the humidity difference is also minimized and the fogging is eliminated. (This is the recommendation to drivers in Norway, and the one used, at least in the past, if not now, by U.S. operators.) Drying the air using an air conditioner/compressor as part of the defrosting is universally considered very effective in eliminating interior fogging, provided that the dry air flows over all parts of the windshield and side windows sufficiently. Poor airflow was cited as more of a problem for side windows than front windshields. It is not, however, standard procedure in all cases to purchase trucks with air conditioning. One department has purchased trucks with air conditioning only in recent years (since 2000); others still don't buy them that way routinely. It would be worth finding out if trucks are purchased routinely with air-conditioning.

In general, it seemed that interior fogging is manageable with proper heating, ventilation and air-conditioning (HVAC) systems in the trucks. This would include drying out the air, satisfactory volume of airflow, and proper direction of dry air. The question of cost, particularly regarding maintenance and

replacement will likely be a factor here. Adding air-conditioners to the systems in the trucks adds another general maintenance cost in addition to the initial cost of the system at purchase time. Also, the air-conditioners cause stress on other systems in the trucks, radiators for instance, possibly increasing the replacement frequency of those systems as well. Questions on such issues should be included in the general survey.

## **II. Exterior Icing**

Exterior icing is a more difficult problem and does not have as satisfactory a solution as the interior-fogging problem. Far and away, icing on the windshield is the biggest problem.

### **Causes and Sources**

Icing on the windshield grows as a problem as the temperatures get colder. Therefore, regions with milder winters (e.g., Missouri) have less of a problem with icing than regions with harsher, colder winters.

Generally, the center of the windshield is kept warm and free from ice by the use of standard defrosting systems (with or without air-conditioning), but the outside edges and the cowlings below have wet snow pushed onto them by the wipers. The slush of snow and water then re-freezes, building ice dams and progressively obscuring the windshield. As these dams get built up, the wipers are also affected. If the temperature is cold enough, the ice will creep across the windshield from the outside edges. This would seem to be due both to the fact that the frame of the windshield is only warmed passively via conduction of heat through the glass, therefore never getting warm enough to completely melt the ice, and because the HVAC system may not be able to warm the windshield enough in very cold temperatures. We suspect that such problems occur more frequently during nighttime plowing, when temperatures are coldest. These conditions may also be outside of the standard parameters for the HVAC systems.

There is some question regarding the source of the ice/snow. From most of our discussions, falling snow seems to be the primary source. However, in some cases, it may be that snow and ice from the roadway, tossed up by the plow itself, may also be a source. In Ontario, this seemed to be the biggest concern – keeping plowed snow off the windshield. They consider it an issue of specifying the correct equipment, not as much a problem in need of a solution. Lee Smithson, now with the American Association of State Highway and Transportation Officials, has done a great deal of work in plow design and configuration through the Concept Highway Maintenance Vehicle pooled fund studies. He also indicated that plowed snow is a big source of snow contributing to windshield icing. Given some uncertainties regarding the parameters and statement of the problem itself, we think it will be useful to ask some questions in the survey to specify the scope and character of the problem as clearly as possible.

### **Mirrors**

Icing on the exterior mirrors has been a problem in the past, but everyone questioned about it used heated mirrors to solve the problem and were pleased with the solution. Some mount the heated mirrors as an after-market addition. Others order them as OEM products when buying the trucks.

### **Wipers**

The build-up of ice on the wipers has been a problem generally addressed by using winter-grade wipers that have coverings over the flexible parts of the wiper to prevent ice build-up from stiffening them. Many people also cited positive experience with the Slap Wiper system and were planning to make them standard on their trucks. (Those that had tried them considered them effective.) It was noted that the relatively recent development of trucks with curved windshields exacerbated the problem of icing on the wipers. Some people have also tried heated windshield wipers, which were universally considered ineffective. In both these cases, according to those that order and specify the equipment, the most telling evidence of the effectiveness of a new system is whether or not the system is requested again when specifying a new truck. The Slap system is regularly re-requested. The heated wipers are not. This was also the testimony of the Monroe Truck Equipment representative.

Though not a problem with the wipers per se, some problems have been encountered with breaking wipers and wiper-systems due to ice building up below the windshield under the cowlings of the hood. This

problem cannot be addressed with the wipers themselves, but will likely be solved if the general problem of icing on the windshield is solved.

### **Windshields**

There are wide ranging solutions to the problem of ice on the windshield, though only one person we spoke with was using a solution they considered satisfactory.

The first solution is to keep the snow from sticking to the windshield by keeping the windshield cold. In this case, the operator will not use the truck's defrosting system at all, possibly even opening the windows as well. This solution is fairly effective, though we wonder if it might fail when temperatures are near freezing and the snow is generally wet anyway. This solution isn't considered satisfactory because the driver can get very uncomfortable in the cold weather, compromising safety and effectiveness in other ways than simply through decreased visibility.

The rest of the solutions are very hit-and-miss. Nothing is used uniformly. Several groups are currently trying heated windshield washer fluid and/or new concentrations of anti-icing fluid applied through the windshield washer system, though there isn't any sense yet about the effectiveness of such a solution. Vertical wiper systems were mentioned in the concept vehicle studies, but among those we called, none referred to using such a system. The use of curved windshields will likely be a problem for such a system as well. Most of those called knew of the existence of chemical glass treatments, but did not know anything regarding their effectiveness in snow/ice conditions.

The most frequently desired solution was for a heated windshield. Secondary, after-market heating systems for the windshield, like strip heaters, were essentially unknown and unexplored. Such windshields are generally not an option on trucks, and may not even be available at all – no one we spoke with has ever gotten one. One caveat regarding the heated windshield is that such a solution may not address the problem of ice build-up in the areas bordering the windshield itself – the cowl and the frame. Many people cited ice build-up in those areas as a significant, if not the primary, problem.

One creative solution we encountered is from Bon Homme County DOT in Tyndall, South Dakota (population 1,200). The maintenance people customized several of their older plows by installing a secondary windshield, applied to the inside surface of the primary windshield, essentially making a double-pane windshield. The secondary windshield itself is cut from regular safety glass and ordered to specification from a local glass dealer. They installed it themselves, attaching it with a gasket between the two layers in order to maintain an air-gap. This installation allows the outside windshield to remain cold and clear of snow, yet allowing the interior cab to be heated. According to a representative at the Bon Homme County DOT, the windshield stays clean and clear. They do get some ice-buildup on the outside edges, but don't consider it problematic. They have installed the second pane on curved windshields, but only in the flat section. They haven't had to replace the second pane once installed and have never had one fall out. Bon Homme County received the 1996 Region 8 "You Show Us" LTAP award for developing the system.

In addition to being an interesting solution to the problem, the Bon Homme County case also highlights a kind of innovation and adaptation we ran into on a couple of occasions. A handful of the DOTs have people in maintenance and engineering that are encouraged to think about and pursue in-house solutions to the problems that they encounter. The Iowa DOT stands out in this regard. They have developed in-house systems for blowing snow off of signal and tail lights that utilize the compressed air from the accessory tank used to run the air-ride seats in the trucks. They also have someone working on solving the ice-dam problem around the cowl and windshield edges by installing copper tubing to divert some of the fluid from the radiator system to melt snow and ice. The system seemed to be more in the thinking stage than the development stage, but the case only highlights, again, the power of local, in-house, innovation to solve problems. The fact that no one else uses or even mentioned the double-pane glass solution used in South Dakota points to the problem of distributing the knowledge developed by local innovators, even when some public notoriety is attached with the development.

## **Aviation**

We spoke with representatives of two companies in the aircraft manufacturing industry.

Perkins Aircraft Services, Inc. specializes in aircraft windscreens for a wide variety of aircraft. According to their representative, the industry standard is to use heated windscreens, constructed either with very fine embedded wires or coated with gold. The representative knew of no one doing research or development towards new solutions in this area. The heated windshields used in aircraft are very effective at maintaining visibility and keeping snow and ice off, however, they are extremely expensive—\$10-15,000 for embedded wire windscreens and more for gold-coated ones. Given that this price is a significant fraction of the cost of a new truck and that the windscreens on snowplows may be replaced several times in the life of the trucks, it seems like an unsatisfactory solution.

Weeping Wings, Inc. markets and installs the TKS system for de-icing aircraft wings, stabilizers, rudders, and windscreens. The system works by applying de-icing fluid through small holes in titanium “pipes” to the leading edges of the aircraft and allowing the airflow to distribute the fluid over the wings and other parts. The windscreens receive the de-icing fluid from the prop, having the fluid flung (to use their word) onto the windscreen. The windscreen de-icing system is mounted only on prop-driven aircraft. Given this, it seems unlikely that this product in particular would be directly adaptable to snowplows.

Nevertheless, it seems to be the kind of solution that might be brought to fruition through some research and development. Given their product, a more uniform application of anti-icing/de-icing fluid to the windshield of the snowplow might be more effective than applying it as standard window-wash fluid, which seems to be the current method, even for fancy wash/anti-ice fluid systems.

## **Truck Manufacturers**

We spoke with a Mike Hermanson, a representative of Monroe Truck Equipment, which provides after-market modifications for trucks, and with an engineer in charge of cab design in the Custom-Solutions division of Sterling Trucks. Neither considered the fogging/icing a problem that they are directed to by their customers. Mr. Hermanson said he’d never had a request for heated windshields but sometimes gets requests for heated mirrors. His company does less work with the chassis proper, and more work with add-ons like salt or deicing spreaders. According to Mr. Walsh, there are regulations regarding HVAC systems that determine many of the specifications for them. He was not aware of any research being done regarding the particular needs of such systems in snowplows, but seemed to doubt if there was any such work being done. According to him, the HVAC system is supposed to solve these problems. It is supposed to prevent fogging inside the cab and prevent ice on the windshield outside of the cab. We did not get into details with him regarding the particular specifications currently in use in order to determine the likelihood of whether the typical environment of a snowplow cab would be outside of them. More footwork could be done in this area, but it would be beneficial to know more about which trucks are purchased and if some models have more problems than others.

## **ICE Technology**

At the cutting-edge of research and development is a technology invented by Victor Petrenko, a physicist at Dartmouth College in New Hampshire. His research has focused on using low-wattage electrical systems to modify the adhesion properties of ice to all kinds of surfaces – both increasing and decreasing the adhesion. One product currently developed is a cross-country ski that uses the system as braking – increasing the adhesion of the ski to the snow and ice. Depending upon the system, ice can be intermittently removed, kept continuously at bay, or merely loosened in preparation for mechanical removal. The technology has been patented and is in development by Petrenko through his company, ICE Technology, and will be further developed and marketed through several other companies. Torvec, Inc. through their newly acquired subsidiary Ice Surface Development, Inc. has the distribution rights for all land-based vehicle applications. According to the company vice-president and head-engineer, John Tobias, the first work being done is the development of automotive windshields. The company is currently looking for about \$5 million in venture capital and is currently privately owned, though may go public sometime in the future. Interestingly, they also hope to develop traction systems for tires.

### **International DOTs**

We tried to contact DOT representatives in Norway, Canada, Sweden, Japan, and Finland. We were successful only with Canada and Norway. In the cases of the others, we sent multiple email messages and also cold-called them. We did not receive replies to those email messages (our messages may have been deleted by junk-mail filters) and we had difficulty getting past the official front-office answering machine by phone.

We did reach individuals in Canada and Norway. None of them considered icing and fogging to be as significant a problem as did many we spoke to in the U.S. The concern in Canada seems to be keeping plowed snow off the front of the truck. Since Canada contracts out their snow-removal, it will be necessary when sending out the survey to obtain names and numbers of the contractors. In Norway, they seem to rely on the HVAC systems in their trucks or have the drivers keep the windshield cold. They do have a secondary windshield, a circle about 40 cm in diameter, which is mounted outside the vehicle to increase visibility in snowstorms. It's not clear exactly how it works and when it comes into use. We did not pursue it in detail because it wasn't directly related to icing and fogging.

### **III. Conclusions and Speculations**

Below is a summary of our conversations from the phone interviews with regard to potential solutions.

