Mn/DOT Anti-Icing Guide

9/13/2010

Main Sections

Appendices

Examples

Handy Tables+

Sampling of Anti-Icing Success Stories

Location	Description
D8 - Willmar	- They treat eight bridges. - Big reduction in accidents (due to bridge deck frost). They know of **[zero]** accidents due to deck frost since their program (anti-icing) has been in-place. - No overtime for bridge frost treatments - Feel they have completely "eliminated" bridge frost events
D1	Effectively eliminated the need for overtime for frost events (especially noted for weekends)
D6 - Austin	- Snowpack/bonding on the interstate was a big problem in the past, and took a lot of work and time to remove. It is now rarely an issue. - Have had good success with partnerships with City and County. They sell chemicals to these agencies.
D6 – Stewart-ville	They have had good success with just salt brine for anti-icing bridge decks and other trouble-spots. Their areas are out of the wind with low ADT. One application carries through typical weekend frost events. Use ¾ ton pickup.
D7 - Windom	Good success removing snow-pack using combination of both direct liquid and direct granular application.
D3	Have had good success in anti-icing for frost events at bridge decks and ie guardrail locations
D8 - Marshal	They are in an extremely open windy region, but still use and benefit from anti-icing. They focus on protected areas such as towns, and anti-ice before snow events. This buys them time during the event. They have greatly reduced overtime by anti-icing within 24 hours of the event during regular hours. They use just a ¾ ton pickup.
Metro – Arden Hills	Have had success in greatly reducing snowpack on the interstate. In addition to their regular anti-icing equipment, they also like to utilize the plow trucks with pre-wetting tanks to anti-ice roadways. They do this very early during the storm which they find effective because the team is already on hand and ready.
Metro	- They have reduced weekend patrol trucks to now only one or two trucks per shop from three. - Public complaints in regard to frost related slippery conditions are now rare - Anti-icing has helped them optimize material usage, resulting in minimizing impacts (ie environmental, infrastructure, vehicle)
D8 – Alexandria, Olivia	Have found a way (and only $20) to utilize smaller side liquid tanks on plow trucks to implement anti-icing, which has helped them optimize overall material use and reduced snowpack.

Please send your success stories to the Mn/DOT Office of Maintenance so we can add them to this list

Credits

The development of this guide involved all Mn/DOT anti-icing experts. The following list is an attempt to recognize some of these individuals for contributing so much time and expertise to this project.

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Why Anti-Ice?

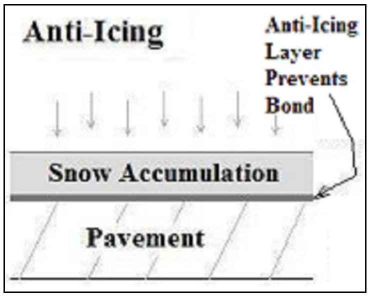
I. Why Anti-Ice?

1. What is Anti-Icing?

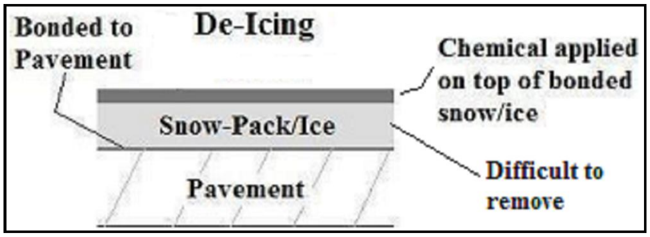
Anti-icing is the technique of applying a thin liquid chemical layer/coating on the pavement surface.

The application is often done before or early in the event.

The chemical is applied to a surface that does not have snow accumulation or ice/snowpack formation.



Anti-icing (preventing-icing) is pro-active, compared to de-icing (removing-icing) which is reactive.



2. Why Anti-Ice?

Anti-icing prevents the formation of frost and bonding of snow and ice to the pavement. This can result in safer road surfaces and savings in material and time.

<u>Frost</u>

Anti-icing prior to forecasted frost events helps to eliminate or minimize frost formation. Under some conditions, <u>one anti-icing treatment</u> has proven effective for <u>multiple days</u> and <u>over weekends</u>, and can sometimes treat two frost events.

<u>Snow</u>

Anti-Icing prior to forecasted snow events helps to prevent the formation of bonding between snow and ice and pavement which eases snow plowing.

<u>Wasted Energy and Money</u>

The rule-of-thumb is that removing ice or snowpack <u>after</u> it forms (de-icing) takes <u>ten times more energy</u> than preventing the formation (anti-icing).

Minimizing Impacts

All of the effective roadway chemicals have a negative effect of some kind to the environment. These include impacts to vegetation, wildlife and water quality. They also have a negative effect of some type on the infrastructure. Salt brine is known to corrode steel. It is suspected that the non salt-brine chemicals may have a more severe negative effect on concrete.

The best overall approach to minimize impacts is through **efficient chemical usage**. Anti-icing has proven an effective tool to help optimize chemical usage while improving road conditions.

3. Anti-Icing Coverage Advantage

The following table and graphic illustrates why only a thin layer of liquid is required on the roadway while providing a lot of coverage.

Illustration of Anti-Icing Coverage
Compare "Roadway Lane-Miles Treated" for 10 tons of salt

Type	Roadway Lane-Miles Treated	Example of Distance
Liquids @ 20 gal/lane-mile (20 gal/ln-mi = 45.44 lb/ln-mi)	440 miles	Austin, MN to Thunder Bay, Canada
Granular @ 300 lb/lane-mile	67 miles	Austin, MN to Faribault, MN

Graphic to Illustrate Anti-Icing Coverage
Compare "Roadway Lane-Miles Treated" for 10 tons of salt

Note that that the above illustration assumes continuous roadway anti-icing. Targeted anti-icing (trouble-spot) will provide even more coverage.

When to Anti-Ice?

II. When to Anti-Ice?

This section starts with tips for when to anti-ice followed by a discussion of weather as it relates to anti-icing.

1. Practical Tips

Need for Anti-Icing - Frost

Frost Forecast[1]	Pavement Temperature[2]	Need for Anti-Icing	Rate[3,4] (gplm)
Road frost probability 20% or above	Any	Consider anti-icing for frost prevention	20
Unknown	Cold (remaining 20°F or colder)	Frost Prevention usually not needed.	
Unknown	20°F - 40°F and pavement temperature could drop close to dew point.	Consider anti-icing for frost prevention	20
Black Ice[5]		*Black ice* is often removed in de-icing mode after it has been identified	
Add more criteria below based on local weather and experience			

Notes
1) Frost is more common under calm conditions (but may occur in windy conditions as well)
2) Consider the pavement temperature "trend" (forecast). For example, if the current pavement temperature is 25°F, and the forecasted pavement temperature is 15°F, you should consider the more limiting temperature (ie 15°F in this example).
3) Application rate in gallons per lane mile (gplm)
4) Use ½ of application rate for 1st and 2nd event of winter season or after extended dry periods
5) Black ice is often dependent on traffic and more common in larger metro areas.

