

Alternative Deicer Performance Characterization: Know Before the Snow (Addendum)

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Minnesota State University, Mankato

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Research Report

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16. Abstract (Limit: 250 words) MnDOT has been using alternative deicers (potassium chloride, magnesium chloride, and calcium chloride) to melt roadway ice at temperatures colder than sodium chloride can melt it alone. Using alternative deicers in brine form has been a way to leverage treatment techniques at temperatures below 15° F. However, these alternative deicers have not yet had the “phase diagram” or “ice melt capacity relationship” developed to characterize their melting ability (potential and performance) by temperature and deicer concentration. Without these tools, MnDOT operators have been working on past observations, hunches and vendor recommendations, without the benefit of the science that guides their use of sodium chloride in rock salt brine. In colder regions of the state, the lack of scientific determination can be particularly troublesome as operators fight refreeze when either temperatures drop or deicer concentrations dilute down, which can result in either unsafe conditions or significantly extra material expense and environmental degradation. This addendum reports the field test and performance comparison of the alternative deicer most in use by MnDOT, under actual winter maintenance operations. Differing rates, blends, distribution equipment and traffic levels were evaluated.					
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Alternative Deicer Performance Characterization: Know Before The Snow

Addendum: On-Pavement Field Comparison, Second Winter

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Executive Summary

The goal of this project addendum was to evaluate the alternative deicer most in use by MnDOT in the field under conditions modeling actual highway conditions, extending the work done during the previous winter. Specific to this second winter's evaluation, the alternative deicer BEET HEET® was tested in an on-pavement treatment comparison, allowing for performance of the alternative deicer to be compared across times and rates of application and co-treatment with rock salt. The Emergence Vehicle Operator Course at the Minnesota National Guard Camp Ripley facility was used for the on-pavement testing, where an artificial snow and ice pack was created through a blending of existing dry snow and applied water at temperatures of -5 to 8° F in the days before testing. Factors evaluated included:

- Roadway surface response to deicing and traffic over time
- Comparison to control sections representing no traffic or no treatment sections
- Liquid deicer rate
- Liquid and solid delivery system
- Liquid deicer co-delivered with the rock salt compared to no liquid or liquid of stockpile treatment
- Liquid blend

The evaluation did not show significant response of roadway clearing due to treatments, likely related to the cold temperature and the low rates of deicer application. Both the temperature and the deicer rate were selected by the research team in extended consultation with the Technical Advisory Panel subcommittee, as the goal of this effort was to evaluate extreme conditions of temperature (below the melting range of rock salt) and deicer rate (low levels of treatment to assess the limit of effectiveness).

Chapter 1: Introduction

MnDOT has been using alternative deicers (potassium chloride, magnesium chloride, and calcium chloride) to melt roadway ice at temperatures colder than sodium chloride can melt it alone. Using alternative deicers in brine form, a technique called direct liquid application (DLA), has been a way to leverage treatment techniques at temperatures below 15° F. However, these alternative deicers for DLA have not yet had the “phase diagram” or “ice melt capacity relationship” developed to characterize the melting ability (potential and performance) by temperature and deicer concentration. Without these tools, MnDOT operators are working on past observations, hunches and vendor recommendations, without the benefit of the science that guides their use of sodium chloride in rock salt brine.

In colder regions, the lack of scientific determination can be particularly troublesome as snowplow operators fight refreeze when either temperatures drop or deicer concentrations dilute down, which can result in either unsafe conditions or significantly extra material expense and environmental degradation.

The goal of this project is to develop a phase diagram and assess the ice melt capacity of the alternative deicer most in use by MnDOT. The goal of this task is to perform a second season of on-pavement treatment comparisons, refining observations and evaluation performance made during Task 5 of this project during the previous winter. The report for this task will be published as an addendum to MnDOT report 2026-09 (<https://mdl.mndot.gov/items/202609>).

Chapter 2: Materials and Methods

For this task, BEET HEET® (K-Tech Specialty Coatings, Inc., Ashley, Indiana) (K-Tech) was selected for study from available deicing brines used for direct liquid application (DLA) by the MnDOT Technical Assistance Panel of this project. BEET HEET® is a brown, slightly odorous, liquid with a viscosity that appears to be similar to the viscosity of water; it is not “thick” but quite “loose”, like water. The odor is faint and sweet as in sugar or molasses-like sometimes with a fragrance of alcohol and fermentation, particularly in the older samples (Standard Methods 2170; Rice, et al., 2012). According to K-Tech (2024), BEET HEET® contains four chlorides and four carbohydrates (listed in the order listed by K-Tech):

- Calcium chloride, magnesium chloride, sodium chloride, and potassium chloride; and,
- Sucrose, glucose, fructose and raffinose sugars.

MnDOT has worked with K-Tech to have the magnesium chloride not in the mixture, due to difficult experiences in the past with magnesium chloride. K-Tech responded with Mn-BEET HEET®.

Rock salt and BEET HEET® were both provided by MnDOT from standard operational stockpiles and tankage working out of the Little Falls, Minnesota truck station. Additional rock salt pretreated with a magnesium chloride product (not specified) at 4 gal/ton was supplied by the Walker, Minnesota truck station.

2.1 Test Pavement Location and Facility Configuration

MnDOT arranged for the Emergence Vehicle Operator Course (EVOC) at the Minnesota National Guard Camp Ripley facility to be used for on-pavement testing, as MnDOT had used the course previously. The course consists of an approximately 2.5-mile paved perimeter track, several gravel road sections, and a paved 700 ft by 300 ft center pad called the Wet Skid Pad (Skid Pad). The perimeter track is configured with a two-lane highway geometry for about 2 miles and a four-lane divided highway geometry for about 1 mile. The EVOC was reserved and through Camp Ripley Range Control, who also managed the access through normally-locked gates.

The Camp Ripley EVOC offered several advantages:

- Access is controlled, and can be reserved ahead during winter months within the window around weather forecasting of snow and temperature conditions;
- Post-storm traffic can be prevented until testing time;
- Pavement conditions are highly uniform;
- Camp Ripley is centrally located within Minnesota, allowing both support from MnDOT facilities and staff plus easy access to researchers; and,
- Camp Ripley’s geographical position provides the potential for sub-zero temperatures and accompanying snow to support the targeted test conditions.

A subcommittee of the Technical Advisory Panel for this project met weekly with the project Principal Investigator during January to review upcoming forecasts and plan deployment and testing at the Camp Ripley EVOC (hereafter referred to as “the test track” for purposes of this report). The subcommittee consisted of Maintenance Engineers, Supervisors and technical staff from Districts 1 and 3 plus Central Office who could advise on application procedures, equipment, and EVOC use, and commit resources.

2.2 Proposed Application Areas

Test locations at the test track were planned out ahead and applications proposed for testing during work with the Technical Advisory Panel subcommittee. Appendix A provides the Experimental Plan developed for the on-pavement field testing of the deicer blends. The plan included the following summary aspects:

- Base application amounts off a standard deicer treatment of 200 pounds per lane mile for rock salt with rates of 15 or 30 gallons per lane mile liquid co-application;
 - Note: A lane mile is a 12-foot width of pavement 1.0 mile (5,280 feet) long, or 63, 360 square feet, an area approximately 1.4 acres in size.
- On the perimeter roadway of the test track, eleven 700-foot-long sections were set up.
 - Testing the following factors:
 - Two different deicer treatments:
 - 80:20 salt brine:BEET HEET® mixture at 15 and 30 gallons per lane mile with 200 pounds per lane mile untreated rock salt (done on two lanes to create a replicate for comparison); and,
 - 70:30 salt brine:BEET HEET® mixture at 8, 15 and 30 gallons per lane mile with 200 pounds per lane mile untreated rock salt.
 - Three different deicer distribution systems:
 - Liquid applied to rock salt on a spinner;
 - Liquid applied to rock salt in a chute; and,
 - Liquid applied to rock salt within an auger.
 - Non-treatment controls:
 - One control section located after approximately 2000 feet of bare lane pavement, done to limit drag-through of deicer from previous sections during traffic application; and,
 - One control section in the middle of the treated sections to test for effects of drag-through of deicer during traffic application.
 - Lanes were designated by phonetic alphabet terms Zulu, Alpha, Bravo, Charlie, Delta, Echo, Foxtrot, Golf, Hotel, Indigo, and Juliet.
 - Observations for the perimeter roadway sections were made at 15 to 20-minute intervals using two Nikon D3000 single lens reflex digital cameras (done by two separated photographers looping the perimeter roadway section by section to increase reliability).
- On the skid pad, seven parallel lanes of approximately 20 feet wide by 300-feet long were set up, separated by 10 feet of spoil pile bermed up to prevent cross-treatment possibilities.
 - Test five different deicer treatments:
 - 90:10 salt brine:BEET HEET® mixture at 15 gallons per lane mile with 200 pounds per lane mile untreated rock salt;