It seems as though interior fogging problems are best solved by proper HVAC systems. When this solution is insufficient, it is because the either the system doesn't circulate enough air (essentially it is underpowered) or it doesn't circulate air in the necessary locations. It seems likely that some truck manufacturers have better systems than others in this regard.

Icing on exterior mirrors appears to be eliminated using heated mirrors.

Some individuals had success using the Slap Wiper system, though it is fairly new and not universally used.

No general solution for icing on windshields emerged other than the use of the HVAC system, which is intended to be the solution, according to at least one manufacturer, but which doesn't genuinely solve the problem according to most people we spoke with. Trials are being made of heated washer fluid and other fluid anti-icing system applied through the windshield washing system, but no conclusions have been reached. The dual-pane windshield solution seems promising but is being used, solely it seems, in Bon Homme County, South Dakota.

Any solution will need to contend with some complicated cost-benefit calculations, which vary from department to department and state to state. The fragmented nature of the market and the limited communication between DOTs, means that almost all of the generic solutions need to come through the manufacturers, who, on initial, limited inspection, don't see this as a problem.

We have the following general recommendations for the survey. First, part of the survey should clarify the dimensions of the problem itself. While not being the primary task, it is important to clarify how the problem is understood by the DOTs themselves. For instance, what are the symptoms and how frequent are they? Secondly, regardless of the results of the survey, effective follow-up will require uniformity, consistency and clarity in understanding potential solutions. This will likely take a clearly directed research project with particular parameters. It would be beneficial, for example, if such a project addressed the extent to which HVAC improvements could solve the problem, whether the double-paned window works in all cases, or whether a new technology like that being developed by Torvec, Inc. is worth pursuing.

## **Phone Interview List of Contacts**

### Transportation Departments/Winter Maintenance

Wayne Lupton, Colorado DOT  
Randy Jenson, Colorado DOT  
Rudy Persaud, FWHA-DC  
Benjamin Zwart, Minnesota DOT  
Randy Cameron, Minnesota DOT  
Norm Ashfeld, Minnesota Metro  
Tim Croze, Michigan DOT  
Dennis Belter, Indiana DOT  
Diana Evans, Ohio DOT  
Dennis Burkheimer, Iowa DOT  
Brad Osbourne, Iowa DOT, mechanical  
Jim Dowd, Iowa DOT, equipment research,  
Tim Jackson, Missouri DOT  
Bob Lannert, Missouri DOT  
Lee Smithson, AASHTO  
Randy Cameron, Minnesota DOT  
Paul Pisano, FHWA – Washington, D.C.  
Mike Einrem, Bon Homme County Road Commission, South Dakota  
Pete Garcia, FHWA

### Canada

Max Perchanok, Ontario Ministry of Transportation  
Torbin Fredrickson, equipment coordinator

### Norway

Torgim Dahl, Public Roads Admin. Norway  
Torgeir Vaa

### Japan

Yasukiko Kajiya

### Finland

Mikko Malmivuo, VTT Tech. Research

### Sweden

Jan Olander

## **Truck Manufacturing/Sales**

Mark Hermanson, Monroe Truck Equipment  
Jacob Walsh, head project engineer of cab design, Sterling Manufacturing

## **Aircraft**

Perkins Aircraft Services,  
Weeping Wings

## Appendix C

### Agency/Contractor Survey Questions and Responses

#### Page 1. Experience with Icing and Fogging

1. All survey respondents will receive a copy of this project's final report in late summer via e-mail. Please provide your name and contact information so we may send you this report.







		Response Percent	Response Total
Name	<input type="text"/>	100%	211
Organization	<input type="text"/>	100%	211
Location of organization	<input type="text"/>	100%	211
Position	<input type="text"/>	100%	211
E-mail address	<input type="text"/>	100%	211
Total Respondents			211
(skipped this question)			0

2. What type of organization do you work for?			
		Response Percent	Response Total
State DOT or provincial transportation agency	<div></div>	81.2%	169
FHWA or other national transportation agency	<div></div>	0.5%	1
County highway department	<div></div>	4.8%	10
Local government (city, township, etc.)	<div></div>	7.7%	16
Private contractor	<div></div>	2.9%	6
University	<div></div>	0%	0
Other (please specify)	<div></div>	2.9%	6
Total Respondents			208
(skipped this question)			3

3. Are you familiar with the following problems that may affect trucks used for snowplowing? (See explanations above.)

	Our drivers have experienced this problem	Aware of it, but not experienced by our drivers	Aware of it, but don't know if our drivers have experienced	Not aware of this problem	Response Total
Icing on exterior (side) mirrors	<b>87% (178)</b>	9% (18)	3% (6)	1% (3)	<b>205</b>
Icing on exterior surface of windshield	<b>94% (195)</b>	4% (8)	1% (2)	1% (3)	<b>208</b>
Icing on exterior of side windows	<b>85% (175)</b>	6% (12)	5% (10)	4% (9)	<b>206</b>
Ice buildup on windshield wipers	<b>97% (201)</b>	0% (1)	1% (3)	1% (3)	<b>208</b>
Fogging on interior surface of windshield	<b>83% (170)</b>	7% (14)	4% (8)	6% (12)	<b>204</b>
Fogging on interior surface of side windows	<b>82% (168)</b>	7% (15)	4% (9)	6% (12)	<b>204</b>
<b>Total Respondents</b>					<b>209</b>
(skipped this question)					<b>2</b>




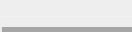
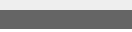
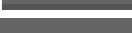


4. In your opinion, how big a problem is each of the following conditions for plow drivers?							
	Not a problem 1	2	3	4	Very big problem 5	Don't know/haven't experienced	Response Total
Icing on exterior (side) mirrors	9% (18)	15% (32)	20% (41)	27% (56)	27% (56)	2% (5)	208
Icing on exterior surface of windshield	2% (5)	8% (16)	13% (28)	30% (62)	45% (95)	1% (3)	209
Icing on exterior of side windows	4% (8)	18% (37)	23% (48)	25% (52)	27% (56)	3% (7)	208
Ice buildup on windshield wipers	1% (3)	3% (7)	7% (14)	18% (38)	67% (137)	3% (7)	206
Fogging on interior surface of windshield	8% (16)	17% (35)	26% (54)	22% (46)	23% (48)	4% (8)	207
Fogging on interior surface of side windows	8% (16)	17% (36)	23% (48)	27% (56)	20% (41)	4% (9)	206
Total Respondents							209
(skipped this question)							2

5. Ice may accumulate on windshields because of plowed snow blowing over the top of the plow, or from snow hitting the windshield as it falls from the sky. In your organization, which source(s) tend to lead to ice formation?			
		Response Percent	Response Total
Primarily plowed snow blowing over the top of the plow		23.9%	50
Primarily falling snow		6.2%	13
Both sources		65.6%	137
Not sure		1%	2
Have not experienced icing on exterior windshields at my organization		2.4%	5
Other (please specify)		1%	2
Total Respondents			209
(skipped this question)			2

6. At times, ice and snow may build up around the edges of a truck's windshield (along the sides and over the cowling). How much does this buildup contribute to windshield visibility problems in your organization?

	Don't know/not aware of problem	Does not affect windshield visibility 1	2	3	4	Significantly affects windshield visibility 5	Response Total
Ice and snow buildup around windshield edges	7% (15)	4% (8)	12% (24)	27% (56)	<b>28% (58)</b>	23% (47)	<b>208</b>
Total Respondents							<b>208</b>
(skipped this question)							<b>3</b>

7. Have you noticed a difference in icing or ice buildup on curved windshields compared with standard/flat windshields? Select all that apply.

		Response Percent	Response Total
Don't know/don't own trucks with curved windshields		20.8%	43
More icing on curved windshields		10.6%	22
Less icing on curved windshields		11.1%	23
<b>About equal icing on curved and standard/flat windshields</b>		<b>37.7%</b>	<b>78</b>
More ice buildup on wipers used with curved windshields		9.7%	20
Less ice buildup on wipers used with curved windshields		5.8%	12
About equal ice buildup on wipers used with curved and standard/flat windshields		31.4%	65
Other (please specify)		5.8%	12
Total Respondents			<b>207</b>
(skipped this question)			<b>4</b>

8. Please use the space below to give more information on any of your answers above, and to list any other problems that affect snowplow operators' field of vision.

Total Respondents		86
(skipped this question)		125

9. Are you aware of any completed research or research in progress that addresses icing or fogging on winter maintenance vehicles, including research sponsored by your organization?

		Response Percent	Response Total
No		95.1%	196
Yes (please specify)		4.9%	10
Total Respondents			206
(skipped this question)			5

## Page 2. Solutions

1. Please indicate your familiarity and experience with each of the following strategies used to address INTERIOR FOGGING.

	Our drivers have used this strategy	Aware of it, but not used by our drivers	Aware of it, but don't know if our drivers have used it	Not aware of this strategy	Response Total
Using air conditioning to dry the air	23% (44)	15% (28)	23% (44)	<b>39% (74)</b>	<b>190</b>
Adding fans to increase airflow over windows	<b>51% (97)</b>	20% (38)	12% (22)	17% (33)	<b>190</b>
Turning off heat in the cab to keep the windshield cold	<b>42% (82)</b>	15% (29)	16% (31)	26% (51)	<b>193</b>
Adding aftermarket windshield heaters	6% (12)	29% (55)	10% (18)	<b>55% (102)</b>	<b>187</b>
Total Respondents					<b>197</b>
(skipped this question)					<b>14</b>

2. Please indicate how effective drivers in your organization have found each strategy for addressing INTERIOR FOGGING.

	Don't know/haven't used	Not at all effective 1	2	3	4	Extremely effective 5	Response Total
Using air conditioning to dry the air	<b>63% (120)</b>	3% (5)	6% (11)	16% (30)	10% (19)	3% (6)	<b>191</b>
Adding fans to increase airflow over windows	<b>44% (84)</b>	1% (1)	11% (22)	29% (55)	14% (26)	2% (4)	<b>192</b>
Turning off heat in the cab to keep the windshield cold	<b>43% (84)</b>	7% (14)	14% (27)	19% (36)	14% (27)	3% (6)	<b>194</b>
Adding aftermarket windshield heaters	<b>87% (166)</b>	2% (4)	5% (9)	2% (4)	3% (6)	1% (1)	<b>190</b>
<b>Total Respondents</b>							<b>195</b>
(skipped this question)							<b>16</b>

3. Has your organization found the HVAC system on any specific makes or models of trucks to be particularly effective or ineffective at addressing INTERIOR FOGGING? Please list below.

<b>Total Respondents</b>	<b>83</b>
(skipped this question)	<b>128</b>

4. Have you encountered any disadvantages to using air conditioning on your organization's trucks (such as costs, maintenance, increased stress on radiator systems, etc.)? Please list below.

<b>Total Respondents</b>	<b>99</b>
(skipped this question)	<b>112</b>

5. Please indicate your familiarity and experience with each of the following strategies used to address icing on WINDSHIELDS.

	Our drivers have used this strategy	Aware of it, but not used by our drivers	Aware of it, but don't know if our drivers have used it	Not aware of this strategy	Response Total
Deflector attachments for p (to keep plowed snow from hitting windsh	<b>88% (171)</b>	7% (13)	4% (7)	2% (3)	<b>194</b>
Turning off heating/defrosting system in cab (to keep windshield cold and keep snow from sticking)	<b>44% (86)</b>	18% (35)	16% (31)	22% (42)	<b>194</b>
Opening side windows	<b>72% (140)</b>	7% (13)	11% (22)	10% (19)	<b>194</b>
Double-paned windshields	4% (7)	9% (18)	3% (5)	<b>84% (160)</b>	<b>190</b>
Using standard heating/defrosting system (to keep windshield warm and melt accumulated ice and snow)	<b>95% (185)</b>	3% (6)	1% (2)	1% (2)	<b>195</b>
Heated windshield washer fluid	6% (11)	34% (66)	7% (14)	<b>53% (101)</b>	<b>192</b>
Heated windshield (heated with strip heaters, embedded wires, etc.)	11% (21)	37% (71)	8% (15)	<b>45% (86)</b>	<b>193</b>
High concentrations of anti-icing fluid applied through windshield washer system	<b>39% (74)</b>	21% (40)	14% (27)	27% (51)	<b>192</b>
Chemical glass treatments	26% (51)	21% (41)	14% (27)	<b>38% (74)</b>	<b>193</b>
Vertical wiper systems	7% (14)	19% (37)	4% (8)	<b>69% (134)</b>	<b>193</b>
<b>Total Respondents</b>					<b>195</b>
(skipped this question)					<b>16</b>

6. Please indicate how effective drivers in your organization have found each strategy for addressing icing on WINDSHIELDS.