Need for Anti-Icing – Snow and Other Precipitation Events

Event Type	Pavement Temperature[1]	Need for Anti-Icing
Light freezing rain/drizzle	All	Consider anti-icing[2]
Rain, Medium/Heavy Freezing Rain, Sleet	All	Liquid anti-icing not suggested
Powder (Dry) Snow	Cold (about 12°F or colder)	Anti-icing often not required (less chance of ice/snow to pavement bonding)
Light to Moderate Snow	Between 12°F and 32°F	Consider anti-icing[2]
Light to Moderate Snow	Warm (Remaining above 32°F)	Usually will not produce bond. Anti-icing usually not required.
Heavy/Wet Snow	All	Liquid anti-icing not suggested because of rapid dilution of solution (DOS) potential.
Add more criteria below based on local weather and experience		

1) Consider the pavement temperature "trend" (forecast). For example, if the current pavement temperature is 25°F, and the forecasted pavement temperature is 15°F, you should consider the more limiting temperature (ie 15°F in this example).
2) 20 gallons per lane mile (gplm) suggested as most effective application rate

Adjusting Anti-Icing for Weather Conditions

For the 1st and 2nd winter precipitation events of the year (or after extended "dry" periods)	Cases have been observed where anti-icing chemicals "scrub" the oils up from the pavement and can worsen the road conditions by making the road slippery. It is suggested that anti-icing be **adjusted** by reducing application rates by ½ for these events.
Dry Road and Blowing Snow Conditions	Liquid or solid on a dry road may worsen road conditions. Blowing snow may stick to the wetted road causing icy spots and snow-pack spots. Suggested **adjustments** to anti-icing are explained in the guide for this case.
Respect Colder Temperatures and Chemical Dilution Potential	Respect cold temperatures. Experience has found anti-icing is most effective with pavement temperatures above 20°F. No matter what the chemical freezing point is, always consider chemical dilution potential (added moisture from melting snow) which makes the chemical more "water-like" and more susceptible to re-freeze.

2. Weather Factors

Understanding weather is important for successful anti-icing. Weather forecasting will include utilization of forecasting tools like RWIS, your experience, and your judgment.

Gaining Familiarity with Local Weather

It is suggested that you explore more and learn as much as possible about general and local weather. You may consider talking to winter maintenance persons or residents who have worked and/or lived in the area for many years and prepare a short summary document you can build on.

Weather Principles

Weather forecasting is not an exact science. However, forecasts are continually improving and we can usually plan anti-icing based on them while being prepared for changes and surprises.

Always consider chemical dilution potential and possible refreeze.

Pavement Temperatures

While anti-icing, pay close attention to pavement temperatures. The following table presents factors related to pavement temperatures.

Pavement Temperatures Factors

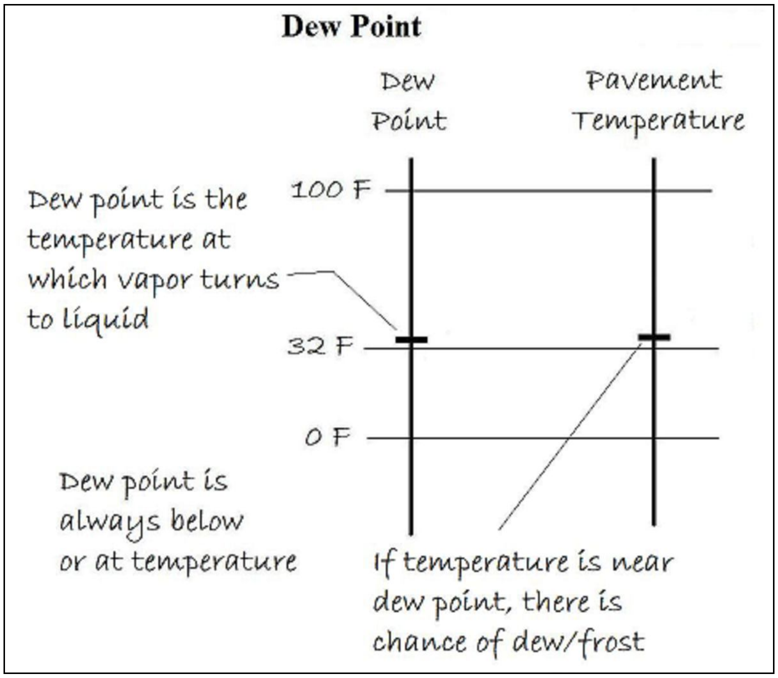
Factor	**Description**
Bridge Decks	Bridge decks (as compared to road pavements) are often more dependent on air temperature. This is because they have air on both sides and do not have the warmer/cooler soils beneath. So, at night if bridge decks get colder, they often have a better chance of dropping to the dew point and producing dew and then frost.
Subsurface Soils	In the Fall, the subsurface is usually not frozen so tends to provide some "warming" of the road above (especially at night). In the Spring, the opposite may occur, where the subsurface is often colder and tends to "cool" the roadway (especially during the day).
Shaded Areas	Shaded areas will not experience as much warming from sunlight. Therefore, they often have a better chance of dropping to the dew point and producing dew and then frost.
Note: This is a partial list of factors	

Frost

Liquid anti-icing has proven to be extremely effective for preventing or minimizing frost events.

Frost is likely warranted in frost susceptible and trouble-spot locations when RWIS shows a greater than 20% chance of frost. Be aware that some locations are more susceptible to frost and that weather stations may not be reporting conditions in those frosts susceptible areas.

To help understand frost, it is a good idea to have a good understanding of dew point. The following graphic illustrates dew point.



Snow and Other Precipitation Events

Anti-icing has proven to be effective for snow and other precipitation events.

Many snow events occur at warmer temperatures such as 20°F and above. Liquid anti-icing is most effective at pavement temperatures above 20°F. Determining when there is a high probability of these favorable event conditions will help maximize the benefit from anti-icing.

Also snow events can vary greatly in moisture content: dry, typical or wet/heavy.

Humidity

Relative humidity helps determine how much moisture is in the air relative to how much it can hold. Dew point (as described above) is typically a more helpful measure of moisture available in the air (because dew point considers both current temperature and relative humidity). See the definition for "Hygroscopic Property" on page 53 to see how it relates to relative humidity.

Wind and Blowing Snow

Expected blowing snow requires special consideration as shown below. Use **Caution** when considering anti-icing in areas prone to blowing snow.

Experience has shown that it is best **not** to apply any chemical to a dry road if blowing snow conditions are expected. Blowing snow may stick to the wetted road causing icy spots and snow-pack spots. However, there are adjustments that can be considered to overcome the challenges of blowing snow (see "Adjustments for Blowing Snow Conditions" on page 58 in the "Special Considerations" appendix).

The following factors related to potential blowing snow will be evaluated for each of your anti-icing target locations.

Blowing Snow Factors

Factor	**Description**
Open/Protected	Open areas tend to experience stronger winds, while protected areas (towns, forested, snow fenced, etc) may provide some shielding from winds.
Forecasted Wind Speeds	Forecasted wind speeds before, during and after events influence the amount of blowing snow.
Snow depth in ditches	Ditches that are full of snow can increase the amount of blowing snow
Snow cover	Crusty snow cover will reduce the amount of blowing snow. Loose, dry snow tends to blow more.
Roadway geometry	Some roadway geometry may cause more blowing snow (i.e. long back slopes, curves and hills).
Wind speeds that may cause problems	Forecasted wind speeds over 10 MPH should be assessed for the chance to cause significant blowing snow. In some cases 10-20 MPH winds may be more problematic than stronger winds because they may "drop" blowing snow onto the roadway.
Bridge Decks	Bridge decks should be assessed on a case-by-case basis. Some bridge decks are susceptible to blowing snow; others are not.
Note: This is a partial list of factors	

Black Ice

It is suggested that you learn if black ice is a problem in your area. Black ice is often dependent on traffic and more common in larger metro areas. Black ice is often removed in de-icing mode after being identified (with liquid or solid chemical).