- 80:20 salt brine:BEET HEET® mixture at 15 gallons per lane mile with 200 pounds per lane mile untreated rock salt (done on two lanes to create a replicate for comparison);
- 70:30 salt brine:BEET HEET® mixture at 15 gallons per lane mile with 200 pounds per lane mile untreated rock salt;
- No liquid with 200 pounds per lane mile untreated rock salt; and,
- No liquid with 200 pounds per lane mile rock salt stockpile treated with 4 gallons per ton of a magnesium chloride product (not specified).
- Use one lane for a non-traffic, non-treatment control.
- Lanes were designated by phonetic alphabet terms Oscar, Papa, Quebec, Romeo, Sierra, Tango and Uniform.
- Observations for the skid pad lanes were made after 10-minute intervals using two Nikon D3000 single lens reflex digital cameras (done by two photographers in parallel to increase reliability).

The proposed test locations and applications are shown at the locations indicated on the aerial photo of the perimeter roadway (Figure 1) and on the sketch of the skid pad (Figure 2), and listed in Table 1. The colors in the figures represent the field flagging colors of the markers for the test sections. Note that compacted snow and ice on the skid pad did not extend to the full borders as shown, necessitating change during testing such that return lanes were moved outside of the snow and ice area. A return lane on the north (top) side was created for the vehicles on the Romeo, Sierra and Tango lanes, and a return lane on the south (bottom) side for the vehicles on the Oscar, Papa and Quebec lanes.

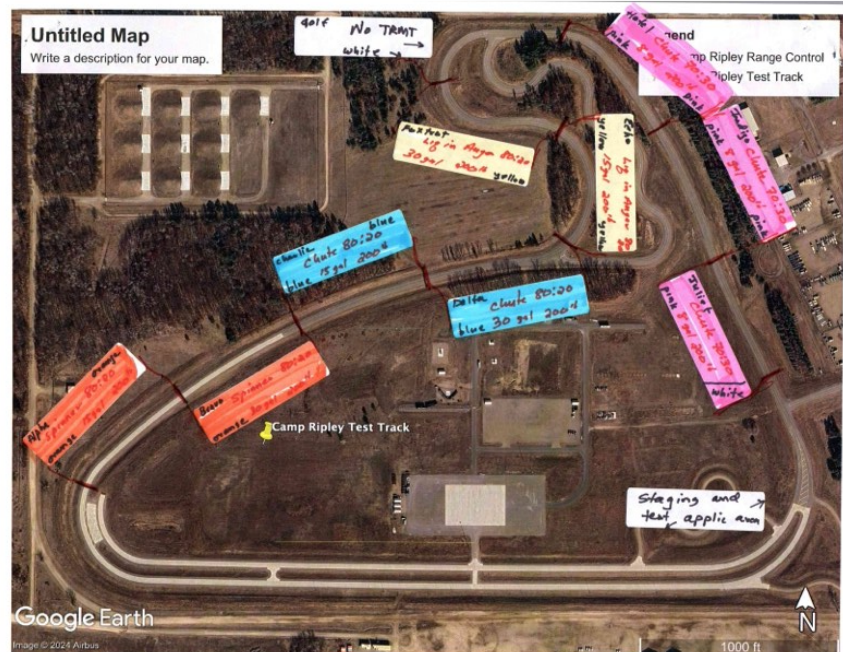


Figure 1. Test track experimental layout, showing proposed applications.

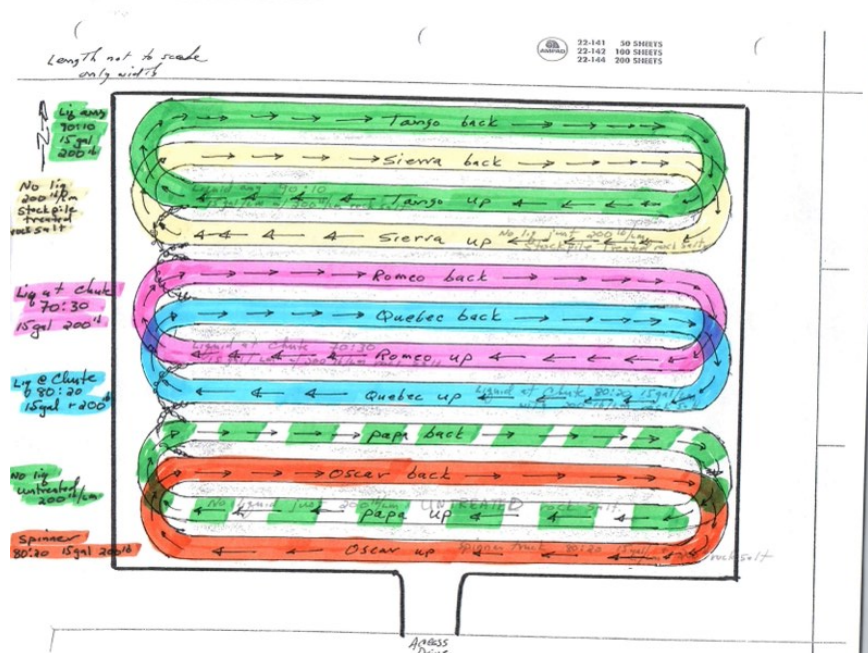


Figure 2. Skid pad experimental layout, showing proposed applications.

2.3 Test Weather Conditions

A weather summary of January 29, 2026 for Little Falls, Minnesota from Weatherunderground.com is provided in Appendix B. It includes hourly temperature, wind, and wind gust information plus minimum, maximum and daily average dew point information. Weather conditions at the test track during the period of testing may be summarized as:

- Temperatures: rising from an early morning low of -15°F to a midday temperature of between 0 and 5°F ;
- Wind: winds from $5 - 8$ mph from the southwest;
- Dewpoint of -8°F , rising slightly to -4°F ; and,
- Fair and mostly sunny with some moments of transitory cloudiness.

2.4 Snow and Ice Conditions on Pavement Areas for Testing

While snow was on the ground generally, reconnaissance on Monday of the week proposed for testing found the pavement bare as the snow was dry and had blown off in strong winds. MnDOT proceeded to apply water to the perimeter roadway and the skid pad using a tanker truck, and pushed and plowed on snow that had drifted to areas adjacent to the roadway or pad.

Conditions on the perimeter roadway section consisted of a dense and hard compaction of snow and ice, some loose granular snow but most as white to gray solid ice with an estimated thickness of $3/8$ ths of an inch (Figure 3). No additional preparation was done on the day of the testing.



Figure 3. Conditions on the perimeter roadway section, location Zulu just after the test beginning.

Conditions at the skid pad were adjusted during preparation for testing by underbody plowing done by a motor grader (Cat 140 AWD; 44,600 pounds weight with a 12-foot blade according to https://www.cat.com/content/catdotcom/en_US/products/new/equipment/motor-graders/motor-graders.html) and a plow truck to cut and shape the lanes (Figure 4). It was theorized by by Jamie Hukriede of MnDOT District 3 that underbody plow action would crack any hard ice compaction and make the ice more amenable to deicing. This procedure was consistent with MnDOT procedures for deicing compacted snow and ice in near-zero conditions. Conditions at the skid pad lanes consisted of a stiff (but not hard) compaction of snow and some ice with an estimated thickness of 1/4th of an inch (Figure 5).



Figure 4. Motor grader and plow truck using underbody plow to cut and shape lanes at the skid pad prior to testing.

Perimeter roadway test sections and skid pad test lanes were measured then laid out using pin flags and flagging tape attached to bricks to limit effects from wind. A complete directory of locations is provided in Appendix C., with forward and back photographs of the roadway and lane surfaces as taken from the marked section or lane center.