	Don't know/haven't used	Not at all effective 1	2	3	4	Extremely effective 5	Response Total
Deflector attachments for plows (to keep plowed snow from hitting windshield)	8% (15)	7% (13)	9% (18)	<b>34% (65)</b>	29% (56)	13% (26)	<b>193</b>
Turning off heating/defrosting system in cab (to keep windshield cold and keep snow from sticking)	<b>31% (59)</b>	14% (26)	20% (39)	24% (47)	10% (19)	1% (2)	<b>192</b>
Opening side windows	12% (24)	11% (21)	23% (45)	<b>39% (75)</b>	13% (26)	2% (3)	<b>194</b>
Double-paned windshields	<b>94% (181)</b>	3% (6)	1% (1)	1% (2)	0% (0)	1% (2)	<b>192</b>
Using standard heating/defrosting system (to keep windshield warm and melt accumulated ice and snow)	3% (6)	2% (4)	21% (41)	<b>37% (72)</b>	32% (62)	4% (8)	<b>193</b>
Heated windshield washer fluid	<b>92% (177)</b>	1% (1)	2% (4)	3% (6)	2% (4)	0% (0)	<b>192</b>
Heated windshield (heated with strip heaters, embedded wires, etc.)	<b>89% (171)</b>	2% (4)	2% (3)	4% (7)	2% (4)	2% (4)	<b>193</b>
High concentrations of anti-icing fluid applied through windshield washer system	<b>59% (113)</b>	4% (7)	14% (27)	15% (28)	8% (15)	1% (1)	<b>191</b>
Chemical glass treatments	<b>66% (127)</b>	5% (10)	17% (33)	8% (15)	3% (6)	0% (0)	<b>191</b>
Vertical wiper systems	<b>90% (170)</b>	3% (6)	3% (6)	3% (5)	1% (1)	1% (1)	<b>189</b>
<b>Total Respondents</b>							<b>194</b>
(skipped this question)							<b>17</b>

7. In addition to deflector attachments, are you aware of any solutions that specifically address the problem of plowed snow blowing over the top of the plow and obscuring the driver's visibility? Please list below.

**Total Respondents** **87**

(skipped this question) **124**

8. Please indicate your familiarity and experience with each of the following strategies used to address ice buildup on windshield WIPERS.

	<b>Our drivers have used this strategy</b>	<b>Aware of it, but not used by our drivers</b>	<b>Aware of it, but don't know if our drivers have used it</b>	<b>Not aware of this strategy</b>	<b>Response Total</b>
Winter-grade wipers with covers to prevent ice buildup	<b>87% (170)</b>	3% (5)	3% (6)	7% (14)	<b>195</b>
"Slap Me" wiper system (uses air pressure to "slap" wipers against windshield to clear ice buildup)	4% (7)	12% (23)	4% (7)	<b>81% (157)</b>	<b>194</b>
"Wiper Shaker" system (vibrates wipers to clear ice buildup)	2% (4)	11% (21)	3% (6)	<b>84% (162)</b>	<b>193</b>
Heated wipers	23% (45)	32% (61)	6% (11)	<b>39% (76)</b>	<b>193</b>
<b>Total Respondents</b>					<b>195</b>
(skipped this question)					<b>16</b>

9. Please indicate how effective drivers in your organization have found each strategy for addressing ice buildup on windshield WIPERS.

	Don't know/haven't used	Not at all effective 1	2	3	4	Extremely effective 5	Response Total
Winter-grade wipers with covers to prevent ice buildup	12% (24)	6% (11)	22% (43)	<b>35% (68)</b>	20% (39)	5% (10)	<b>195</b>
"Slap Me" wiper system (uses air pressure to "slap" wipers against windshield to clear ice buildup)	<b>94% (182)</b>	2% (3)	3% (6)	2% (3)	0% (0)	0% (0)	<b>194</b>
"Wiper Shaker" system (vibrates wipers to clear ice buildup)	<b>98% (190)</b>	1% (2)	1% (1)	0% (0)	0% (0)	1% (1)	<b>194</b>
Heated wipers	<b>72% (139)</b>	8% (15)	7% (14)	7% (13)	6% (11)	1% (2)	<b>194</b>
Total Respondents							<b>195</b>
(skipped this question)							<b>16</b>

10. Please indicate your familiarity and experience with each of the following strategies used to address icing on exterior (side) MIRRORS.

	Our drivers have used this strategy	Aware of it, but not used by our drivers	Aware of it, but don't know if our drivers have used it	Not aware of this strategy	Response Total
Heated mirrors	<b>95% (184)</b>	2% (4)	1% (2)	2% (3)	<b>193</b>
Airfoil attached to top of mirror to keep snow off mirror	6% (11)	18% (35)	7% (14)	<b>68% (130)</b>	<b>190</b>
Vertical wiper system integrated with anti-icing fluid dispenser	3% (6)	15% (29)	3% (6)	<b>79% (151)</b>	<b>192</b>
Total Respondents					<b>193</b>
(skipped this question)					<b>18</b>

11. Please indicate how effective drivers in your organization have found each strategy for addressing icing on exterior (side) MIRRORS.

	Don't know/haven't used	Not at all effective 1	2	3	4	Extremely effective 5	Response Total
Heated mirrors	3% (6)	0% (0)	3% (5)	8% (16)	26% (51)	60% (115)	193
Airfoil attached to top of mirror to keep snow off mirror	90% (173)	2% (4)	2% (4)	2% (4)	4% (7)	1% (1)	193
Vertical wiper system integrated with anti-icing fluid dispenser	92% (179)	2% (3)	2% (3)	3% (5)	2% (3)	1% (1)	194
Total Respondents							195
(skipped this question)							16




12. Please list any other strategies for addressing icing or fogging not mentioned above. Also, if you have details on the effectiveness, advantages or disadvantages of any icing or fogging solutions, please list below.

Total Respondents	36
(skipped this question)	175


13. Do you face any obstacles to implementing any of the strategies above (cost, maintenance, time required to install, unavailable, etc.)? Please list below, indicating which strategies are affected.

Total Respondents	87
(skipped this question)	124

14. We would appreciate receiving photos of icing and fogging solutions or documentation/specifications related to those solutions for inclusion in our final report. If you have photos or documents to share, please check "Yes" below and we will contact you.

		Response Percent	Response Total
Yes		11%	19
<input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <b>No</b>		86.6%	149
(If you prefer, you may include links to the images or more information below)		2.3%	4
<b>Total Respondents</b>			<b>172</b>
(skipped this question)			39

15. Does your job involve truck and equipment management or purchasing? (Choosing "Yes" will take you to a short page of questions on trucks and plow equipment; choosing "No" will end the survey. Please select one and then click "Next.")

		Response Percent	Response Total
Yes		48.7%	94
<input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <b>No</b>		51.3%	99
<b>Total Respondents</b>			<b>193</b>
(skipped this question)			18

### Page 3. Equipment Management







1. What types of vehicles does your organization use for snowplowing? Select all that apply.

		Response Percent	Response Total
Light trucks/pickup trucks	<div></div>	45%	45
Heavy trucks/dump trucks	<div></div>	98%	98
Earth movers/construction equipment	<div></div>	52%	52
Other (please specify)	<div></div>	12%	12
Total Respondents			100
(skipped this question)			111








2. To what extent does icing and fogging contribute to vehicle maintenance costs at your organization?

	Don't know	Does not contribute to vehicle maintenance costs 1	2	3	4	Significantly contributes to vehicle maintenance costs 5	Response Total
Icing and fogging	25% (25)	5% (5)	42% (42)	20% (20)	7% (7)	1% (1)	100
Total Respondents							100
(skipped this question)							111




3. During the time your organization owns a typical truck used for snowplowing, about how often do you replace the truck's windshield?

		Response Percent	Response Total
Never during the time we own the truck		4%	4
Every 1-2 years		24%	24
Every 3-4 years		24%	24
Every 5 years or more		15%	15
Don't know		12%	12
Other (please specify)		21%	21
Total Respondents			100
(skipped this question)			111

4. About how much per truck would your organization consider spending on a product that effectively addressed icing or fogging (either as an aftermarket purchase or added to the price of a new truck)? Values are in US dollars; please use the "Other" field to answer using another currency.

		Response Percent	Response Total
Under \$250		21.2%	21
\$250 to \$499		22.2%	22
\$500 to \$999		14.1%	14
\$1,000 to \$2,999		3%	3
\$3,000 or more		1%	1
Don't know		36.4%	36
Other (please specify)		2%	2
Total Respondents			99
(skipped this question)			112

5. In your experience, are newer trucks more effective than older trucks at addressing icing or fogging?

		Response Percent	Response Total
Don't know		17%	17
No		20%	20
Yes (please explain)		63%	63
Total Respondents			100
(skipped this question)			111

6. About what percentage of your organization's snowplows have a deflector attachment at the top of the plow to keep snow from blowing over the plow and landing on the truck?			
		Response Percent	Response Total
0%		9%	9
25%		11%	11
50%		4%	4
75%		13%	13
100%		55%	55
Don't know		2%	2
Other (please specify)		6%	6
Total Respondents			100
(skipped this question)			111

7. About what percentage of the trucks that your organization uses for snowplowing have air conditioning?			
		Response Percent	Response Total
0%		16%	16
25%		21%	21
50%		15%	15
75%		17%	17
100%		20%	20
Don't know		6%	6
Other (please specify)		5%	5
Total Respondents			100
(skipped this question)			111

8. Is air conditioning offered as a standard feature on the make and model of heavy truck that your organization purchases most often?			
		Response Percent	Response Total
Yes, offered as a standard feature	<div><div></div></div>	49.5%	49
No, but can be ordered	<div><div></div></div>	31.3%	31
No -- air conditioning is not available	<div><div></div></div>	3%	3
Don't know	<div><div></div></div>	12.1%	12
Other (please specify)	<div><div></div></div>	4%	4
Total Respondents			99
(skipped this question)			112

9. Please use this space to provide details on any of the answers you gave above, or to provide any other comments about truck features that affect icing and fogging.		
	Total Respondents	11
(skipped this question)		200



## Appendix D

### Manufacturer Survey Questions and Responses

Page 1

1. All survey respondents will receive a copy of this project's final report in late summer via e-mail. Please provide your name and contact information so we may send you this report.