Forecasting Tools

It is suggested that you use a weather forecasting tool that you have the most confidence in for your geographic area. RWIS is one tool that is commonly used by anti-icers. Weather station cameras can help you assess approaching storms.

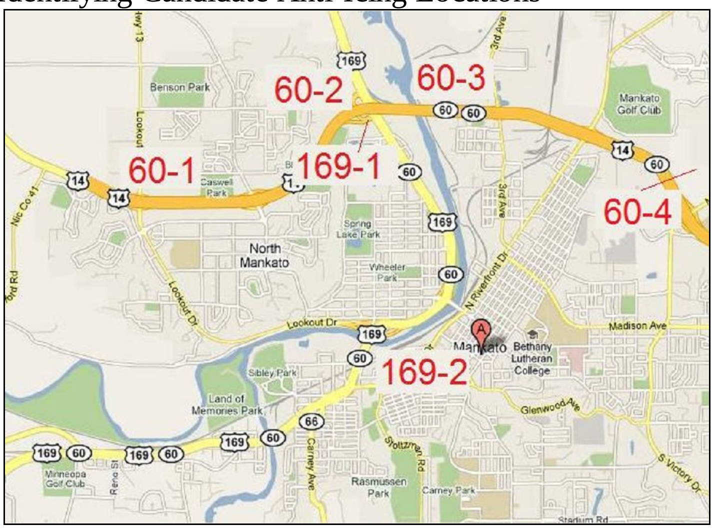
Where to Anti-Ice?

III. Where to Anti-Ice?

1. Identifying Anti-Icing Locations and Strategies

The following pages show an illustrative example for identifying anti-icing locations and developing anti-icing strategies. The following map is an example area for anti-icing consideration. Two simple forms and “steps” for using the forms follow.

Identifying Candidate Anti-Icing Locations



Locations Form (illustrative example)

(1) Locations Prone to Frost	**(2) Trouble-Spots**	**(3) Higher Priority Routes**
B = Bridge Deck C = Concrete Section S = Shaded Area *(enter more below)*	M = Maintenance Area Border I = Intersection A = Known Accident Area R = Ramp H = Hill U = Curve T = Town in Rural Route N = Narrowing *(enter more below)*	H = Hospital Route V = Higher Volume Route O = School Routes *(enter more below)*

Plow Route[1]	Anti-Icing Location	Type	Open[2]	Length (miles)	Notes
(scheduled frost prevention routes)					
60-A	*60-1*	*H*	*Yes*	*0.5*	*hospital route segment*
	60-2	R		*0.5*	
	60-3	*B*		*0.5*	*History of frosting (over water)*
	60-4	*M*		*2*	*Problematic border (near curve)*
	Route Total			***3.5***	
169-A	*169-1*	*R*	*Yes*	*0.5*	
	169-2	*B*		*1*	*History of frosting (over water)*
				1.5	
	Route Total			**2.5**	

Notes
1) Optionally, prioritize anti-icing locations per local conditions and experience (i.e. if certain bridge decks or other locations have a history of frost occurring more often than other locations)
2) Yes if location is in “open area” that is susceptible to blowing snow (when blowing snow conditions exist)

Strategy Form (illustrative example)

<table>
<tr><td>Maintenance Area: Sample</td><td>Year: 2009-2010</td></tr>
<tr><td colspan="2">Event Types: Frost</td></tr>
<tr><td>Chemicals and Application[1]

Salt Brine,
20 gallons/lane-mile
10 gallons/lane-mile 1st event of year

- Use 300 gallon tank mounted on ¾ ton
- Reload when needed at Iron City Station;(have coordinated)</td><td>Criteria (triggering anti-icing) [1]

1) If RWIS shows 20% or more chance of road frost

2) Or if pave. temperature is mild (above 20°F) and we think the temperature has a chance to drop to dew point.</td></tr>
<tr><td>Schedule/Timing

Tuesday and Friday

Night shift when available, otherwise day shift</td><td>Blowing Snow Adjustment[1]

For areas marked as “Open” on locations form, do not anti-ice if blowing snow conditions (loose snow cover, wind speed 10 MPH more, assess snow depth in ditch)</td></tr>
<tr><td colspan="2">Notes
1) See information in guide to help determine strategies</td></tr>
</table>

Frost Prevention

Steps for Using Locations and Strategy Form**:**

It is suggested that frost prevention anti-icing be done on a regular schedule as warranted by forecasts. This allows you to keep a "continuous" frost prevention program in place.

Note that *Black ice* is more difficult to forecast because vehicle traffic is often a key factor. Therefore, it is often treated in de-icing mode. Because it is typically a thin layer of ice, some operations have found that liquid de-icing removes it effectively.

Steps for "***Locations*** **Form**" (see *page 16):*

1) Identify locations prone to frost.

2) Identify trouble-spots.

3) Note a "Yes" or "No" in the "Open" column for each location so you can keep track of which areas are Susceptible to Blowing Snow.

4) Prioritize location list per local conditions and experience (i.e. if certain bridge decks or other locations have a history of frost occurring more often than other locations).

*Steps for "**Strategy Form**" (see* page 17):

5) Schedule/Timing Strategy -- **select one or more days of the week** to anti-ice for frost prevention. On these days, you will review weather criteria to determine if anti-icing is warranted. Experience has shown that Friday provides high benefit because an anti-icing treatment can sometimes provide frost prevention through the weekend. It is suggested to start with Tuesday and Friday.

6) Criteria – **Write down the type of weather conditions where you will want to perform anti-icing** for frost prevention. When these conditions are met later during winter season, you will anti-ice. Your knowledge of local weather related to frost will be key. Some anti-icers find that using a road frost forecast of 20% or more is a good criteria. Also see page 10 "Frost".

7) Chemicals and Application - **Select the chemical(s) for your frost prevention program**. Consider selecting an "adhering" chemical for multi-day prevention. Frost prevention anti-icing is typically done at milder pavement temperatures, so we usually will not have to adjust our chemical selection relative to pavement temperatures. Also see page 25 "Anti-Icing Chemical Types".

8) Blowing Snow Considerations – Write down your strategy for "blowing snow" when blowing snow is expected. Caution should be used when considering anti-icing in areas prone to blowing snow. See page 11 "Wind and Blowing Snow".

Storm Events

Steps for Using Locations and Strategy Form**:**

Anti-icing for storm events is typically done **when-needed** based on weather forecasts and your experience with local weather.

Best practice is to “apply” the treatment as close as possible to the storm event. Along with the forecast, other factors such as team availability, shifts times, and traffic will influence the timing of applications. Anti-icers have found it useful to anti-ice during shifts preceding forecasted storms.

Often anti-icing is done before the storm. However, it can also be done early during the storm event or onto a clean plowed road surface. The key is getting the liquid layer “underneath” (prior to) snow accumulation and potential snowpack/bonding.