Figure 5. Conditions at the skid pad, location Uniform just after the test beginning.

2.5 Deicer Treatment and Testing

Deicer was applied at the rates and by the distribution methods listed in Table 1 (Figure 6). For all treatments, deicer was applied on truck left side in a wheel line drop without any wider spray. For the perimeter roadway, both initial plow truck application and subsequent traffic was configured as a two-lane, one-way roadway, with treatment on the left wheel line while driving in the right lane. Deicer was reapplied on the perimeter roadway sections one hour after initial application using the same rates and methods as the first treatment (Figure 7). For the skid pad lanes, deicer was applied in two passes, up and back, focusing treatment on the center of the lane.

Traffic was then applied to the treatment areas (Figure 8). For the perimeter road, traffic consisting of six plow trucks (no plowing, no additional deicer application) and six light vehicles (sports utility vehicles) looped approximately every 5 minutes, driving approximately 30 miles per hour. In this way, in the two hours after treatment, an estimated 280 total vehicle passes were made. Traffic at this level is roughly equated by the researchers as 2000 vehicles per day (veh/d) of average daily traffic (ADT).

For the skid pad lanes, traffic consisting of one plow truck pass (no plowing, no additional deicer application) followed by one light vehicle looped such that there were about five passes of each vehicle in 5 minutes. Traffic was then stopped for about 5 minutes to allow observations, then restarted. In this way, in the hour after treatment, 60 total vehicle passes (30 passes each of the plow truck and the light vehicle). Traffic at this level is roughly equated by the researchers as a 500 veh/d ADT.

Photography of each section or lane was done from marked locations in the center of each treatment area with photographs oriented in a pattern of: a marker object to denote start of the specific lane, then back long, back pavement, forward long, forward pavement, and any additional pavement photographs as needed. Lane configuration using the “back long” and “forward long” photographs is provided in Appendix C. Roadway pavement temperatures were measured in both point and area (graphical) format using a FLIR E6 (FLIR Systems, Inc., Wilsonville, Oregon) infrared camera (Figure 9).

Snow strength and consistency were assessed at the skid pad lanes using visual-manual methods (Figure 10). Typical results are shown for a perimeter roadway section (Figure 11) and a skid pad lane (Figure 12).

All pavements were plowed clear at the completion of the testing (Figure 13). Once freed from the constraints of the testing protocol, maintenance personnel were able to quickly clear the pavements using motor grader and plow truck underbody plowing combined with deicer rates higher than used during the experiments.



Figure 6. Deicer being applied to a test lane at the skid pad.

Table 1. Test sections and deicer applications.

Test Section	Solid Deicer Applied ²	Liquid Deicer ¹ Applied ²	Comments	
Zulu	none	none	Control section	Perimeter track lanes; 2000 ADT traffic equivalent
Alpha	200 lbs/LM rock salt	15 gal/LM of 80:20	Liquid at spinner	
Bravo	200 lbs/LM rock salt	30 gal/LM of 80:20	Liquid at spinner	
Charlie	200 lbs/LM rock salt	15 gal/LM of 80:20	Liquid at chute	
Delta	200 lbs/LM rock salt	30 gal/LM of 80:20	Liquid at chute	
Echo	200 lbs/LM rock salt	15 gal/LM of 80:20	Liquid mixed in auger	
Foxtrot	200 lbs/LM rock salt	30 gal/LM of 80:20	Liquid mixed in auger	
Golf	none	none	Control section/test for deicer drag through	
Hotel	200 lbs/LM rock salt	8 gal/LM of 70:30	Liquid at spinner	
Indigo	200 lbs/LM rock salt	15 gal/LM of 70:30	Liquid at spinner	

Juliet	200 lbs/LM rock salt	30 gal/LM of 70:30	Liquid at spinner	
Kilo, Lima, Mike and November	Not used	Not used	Insufficient snow or ice therefore not used	
Oscar	200 lbs/LM rock salt	15 gal/LM of 80:20	Liquid at spinner	Pad lanes; 500 ADT traffic equivalent
Papa	200 lbs/LM rock salt	none	Chute	
Quebec	200 lbs/LM rock salt	15 gal/LM of 80:20	Liquid at chute	
Romeo	200 lbs/LM rock salt	15 gal/LM of 70:30	Liquid at chute	
Sierra	200 lbs/LM rock salt	15 gal/LM of 90:10	Liquid at chute	
Tango	200 lbs/LM treated rock salt	none	Rock salt stockpile treated 4 gal/ton	
Uniform	none	none	No traffic; control section	

Note 1: Liquid deicer material, when a mixture of two components, is designated using the industry standard terminology of salt brine proportion:alternative deicer proportion. As discussed in the Materials section of this report, the alternative deicer selected for study was BEET HEET.

Note 2: Deicer treatments were made on the perimeter roadway initially and again as a reapplication 60 minutes after first treatment. Deicer treatments were made on the skid pad lanes twice in separate passes at the test start.



Figure 7. Plow trucks returning from treatment application on perimeter roadway; note MSU research personnel as passenger “ride alongs” to guide treatment location and confirm rates and amounts.



Figure 8. Typical traffic applied to perimeter track.



Figure 9. Observations of roadway surface temperature being collected through thermography. Visual observation of snow and ice condition on the roadway surface were collected separately by photography.



Figure 10. Evaluating snow strength and consistency.



Figure 11. Typical perimeter roadway testing results (Indigo with 200 lbs/LM rock salt and 15 gal/LM 70:30 prewet delivered as liquid to a spinner). From top to bottom: 23 minutes, 57 minutes, and 97 minutes after initial application.



Figure 12. Typical skid pad lane testing results (Quebec with 200 lbs/LM rock salt and 15 gal/LM 70:30 prewet delivered as liquid to the chute). From top to bottom: 5 minutes, 25 minutes, and 47 minutes after initial application.



Figure 13. Clean off of wet skid pad pavement after completion of testing.

Chapter 3: Results

Appendix D presents full results of analyses performed using photograph comparison of test locations by time. Testing on the perimeter roadway sections were conducted at an air temperature of approximately 1° F, while testing on the skid pad lanes were conducted at an air temperature of approximately 5° F. Roadway surface temperatures were measured at the left wheel track of the right-hand lane during the testing on the perimeter roadway sections, with values generally between 2 to 6° F, averaging 4° F. Roadway surface temperatures were similarly measured on the skid pad lanes during testing there. Values on the skid pad lanes were approximately 2° F at the start of the testing, rising consistently across the treated and trafficked lanes to 12° F after 25 minutes and 14° F after 47 minutes since initiation of the tests. Note that the control lane reached a temperature of 6° F after 47 minutes and was not changing consistent with the treated and trafficked lanes.

Chapter 4: Evaluation

Evaluating the results, several trends may be identified and defined:

1. The no-treatment control sections for the perimeter roadway (sections Zulu and Golf) show hard, compact, white and gray colored snow-ice hardpack. Free liquid or melt product was not present at either the beginning of the test just after treatment or after traffic at anytime through the period of the test (out to 107 minutes). With time, the surface white compacted snow disappeared and the hardpack became fully gray with a shined-up, smooth surface.
2. No significant difference was observed in the behavior of the snow-ice hardpack between the no-treatment control section that followed 2000 feet of bare lane (Zulu) and the no-treatment control section that followed treated sections (Golf). This lack of difference is interpreted as lack of evidence of deicer “drag through”, bringing deicer from one section to another by the action of traffic through the treated section.
3. The no-treatment no-traffic control section of the skid pad (lane Uniform) shows compact, white colored snow hardpack with some integral ice. Free liquid or melt product was not present at either the beginning of the test just after treatment or after traffic at anytime through the period of the test (out to 57 minutes). With time, no change in the lane surface was noted. This lack of change is interpreted as lack of effect caused by ambient weather conditions, e.g., sun, temperature and wind. Therefore, any effects noted would have been caused by treatment and traffic, not the ambient weather.
4. All treated sections on the perimeter roadway and lanes on the skid pad showed a brown colored treatment stripe at the beginning of the tests just after treatment that then widened through the test period with time and traffic to a width approximately equal to a travel lane width, or approximately 12 feet. This observed behavior is interpreted as evidence of tire massage of the treated surface such that the treated snow and ice (deicer both in and on the snow and ice crystal structure) are squeezed and ironed out, and subsequently spreading across the roadway surface with traffic.
5. Comparison of adjacent sections with treatment rate increases did not show a significant difference in compacted snow and ice surfaces. Comparison of perimeter roadway test sections of Alpha, Charlie and Echo at 15 gallons per lane mile of 80:20 liquid deicer to sections of Bravo, Delta and Foxtrot, respectively, at 30 gallons per lane mile of 80:20 did not show behaviors different than those for all treated sections of the perimeter roadway. Similarly, comparison of roadway test sections that used 70:30 at rates of 8, 15 and 30 gallons per lane mile did not show significant difference. Roadway surfaces were not observed to have differences related to the treatment differences of either application.
6. Comparison of adjacent section sets with treatment delivery system differences likewise did not show significant difference in compacted snow and ice surfaces on the roadways. Some minor difference was noted with the liquid blended in salt from the auger creating slightly more softened snow and ice structure, but the amount was insufficient to determine conclusively particularly given the potential influence of shade from woods adjacent to some roadway sections being compared. Further consideration is warranted.
7. The effect of liquid deicer compared to either stockpile-treated rock salt or to plain rock salt (no liquid deicer, no stockpile treatment) provided a subtle but definitive difference in the snow and ice surface of the treated areas. The amount of loosened snow or ice created by the deicer with traffic was somewhat less with the stockpile-treated rock salt and definitely less with the plain rock salt. Treatment of rock salt with a liquid while stockpiling the salt is typically done at 4