		Response Percent	Response Total
Name		100%	5
Company		100%	5
Location of company		100%	5
Position		100%	5
E-mail address		100%	5
Total Respondents			5
(skipped this question)			0

2. What type of company do you work for?

		Response Percent	Response Total
Truck manufacturer		40%	2
Truck dealer		0%	0
Automobile manufacturer		0%	0
Equipment/pa rts manufacturer		60%	3
Equipment/part s dealer/retailer		0%	0
Other (please specify)		0%	0
Total Respondents			5
(skipped this question)			0

3. Based on your conversations with customers, how significant are the following problems for drivers of snowplow vehicles? <i>(If your customers do not purchase vehicles or equipment for snowplowing, please skip to Question 4.)</i>							
	Not at all significant 1	2	3	4	Extremely significant 5	Don't know	Response Total
Icing on exterior (side) mirrors	0% (0)	0% (0)	0% (0)	0% (0)	40% (2)	60% (3)	5
Icing on exterior surface of windshield	0% (0)	0% (0)	0% (0)	0% (0)	80% (4)	20% (1)	5
Icing on exterior of side windows	0% (0)	0% (0)	20% (1)	0% (0)	20% (1)	60% (3)	5
Ice buildup on windshield wipers	0% (0)	0% (0)	0% (0)	0% (0)	80% (4)	20% (1)	5
Fogging on interior surface of windshield	0% (0)	0% (0)	20% (1)	20% (1)	20% (1)	40% (2)	5
Fogging on interior surface of side windows	0% (0)	0% (0)	20% (1)	0% (0)	20% (1)	60% (3)	5
Total Respondents							5
(skipped this question)							0

4. Does your company offer solutions to address any of the problems mentioned in Question 3? Please provide as much detail as possible, including links to more information online if available. We would also appreciate receiving photos of icing and fogging solutions or documentation/specifications related to those solutions for inclusion in our final report. If you have photos or documents to share, please include their Web addresses here, or e-mail them to Info@ctcandassociates.com.	
Total Respondents	4
(skipped this question)	1

5. Is your company developing any other solutions to the problems mentioned in Question 3, or are you aware of any solutions in development at other companies? Please describe in as much detail as you feel comfortable sharing.	
Total Respondents	1
(skipped this question)	4

6. Please use this space to provide any other comments about solutions to icing, fogging and ice buildup.

Total Respondents

2

(skipped this question)

3



## Appendix E

### Survey Written Responses

#### Agency/Contractor Survey

Responses by question: Text of "Other" and open-ended responses

##### Survey Page 1

<b>5. Ice may accumulate on windshields because of plowed snow blowing over the top of the plow, or from snow hitting the windshield as it falls from the sky. In your organization, which source(s) tend to lead to ice formation?</b>
both conditions especially in a blizzard situation
Freezing rain

<b>7. Have you noticed a difference in icing or ice buildup on curved windshields compared with standard/flat</b>
Haven't pay attention
not an issue
All our trucks have curved and we do have a problem with buildup. Cannot compare to flat windshields.
not sure
Wipers designed with higes internal tend to freeze to the curved part of winshield then won't touch all of windshield wher it is flat.
not for sure
not sure
Generally there is less buildup at the bottom of the curved windshields at the edges.
Not sure
unknown
not sure
Don't have any flat windshields

<b>8. Please use the space below to give more information on any of your answers above, and to list any other problems that affect snowplow operators' field of vision.</b>
Newer trucks are less of a problem, but icing and fogging conditions on the windshields continues to be a hazard for our
With curved windshields, the larger the surface area the worst the ice buildup and the longer the wiper blades, the less effective they are when iced over Big panoramicand curved windshields are harder to keep clean during snow removal operations and
Use of heated mirrors and freeze-proof wipers has helped a little with these problems. Heated wiper arms are another advance which has provided some help but all of the technologies also have maintenance problems associatd with them.
Snow & blowing snow is a prblem and does make it hard for drivers to see during a storm.
Our plow trucks need a better head lighting system and the lights need put on the frenders of the trucks instead of on the hood.

Our operators have expressed interest in going back to a single blade on the plow rather than using a double blade with one of the blades being carbide for extended life. Single blades cut to the pavement much better than double blades but we have to change them out more frequently (as much as 5 times a season). We have set up 12 out of our 19 route trucks with a Joma blade (A carbide incased in rubber single blade). The reports back from our personnel is that they are extremely happy with the way the blade cuts to the pavement but they are getting more than usual snow & Ice build up back on the windshield and wipers. This is causing them to have to stop and clean off snow and ice more frequently. This has been a real issue with some of our personnel this past season. We have been and are currently investigating ways to prevent this. With the mild winter we have experienced we feel this is part of the cause. We tried the blades for the 1st time in January of 05 and ran them the rest of the season and didn't have the complaints from the operators like we experienced this year. We talked to other municipalities in Northern Wisconsin where the snow is generally more fluffy we think and they reported no problems with the blades. We have recently been experimenting with longer flaps on the plow but haven't had enough feed back on how that works and with the season coming to an end we will have to wait until next year.
Windshield scratching from abrasion of chemicals and abrasives in snow 'blow-back'
Most of our plowing is done at lower speeds (25 mph and under) so we probably don't experience these things as much as road crews.
When trucks with curved windshields are turned off, wipers are kept in up position so that they don't freeze to the curved
Visibility is decreased by the plow lights being obscured by blowing snow from the plow.
ice buildup on wipers is biggest problem occurring I have thought about purchasing heated wipers for a couple of trucks to see if they would help eliminate this problem
heated mirrors and wipers help but manual removal of the snow is still needed. no true 100% solution to date
Blowing and drifting snow and freezing rain.
We have used heated wiper blades on some trucks that help a little, but there is still a problem with the buildup.
All plow trucks have heated mirrors, so icing on the mirror is not the problem that it would be without the heating option. The major issue in our climate is from the snowcloud off the plow swirling up to the windows and mirrors; operators are trained to make frequent stops off the highway to clear wipers, lights and windows.
Snow and ice decreases visibility. Wiper blades start freezing up and will not clean the windshield. Ice build up if not cleaned by stopping and removing by hand scrapers will result in the wiper blades being destroyed or the linkage in the wiper system breaking.
Our biggest is the blow over the plow. Hood deflectors helped but our new trucks have no deflector.
Most of the time snow blowing over the plow means your driving to fast unless you pushing more of a powdery snow. Side and windshield fogging occurs a lot when you try to split the heat to do defrost and floor heat to keep your feet from freezing. Backup lights affect your vision a lot because they do not put out enough light. The trucks come with the new LED bulbs in them but they don't do very well. They're bright to look at but when you're on a rural route with limited space to turn they don't light up the area enough.
Drivers must frequently stop and clear these areas to continue driving safely.
We do not have an icing problem. Our trucks are equipped with high output heaters as well as heated mirrors and power windows for quick cleaning. The snow spray is not an issue either as it is directed away from the truck.
I have always wondered why the wipers are not mounted at the top of the windshield instead of the bottom to keep them from freezing down and being covered with snow coming over the hood and laying in the cowl.
Other than lighting problems, this is one of the most major safety issues that the drivers deal with.
The problem with ice buildup on the wipers tends to start by pilling up on the base of the windshield/hood and buildup from there. The truck/hood design tends to have a greater impact on that than the type of windshield. In extreme cold and falling weather, the wipers will freeze without having a buildup around them causing them not to clear the windshield.
Blowing snow over the top of the plow is probably the biggest problem
Fatigue
We currently spec heated mirrors to help with icing/fogging. We have included electric windows also, this allows the driver to lower the window if fogged in a backing situation.

The Iowa DOT has installed heated mirrors on all trucks and this has eliminated the mirror icing problems. The biggest problem now is windshield icing especially with Navistar International trucks as they all have flat windshields and that's all the Iowa DOT has purchased in recent years. The operators tend to leave their defrosters on the maximum heat level and open the side windows to keep themselves cool. Others believe that keeping the windshield cold helps.
We have gone to heated mirrors that seems to help. We still have problems with windshields icing up and wiper motors failing. Ice build up and fog on the inside of windows is a constant problem. This condition is even greater in vehicles that are of size with quad cab doors and or vehicles like the expedition and or suburban style vehicles. As for ice buildup on flat versus curved windshields, we are unsure of the answer that you are looking for. We only have one truck that is cab-over style with a semi flat windshield and it is only used during emergency events in the winter. All of our trucks are GMC or Chevy and have slightly curved windshields that always have an icing problem, especially in a heavy snow situation.
Visibility can be problems with blowing snow and traffic volume on interstates.
A little less ice on curved windshield mostly because the truck fender curves away at the same time as the windshield.
Build-up on windshield and wipers are a big problems with us. Most comes from blowing snow over the windshield. Along with fogging on windshield makes it hard to see out.
Snow and ice buildup is #1 factor to reduced visibility
Ice collects on both styles of windshields and wipers but for two different reasons. On the flat style the ice does not slide off the top corners so it gathers and then starts lifting the blade and ice then gathers on the blade. The curved style lets the ice slide off but the blade tends not to wipe the top corners and then ice forms there and soon after starts lifting the blade and ice starts there to. As for the fog on the inside we have noticed that the trucks with A/C units don't do it as bad due to the fact that it de-
Some of our trucks have heated mirrors. This is good to prevent ice build up on the mirrors.
The biggest problem is the ice that forms on the wipers and windows due to falling snow and snow from the blade
We use heated mirrors. This helps with icing on mirrors. Also using electric windows to help with visibility if windows fog up or icy.
conventional windshield wipers located at the bottom of the windshield continually pack snow down around the cowl and wiper arms. This blocks the air intake located on the cowl and breaks the wiper arms and puts a strain on the wiper motor causing it to fail. Perhaps a wiper system that has the motor and wipers located above the windshield and swung down would eliminate the compaction problems. Then a heat strip along the bottom the windshield could keep the air intake vent open
Icing on mirrors is not as big a problem as it once was. All of my snowplow trucks have heated mirrors. The snowplow trucks either came with them, or I had them added.
Icing tends to be determined by the effectiveness of the defroster on the individual equipment. Ice resistant wiper blades do help, but do not always prevent the problem. If there were some way to run heating elements along the bottom of the windshield like those on back glasses, I feel this would help. Heated mirrors have solved most of the problems with exterior mirror icing.
Traffic passing will throw the slush and snow onto side windows and mirrors as well as the windshield.
Defroster has a hard time keeping up during the storm on all models from our experience.
Fog is definitely a concern in certain situations.
Our fleet consists of both curved and flat windshields. Our experience seems to be more with the problem of icing on the wiper blades and then causing a field of vision problem, than having a lot of ice on the windshields.
Headlights and Plohlights get covered as well.
In most new VDOT trucks today we are ordering with heated mirrors, this has helped greatly with ice build up on them. Rain-X is another helpful solution to icing. Ice build up on headlights is a big problem that affects a driver's vision.
With the newer plow that we have received in the two years. There is not as much build up on the windshields because of the height of the plow.
Ice buildup on wipers has to be the biggest problem for us. We have looked at heated wipers, but we are concerned that adding more electrical draw on a system that is already maxed will create problems down the road.
Heated mirrors have been the greatest improvement.
one of our main problems is snow packing up on the windshields under the wiper blades.
Some of the trucks come with heated mirrors. This should be on all trucks