Steps for “***Locations*** **Form**” (see *page 16):*

1-4) The steps on the previous page for “Locations Form” can be used (steps 1 through 4), with the only difference being in identifying “locations”. For storm events, locations prone to snowpack or bonding should also be considered.

*Steps for “**Strategy Form**” (see* page 17):

5) Schedule/Timing Strategy – Determine the **timing** for when you will perform anti-icing for different event types. Consider equipment availability and **shift hours**. It may help to work through scenarios. For example, if event is expected in AM, determine if PM shift available for possible anti-icing, etc. Add notes to Strategy Form.

6) Criteria **– Write down the type of weather conditions where you will want to perform anti-icing** for snow events. These will be developed based on weather factors and your experience with local weather. Also see page 9 "Weather Factors".

7) Assigning Routes - Assign the selected anti-icing locations to team members and equipment.

8) Chemicals and Application -- Select the chemical(s) that you will use for different possible storm events. Also see page 25 “Chemicals”. Consider selecting an "adhering" chemical for multi-day prevention.

9) Blowing Snow Considerations – Write down your strategy for “blowing snow” when blowing snow is expected. Caution should be used when considering anti-icing in areas prone to blowing snow. See page 11 “Wind and Blowing Snow”

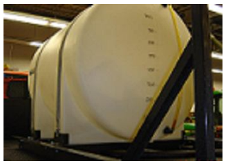
How to Anti-Ice?

IV. How to Anti-Ice?

1. Equipment Capacity and Required Coverage

A variety of units can be used to apply liquids starting with pre-wet tanks or ¾ ton pickups with slide-in tanks. All sizes and shapes of units have proven successful. For all the units, we want to be confident that the anti-icing unit's actual application rate matches the expected application rate (Also see page 31 "Determining Actual Application Rates").

Examples of Approximate Liquid Anti-Icing Coverage

Examples of anti-icing units	Liquid Capacity (gallons)	Frost Prevention or **Trouble-Spot** Anti-Icing (assuming 20 gal/ln-mi) (Number of Trouble-Spots) [1]	**Continuous** Anti-Icing Lane Miles Covered (assuming 20 gal/ln-mi)
	100	10	5
	200	20	10
	250	26	13
	325	32	16
	800	80	40
	1000	100	50

	5000	500	250

Notes:

1) Assuming ½ mile per trouble-spot. This is just a “ball-park” average to give you a general idea of coverage. Coverage will depend on terrain, bridge lengths, etc within your area.
2) A proven technique to even increase anti-icing coverage further is to partner with adjacent maintenance shops and share liquid “loading points”.

2. Anti-Icing Chemicals

This section discusses common anti-icing chemicals. Note that the discussion assumes pavement temperature rather than air temperature.

For additional information, also see:

- Mn/DOT “Office of Maintenance” - http://www.dot.state.mn.us/maintenance/training.html
- LTAP Website http://www.mnltap.umn.edu/

The followings tables compare common anti-icing chemicals.

Anti-Icing Chemical Types

Type	Examples	Adhere[5]	Suggested Min[1] (°F)	Practical Min[1] (°F)	Benefits	Cautions
Basic	NaCl Salt Brine	No[5]	20°	15°	- Handles a high percentage of storm events over a typical season - Shorter road adherence, which can benefit areas prone to blowing snow	- Quality control (23.3% NaCl solution) - If no precipitation will “dry up” and blow off roadway
Adhering (Sticky)	LCS[2,4]	Yes	15°	10°	Can adhere to roadway for multiple days if no precipitation	Ensure concentration is correct (10% corn syrup, 90% NaCl)
Depressed Freezing Point	Blends[3]	No	10°	0°	- More Effective at temperatures below 15°F	- Consider dilution[1], it is suggested to use 0°F as a general practical minimum
Adhering (Sticky) and Depressed Freezing Point	MgCl2, CaCl2, Blends[3,4]	Yes	10°	0°	- More Effective at temperatures below 15°F - Can adhere to roadway for multiple days if no precipitation	- Do not apply if pavement temperature is above 32°F - Consider dilution, it is suggested to use 0°F as a general practical minimum - Blending $MgCl_2$ with salt brine has been reported to be problematic

Notes

1) Minimum forecasted pavement temperature (during or after event). Always consider dilution and refreeze potential. The “suggested” value is the temperature (at or above) where all experts agree that the chemical is effective. The “practical” value is the temperature (at or above) where some experts have found the chemical effective when considering other factors.
2) Organic chemicals like LCS (liquid corn salt) do provide some freezing point depression as indicated on the chart
3) To achieve lowered freezing point down to 0°F, a blend should have at least 10% of $MgCl_2$ or $CaCl_2$. This is 10% of these products in solution; (respective solutions concentrations shown in tables below).
4) To achieve the “adhering” property, a blend should have at least 10% of organic (corn syrup, beet juice, molasses, etc). There are new blends that are strictly $CaCl_2$ solution with NaCl without the organic. It has not yet been determined at what concentration these provide the “adhering” property.
5) Even basic chemicals without the “adhere” property have proven to be effective for multiple days (i.e. over weekends) in some conditions. However, the conditions must be relatively calm (protected), with relatively low traffic volumes and speeds. Your experience will also help determine how long chemicals will remain effective on the roadway under different conditions.
6) Also see page 50 “Glossary”

Anti-Icing Chemical Concentrations and Practical Effective Temperatures

Chemical	**Practical/Effective Minimum**	**Eutectic Freezing Point (Lab Only)**	**Concentration**
NaCl	15°F (20°F desired)	-6°F (-21°C)	23.3%
LCS	10°F (15°F desired)		10% Liquid Corn and 90% NaCl
$MgCl_2$	0°F (10°F desired)	-28°F (-33°C)	21.6%
$CaCl_2$	0°F (10°F desired)	-60°F (-51°C)	29.8%
CMA	20°F	-17°F (-27°C)	32.5%
KAc (Potassium Acetate)	0°F	-76°F (-60°C)	49%
(add more chemicals below)			

Notes:
- Concentrations shown above are with water unless otherwise noted (ie 23.3% dry NaCl and 76.7% water)
- LCS is mixed with salt brine and not water
- Pavement temperatures should be considered before, during and after the event
- Consider multi-day forecast
- When NaCl is part of mix, the NaCl concentration should always be 23.3%
- Note that these temperatures may vary based on other field conditions
- Also see page 50 "Glossary" in Appendix for chemical abbreviations

3. Chemical Quality Control

Quality control of chemical concentrations is fundamental to anti-icing success. Incorrect concentrations can produce the following problems:

- Higher freezing point temperatures reducing effectiveness of chemical and increasing chance of refreeze or slippery cases
- Rapid dilution of chemical increasing chance of refreeze or slippery cases

Blends

Special care must be taken to maintain quality control on mixes and blends. Blends often consist of smaller concentrations of a chemical(s) with larger concentrations of NaCl salt brine.

The following three examples demonstrate mixing/blending chemicals. Note, different chemicals than those shown in the examples are done in a similar way.

Example #1: Mixing Chemicals

Here is an example where we start with 500 gallons of 50% LCS mix (mixed with 50% salt brine). We want to end up with a final 10% LCS mix (with 90% salt brine). So we determine how much salt brine to add.