gallons per ton; in the experiment, rock salt was applied at 200 pounds per lane mile. Carrying the rate through, a stockpile-treated rock salt at 200 pounds per lane mile therefore has a liquid deicer of 0.4 gallons per lane mile; much reduced from the 15 gallons per lane mile being applied in parallel during the experiment. Note that while the stockpile-treated rock salt had a dark green tint suggesting a magnesium chloride-based treatment, not BEET HEET as used elsewhere in the testing, the ice melt capacity at the ambient temperatures during the test would have a similar value.

8. Comparison of effects from different liquid deicer blends (90:10, 80:20, and 70:30) showed a slight effect on the snow and ice surface of the test sections. Specifically, the higher amounts of BEET HEET in the liquid mixture seemed to cause the snow and ice surface to smooth and polish into a softer surface that at the start of the test, whereas the lower amounts of BEET HEET created loose snow and ice particles on the surface. This effect could be observed through the enhancement of a surface compacting with additional traffic on the stronger mixture sections compared to an increase in dry spray of material coming off the vehicle tires (an observation suggested by Randy Strassburg of MnDOT District 3 during the traffic application) on the weaker mixture sections.

Chapter 5: Conclusions

The alternative deicer BEET HEET® was tested in an on-pavement treatment comparison, allowing for performance of the alternative deicer to be compared across times and rates of application and co-treatment with rock salt. The Emergence Vehicle Operator Course at the Minnesota National Guard Camp Ripley facility was used for the on-pavement testing, where an artificial snow and ice pack was created through a blending of existing dry snow and applied water at temperatures of -5 to 8° F in the days before testing. Materials, equipment and personnel were supplied by MnDOT. Ambient weather during the time of testing was a temperature of between 0 and 5° F and steady, mostly cloudy skies, winds were from the southwest at 5 to 8 mph, and an average dew point of -4° F.

Comparative tests were performed on selected locations using photograph documentation of test locations by time after deicer treatment. Six plow trucks were used for differing deicer material combinations. Traffic was applied using both the plow trucks and light vehicles from MnDOT, driven by MnDOT personnel. Factors evaluated included:

- Roadway surface response to deicing and traffic over time
- Comparison to control sections representing no traffic or no treatment sections
- Liquid deicer rate
- Liquid and solid delivery system
- Liquid deicer co-delivered with the rock salt compared to no liquid or liquid of stockpile treatment
- Liquid blend

The evaluation did not show significant response of roadway clearing due to treatments, likely related to the cold temperature and the low rates of deicer application. Both the temperature and the deicer rate were selected by the research team in extended consultation with the Technical Advisory Panel subcommittee, as the goal of this effort was to evaluate extreme conditions of temperature (below the melting range of rock salt) and deicer rate (low levels of treatment to assess the limit of effectiveness).

However, slight and subtle effects were observed due to the use of liquid deicer in addition to rock salt, primarily evidenced by the snow and ice surface becoming smoother, shinier and with less loose material than with rock salt alone when subject to traffic after treatment.

These results likely were caused by the rock salt especially having very limited ice melt capacity to support deicing, and even BEET HEET having an ice melt capacity of about 2, for example, the amount of melting would be twice the amount of deicer applied. Focusing on the BEET HEET application:

- 80:20 applied at 15 gallons per lane mile is an effective rate of pure BEET HEET rate of 3 gallons per lane mile.
- If the treated width is just 3 feet, representing the initial conditions under a left wheel lane drop distribution as was used in these tests, a treated area of 15,840 square feet per lane mile is achieved.

- Spreading 3 gallons per lane mile over 15,840 square feet, and noting that 1.0 gallon equals 0.134 cubic feet in volume, an average thickness would be 00.0000085 foot, or 0.000102 inches, also equal to 0.10 mil.
- Applying an ice melt capacity factor of 2, the average depth of melt would be 0.00020 inches.

This average depth of melt is unlikely to create even a sheen of wetness on the snow and ice layer. However, some of the top surface of the snow and ice layer would likely soften, not melt, in response to the deicer materials, as the ice structure is weakened by ionic absorption into the ice crystal structure. Softening under traffic would likely show as smoothing of the surface.

One related and anecdotal observation is how the snow and ice surface of the skid pad lanes were more uniform and deiced easier (after test completion) than the perimeter roadway sections, even though the deicer rates were similar and the traffic was less with the skid pad lanes. A significant difference between the snow and ice surfaces may have been caused by MnDOT adjustment of preparation on the skid pad, in which employees scraped the ice sheet with the underbody plows using first a motor grader then a fully loaded plow truck. This observation does fit with the theory advanced by Jamie Hukriede of MnDOT District 3 that the heavy pressure of underbody plowing, pushing against the weight of the equipment, can crack the ice structure at cold temperatures and enhance deicing.

The snow and ice sheet for testing constructed by MnDOT during the preparation was greatly appreciated by the researchers; in the future, it would be helpful to be able to gather the Technical Advisory Panel subcommittee to make a last judgement about application rates once the thickness and condition of the snow and ice sheet has been assessed in the hours before testing. This review would be similar to how the Technical Advisory Panel subcommittee performed a “go/no-go” decision in the days before testing related to the 48-hour temperature and snow forecasts once available. Furthermore, having a MnDOT-defined procedure for deicing under extreme cold would have been a great help.

Appendix A

Experimental Plan

Camp Ripley Test Plan	Shannon Holland	XXX-XXX-XXXX
Draft January 21, 2026 - - Revised January 27, 2026	Steven Druschel	YYY-YYY-YYYY
Revised February 10, 2026 for actual times and occurrences		
S. Druschel	Jamie Hukriede	ZZZ-ZZZ-ZZZZ

Six plow trucks:

1. Liquid at spinner truck loaded with 80:20 BEET HEET w/untreated rock salt; D3 Truck 220563; Sections AB+pad O
2. Liquid at chute truck loaded with 80:20 BEET HEET w/untreated rock salt; D3 Truck 222551; Sections CD+pad P
3. Liquid mixed in auger loaded with 80:20 BEET HEET w/untreated rock salt; D6 Truck 222560; Sections EF+pad Q
4. Liquid at chute truck loaded with 70:30 BEET HEET w/untreated rock salt; D3 Truck 221562; Sections HIJ+pad R
5. Liquid at chute truck loaded with 90:10 BEET HEET w/untreated rock salt; D3 Truck 222553; pad S
6. Chute truck loaded with TREATED rock salt w/ 90:10 (no liquid from this truck); D2 Truck 219554; pad T

Perimeter track: eleven sections at 700 ft. Four trucks (delivering product). Traffic to loop clockwise direction; no counter direction travel for safety reasons. Treatment left wheel lane drop of right travel lane (not passing lane).