snow and ice buildup on windshield where wipers do not reach.
With the use of bug deflectors and longer snow plow flaps we have eliminated most of the icing problems during most conditions. There are certain conditions that nothing works. If temps and amount of moisture in the snow are wrong the operators just do the best they can.
Ice build up on wipers and around the outside of the windshield.
Side mirror icing almost eliminated when mirrors became heated
We feel the wiper design themselves are more of a contributing factor than the curvature or flatness of the windshield.
This is one of the two biggest problems I feel as an operator we have to put up with. I inquired to see if you could get a windshield with the defroster coils around them like your rear defrosters work in your personal vehicle. This does not hamper vision and I feel would be fairly affordable. How hard could that be?
One major problem is the left and right wipers tend to feed snow and ice down under the left windshield wiper, piling up, pounding and eventually failing the wiper arm or motor.
With the problem of plowed snow blowing over the top of the plow, we usually modify the plow so that the top of the curl extends out further away from the truck. This usually prevents this. With snow/ice sticking to wipers, we tried installing a vibrator to the wiper arm. With the press of a button in the cab of the truck, the vibrator is activated, and the snow/ice usually comes off. <u>Wet snow is usually the worst condition for visibility as it will stick to everything and build up quickly.</u>
We have tried to correct the problems we have had with the installation of heated mirrors and heated wiper blades. Seems to improve the drivers visibility problems.
None
#7 NOT SURE
With DOT vehicles and being out for the duration of storms we find that slowing down to keep the snow from going over the plow helps to reduce the accumulation on the windshield, but it's still a large problem and the falling snow has just as big an impact as blowing snow. We have had a certain amount of good from reducing the heat to the inside of the glass, not causing a melting wet surface for more snow to collect on. Side windows also cause us problems when turning into the wind, the snow when coming off the wing really loads the window, we cannot keep the side glass hot enough to melt this kind of build up. Curved or flat w/s has no difference, it still builds up on the corners and lower center of the w/s to the point the wipers start to raise up off the glass and by this time your wipers are 'swinging hammers'. We have noticed that when you wipe on a product such as 'RainX' it does help in the removal in the corners and center of w/s.
We have some new wiper blades for snow trucks that work very good called dura klear.
Ice builds up on the cowling which will freeze the wipers lessen the effectiveness of heat/defrost to the windshield.
In particularly bad conditions windscreens are treated with an external water dispersal polish/treatment, interior can be treated with anti fogging treatment. Heater and blower in cabs are very powerful plus additional cab heater installed. Ploughs have snow covers fitted to the tops of the ploughs to reduce volume of snow being blown back onto the windscreen. Temperatures are such that 70% of the time snow is melting hence little problem from cold snow as experience in Europe and America.
Mack trucks have a curved windshield with a pillar in the middle, we have gone to a heated windshield on these trucks. Still have problems with side ice build up.
Hi: The trucks that we use in our snow operation all have heated mirrors. All the units are equipped with winter snow blades. All of our plows have snow deflectors on the front top edge. Our units all so use a deicing agent in our windshield solution.
The worst visibility problem from fogging is when we need to push (wing) snow against a strong wind.
Night conditions Blowing snow - blizzards Snow blowing (straight)directing on truck
Wiper ice buildup is a constant problem, also prevents use of windshield solvent, we tried heated wipers, but they were junk.
Have Fords and IH's, problem seems equal on both. Best solution seems to be mechanical removal of snow buildup. Does not always happen, but the right type of snow under the right conditions will stick all over the truck.
The colder the weather the more we see this problem. With the newer truck this is getting better.but the problem is still there. We have add AC to help with the problem and it seems to have made a difference in how much we get on the inside of the truck now
Snow blowing over plow, freezing on wipers and on front of grills and engine air intakes
Snow blow back onto Radiators sometimes cause over heating of vehicle.
We do have heated mirrors that help with ice and fog on mirrors. We also have some Mack trucks with the older style split curved windshields. These are much worse for snow/ice buildup because the wipers do not cover the center of the windshield.

We own Sterlings and International snow plow trucks. I would say the icing is the same with both
We have noticed proper plow specifications play a major part in reducing the amount of snow and ice blowing over the plow blade onto the hood and windshield area. The proper plow adjustments and height of the mould board is a key factor. We've had problems over the years it appears to be less of an issue with our new plows. Note: MTO contracts out most of our winter operations although I am familiar with the issue.
White out conditions
Ice and snow build up on wipers not only cause problem seeing but also cause mechanical failures during emergency winter operations.
Wyoming has used heated mirrors to reduce the problems associated with icing on rear-view mirrors. Icing on windshields depends on conditions being experienced. Wind direction has a big effect on the severity of the icing and/or fogging problem on any window surfaces. Consistency of snow, temperature both inside the cab and externally also play a big role. Even though the ice buildup on wipers seems to be similar in severity, it has a more profound affect on trucks with curved windshields, since it's harder for the wiper to change shape and follow the windshield contour when restricted by ice buildup.
High Winds give us trouble at times but fleet has good defrosters and heated mirrors.
We have heated mirrors on our trucks but the biggest problem experienced is ice buildup at bottom of windshield that effects windshield wipers. Power adjustable mirrors would also be a big help for our drivers.
Flat wind shield seem to ice less. Ice build up on lights (headlights and safety lights) is also a problem.
We have problems with snow buildup on the cowl to the point that the wiper arms can come off of the wiper motor.
White-out conditions

<b>9. Are you aware of any completed research or research in progress that addresses icing or fogging on winter maintenance vehicles, including research sponsored by your organization?</b>
We have tried heated wipers and windshield with mixed results
The way we stop a lot of snow build up on the windshield is to open the side window wing, turn the defroster off. This lets the windshield cool so the snow does not stick to it as much.
Only what was just expressed in question #8. We do have heated mirrors on all our trucks and that does help only if the side windows don't build up with snow & ice. We did try a set of heated wipers a few years ago. They didn't work because for one they weren't a winter blade and they were too fragile to keep up with the amount of snow & ice coming at them. 1/2 of our County is still pretty rural so wind plays a major factor with direction and how the snow & ice comes off the plow on how much snow & ice build up will get on the windows.
Evaluated one brand of heated wiper blades with poor results
Nevada DOT is working w/ the University of Nevada Reno, (Mechanical Engineering Dept) to address these issues.
Our winter equipment committee did some trial periods with the heated wipers and mirrors before we purchased the heated mirrors on all trucks.
Dennis Burkheimer of the IDOT has information
I know that if I put an application of 'Rain-X' on the windshield it helps with not as much accumulation of ice/snow.
Our Maintenance research is looking at heated windshield fluid and snow shield for plows

## Survey Page 2

<b>3. Has your organization found the HVAC system on any specific makes or models of trucks to be particularly effective or ineffective at addressing INTERIOR FOGGING? Please list below.</b>
Not to my knowledge.
Newer Sterlings seem to work the best
It tends to work really good on the Kenworths and the Macks. The Volvos and Fords with large windshields it is not as effective.

don't know
no
The newer part of our fleet consist primarily of Sterling models equiped with HVAC. These systems work better than past equipment and we are finding our personnel are not using the auxillary fans so we have been removing them to the extent of not even putting them in specifications.
At this location we have older trucks without A/C ayatem
do not use
Our plow trucks do not have air conditioning.
Not aware of any
no
No difference
not to my knowledge
Haven't pay any attention to this.
no A/C on our trucks
Not sure
Don't know.
NO KNOWLEDGE
effective
NA
Found it makes no real difference.
Don't Know
Not sure
no experience to relate.
NO
We just started buying units with ac so not much experience
no different
N/A
Don't know of any.
Do Not have in trucks.
No we have not
N/A
NO
N/A
No difference
No
Heavy equipment tends to be less effective. No particular brand of truck appears to show patterns. Some moddles may be better, or worse depending on defroster placement, and heater output.
Don't know
Have not seen any difference
no
We starting purchasing dump trucks with AC in 2000 and remi=oved the dash mounted fan. both Sterling and Macks work well at clearing or prohibiting fogging.
not that I know
No
Haven't noticed any real difference.
No major advantage from one make to another.
Don't know
Don't have any.
No
not really
N/A

no, all the same, which is poor performance.
Dont Know
No
Not to sure.
No
Don't know
N/A
Don't know.
Use only Ford and International - have nothing to compare.
DON'T KNOW
none
Temporarily using the a/c does reduce fogging of the windshield.
Both Freightliner and Sterling work quite well.
We use all Friehtliner trucks.
normally drivers just use defrosters
We use Strealings stock system
Not familar with this system.
The a/c runs with the defroster and some drivers have found if they turn tempiture on high and crack open the drivers windowthe windshield stays warm and they can adjust cab temp with the divers window
I had a 1993 Chevy pickup truck that cleared the windshield faster than any other vehicle I ever seen. Other people said the same thing.
Trucks don't have air conditioning.
NO
N/A
As I mentioned before we us private contractors to plow our highways. It would be a number of different solutions.
no certain model seems to be better .
NO
All HVAC systems do an adequate job in this process.
Haven't specifically looked at this detail.
Don't know
I have not had this trouble.
no
no
Most of our trucks are Volvo Autocars and Macks. The heating/defrosting systems have been adequate. We did retrofit one Mack truck with a heated glass windshield. Similar to rear window defoggers. This works exceptionally well and are considering purchasing on all future trucks depending on price.

<b>4. Have you encountered any disadvantages to using air conditioning on your organization's trucks (such as costs, maintenance, increased stress on radiator systems, etc.)? Please list below.</b>
Drivers not using air conditioning.
Not really, at least none that I know of.
No
no
no
Not that I am aware of.
Our fleet that is equiped with the system only dates back to the year 2000 and we haven't experienced any problems to date.
N/A
do not use
Our plow trucks do not have air conditioning.
do not have a/c on our trucks

no
no
No
WE Donot have AC in trucks
not to my knowledge
Not aware of this.
No
No
Don't use air conditioning during snow and ice events.
Would be to cold to use in the winter months especially during snow and ice situations
NEVER USED DUE TO TEMPERATURES OUTSIDE AND DRIVE COMFORT
none
no
It's just another item that will down the truck.
No disadvantages noted.
Same as above
Don't Know
None
N/A
NO
n/a
unaware
N/A
None.
No
Have not used it
First year with a truck with air.
Not at this time, but we are consdiering going with A/C in out snow plow trucks for better air movement in the cab.
Current truck fleet does not have air conditioning
None that I am aware of.
no
Not on newer vehicles
Our trucks are not equipped with air conditioning
First year with air conditioning
None that I'm aware of.
No
Not to my knowledge
Loose some power but not problems
no
Nothing aappreciable. We feel you will get the added initial cost when you sell the truck and although their is additional maintenance required it is not consequential.
Majority of older trucks do not have air conditioning
There is defiantly more maintenance costs with trucks with air conditioning. More cab filters, damaged condenser cores and not to mention having in house techs certified to work on these units.
No.
Haven't noticed any disadvantages from a operators stand point.
No
Don't use.
None
No
Operators will stay in the truck more in the summer months.

most of our trucks do not have air conditioning
N/A
No
only have 1 truck with ac
Not that we are aware of.
If you try and use the ac to move the warm air not enough comes through the defroster vents and you completely lose the windshield.
Not sure.
Not all of our trucks have A/C
Air conditioning systems require a lot more service. We have trained almost all our mechanics to work on air conditioning systems.
None
Don't know
N/A
Don't know.
N/A
OUR DUMP TRUCKS DON'T HAVE AIR COND.
From what I know of air conditioning the compressor does not kick on when a low temp. is reached, so it may not do any good but running air conditioning does take more fuel.
no, most of our vehicles do not have ac
Have no snow trucks with air conditioning.
It doesn't help being cold inside the truck in Wintry weather.
No,
No
I have found by having a fan directed to the windshield and not using heat for defogging but heating the cab, works great. Also the windshield doesn't ice as much but doesn't prevent it.
Not as of yet
salt eats up radiators and condensers
The only disadvantage to using this method is: It's already cold outside, making the cab cold inside makes it uncomfortable for the driver.
NO
N/A
AC would increase the operating cost due to higher maintenance charges.
no disadvantage other than cold drivers.
NO
I'm not aware of any. On light duty vehicles, the air conditioning compressor is engaged whenever the defroster is used to reduce the humidity of the air. This has been happening for some time. I am assuming this feature will make its way into heavy duty vehicles if it hasn't already.
NO
Don't know
No
Our trucks don't have AC
Don't have too much experience...we've only been buying A/C for a few years
The location of the condenser, in front of the radiator, developing leaks due to flying material from plowing.
no
No experience

<b>7. In addition to deflector attachments, are you aware of any solutions that specifically address the problem of plowed snow blowing over the top of the plow and obscuring the driver's visibility? Please list below.</b>
Have used plows with more of a curvature to the plow - seems to help some. Longer deflector shields on the plow. Cab shields at the front of the hood of the truck.
Yes, electrically heated windshields and deflectors mounted on the plow, not on the hood
no
We have seen some extreme attachments on plows but haven't tried for fear if the plow should trip it would be destroyed. We are currently working with a vendor on a flap system where the flap comes out at an angle away from the plow.
Standard mount wind deflectors on hood of truck Proper plow 'lay-back' angle setting Plow at appropriate speed
N/A
We tell our drivers to just slow down
no
No
no
No
No
no
No
I'm not aware of any solutions here.
slow speed of truck plowing snow.Taller trucks with higher hoods block more snow from hitting the windshield
NO
deflectors on the front of the cab as well
no
Extra large snow deflectors.
Yes.
No
None
Deflector mounted on front of plow barrel
We have moved to quite a few high speed under truck mounted plows in addition to the fron mounts and when the snow is blowing or very light and dry the front plow isn't used and no visibility is lost from the snow coming off the under body plow.
no
No
Plow shelds were used but the operators found them blocking visability.
Drive slower
Drive slower.
Ribbing to stiffen rubber flap
Drivers need to slow down.....
NOT AWARE OF ANY OTHER SOLUTIONS
MoDOT has went with a higher angle on the moldboard to eliminate 'bulldozing'. With the higher angle we are turning the snow over fewer times which helps eliminate the wind getting under it and blowing it up on the truck.
Slow down or changing the angle of the plow helps.
No
None that I'm aware of
Ground speed. Sometimes just slowing down will help.
Speed of plowing can be adjusted to snow conditions, where practicle. Wet snow does not blow back as bad as dry, cold snow.
None
no
I have always thought that all of our fleet should have vertical wipers.First it keeps the wipers from getting froze down by packed snow that falls between the hood and the cowlng and would stop the windsheild wiper fuild from freezing.