Determine actual chemical volume

1. Our starting mix is 50% (0.50)
2. Our starting volume is 500 gallons
3. Our actual chemical LCS volume is

   volume * concentration = 500 gallons * 0.50 = 250 gallons (actual raw chemical)

Determine how to make 10% LCS mix

1. Our actual raw chemical = 250 gallons from above
2. Our desired concentration is 10% or 0.10
3. Determine total volume of blend

$$\text{Total Volume} = \frac{\text{actual raw chemical}}{\text{desired concentration}} = \frac{250\text{ gal}}{0.10} = 2{,}500\text{ gallons}$$

4. Do cross check

$$\begin{matrix}\text{LCS}\\ \text{concentration}\end{matrix} = \frac{\text{chemical volume}}{\text{total volume}} = \frac{250\text{ gal}}{2{,}500\text{ gal}} = 0.1\ (10\%) \quad \text{checks okay}$$

5. Determine amount to add to starting mix

= 2,500 gallons total – 500 gallons starting = 2,000 gallons salt brine to add

So, if we add 2,000 gallons to our original 500 gallons, we'll have our 10% LCS mix.

This procedure can be used for other blends (CaCl2, MgCl2, beet juice,…)

Example #2: Mixing Chemicals (Brine and Pre-Mixed Chemical)

Here is an example where we start with 1,000 gallons of pre-mixed chemical. Assume the pre-mixed chemical has 40% Molasses and 50% $CaCl_2$ solution.

Assume we want a final mix of 5,000 total gallons with a 10% $CaCl_2$ solution.

We follow similar steps as in example #1.

<u>Determine actual chemical volume</u>

4. Our starting mix is 50% (0.50) $CaCl_2$
5. Our starting volume is 1,000 gallons
6. Actual $CaCl_2$ solution concentration = 1000 gallons * 0.50 = 500 gallons
7. Actual Molasses concentration = 1000 gallons * 0.40 = 400 gallons

<u>Determine how to make 10% $CaCl_2$ mix</u>

4. Our actual $CaCl_2$ solution = 500 gallons from above
5. Our desired concentration is 10% or 0.10
6. Determine total volume of blend

$$\text{Total Volume} = \frac{\text{actual raw chemical}}{\text{desired concentration}} = \frac{500\ \text{gal}}{0.10} = 5{,}000\ \text{gallons}$$

6. Do cross check

$$\begin{array}{c}CaCl_2\ \text{solution}\\ \text{concentration}\end{array} = \frac{\text{chemical volume}}{\text{total volume}} = \frac{500\ \text{gal}}{5{,}000\ \text{gal}} = 0.1\ (10\%) \quad \text{checks okay}$$

7. Determine amount to add to starting mix

= 5,000 gallons total – 1,000 gallons starting = 4,000 gallons salt brine to add

8. We now determine molasses concentration in mix (from above our actual molasses volume is 400 gallons).

$$\text{Molasses concentration} = \frac{\text{chemical volume}}{\text{total volume}} = \frac{400 \text{ gal}}{5{,}000 \text{ gal}} = 0.08\ (8\%)$$

Note: See note in Example #3 below for "$CaCl_{2\ \text{solution}}$"

Example #3: Mixing Chemicals (Three Types)

Here is an example where we mix three chemicals (salt brine, molasses, and $CaCl_2$).

<u>Our desired final product</u>

Total volume = 5,000 gallons
$CaCl_2$ Solution = 10%
Molasses solution = 10%

<u>Determine how much we need of each</u>

$CaCl_2$ solution volume needed = 5000 * 0.1 = 500 gallons
Molasses volume needed = 5000 * 0.1 = 500 gallons
Salt brine volume needed = 5000 – 500 – 500 = 4,000 gallons

<u>Do cross check</u>

Total = 500 + 500 + 4000 = 5,000 gallons (checks okay)
$CaCl_2$ solution = 500 / 5000 = 0.1 = 10% (checks okay)
Molasses solution = 500 / 5000 = 0.1 = 10% (checks okay)

Note: "$CaCl_2$ solution" typically consists of about 30% "dry" $CaCl_2$ chemical mixed with water.

4. Knowing Actual Application Rates

It is important to have confidence that the actual liquid application rate matches relatively closely your expected application rate. It is also important to know the concentration of your chemical.

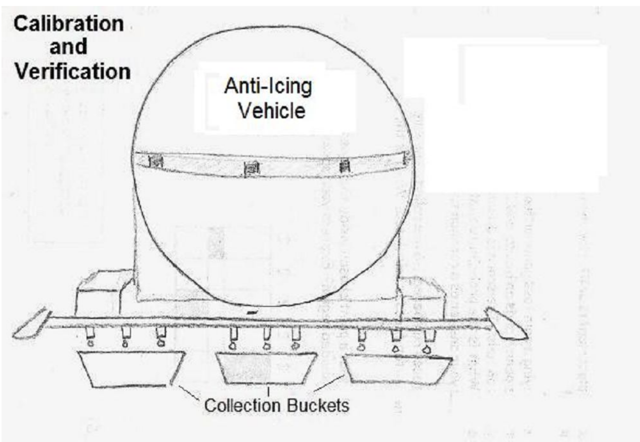
It is important to keep equipment calibrated. Calibration should be done at least annually. Over or under-application of chemical onto the roadway may lead to many problems such as refreezing.

There is a great variety of liquid application equipment of both automatic and manual types. Customization of equipment is common.

Therefore, it is important to ensure you are getting your expected (target) flow rates. This is done by determining your application rate

<u>Determining Actual Application Rate</u>

For manual gravity systems you will just open valve to turn on, for automatic systems, you will need to simulate a vehicle speed. We will collect liquid in buckets over a timed period to determine the unit's actual application rate.



In the example below, we determine our actual anti-icing unit application rate assuming a 30 MPH operating speed. We determined that the actual rate is 15 gal/lane-mile. See appendix for a blank quick form.

Determining Actual Application Rate Quick Form

Anti-Icing Unit Description	***Sample, 800 gallon capacity, slide in, gravity feed***	
Anti-Icing Unit Speed	**30 MPH**	
Place collection bucket(s) below discharge nozzles		
Start timer and fill buckets (T)	**2 minutes**	
Determine volume[1] (V)	**15 gallons**	If weighing buckets, see "Conversion Tips" below
Calculate flow rate (V/T)	**7.5 gpm**	
Look up application rate[2] using flow rate (gpm) and vehicle speed (MPH)	**15 gplm**	Also see page 47 ("Application Rate Lookup Table")
Notes: 1. CAUTION - Never lift more weight than the maximum weight allowed by your governing safety regulations. 2. gplm = gallons/lane-mile		