- No treatment (Section Zulu)
- Liquid at spinner truck with 80:20; apply 15 gal/LM along with 200 lb/LM rock salt (Section Alpha)
- Liquid at spinner truck with 80:20; apply 30 gal/LM along with 200 lb/LM rock salt (Section Bravo)
- Liquid at chute truck with 80:20; apply 15 gal/LM along with 200 lb/LM rock salt (Section Charlie)
- Liquid at chute truck with 80:20; apply 30 gal/LM along with 200 lb/LM rock salt (Section Delta)
- Liquid mixed in auger truck with 80:20; apply 15 gal/LM along with 200 lb/LM rock salt (Section Echo)
- Liquid mixed in auger truck with 80:20; apply 30 gal/LM along with 200 lb/LM rock salt (Section Foxtrot)
- SKIP Section Golf – on tight curve with superelevation. Test section for carry through.
- Liquid at chute truck with 70:30; apply 8 gal/LM along with 200 lb/LM rock salt (Section Hotel)
- Liquid at chute truck with 70:30; apply 15 gal/LM along with 200 lb/LM rock salt (Section Indigo)
- Liquid at chute truck with 70:30; apply 30 gal/LM along with 200 lb/LM rock salt (Section Juliet)

Pad: seven sections at 500 ft; dedicated overlapping loops, two photo points per section. Six total trucks delivering product (four from perimeter track plus two additional)

- Liquid at spinner truck with 80:20; apply 15 gal/LM along with 200 lb/LM rock salt (Section Oscar)
- No liquid just 200 lb/LM UNTREATED rock salt (Section Papa)
- Liquid at chute truck with 80:20; apply 15 gal/LM along with 200 lb/LM rock salt (Section Quebec)
- Liquid at chute truck with 70:30; apply 15 gal/LM along with 200 lb/LM rock salt (Section Romeo)
- Liquid at chute truck with 90:10; apply at 15 gal/LM along with 200 lb/LM rock salt (Section Sierra)
- Spinner or chute truck with no liquid just STOCKPILE-TREATED 4 gal/ton rock salt 200 lb/LM rock salt (Section Tango)
- No treatment no traffic control section (Section Uniform)

Note: Nothing is suggested for the divided highway portion of the perimeter track, but if it becomes iced then we could put the three other trucks (the ones from the pad) to application at same and then different rates. (Sections Kilo, Lima, Mike and November)

Regarding traffic: six plow trucks plus six more light trucks or SUVs to drive also. MSU will have two cars, but will be looping the track only every 20-25 minutes, not the every 6-7 minutes of the "convoy", so we shouldn't count these vehicles. MSU won't be able to drive at the pad either, as everyone will be involved in the photo documentation and description work. With six plow trucks and six light trucks/SUVs, an estimate of the modeled ADT is about 2500 veh/d on the perimeter and about 500 veh/d on each pad section.

About the experimental design: We have three similar treatments on the pad as on the perimeter track. This allows us to isolate traffic level as a factor. The list of factors being tested include:

- Effect of liquid rate
- Effect of delivery system
- Effect of liquid vs pre-treated solid only
- Effect of liquid blend
- Effect of traffic level

Section Demarcation:

- Section starting edges will be marked by a small pile of bricks with pin flags standing upright.
- Sections will be marked for identification with one, two or three flags of different heights and colors. Such markers will be placed on the driver's left side.
- Photo locations will be marked by a single brick placed flat with flagging tape only, no pin flag. These markers will also be placed on the driver's left side.
- Locations will be measured on the ground using a measuring wheel.

Schedule as planned:

- Track check on Friday 1/23 before 10 am.
- Go/no go decision during meeting Friday 1/23 at 10 am.
- Possible surface treatments such as brine application for moisture and refreeze to be done by MnDOT perhaps Monday or Tuesday but more likely Wednesday.
- MSU arrives 12 pm Wednesday to do section layout and demarcation on both perimeter track and pad.
- 8:15 am Thursday operation talk/safety talk with all drivers and MSU people.
- 8:30 am begin perimeter treatment; MSU people on ride along to help operators with rate selection and to document.
- 9:00 am begin traffic looping; begin MSU photo documentation.
- 10:00 am begin second treatment; MSU people again ride along to document.
- 11:00 am wrap up perimeter track experiment; move to pad. Take brief hygiene break.
- 11:15 am prepare pad by plowing surface smooth using first a motor grader then a plow truck using the underbody plow.
- 12:45 pm treat pad lanes with two passes in a loop action, distributing material left wheel lane both going and returning.
- 1:00 pm begin traffic looping (one truck and one light truck/SUV per loop); begin MSU photo documentation.
- 2:00 pm wrap up pad experiment. MSU people pick up markers on pad and on perimeter. MnDOT clean up by plowing and treating pad and track as needed.
- 2:30 pm all done/heading off base.
- Friday 1/30 10 am meeting to discuss initial observations.

MSU Measurement Technique:

- Each section of treatment will have two locations where photos will be taken at approximately 10-minute intervals.
 - Locations are to be marked in the center of a 700-foot perimeter track section;
 - Locations on the test pad are to be marked for 200 and 350 feet from the start of a 500-foot pad test section;
- At each photo location for each photo interval, a sequence of pavement photos will be taken including:
 - Behind at flag marker of section beginning;
 - Ahead long;
 - Ahead close;
 - Behind long; and,
 - Behind close.
- Additional photographs will be taken of plow trucks, traffic, markers, personnel and snow condition.
- Two photographers in two separate vehicles will be circling the perimeter track at about 10-minute separation, completing a circle of the 18 or more photo locations about every 20 minutes. Vehicle drivers and a note taker will also be there. The goal is to offset photo documentation such that sections are documented every 10 minutes after treatment.
- Two photographers will cross the lanes of the test pad about every 10 minutes, photographing “up lanes” and “down lanes” both (i.e., both middle-to-ends of a treatment and traffic loop). Traffic will cease as photographers cross the lanes and photograph.

Appendix B

Weather Records of Field Set Up and Test Days

Search Locations

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 Ad Free

 Popular Cities

San Francisco, CA 
49 °F Partly Cloudy (/weather/us/ca/san-francisco/37.78,-122.42)

Manhattan, NY 
34 °F Partly Cloudy(/weather/us/ny/manhat

45.98 °N, 94.36 °W

Little Falls, MN Weather History  

 28° LINDBERGH FLD STATION (/DASHBOARD/PWS/KMNLITTL19?CM_VEN=LOCALWX_PWSDASH) | CHANGE 

- [TODAY \(/WEATHER/US/MN/LITTLE-FALLS/KLXL\)](/WEATHER/US/MN/LITTLE-FALLS/KLXL)
- [HOURLY \(/HOURLY/US/MN/LITTLE-FALLS/KLXL\)](/HOURLY/US/MN/LITTLE-FALLS/KLXL)
- [10-DAY \(/FORECAST/US/MN/LITTLE-FALLS/KLXL\)](/FORECAST/US/MN/LITTLE-FALLS/KLXL)
- [CALENDAR \(/CALENDAR/US/MN/LITTLE-FALLS/KLXL\)](/CALENDAR/US/MN/LITTLE-FALLS/KLXL)
- [HISTORY \(/HISTORY/DAILY/US/MN/LITTLE-FALLS/KLXL\)](/HISTORY/DAILY/US/MN/LITTLE-FALLS/KLXL)
- [WUNDERMAP \(/WUNDERMAP?LAT=45.976&LON=-94.363\)](/WUNDERMAP?LAT=45.976&LON=-94.363)

Daily (/

Weekly (/

Monthly (/

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29)