We specify a heated windshield in trucks where we can get it. Currently only Mack supplies a heated windshield and it works very well.
Some of our operators have stated that in combination with a plow deflector, a simple bug shield has helped to prevent some snow hitting the windshield. This still seems inconclusive yet.
Reduction of plow speed.
no
no
No
No, Slow down.
we have used different types of plows to help reduce the spray from plowing
Rubber flaps hanging from the front of the plow.
No
The barrel-type plows are the most effective.
We use heavy rubber snow tunnel flaps to control discharge of snow outside the drivers path
NO
No
N/A
Sometimes it is just as simple as slowing down the plow vehicle.
NO
A deeper funnel seems to help. We use belting on the top plow edge which helps some. We tried bolt on deflectors but they were tore off by semi wind turbulence.
At least on side windows retro fit rightside doors with a power window and a good seal wiper.
not any mechanical devices.
Hood mounted deflecters
No
Keeping the blade turned as far as it will go helps sometimes it also depends on what type of snow you are pushing, wet - dry - ect.
Flap added to snowplow to deflect snow to the ground.
Drivers are instructed to plow at a lower speed
No
No.
We have one truck with top mounted wipers; we do not see any significant difference. Having the hood waxed, and the windshield rain-x'd is helpful sometimes with drier snow.
Maybe bug shields on hoods
Not aware of any solutions that address the problem.
Wind deflectors on the front of the hood.
no
No
Proper plow specifications.
Change the geometry of the plow. Some manufacturers increase the roll of the plow.
no.
NO
Variable shape plow moldboards that can be changed for the conditions.
No
No
Does not come over the plow.
If you have snow over the top need a bigger plow or slow down
30 inch Rubber flaps on front of snowplow
The shape of the plow curl effects the amount of snow that comes over it as does the angle of the plow in relationship to the road. A stiff flap mounted on the front of the plow curl helps. (stiff so it doesn't 'sail' or cave into the curl)
no

<b>12. Please list any other strategies for addressing icing or fogging not mentioned above. Also, if you have details on the effectiveness, advantages or disadvantages of any icing or fogging solutions, please list below.</b>
None that I know of
We have used heated wiper blades with some success and we try to specify heated windshields when ever available. The problems we have encountered is that operators forget to turn off the wipers when they are no longer needed and the hot wiper blade transfers a skim of rubber on to the windshield glass. We have encountered the same problem with windshield heat. The heating devices for glass or for wiper blades need to be controlled by a timer. Wiper controls need to be disabled when the parking brake is applied so operators cannot leave the wipers running when they leave the truck running for extended periods of time.
None at this time. We have installed electric windows on both sides of the cab to help with visibility.
none
None
The heated mirrors helped a lot we still have icing on the outside of the windshield and the inside we have more problems when plowing or the wind is blowing.
anti fogging sprays and or applications of liquid to the inside of glass
Crack window for some air.
none
N/A
NOT AWARE OF OTHER STRATEGIES
The chemical glass treatment (Rain X) that we have used helped until we started getting road spray (salt & chloride) on the windshield and then it was like looking through a florescent bulb and was very hard to get removed from the glass. As for the high concentrations of anti-icing fluids it can add to the problem if it is very cold or if there is enough moisture falling to delute it.
None
We've tried heated wipers and found them to be very high maintenance
We do have electric side windows to allow the driver to roll down passenger side window if vision is obstructed
None
none
Some of our operators use Rain X or other similar product, on nonheated mirrors or LED Lights that don't generate a lot of heat.
None
none.
none
we have used deicing sprays in aerosol cans that seemed to help somewhat
Stop, and knock ice off.
the heated blades left streaks in the spots the blades were not heated. tried teflon blades. my guy liked them.
N/A
None
none
none
Also used chemicals (Rain X)
Fan works the best and not using heat with defroster.
witer wipers seem to help alot
N/A
We us a number of convex mirrors on the fornt of our vehicles in addition to the vehicle mirrors. We also require passenger window be power activated to remove snow and ice from passenger window.
NONE
Don't know
none

<b>13. Do you face any obstacles to implementing any of the strategies above (cost, maintenance, time required to install, unavailable, etc.)? Please list below, indicating which strategies are affected.</b>
Cost and maintenance of the systems.
No issues
cost
Heated mirrors work great only if you can see out the side windows. Have to wait for the next event to get feedback on strategy applied.
additional costs are always an issue
Heated mirrors and windshields are affordable. Some other products advertised are expensive and they solve a problem of which we generally have not had a problem (eg ice build-up on wipers).
very little input
Cost
cost
not really can pretty do what we want as long as fleet maintenance is on board
Cost
Before any of our maintenance contractors would try out any new strategies, they would need to be shown that it was cost effective, then they'd do a pilot installation on a very small number of trucks. Our maintenance contract specifications do not require any particular visibility options; it is the contractor's responsibility to provide a safe working environment for his employees -- and aids to visibility would be included in that.
ALL OF THE ABOVE. ALL ATTACHMENTS ARE HANDLED BY OUR EQUIPMENT DIVISION
Costs
cost versus gains
cost, unavailable
Cost and red tape of installation.
No. The fleet is well equipped.
For VDOT it would have to be approved by the equipment division to be added to our fleet for any such 'add on' or upgrade to be made to modify equipment. Solvents or fluids would have to be added to our inventory systems.
Cost a big factor
I deal with temperatures to -50C
No
Cost, availability
cost
Cost
I feel Iowa is always ready to test new items to improve the driver and public safety.
\$\$
No
Cost --Maintenance--Time to Install
All of the above
HEATED MIRRORS STANDARD ON ALL NEWER TRUCKS IN FLEET. NO OBSTACLES TO IMPLEMENTATION OF ANY STRATEGIES THAT I AM AWARE OF.
All of the items listed are factors due to the size of the fleet.
cost
Costs
Purchasing costs
I am not aware of some of these systems being available. Our fleet is several years old, and has not been replaced.
Cost and getting the ok to do the project.
no

MoDot General Service set the specs for our fleet and we have never been offered the option to get vertical wipers but I think they would be a asset.
We've utilized heated mirrors for years and they work very well!
Cost and maintenance are the biggest factors.
Cost and time required to install.
Cost and maintenance
cost
Low bid problems
YES; Cost! Unavailable
all of the above obstacles are a daily struggle.
The cost of some of these products have inhibited us from using them.
Unavailable to us.
cost
Heated mirrors have been an added expense. Many have been smashed by plow wings and other similiar damages. Heated mirrors are expensive to replace.
COST alawys effect things like this.....
The primary obstacle is cost/calculated benefit.
N/A
cost
No
If they work we try to use them.
I'm sure the cost would be our big factor.
Cost, approval from equipment services.
none
nONE nOTED
Any additions have to be approved by the Equipment and Safety divisions.
Options available during purchase of vehicles are considered together with the cost / benefit, it is unusal for use to retro fit after market equipment, in some case it may not be feasible to fit. Issues such as ice build up etc are addressed during the specification of the vehicle and where necessary additional items/equipment installed during the construction of the cab/chassis or when the body is fitted and commissioned.
Cost and maintenance
Heated mirrors, winter blades, washer solution
Lack of knowledge about some of the stratgies mentioned in this survey.
Some of the solutions that you have noted are not familar to our organization.
cost
Heated wipers were not able to hold up to weather conditions.
Retrofits of heated/power mirrors are not cost effective for us, but all new equipment gets this for last ten years.
Cost, service, parts, avialbility, training of the system and vendors staying in business after sale
wipers pushing snow leads to motor failures and wiper transmission arms failing
VDOT Specifications limit our input
The heated mirrors were hard to get at first but are now on all newer plow trucks.
Cost effects everything
No
no.
NONE
Some features may be unavailable on certain makes of truck, cost, limited effectiveness in some conditions.
Cost
Cost - any and all additions and improvements. Availability
Cost is always the factor.
Cost and politics on any truck upgrades
Time to install on all trucks and the effectiveness vrs. cost.
Cost and availability

Maintenance, cost.
The cost of heated wiper blades has been prohibitive for the number of trucks statewide.

### Survey Page 3

<b>1. What types of vehicles does your organization use for snowplowing? Select all that apply.</b>
farm tractors
loaders
Blower
grades
JD tractors with front plows
Snow Blowers
26 tonne 6x6 permanently mounted spreaders
small equip with cabs
High Speed Brooms
OsshKosh Dumps, Norland Snow Blowers, Motor Graders, Front End Loaders
Rotary plows (snow blowers)
Motor Patrols

<b>3. During the time your organization owns a typical truck used for snowplowing, about how often do you replace the truck's windshield?</b>
only when damaged
when needed
only if broken or scratched
when bad
only if broken or chipped in drivers line of site.
When damaged, rarely.
as damaged will be replaced
WHEN IT GET CRACK.
very seldom
When needed. Maybe never
unless it is broken
When safety is compramisid or as needed
As needed due to damage or pitting.
When scratched or chipped
unlikely to require replacement except when involved in an accident.
When needed from rocks to pits and cracks
Only if broken or cracked.
as needed
Only if cracked or broken
Situational, mianly replacement is from debris damage.
Twice a year

<b>4. About how much per truck would your organization consider spending on a product that effectively addressed icing or fogging (either as an aftermarket purchase or added to the price of a new truck)? Values are in US dollars; please use the 'Other' field to answer using another currency.</b>
must test to determine effectiveness
Depends on effectiveness

5. In your experience, are newer trucks more effective than older trucks at addressing icing or fogging?
better heating and air conditioning systems. Better location of vents, etc.
Some trucks have vertical wipers, heated windshields and/or deluge systems
heated mirrors
In the last 10 years trucks have more equipment available on them.
HVAC systems, heated mirrors, power windows & windshield de-icing fluid.
Improved heater systems Power windows
Defroster system is better. We now specify the heated windshield option on our newer trucks.
Some of the new equip. comes with heated mirrors.
new trucks have better air flow system
I think design is improving to deflect snow. Also, the heat controls have improved too.
Rounded Windshields
defrosters seem to work better in the newer trucks.
We purchase with heated windshields
better heaters, heated mirrors
The defrosting systems on the newer vehicles are more advanced than the older ones, which better addresses the fogging issue but not the icing issue.
Better heaters/defrosters
Better heaters and defrosters
Going to heated mirrors bigger fan motors for heaters and adding air conditioning.
advances in technology in regards to better blowers, heated mirrors etc.
windshield designs have improved
Fans, heaters more efficient, and 'fresher'
Better Heaters
better heaters
Curved Wind shield and aero- dynamic
Cowls below windshield allow for more snow to run off
THE NEWER TRUCKS HAVE BETTER HEATER IN THEM.
Trucks that are on order will be coming with heated washer systems and one with a heated windshield
newer truck can control air intake for the cab to help reduce moisture in the cab
They have a more effective HVAC
Defrosters seem to work better. Most are equipped with heated mirrors.
Better heating systems
More modern with heated mirrors etc...
Newer trucks are more aerodynamic, most all new trucks are ordered with A/C and heated mirrors.
Better systems to combat these problems
Some of them have heated mirrors etc.
because of the new technologies
Heated mirrors have been a big plus
Better Hvac systems.
better vents. stronger fans
Better wipers and heaters
Navistar 7000 series is better than the old 4900.
systems are better
Better systems and better equiped.
High performance heaters and blowers, tested in Northern Europe i.e. Sweden/Norway etc. Designed for such conditions.
More efficient use of defrosted air
Better heating systems and air flow thru cab, and heated mirrors.
All new trucks have heated mirrors & most come with air conditioning.
Heating & AC systems work much better. Some of newer trucks have heated mirrors.
The heating and AC system are much better along with the cab design has better air flow in it.