Conversion Tips

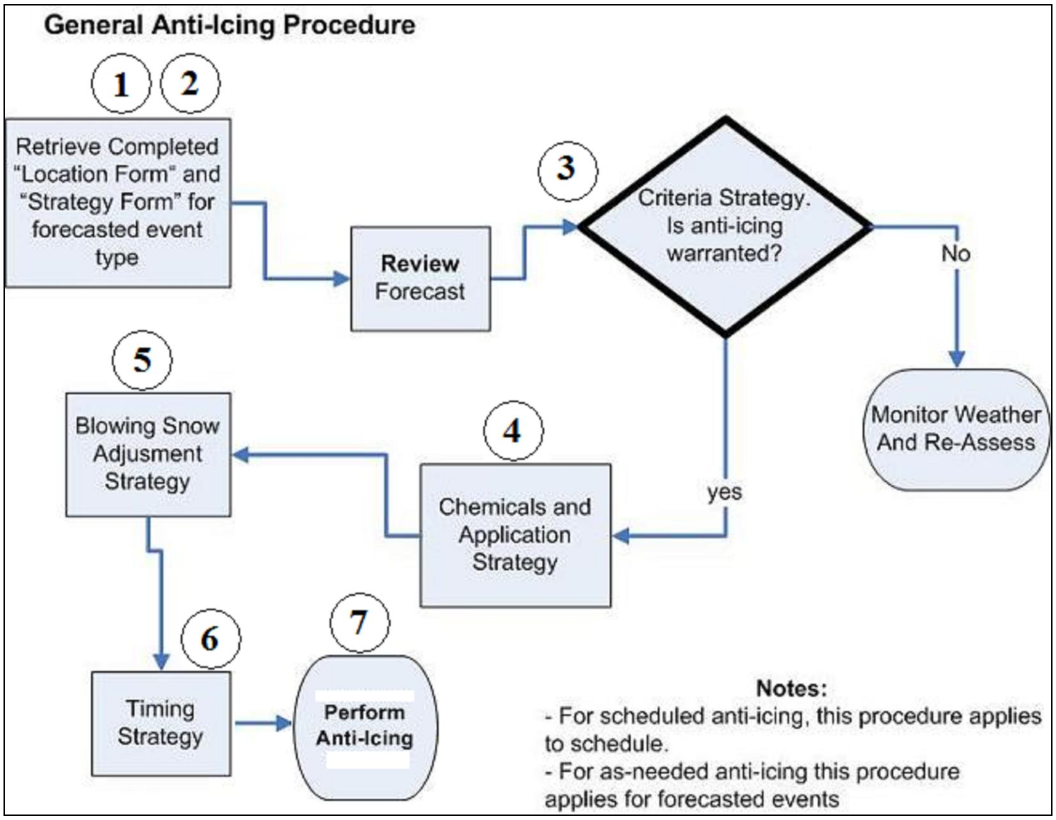
Pounds per gallon (water) = 8.34 pounds/gallon
Pounds per gallon (salt brine) = 10.26 pounds/gallon (15°C / 59°F)

So, for 125 pounds of water
Volume = 125 / 8.34 = 15 gallons

Adjustments and Calibration

If the actual application rate does not match the expected application rate you will need to adjust or calibrate your specific unit. If using an automatic application unit, see the vendor manual for calibration adjustment steps. If using a custom unit, the adjustment will be based on your specific design…

5. General Application Procedure



Anti-Icing Procedure

	Step	Procedure
1	Retrieve Forms	Utilize your completed "**Locations Form**" and "**Strategy Form**" for relevant event type. (See pages 16 and 17)
2	Schedule/Timing	If scheduled anti-icing, review schedule to know which days(s) to consider anti-icing.
3	Criteria (Is anti-icing warranted?)	Compare forecasted conditions with your criteria to determine if anti-icing is warranted. If so, continue.
4	Chemicals and Application	Using forecasted conditions, select chemicals and determine application rates and approach
5	Blowing Snow	Determine if blowing snow is expected at any "Open" anti-icing locations. If so, adjust application approach as needed.
6	Timing	Determine desired timing relative to start of event.
7	Perform Anti-Icing	Conduct anti-icing at target at selected timing.

Application Rates: The experts engaged in this project generally suggested an application rate of **20 gallons/lane-mile**. The rate is high enough to be effective, but also low enough to minimize dilution/refreeze potential. Please see the tables on page 7 and page 8 for additional information. Also see the application terms in the glossary on page 54.

After the Storm

V. After the Storm

1. Performance Measuring (measuring performance of anti-icing)

Performance measuring can be a great benefit and value by allowing your maintenance area to leverage success and adjust for lessons learned.

Capture cases where anti-icing was effective, and cases where it was not effective. Discuss both areas with employees and determine what works and does not work. This will help fine-tune the anti-icing operation.

During post-storm meetings (Monday morning quarterbacking) we take just a few minutes to capture any “stories” that pertain to the success, failures and lessons learned of anti-icing.

An illustrative example is shown on the following page. This is just a simple form with an area for a sketch and notes to describe the event and anti-icing results (good or bad).

A blank form can be found in the Appendix.

2. Winter Wrap-Up

Winter wrap-up meetings are a great way to discuss the results (success and lessons learned) of your anti-icing program.

Snowfighting Story Log

Location *Highway 52, Iron City, 2 mile route*
Time Period *January 25-26, 2009* **By** *jt, bk, ba, da*

Summary

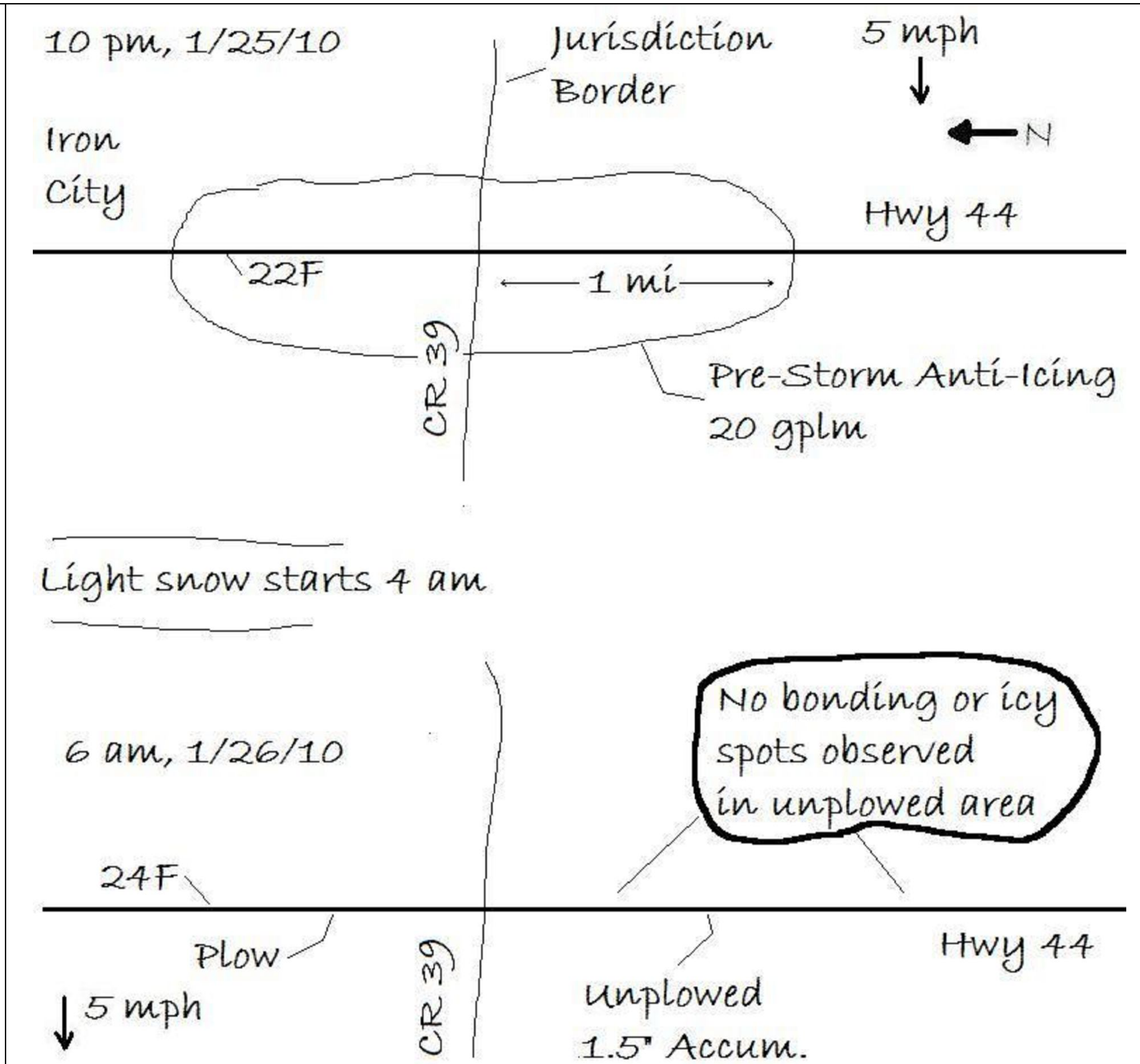
Trying pre-storm anti-icing at a trouble-spot at one of our borders where it has been difficult to match plowing timing with other maintenance area.