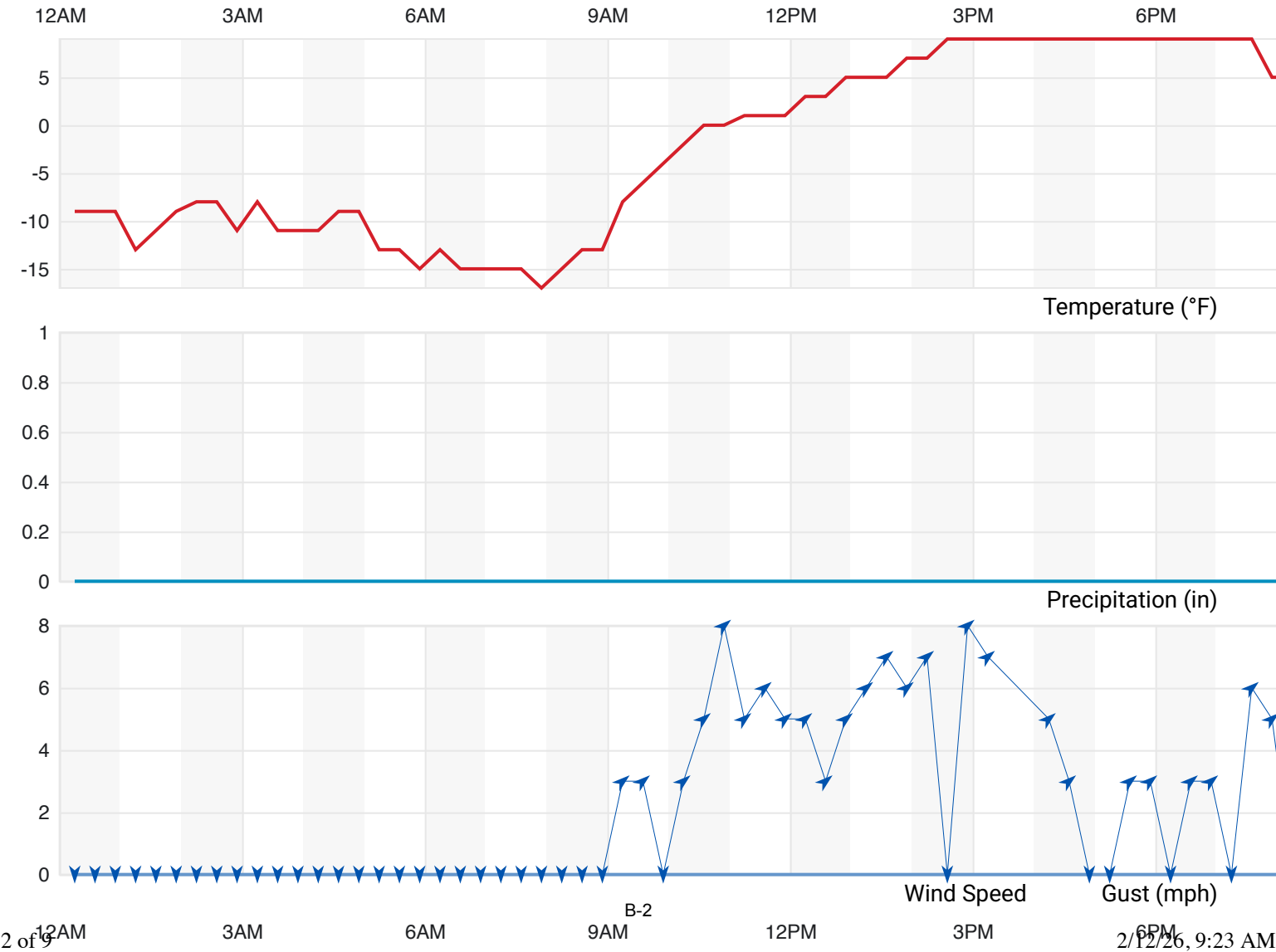
date/2026-1)

January

29

2026

View



Summary

Temperature (°F)	Actual	Historic Avg.	Record	▲
High Temp	9	24.6	47	
Low Temp	-17	2.8	-35	
Day Average Temp	-1.86	13.7	-	
Precipitation (in)	Actual	Historic Avg.	Record	▲
Precipitation (past 24 hours from 06:15:00)	0.00	5.50	-	
Dew Point (°F)	Actual	Historic Avg.	Record	▲
Dew Point	-9.6	-	-	
High	0	-	-	
Low	-22	-	-	
Average	-9.6	-	-	
Wind (mph)	Actual	Historic Avg.	Record	▲
Max Wind Speed	8	-	-	
Visibility	10	-	-	
Sea Level Pressure (in)	Actual	Historic Avg.	Record	▲
Sea Level Pressure	29.21	-	-	
Astronomy	Day Length	Rise	Set	▲
Actual Time	9h 34m	7:44 AM	5:19 PM	
Civil Twilight		7:12 AM	5:51 PM	
Nautical Twilight		6:36 AM	6:27 PM	
Astronomical Twilight		6:01 AM	7:02 PM	
Moon: waxing gibbous		1:18 PM	5:27 AM	

Daily Observations

Time	Temperature	Dew Point	Humidity	Wind	Wind Speed	Wind Gust	Pressure	Precip.	Condi
12:15 AM	-9 °F	-15 °F	77 %	CALM	0 mph	0 mph	29.07 in	0.0 in	Fair
12:35 AM	-9 °F	-15 °F	77 %	CALM	0 mph	0 mph	29.07 in	0.0 in	Fair
12:55 AM	-9 °F	-15 °F	77 %	CALM	0 mph	0 mph	29.07 in	0.0 in	Fair
1:15 AM	-13 °F	-17 °F	84 %	CALM	0 mph	0 mph	29.07 in	0.0 in	Fair
1:35 AM	-11 °F	-15 °F	84 %	CALM	0 mph	0 mph	29.07 in	0.0 in	Fair
1:55 AM	-9 °F	-15 °F	77 %	CALM	0 mph	0 mph	29.07 in	0.0 in	Fair
2:15 AM	-8 °F	-13 °F	77 %	CALM	0 mph	0 mph	29.08 in	0.0 in	Fair
2:35 AM	-8 °F	-13 °F	77 %	CALM	0 mph	0 mph	29.09 in	0.0 in	Fair
2:55 AM	-11 °F	-15 °F	84 %	CALM	0 mph	0 mph	29.08 in	0.0 in	Fair
3:15 AM	-8 °F	-13 °F	77 %	CALM	0 mph	0 mph	29.08 in	0.0 in	Fair
3:35 AM	-11 °F	-15 °F	84 %	CALM	0 mph	0 mph	29.08 in	0.0 in	Fair
3:55 AM	-11 °F	-15 °F	84 %	CALM	0 mph	0 mph	29.08 in	0.0 in	Fair
4:15 AM	-11 °F	-17 °F	77 %	CALM	0 mph	0 mph	29.07 in	0.0 in	Fair
4:35 AM	-9 °F	-15 °F	77 %	CALM	0 mph	0 mph	29.08 in	0.0 in	Fair
4:55 AM	-9 °F	-15 °F	77 %	CALM	0 mph	0 mph	29.08 in	0.0 in	Fair
5:15 AM	-13 °F	-17 °F	84 %	CALM	0 mph	0 mph	29.08 in	0.0 in	Fair
5:35 AM	-13 °F	-18 °F	77 %	CALM	0 mph	0 mph	29.08 in	0.0 in	Fair
5:55 AM	-15 °F	-18 °F	84 %	CALM	0 mph	0 mph	29.07 in	0.0 in	Fair
6:15 AM	-13 °F	-18 °F	77 %	CALM	0 mph	0 mph	29.07 in	0.0 in	Fair
6:35 AM	-15 °F	-18 °F	84 %	CALM	0 mph	0 mph	29.07 in	0.0 in	Fair
6:55 AM	-15 °F	-22 °F	70 %	CALM	0 mph	0 mph	29.07 in	0.0 in	Fair
7:15 AM	-15 °F	-20 °F	77 %	CALM	0 mph	0 mph	29.08 in	0.0 in	Fair