We do have heated wipers and mirrors
Better heaters. Heated mirrors, Better wiper coverage.
Better heating systems
better heating systems,haeted mirrors
Defrost systems are more effective.
New system
Heated mirrors and better Defroster
Curved windshield, better heaters / defrosters
They have heated windshields, wipers and mirrors.
Newer trucks have a better heater system and don't seem to fog as bad.
The newer trucks equipped with air conditioning seem to keep the windshield clearer.
The heating and defrosting systems are much improved.
They come with better heaters and heated mirrors
Heated Mirrors

6. About what percentage of your organization's snowplows have a deflector attachment at the top of the plow to keep snow from blowing over the plow and landing on the truck?
No attachment at the top of the plows. Instead each plow has a wide rubber belting haning in front of the plow.
All here.
100% at this office
We don't use deflectors, we us rubber flaps that hang down the front
only a handfull, experimental
we use a flap attached to the front edge of the plow. The flap is made of belting material and is 12' tall.

7. About what percentage of the trucks that your organization uses for snowplowing have air conditioning?
Older not equiped.
75% at this office
Less than 20 %
1 truck out of 10
very few, some of the newer ones.

8. Is air conditioning offered as a standard feature on the make and model of heavy truck that your organization
light trucks only here
just in the last few years we can get ac
Not in the past but new orders do include as standard
not sure

9. Please use this space to provide details on any of the answers you gave above, or to provide any other comments about truck features that affect icing and fogging.
Windshields are replaced as often because sand is not used in the operation any more. All of our new purchases are specified with HVAC systems. Snow plow deflector attachments still need to be enhanced and plow blade investigated.
All new products must be tested and evaluated by the Department at no cost to the Depatment
None
Of coarse the newer trucks are more effective than the old however,we are doing the best with what we have.
Don't know specific numbers for entire State or district, only what I have at this office.
All trucks ordered after 2000 have air conditioning. We have trucks in our fleet that are 22 years old
none
AC seems to help windshields, and heated mirrors work the best.
We are look all the time in how to improve our truck design and still saty with in budgets keep SAFTEY in mind all the time

Air conditionong is desired by the operators but not approved by the organization.
NONE

## Manufacturer Survey

### Responses by question: Text of "Other" and open-ended responses

**4. Does your company offer solutions to address any of the problems mentioned in Question 3? Please provide as much detail as possible, including links to more information online if available. We would also appreciate receiving photos of icing and fogging solutions or documentation/specifications related to those solutions for inclusion in our final report. If you have photos or documents to share, please include their Web addresses here, or e-mail them to [Info@ctcandassociates.com](mailto:Info@ctcandassociates.com).**

#### Heated Windshields Heated wiper blades

We manufacture ClearFast, a washer fluid heating system that prevents ice and snow buildup on the vehicle windshield and wiper blade leading edge. This system provides 150ml of heated fluid (3 times more than other systems) to insure effective cleaning on large truck and bus windshields. Hot (120F) fluid is available 18 seconds from a cold start and this temperature is automatically maintained by microprocessor and thermistors. This temperature is critical because the alcohol in washer fluid begins to evaporate between 140-150F. Several safety features are incorporated to prevent the unit from overheating and causing damage to the unit or the vehicle. ClearFast uses the existing vehicle washer fluid button and pump system, so no other switches are required, and the driver has total control of how much fluid is dispensed to the windshield. If the vehicle system voltage drops below 12.8, ClearFast automatically shuts off, preventing excess current draw and electrical system overload. At initial turn-on, ClearFast will begin heating once system voltage has reached 13.2. During non-winter climates, ClearFast provides much more efficient windshield cleaning of bugs and road grime than cold fluid. The hot fluid also extends wiper blade and motor life by cleaning faster (less wipes) and washes away the rubber-damaging contaminants (ozone, acids, etc.) at select distributors in the midwest.

Our Ottawa, Canada based firm, Wiper Shaker Technology Inc. has had good success in getting our product, the "SHAKER Wiper De-icer Plus", into use at various Canadian Provincial highway snow plow departments and are now starting to bring the product to the attention of applicable DOT departments in the U.S. The SHAKER has had excellent reviews by those in the heavy trucking & maintenance industry here in Canada and as such, we are now starting to make contact with appropriate organizations in the various U.S. states such as the DOT's. The SHAKER simply clamps onto an existing wiper arm & blade assembly and then addresses a very real problem - that of obscured vision while driving. As you may be aware, when a wiper blade (of any type) builds up frozen debris around and under its' blade edge, it causes streaking on the windshield, thus obscuring the drivers' forward vision. No wiper blade, e.g., Winter, Teflon, heated blades, Flat blades etc. can quickly and effectively deal with this problem. The SHAKER enhances an existing wiper blade as so to deal with such problems at the push a button, from inside the cab. How does it do this - quite simply actually. The SHAKER contains a specially designed eccentric motor / weight combination that creates sufficient vibration once activated, to lift a moving wiper blade (very rapidly) about 1/16" thus somewhat simulating a "flick" of the wiper blade, but without having to stop or reach out a window to do so. I've taken the Nova Scotia DOT (they've been using our product since last year). The SHAKER makes any blade better and could potentially increase safety. The SHAKER is available in the U.S. from our US distributor, Commercial Vehicle Group. Please feel free to visit our website, Videos, FAQ's, Testimonials etc. We would be happy to answer any questions you might have about our product once you've had a chance to review it. website:

"[www.wipershaker.com](http://www.wipershaker.com)"

Testimonial Link: <http://www.wipershaker.com/reviews.html#T2>

Photo Link: <http://www.wipershaker.com/DOTPHOTOS.htm>

Everblades Heated Windshield Wipers. <http://www.everblades.com>

**5. Is your company developing any other solutions to the problems mentioned in Question 3, or are you aware of any solutions in development at other companies? Please describe in as much detail as you feel comfortable sharing.**

None

**6. Please use this space to provide any other comments about solutions to icing, fogging and ice buildup.**

We will send photos and documentation of ClearFast test results to your email.

Wiper Blade technology from a concept point of view has not significantly changed in many decades, i.e., there is still a rubber squeegee edge that sweeps across the windshield screen. Regardless if a winter blade (or any type of blade for that matter) is used, frozen debris can still become trapped under the blade edge itself from freezing rain or from the A-pillar etc., causing streaking. The SHAKER deals with this problem by invoking sufficient impact vibration to shatter or displace the frozen debris. This vibration also allows for other benefits such as reduced A-pillar build up and improved washer fluid efficiency (because of the skipping blade effect). The SHAKER is only activated when such a problem occurs with the blade and then the driver activates the SHAKER for a few seconds to correct the problem. Other wise, most would not even know the SHAKER is installed.

**Below is some additional information we received from manufacturers via e-mail.**

**Clear Fast**

Reed City, Michigan  
231-832-5525  
sales@nartron.com

*Safety*

Hot washer fluid dramatically improves **CLEAR VISION**,

- Heats the windshield washer fluid to 120° F in 18 **seconds**,
- Prevents wiper freeze-up in cold weather,
- Eliminates the need for ice/snow scraping and bug removal,
- Dramatically improves wiper performance; extends blade life,
- Eliminates interior windshield fogging in most weather conditions,
- Quickly removes snow and ice from windshield,
- Dramatic improvement in warm weather windshield cleaning; quickly removes bug residue and road film,
- Compact – easily installed.

**FULLY AUTOMATIC**

- Automatically powers on when engine operates (and system voltage is greater than 13.2 volts); remains activated until the engine is shut off,
- Automatically goes to high heat when windshield washers are used, modulates to low power when the wash cycle is

**EFFICIENT Fast Removal of Bugs/Ice and Other Residue**

- The hot fluid efficiently removes bug/wax, grime, ice and snow from windshield,
- Provides clean, non-streak windshield for clear vision and safe driving in any weather.

**SPECIAL FEATURES**

- 150 ml heated fluid makes it the only product capable of cleaning large windows (bus, truck emergency vehicles) in any
- Fluid is dispensed through existing nozzle system or wiper blades,
- Conveniently operates through existing wiper controls,
- Simple installation: 3 wires (15 ft. harness), 2 tube clamps, 2 screws,
- Does not operate prior to, or during, engine start-up. Operates only after the motor is running and no battery draining is
- Proprietary micro-computer slowly ramps-up power and slowly ramps power-down to eliminate power variations,
- Dual heating system provides immediate (18 seconds) heating, followed by a second heating cycle for the full 150 ml of
- Operates at all vehicle angles – inclines, hills and level ground,
- System diagnostics.

**Wiper Shaker Information**

Mike Kelly

Wiper Shaker Technology Inc.

(613) 830-1300

website: <http://www.wipershaker.com>

**Why The *SHAKER*™ ?**

*SHAKER*™ utilizes vibration to shatters or dislodge "Trapped" debris (including leaves, twigs and pine needles etc. from *SHAKER*™ also effectively deals with "Conformance" & "A-Pillar Build-up" problems at the early stage. It will even free up a wiper blade frozen in the parked position caused by initial freezing rain or car wash run off.

*SHAKER*™ allows a wiper blade to make much more efficient use of washer fluid. This is made possible because, when activated, the resultant vibrating action causes a moving wiper blade to literally skip across the windshield in ~1/2" to 1" increments (jumping only 1/16" off the windshield). Because of this skipping action, the blade stays wetter longer, with only a *SHAKER*™ clamps onto to any type of existing wiper arm that uses a "hook" wiper arm (Pin & Side Adapter available *SHAKER*™ is a sealed system allowing it to function in any winter environment (e.g., snow, freezing rain, hail etc.).

*SHAKER*™ only requires approximately one ampere to operate and only while the unit is vibrating! Thus, there is no fear of excessive battery drain or a waning alternator system in extreme situations.

*SHAKER*™ is environmentally friendly and does not require the use any consumables (other than fluid when removing bird *SHAKER*™ is activated from inside the vehicle at the push of a button.

*SHAKER*™ has no comparable competition.

*SHAKER*™ is portable when using the cigarette lighter version, should you decide to sell your vehicle.

The *SHAKER*™ - drivers have been waiting decades for such a simple solution!

The *SHAKER*™ is manufactured under ISO 9000 guidelines and utilizes only high quality components that will ensure reliable usage. As an example, a high quality motor (e.g., wide temperature range & high MTBF), flame, UV and Ozone resistant rubber, and automotive approved adhesives and corrosion resistant materials such as powder coat and Stainless Steel etc.

# Appendix F

## Survey Respondents

### Agency/Contractor Survey

#### UNITED STATES

##### **Alaska (2)**

Northern Region Maintenance and Operations, State of Alaska Department of Transportation  
Foreman, State of Alaska Department of Transportation

##### **California (1)**

Chief of Maintenance Equipment and Transportation, Caltrans

##### **Colorado (2)**

Operations Supervisor, City & County of Denver  
Deputy Maintenance Superintendent, Colorado Department of Transportation

##### **Connecticut (3)**

President, Four Seasons Landscaping, Inc.  
Transportation Equipment Repair Manager, State of Connecticut Department of Transportation  
Public Works Superintendent, Town of Bloomfield DPW

##### **Delaware (1)**

Engineer IV, Delaware Department of Transportation

##### **Idaho (1)**

Equipment Superintendent, Idaho Transportation Department

##### **Illinois (5)**

Supervisor of Streets, City of Lake Forest  
Assistant General Superintendent, Department of Streets & San., City of Chicago  
County Engineer, Knox County Highway Department  
Assistant Maintenance Superintendent, McHenry County Division of Transportation  
Owner, Shrimp Co.