Typical medium snow for area.

We plowed at border earlier than other area.

No icy spots were observed in unplowed area. Anti-icing helped us buy time here.

Pre-storm anti-icing was effective at border trouble-spot for buying time for medium snowfall event.



Tools

VI. Tools

1. Equipment

It is suggested that the application unit should be:

- Solid stream nozzles
- Bar height of 12-14 inches
- Nozzle spacing of approximately 10 inches
- For higher operating speeds and/or with high winds (ie 15 MPH or more), consider extension tubes that reach closer to the road surface (although some have found that extension tubes can slightly reduce application pressure).
- If wind speeds are too excessive (ie 15 MPH is commonly used) you may decide not to anti-ice as it may not be effective

Liquid anti-icing operations are most effective with an application unit operating speed of 20 MPH to 30 MPH. Some experts have designed “shields” allowing higher operating speeds. Also see page 23 “Examples of Approximate Liquid Anti-Icing Coverage” for example anti-icing units.

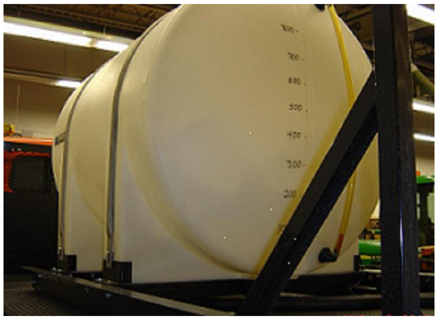
If applying with a vehicle speed of greater than 30 MPH, it is suggested that special considerations should be given to the liquid nozzle configuration such as rubber tubing extensions, shields, etc.

See the following pictures for examples of anti-icing application units.

Examples of Anti-Icing Application Units
***Always know your actual application rates** (Also see page 31 "Determining Actual Application Rate"

	Combination Unit District 1 Liquid Anti-Icing (1,000 gallon) Snow plow with wing and underbody Early warning device for road maintenance
	Anti-Icing Unit on ¾ Ton Pickup District 6 250-350 gallon
	Designated Anti-Icing Unit District 6 900-1,000 gallon
	Tanker Districts 6, 7, and Metro 4,500-5,500 gallon

Examples of Anti-Icing Application Units
***Always know your actual application rates** (Also see page 31 "Determining Actual Application Rate")

	Combination unit District 4, District 8, Metro District Custom-made anti-icing bar hooked up to pre-wet tanks (apply liquid and/or granular) 100-200 gallon
	Slide-In Anti-Icing Tank Metro District 800 gallon
	Anti-Icing Unit District 1 325 gallon
	Anti-Icing Bar Preferred height above ground = 12 inches (adjust height if needed for truck configuration) Optional Nozzle Hose Extensions
	Anti-Icing Nozzle Hose Extensions

2. Facilities

Make the setup for loading liquids as user-friendly as possible. Loading granular materials is usually relatively simple and requires minimal time outside during precipitation. It is suggested that liquid loading should also be user-friendly. This will help you get buy-in from your team in regard to adding liquids to your toolbox. If team members have to spend a significant amount of time outside loading liquids, i.e. getting wet during their work shift, "buy-in" may be difficult.

If just getting started with anti-icing consider purchasing salt brine from nearby maintenance area load point. Experience will help when you plan and setup your facility.

Call and visit nearby shops. See "Appendix 1 - Expert Contact List".

User-Friendly Clearly-Identified Loading Areas

Appendices

VII. Appendices

Appendix 1 - Expert Contact List

Expert Contact List (this is a partial list – blank lines below for adding more contacts)
(ask for "winter maintenance expert" or "anti-icing expert")

Subject	**Contact**
Blending $CaCl_2$ and NaCl	Mn/DOT Windom
Large brine production facilities	Mn/DOT Maryland/Windom
Frost prevention	Mn/DOT Willmar/ Metro/ Duluth/Virginia/ Austin/ Saint Cloud
Buying time	Mn/DOT Marshall/ Stewartville
Anti-Icing early during-storm	Mn/DOT Arden Hills/Olivia
Combination plow/anti-icing unit	Mn/DOT Virginia/ Olivia/Arden Hills
Meteorology	Mn/DOT Meteorology (Saint Cloud)
Use of $MgCl_2$	Mn/DOT Duluth/Virginia/Willmar
Applicator Shields allowing increased anti-icing application unit vehicle speed	Mn/DOT Mankato
Anti-Icing strategies in windy regions	Mn/DOT Marshall/Olivia
During-storm and post-storm liquid use	Mn/DOT Mankato/Windom
Recent user-friendly liquid loading station designs	Mn/DOT Austin/Willmar/Metro
Slurry applications in de-icing mode	Mn/DOT Rochester
Slurry applications in anti-icing mode	Washington DOT
General Assistance	Mn/DOT Office of Maintenance (651) 366-3586 or (651) 366-3575
Add more expert contacts below	

Appendix 2 – Conversions, Etc.

For every lane mile of applied material

Granular to Liquid Conversions

1 lb salt ~= 0.44 gal salt brine
1 gal salt brine ~= 2.272 lb salt

1 lb/ln-mi salt ~= 0.44 gal/ln-mi salt brine
1 gal/ln-mi salt ~= 2.272 lb/ln-mi salt brine

Liquid to Granular Conversions

Salt Brine (23.3% NaCl) (gallons)	Granular Salt (NaCl) (pounds)
10	22.7
15	34.1
20	45.4
25	56.8
30	68.2
35	79.5
40	90.9
50	113.6
60	136.3
70	159.0
80	181.8
90	204.5
100	227.2

Liquid to Granular Conversions

Granular Salt (NaCl) (pounds)	Salt Brine (23.3% NaCl) (gallons)
50	22
75	33
100	44
125	55
150	66
175	77
200	88
225	99
250	110
275	121
300	132

Density of Liquids

Pounds per gallon (water) = 8.34 pounds/gallon
Pounds per gallon (salt brine) = 10.26 pounds/gallon (15°C / 59°F)

Application Rate Lookup Table (gallons/mile)

		Liquid Flow Rate (Gallons Per Minute - gpm)							
		5	7.5	10	12.5	15	17.5	20	22.5
Truck Vehicle Speed (MPH)	5	60.0	90.0	120.0	150.0	180.0	210.0	240.0	270.0
	10	30.0	45.0	60.0	75.0	90.0	105.0	120.0	135.0
	15	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0
	20	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5
	25	12.0	18.0	24.0	30.0	36.0	42.0	48.0	54.0
	30	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0
	35	8.6	12.9	17.1	21.4	25.7	30.0	34.3	38.6
	40	7.5	11.3	15.0	18.8	22.5	26.3	30.0	33.7
	45	6.7	10.0	13.3	16.7	20.0	23.3	26.7	30.0
	50	6.0	9.0	12.0	15.0	18.0	21.0	24.0	27.0
	55	5.5	8.2	10.9	13.6	16.4	19.1	21.8	24.5

Note: If applying liquid on more than one lane your application rate will be reduced, divide by number of lanes. You may need to consider a second pass to maintain desired application rate.