Time	Temperature	Dew Point	Humidity	Wind	Wind Speed	Wind Gust	Pressure	Precip.	Conditi
7:35 AM	-15 °F	-18 °F	84 %	CALM	0 mph	0 mph	29.08 in	0.0 in	Fair
7:55 AM	-17 °F	-22 °F	76 %	CALM	0 mph	0 mph	29.08 in	0.0 in	Fair
8:15 AM	-15 °F	-20 °F	77 %	CALM	0 mph	0 mph	29.09 in	0.0 in	Fair
8:35 AM	-13 °F	-18 °F	77 %	CALM	0 mph	0 mph	29.09 in	0.0 in	Fair
8:55 AM	-13 °F	-17 °F	84 %	CALM	0 mph	0 mph	29.10 in	0.0 in	Fair
9:15 AM	-8 °F	-13 °F	77 %	SW	3 mph	0 mph	29.10 in	0.0 in	Fair
9:35 AM	-6 °F	-11 °F	77 %	SW	3 mph	0 mph	29.10 in	0.0 in	Fair
9:55 AM	-4 °F	-9 °F	78 %	CALM	0 mph	0 mph	29.10 in	0.0 in	Fair
10:15 AM	-2 °F	-8 °F	78 %	SW	3 mph	0 mph	29.10 in	0.0 in	Fair
10:35 AM	0 °F	-8 °F	72 %	SW	5 mph	0 mph	29.10 in	0.0 in	Fair
10:55 AM	0 °F	-8 °F	72 %	SW	8 mph	0 mph	29.10 in	0.0 in	Fair
11:15 AM	1 °F	-8 °F	66 %	SW	5 mph	0 mph	29.10 in	0.0 in	Fair
11:35 AM	1 °F	-8 °F	66 %	SW	6 mph	0 mph	29.10 in	0.0 in	Fair
11:55 AM	1 °F	-6 °F	72 %	SW	5 mph	0 mph	29.09 in	0.0 in	Fair
12:15 PM	3 °F	-6 °F	66 %	SW	5 mph	0 mph	29.09 in	0.0 in	Fair
12:35 PM	3 °F	-6 °F	66 %	SW	3 mph	0 mph	29.08 in	0.0 in	Fair
12:55 PM	5 °F	-6 °F	61 %	SW	5 mph	0 mph	29.08 in	0.0 in	Fair
1:15 PM	5 °F	-6 °F	61 %	SW	6 mph	0 mph	29.07 in	0.0 in	Fair
1:35 PM	5 °F	-4 °F	66 %	SW	7 mph	0 mph	29.07 in	0.0 in	Fair
1:55 PM	7 °F	-4 °F	61 %	SW	6 mph	0 mph	29.06 in	0.0 in	Fair
2:15 PM	7 °F	-4 °F	61 %	SW	7 mph	0 mph	29.06 in	0.0 in	Fair
2:35 PM	9 °F	-4 °F	57 %	CALM	0 mph	0 mph	29.06 in	0.0 in	Fair
2:55 PM	9 °F	-4 °F	57 %	SW	8 mph	0 mph	29.06 in	0.0 in	Fair
3:15 PM	9 °F	-4 °F	57 %	SW	7 mph	0 mph	29.06 in	0.0 in	Partly Cloudy

Appendix C

Directory of Testing Locations

Test Section	Treatment and Distribution System	Forward Photo of Location	Backward Photo of Location
Zulu	None (Control Section)		
Alpha	15 gal/LM 80% Salt Brine 20% BEET HEET (80:20) and 200 lb/LM rock salt Distributed with liquid on spinner		
Bravo	30 gal/LM 80% Salt Brine 20% BEET HEET (80:20) and 200 lb/LM rock salt Distributed with liquid on spinner		
Charlie	15 gal/LM 80% Salt Brine 20% BEET HEET (80:20) and 200 lb/LM rock salt Distributed with liquid on chute		

Delta	30 gal/LM 80% Salt Brine 20% BEET HEET (80:20) and 200 lb/LM rock salt Distributed with liquid on chute		
Echo	15 gal/LM 80% Salt Brine 20% BEET HEET (80:20) and 200 lb/LM rock salt Distributed with liquid mixed in auger		
Foxtrot	30 gal/LM 80% Salt Brine 20% BEET HEET (80:20) and 200 lb/LM rock salt Distributed with liquid mixed in auger		
Golf	None (Control Section) Test of deicer drag through		

Hotel	8 gal/LM 70% Salt Brine 30% BEET HEET (70:30) and 200 lb/LM rock salt Distributed with liquid on chute		
Indigo	15 gal/LM 70% Salt Brine 30% BEET HEET (70:30) and 200 lb/LM rock salt Distributed with liquid on chute		
Juliet	30 gal/LM 70% Salt Brine 30% BEET HEET (70:30) and 200 lb/LM rock salt Distributed with liquid on chute		
Kilo, Lima, Mike and November	Not used as not prepared with snow and ice	No photo taken	

Oscar	15 gal/LM 80% Salt Brine 20% BEET HEET (80:20) and 200 lb/LM rock salt Distributed with liquid on spinner		
Papa	No liquid; 200 lb/LM rock salt Distributed with chute		
Quebec	15 gal/LM 80% Salt Brine 20% BEET HEET (80:20) and 200 lb/LM rock salt Distributed with liquid on chute		
Romeo	15 gal/LM 70% Salt Brine 30% BEET HEET (70:30) and 200 lb/LM rock salt Distributed with liquid on chute		

Sierra	15 gal/LM 90% Salt Brine 10% BEET HEET (90:10) and 200 lb/LM rock salt Distributed with liquid on chute		
Tango	No liquid; 200 lb/LM stockpile- treated (4 gal/ton) rock salt Distributed by chute		
Uniform	No treatment, no traffic. Control.		

Appendix D

Treatment Effects by Time

Test Section and Treatment: “Zulu”. No treatment; control section. Estimated 2000 veh/d annual daily traffic equivalent.

Time After Treatment	Forward Photo of Location	Behind Photo of Location
12 minutes		
30 minutes		
45 minutes		
88 minutes		
101 minutes		

Test Section and Treatment: “Alpha”. 15 gal/LM of 80% Salt Brine 20% BEET HEET (80:20) and 200 lb/LM rock salt. Distributed with liquid on spinner. Estimated 2000 veh/d annual daily traffic equivalent.

Time After Treatment	Pavement Forward at Location	Pavement Behind at Location
16 minutes	 A photograph showing a snowy road surface with visible tire tracks and a person standing on the left side. The snow is white with some blueish-grey patches.	 A photograph showing a snowy road surface with visible tire tracks and a person standing on the left side. The snow is white with some blueish-grey patches.
30 minutes	 A photograph showing a snowy road surface with visible tire tracks and a person standing on the left side. The snow is white with some blueish-grey patches.	 A photograph showing a snowy road surface with visible tire tracks and a person standing on the left side. The snow is white with some blueish-grey patches.
48 minutes	 A photograph showing a snowy road surface with visible tire tracks and a person standing on the left side. The snow is white with some blueish-grey patches.	 A photograph showing a snowy road surface with visible tire tracks and a person standing on the left side. The snow is white with some blueish-grey patches.
91 minutes	 A photograph showing a snowy road surface with visible tire tracks and a person standing on the left side. The snow is white with some blueish-grey patches.	 A photograph showing a snowy road surface with visible tire tracks and a person standing on the left side. The snow is white with some blueish-grey patches.

103 minutes		
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Test Section and Treatment: “Bravo”. 30 gal/LM of 80% Salt Brine 20% BEET HEET (80:20) and 200 lb/LM rock salt. Distributed with liquid on spinner. Estimated 2000 veh/d annual daily traffic equivalent.

Time After Treatment	Pavement Forward at Location	Pavement Behind at Location
19 minutes		
35 minutes		
51 minutes		
93 minutes		
105 minutes		

Test Section and Treatment: “Charlie”. 15 gal/LM of 80% Salt Brine 20% BEET HEET (80:20) and 200 lb/LM rock salt. Distributed with liquid on chute. Estimated 2000 veh/d annual daily traffic equivalent.

Time After Treatment	Pavement Forward at Location	Pavement Behind at Location
21 minutes		
41 minutes		
54 minutes		
96 minutes		
105 minutes		

Test Section and Treatment: “Delta”. 30 gal/LM of 80% Salt Brine 20% BEET HEET (80:20) and 200 lb/LM rock salt. Distributed with liquid on chute. Estimated 2000 veh/d annual daily traffic equivalent.

Time After Treatment	Pavement Forward at Location	Pavement Behind at Location
26 minutes		Not taken
46 minutes		
57 minutes		
98 minutes		
106 minutes		

Test Section and Treatment: “Echo”. 15 gal/LM of 80% Salt Brine 20% BEET HEET (80:20) and 200 lb/LM rock salt. Distributed with liquid mixed in auger. Estimated 2000 veh/d annual daily traffic equivalent.

Time After Treatment	Pavement Forward at Location	Pavement Behind at Location
27 minutes		
43 minutes		
60 minutes		
101 minutes		

Test Section and Treatment: "Foxtrot". 30 gal/LM of 80% Salt Brine 20% BEET HEET (80:20) and 200 lb/LM rock salt. Distributed with liquid mixed in auger. Estimated 2000 veh/d annual daily traffic equivalent.