##### **Indiana (11)**

Assistant Administrator, DPW/ Street Maintenance, City of Indianapolis  
Operations Manager, Indiana Department of Transportation  
Roadway Services Liaison, Indiana Department of Transportation  
OPS Manager, Indiana Department of Transportation  
OPS Manager, Indiana Department of Transportation  
Operations Manager, Indiana Department of Transportation  
Operations Manager, Indiana Department of Transportation  
Liaison, Indiana Department of Transportation  
Operations Manager, Indiana Department of Transportation  
Operations Manager, Indiana Department of Transportation  
Operations Manager, Indiana Department of Transportation

##### **Iowa (37)**

Street & Sewer Maintenance Supervisor, City of Dubuque  
Supervisor, Iowa Department of Transportation  
Supervisor, Iowa Department of Transportation

G.O.A., Iowa Department of Transportation  
 Highway Maintenance Supervisor, Iowa Department of Transportation  
 Highway Maintenance Supervisor, Iowa Department of Transportation  
 Highway Maintenance Supervisor, Iowa Department of Transportation  
 Highway Maintenance Supervisor, Iowa Department of Transportation  
 Supervisor, Iowa Department of Transportation  
 Supervisor, Iowa Department of Transportation  
 Supervisor, Iowa Department of Transportation  
 Highway Maintenance Supervisor, Iowa Department of Transportation  
 G.O.A., Iowa Department of Transportation  
 Highway Maintenance Supervisor, Iowa Department of Transportation  
 Highway Maintenance Supervisor, Iowa Department of Transportation  
 Highway Maintenance Supervisor, Iowa Department of Transportation  
 Supervisor, Iowa Department of Transportation  
 Equipment Operator Sr., Iowa Department of Transportation  
 Highway Maintenance Supervisor, Iowa Department of Transportation  
 Highway Maintenance Supervisor, Iowa Department of Transportation  
 Highway Maintenance Supervisor, Iowa Department of Transportation  
 Supervisor, Iowa Department of Transportation  
 Supervisor, Iowa Department of Transportation  
 Highway Maintenance Supervisor, Iowa Department of Transportation  
 Winter Operations Research Analyst, Iowa Department of Transportation  
 Highway Maintenance Supervisor, Iowa Department of Transportation  
 Highway Maintenance Supervisor, Iowa Department of Transportation  
 Highway Maintenance Supervisor, Iowa Department of Transportation  
 Supervisor, Iowa Department of Transportation  
 Supervisor, Iowa Department of Transportation  
 Highway Maintenance Supervisor, Iowa Department of Transportation  
 Supervisor, Iowa Department of Transportation  
 Highway Maintenance Supervisor, Iowa Department of Transportation  
 Highway Maintenance Supervisor, Iowa Department of Transportation  
 Mechanic/ Operator, Iowa Department of Transportation  
 Highway Maintenance Supervisor, Iowa Department of Transportation  
 Maintenance Supervisor, Iowa Department of Transportation

#### **Kansas (2)**

Equipment Engineer, Kansas Department of Transportation  
 Assistant Chief, Bureau of Construction and Maintenance, Kansas Department of Transportation

#### **Maine (1)**

Director of Snow Removal Operations, Piscataqua Landscaping Co. Inc

#### **Maryland (5)**

District Equipment Supervisor, Maryland State Highway Administration  
 Fleet Supervisor, Maryland State Highway Administration  
 District Equipment Supervisor, State Highway Administration  
 District Equipment and Safety Supervisor, State Highway Administration  
 Division Chief, Maryland State Highway Administration

#### **Michigan (6)**

Field Operations Manager, City of Kalamazoo  
 Maintenance Superintendent, Michigan Department of Transportation  
 Fleet Manager, Michigan Department of Transportation  
 Maintenance Superintendent, Michigan Department of Transportation  
 Region Maintenance Superintendent, Michigan Department of Transportation  
 Supervisor, Western Michigan University

**Minnesota (4)**

Maintenance Superintendent, Minnesota Department of Transportation  
Winter Maintenance Coordinator, Minnesota Department of Transportation  
Fleet Manager, Minnesota Department of Transportation  
Highway Maintenance Support, Minnesota Department of Transportation

**Missouri (6)**

Main Supt. II, Missouri Department of Transportation  
Maintenance Superintendent, Missouri Department of Transportation  
Maintenance Superintendent II, Missouri Department of Transportation  
Maintenance Superintendent, Missouri Department of Transportation  
Maintenance Superintendent II, Missouri Department of Transportation  
Tech Support Engineer, Missouri Department of Transportation

**Montana (12)**

Shop Superintendent, Montana Department of Transportation  
Shop Superintendent, Montana Department of Transportation  
Maintenance Chief, Montana Department of Transportation  
Maintenance Review, Montana Department of Transportation  
Shop Superintendent, Montana Department of Transportation  
Shop Superintendent, Montana Department of Transportation  
Shop Supervisor, Montana Department of Transportation  
Bureau Chief, Montana Department of Transportation  
Shop Superintendent, Montana Department of Transportation  
Shop Superintendent, Montana Department of Transportation  
Maintenance Supervisor, Montana Department of Transportation  
Shop Foreman, Montana Department of Transportation

**Nebraska (2)**

District Operations Manager, Nebraska Department of Roads  
Maintenance Engineer, Nebraska Department of Roads

**Nevada (1)**

Highway Maintenance Supervisor II, Nevada Department of Transportation

**New Jersey (1)**

Winter Operations, New Jersey Department of Transportation

**New York (4)**

Section Maintenance Supervisor, New York State Thruway  
Highway Maintenance Engineer, New York State Thruway Authority  
Highway Maintenance Supervisor II, NYSDOT  
Snow and Ice Program Engineer, NYSDOT

**Ohio (4)**

Local Public Agency Construction Monitor, Ohio Department of Transportation  
Equipment Service Area Coordinator, Public Services, City of Cincinnati  
Grounds Supervisor, The Ohio Masonic Home  
President, Yard Smart Inc.

**Oregon (1)**

Program Coordinator, Oregon Department of Transportation

**Pennsylvania (3)**

Director of Public Works, Municipality of Norristown

Assistant District Executive, Pennsylvania Department of Transportation  
Chief Equipment Division, Pennsylvania Department of Transportation

**Rhode Island (1)**

Highway Superintendent, D.P.W., City of Providence

**Tennessee (2)**

Equipment Mechanic II, Tennessee Department of Transportation  
Supervisor I, Tennessee Department of Transportation

**Utah (2)**

Engineer of Maintenance, Utah Department of Transportation  
Methods Engineer, Utah Department of Transportation

**Vermont (6)**

General Manager, State of Vermont District I  
Transportation General Maintenance Manager, Vermont Agency of Transportation  
General Manager, Vermont Agency of Transportation  
General Maintenance Manager, Vermont Agency of Transportation  
General Manager, Vermont Agency of Transportation  
General Maintenance Manager, Vermont Agency of Transportation

**Virginia (55)**

Transportation Operations Manager II, Virginia Department of Transportation  
Superintendent, Virginia Department of Transportation  
Transportation Operations Manager II, Virginia Department of Transportation  
Transportation Operations Manager II, Virginia Department of Transportation  
District Maintenance Engineer, Virginia Department of Transportation  
Transportation Operations Manager III, Virginia Department of Transportation  
B&T Superintendent, Virginia Department of Transportation  
Transportation Operations Manager I, Virginia Department of Transportation  
Transportation Operations Manager III, Virginia Department of Transportation  
Transportation Operations Manager II, Virginia Department of Transportation  
Transportation Operations Manager II, Virginia Department of Transportation  
Equipment Repair Supervisor, Virginia Department of Transportation  
Transportation Manager II, Virginia Department of Transportation  
Supervisor, Virginia Department of Transportation  
Maintenance Superintendent, Virginia Department of Transportation  
Maintenance Operations Manager, Virginia Department of Transportation  
Transportation Operations Manager, Virginia Department of Transportation  
Transportation Operations Manager III, Virginia Department of Transportation  
Transportation Operations Manager II, Virginia Department of Transportation  
Transportation Operations Manager II, Virginia Department of Transportation  
Transportation Operations Manager III, Virginia Department of Transportation  
Transportation Operations Manager II, Virginia Department of Transportation  
Transportation Operations Manager I, Virginia Department of Transportation  
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Transportation Operations Manager II, Virginia Department of Transportation  
Transportation Operations Manager I, Virginia Department of Transportation  
Transportation Operations Manager III, Virginia Department of Transportation  
Transportation Operations Manager I, Virginia Department of Transportation

Transportation Operations Manager II, Virginia Department of Transportation  
Transportation Operations Manager III, Virginia Department of Transportation  
Transportation Operations Manager I, Virginia Department of Transportation  
Transportation Operations Manager II, Virginia Department of Transportation  
Superintendent, Virginia Department of Transportation  
Maintenance Supervisor, Virginia Department of Transportation  
Superintendent, Virginia Department of Transportation  
Superintendent, Virginia Department of Transportation  
Maintenance Superintendent, Virginia Department of Transportation  
Area Superintendent, Virginia Department of Transportation  
Superintendent, Virginia Department of Transportation  
Maintenance Superintendent, Virginia Department of Transportation  
Shop Forman, Virginia Department of Transportation  
Transportation Operations Manager, Virginia Department of Transportation  
Transportation Operations Manager II, Virginia Department of Transportation  
Operator, Virginia Department of Transportation  
Transportation Operations Manager II, Virginia Department of Transportation  
Superintendent, Virginia Department of Transportation  
Maintenance Manager, Virginia Department of Transportation  
Transportation Operations Manager I, Virginia Department of Transportation  
Maintenance Operations Manager, Virginia Department of Transportation  
Transportation Operations Manager II, Virginia Department of Transportation

#### **Washington D.C. (2)**

Snow & Street Operations Manager, Department of Transportation  
Equipment Programs Coordinator, Metro Washington Airports Authority

#### **Wisconsin (7)**

Shop Lead Worker, Jefferson County Highway Department  
Shop Superintendent, Manitowoc County Highway  
Purchasing Agent/ Shop Supervisor, Marinette County Highway Department  
Commissioner, Pepin County Highway Department  
Fleet Supervisor, Polk County Highway Department  
Shop Superintendent, Rock County DPW  
Shop Foreman, Taylor County Highway Department

#### **Wyoming (2)**

Avalanche Technician, Wyoming Department of Transportation  
State Maintenance Engineer, Wyoming Department of Transportation

### **INTERNATIONAL**

#### **Canada (10)**

Operations Standards Engineer, Alberta Infrastructure and Transportation (Edmonton, Alberta)  
Pavement Management Supervisor, City of Edmonton (Edmonton, Alberta)  
Operations Manager, County of Wellington (Ontario, Canada)  
Owner/ President, MarKham Property Services Ltd. (Ontario, Canada)  
Fleet Coordinator, Ministry of Transportation (Ontario, Canada)  
Snowfighter Program Coordinator, NB Department of Transportation (New Brunswick, Canada)  
Fleet Manager, Nova Scotia Department of Transportation (Halifax, Nova Scotia)  
Transportation Operations Manager, Regional Municipality of Niagara  
Technical Analyst, Region of Peel (Brampton)  
Fleet Safety & Training Officer, Region of Peel

#### **Japan (1)**

Deputy Director of Traffic Engineering Division, Civil Engineering Research Institute (Hokkaido, Japan)

**Sweden (3)**

Senior Researcher, Swedish Road and Transportation Research Institute

Project Manager, Swedish Road Administration

Senior Researcher, VTI

**United Kingdom (2)**

Senior Technical Manager, TRL Ltd.

Motorway and Truck Road Winter Maintenance Officer, Transport Wales, Welsh Assembly Government

**Finland (1)**

Supervisor, YIT Rakennus Oy

**Manufacturer Survey**

Mack Trucks, Inc.

International Truck

Nartron Corporation

Wiper Shaker Technology Inc.

W N Miller Company, Inc.



research for winter highway maintenance

Lead state:

**Wisconsin Department of Transportation**  
4802 Sheboygan Ave.  
P.O. Box 7965  
Madison, WI 53707-7965