Time After Treatment	Pavement Forward at Location	Pavement Behind at Location
31 minutes		
48 minutes		
63 minutes		
104 minutes		

Test Section and Treatment: “Golf”. None (Control Section). Test of deicer drag through.
Estimated 2000 veh/d annual daily traffic equivalent.

Time After Treatment	Pavement Forward at Location	Pavement Behind at Location
33 minutes		
52 minutes		
66 minutes		
91 minutes		
107 minutes		

Test Section and Treatment: “Hotel”. 8 gal/LM of 70% Salt Brine 30% BEET HEET (70:30) and 200 lb/LM rock salt. Distributed with liquid on chute. Estimated 2000 veh/d annual daily traffic equivalent.

Time After Treatment	Pavement Forward at Location	Pavement Behind at Location
22 minutes		
35 minutes		
54 minutes		
68 minutes		

94 minutes		
109 minutes		

Test Section and Treatment: “Indigo”. 15 gal/LM of 70% Salt Brine 30% BEET HEET (70:30) and 200 lb/LM rock salt. Distributed with liquid on chute. Estimated 2000 veh/d annual daily traffic equivalent.

Time After Treatment	Pavement Forward at Location	Pavement Behind at Location
23 minutes		
38 minutes		
57 minutes		
70 minutes		
99 minutes		

Test Section and Treatment: "Juliet". 30 gal/LM of 70% Salt Brine 30% BEET HEET (70:30) and 200 lb/LM rock salt. Distributed with liquid on chute. Estimated 2000 veh/d annual daily traffic equivalent.

Time After Treatment	Pavement Forward at Location	Pavement Behind at Location
26 minutes	 A photograph showing a snowy road curving to the right. A yellow school bus is visible in the distance on the road. The snow is relatively smooth with some tire tracks.	 A photograph showing a wide, straight snowy road. The surface is covered in a layer of snow with visible tire tracks and some darker patches.
40 minutes	 A photograph showing a snowy road with more pronounced tire tracks and some darker patches of pavement visible compared to the 26-minute mark.	 A photograph showing a snowy road with visible tire tracks and some darker patches of pavement visible.
97 minutes	 A photograph showing a snowy road with very pronounced tire tracks and significant darkening of the pavement surface.	 A photograph showing a snowy road with very pronounced tire tracks and significant darkening of the pavement surface, appearing more worn than the 40-minute mark.

Test Section and Treatment: "Oscar". 15 gal/LM of 80% Salt Brine 20% BEET HEET (80:20) and 200 lb/LM rock salt. Distributed with liquid on spinner. Estimated 500 veh/d annual daily traffic equivalent.

Time After Treatment	Pavement Forward at Location	Pavement Behind at Location
5 minutes		
15 minutes		
25 minutes		
37 minutes		
47 minutes		

57 minutes	 An aerial photograph showing a wide, sandy beach. A distinct line of blue water or ice runs horizontally across the upper portion of the frame, separating the beach from a darker area. The sand is light-colored with some darker patches.	 An aerial photograph of a beach, similar to the one on the left. A line of blue water or ice is visible. In the upper right corner, a small red object, possibly a vehicle or marker, is visible on the beach.
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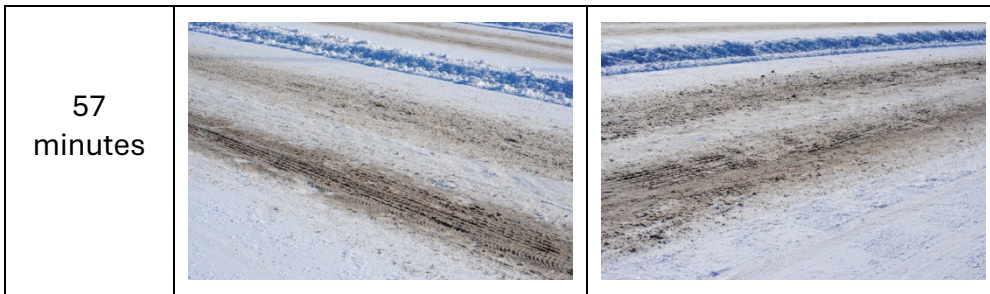
Test Section and Treatment: “Papa”. No liquid; 200 lb/LM rock salt. Distributed with chute. Estimated 500 veh/d annual daily traffic equivalent.

Time After Treatment	Pavement Forward at Location	Pavement Behind at Location
5 minutes		
15 minutes		
25 minutes		
37 minutes		
47 minutes		

57 minutes		
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Test Section and Treatment: "Quebec". 15 gal/LM of 80% Salt Brine 20% BEET HEET (80:20) and 200 lb/LM rock salt. Distributed with liquid on chute. Estimated 500 veh/d annual daily traffic equivalent.

Time After Treatment	Pavement Forward at Location	Pavement Behind at Location
5 minutes		
15 minutes		
25 minutes		
37 minutes		
47 minutes		



Test Section and Treatment: "Romeo". 15 gal/LM of 70% Salt Brine 30% BEET HEET (70:30) and 200 lb/LM rock salt. Distributed with liquid on chute. Estimated 500 veh/d annual daily traffic equivalent.

Time After Treatment	Pavement Forward at Location	Pavement Behind at Location
5 minutes		
15 minutes		
25 minutes		
37 minutes		
47 minutes		

57 minutes		
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Test Section and Treatment: “Sierra”. 15 gal/LM of 90% Salt Brine 10% BEET HEET (90:10) and 200 lb/LM rock salt. Distributed with liquid on chute. Estimated 500 veh/d annual daily traffic equivalent.

Time After Treatment	Pavement Forward at Location	Pavement Behind at Location
5 minutes	 A photograph showing the pavement surface 5 minutes after treatment. The surface is covered in a layer of white snow, with some darker patches visible. A snowplow is visible in the background.	 A photograph showing the pavement surface 5 minutes after treatment. The surface is covered in a layer of white snow, with some darker patches visible. A snowplow is visible in the background.
15 minutes	 A photograph showing the pavement surface 15 minutes after treatment. The surface is covered in a layer of white snow, with some darker patches visible. A snowplow is visible in the background.	 A photograph showing the pavement surface 15 minutes after treatment. The surface is covered in a layer of white snow, with some darker patches visible. A snowplow is visible in the background.
25 minutes	 A photograph showing the pavement surface 25 minutes after treatment. The surface is covered in a layer of white snow, with some darker patches visible. A snowplow is visible in the background.	 A photograph showing the pavement surface 25 minutes after treatment. The surface is covered in a layer of white snow, with some darker patches visible. A snowplow is visible in the background.
37 minutes	 A photograph showing the pavement surface 37 minutes after treatment. The surface is covered in a layer of white snow, with some darker patches visible. A snowplow is visible in the background.	 A photograph showing the pavement surface 37 minutes after treatment. The surface is covered in a layer of white snow, with some darker patches visible. A snowplow is visible in the background.
47 minutes	 A photograph showing the pavement surface 47 minutes after treatment. The surface is covered in a layer of white snow, with some darker patches visible. A snowplow is visible in the background.	 A photograph showing the pavement surface 47 minutes after treatment. The surface is covered in a layer of white snow, with some darker patches visible. A snowplow is visible in the background.

57 minutes		
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Test Section and Treatment: “Tango”. No liquid; 200 lb/LM stockpile-treated (4 gal/ton) rock salt. Distributed by chute. Estimated 500 veh/d annual daily traffic equivalent.

Time After Treatment	Pavement Forward at Location	Pavement Behind at Location
5 minutes		
15 minutes		
25 minutes		
37 minutes		
47 minutes		

57 minutes		
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Test Section and Treatment: "Uniform". No treatment, no traffic; control.

Time After Treatment	Pavement Forward at Location	Pavement Behind at Location
5 minutes		
15 minutes		
25 minutes		
37 minutes		
47 minutes		

57 minutes	 An aerial photograph showing a wide, snow-covered road or field. Multiple sets of parallel tire tracks are visible, curving from the bottom left towards the top right. A distinct line of snow or a change in surface texture runs diagonally across the upper portion of the image.	 An aerial photograph of a snow-covered road, similar to the one in the adjacent image. Tire tracks are visible on the road surface. In the background, several vehicles, including what appear to be snowplows or maintenance trucks, are parked or moving near some buildings.
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