<u>Sample Calculation</u>

10 gpm @ 30 MPH

(10 gallons/minute) * (60 minutes/hour) * (1 hour / 30 miles) = 20 gallons/mile

note: ‘minute’ and ‘hour’ cancel out; leaving us with gallons/mile

*This value (20 gallons/mile) can also be obtained in chart above:

Using 30 MPH (side) and 10 gpm (top) to obtain 20 gallons/mile

<u>Determining rate when applying liquid onto multiple lanes</u>

Sample using 20 gallons/mile from above

Number of Lanes	Application rate (gallons/mile)	Application rate Adjusted to Lanes (gallons/lane-mile)
1	20	20
2	20	20/2 = 10
3	20	20/3 = 6.7

Hydrometer/Salimeter Chart for Salt Brine

Freezing Point (F)	Percent Salt Concentration By Weight	Hydrometer Specific Gravity	Salimeter Percent of Saturation
32.0	0	1	0
31.0	1	1.007	4
30.0	2	1.014	7
28.8	3	1.021	11
27.8	4	1.028	15
26.7	5	1.036	19
25.5	6	1.043	22
24.2	7	1.051	26
22.9	8	1.059	30
21.6	9	1.067	33
20.2	10	1.074	37
	11	1.082	41
17.3	12	1.089	44
15.7	13	1.097	48
	14	1.104	52
12.4	15	1.112	56
10.6	16	1.119	59
8.7	17	1.127	63
6.7	18	1.135	67
4.6	19	1.143	70
2.4	20	1.152	74
0.0	21	1.159	78
-2.5	22	1.168	81
-5.2	23	1.176	85
-1.4	24	1.184	89
13.3	25	1.193	93
27.9	26	1.201	96
	27	—	100

Gallons of Road Guard Plus added to 1000 Gallons of Salt Brine	Specific Gravity of Blended Brine	%	Crystallization Temp °F
50	1.1868	5.00	
100	1.1938	10.00	-7
120	1.1965	12.00	
140	1.1990	14.00	
160	1.2015	16.00	
180	1.2039	18.00	
200	1.2062	20.00	-8
220	1.2084	22.00	
240	1.2105	24.00	
260	1.2126	26.00	
280	1.2147	28.00	
300	1.2166	30.00	-9.4
320	1.2185	32.00	
340	1.2204	34.00	
360	1.2221	36.00	
380	1.2239	38.00	
400	1.2256	40.00	-10.3
420	1.2272	42.00	
440	1.2288	44.00	
460	1.2304	46.00	
480	1.2319	48.00	
500	1.2333	50.00	-11.2
520	1.2348	52.00	
540	1.2362	54.00	
560	1.2375	56.00	
580	1.2388	58.00	
600	1.2401	60.00	-13
620	1.2414	62.00	
640	1.2426	64.00	
660	1.2438	66.00	

Appendix 3 - Glossary

Common Definitions

Basic Definitions	
Anti-Icing	anti-icing places a thin chemical layer "coating" directly onto the "clean" pavement surface before frost or ice/snow bonding exists. When done before frost events, it helps prevent frost formation. When done before events, it helps prevent the snow/ice bond. Anti-icing takes approximately 1/10 as much energy as de-icing.
De-Icing	de-icing places a thicker layer of chemicals on top of snow-pack/ice that is already bonded to the pavement surface. It must melt through the existing layer. It requires approximately 10 times as much energy as preventative anti-icing.
Liquid Anti-Icing	Anti-Icing done with liquid chemicals. This will be the focus of this guide.
Target locations	Roadway locations that have been identified as benefiting the most from anti-icing. These generally include roadway segments prone to frost, trouble-spots and higher priority routes.
Pavement Temperature	This is the temperature we are primarily concerned with for anti-icing. It can vary greatly within a short distance on pavement (i.e. a short distance from a weather station point). Always consider forecasted pavement temperatures before, during and after the event. Note shaded area pavement temps be less.
Timing	
Pre-Storm	Before the storm event. Most anti-icing described in this guide is pre-storm.
Early-During-Storm	The early part of the storm event (with little snow accumulation). Most "Pre-Storm" anti-icing can also be done during this period. In some cases this is the best period for anti-icing (Also see page 58 "Adjustments for Blowing Snow Conditions").
During-Storm	The period during the storm. Activities include plowing and de-icing.
Post-Storm	After the storm event (storm "cleanup" activities such as de-icing to remove remaining snow-pack).
Event Types	
Light Snow	Often specified as less than 0.5 inch/hour. Visibility is greater than ½ mile.
Moderate Snow	0.5 to 1.0 inches per hour. Visibility is between ¼ mile and ½ mile.
Heavy Snow	1.0 inches per hour or more. Visibility less than ¼ mile.
Frost	Ice crystals formed on surfaces, frozen dew. Also called 'hoar frost' or 'white frost'.

Freezing Rain	Liquid precipitation around freezing temp resulting in hard slick thick glaze or clear ice coating on surfaces. Supercooled droplets falling on surface whose temperature is around freezing
Black Ice	Very thin bubble free coating of clear ice on a pavement at or slightly above freezing
Sleet(Ice Pellets)	A mixture of rain and of snow. Precipitation is transparent or translucent pellets of ice.
Slush	Snow saturated with water
Note – Typical ice content of 90-100% for sleet, freezing rain, packed snow and glaze. ice content of 10-90% for snow	
Chemical Abbreviations	
NaCl	Sodium Chloride (salt brine)
$MgCl_2$	Magnesium Chloride
$CaCl_2$	Calcium Chloride
LCS	Liquid Corn Syrup
CMA	Calcium Magnesium Acetate
KA_c	Potassium Acetate

Common Principles

General Principles	
Keep It Simple (KIS)	Getting anti-icing "buy-in" from the snow fighting team will in part be based on ease-of-use of your anti-icing equipment setup and procedures. For example, loading and applying material should be no more difficult (for liquids relative to solids).
User-Friendly	Like any tool, a big factor determining if it will get "buy-in" from your team, will be ease-of-use. Anti-icing liquid loading, application equipment etc. should be as user-friendly as it is with granular materials. .
Don't expect too much from chemical	Anti-icing is one tool from a toolbox to be used along with other tools (i.e. effective plow cutting edges, effective de-icing techniques, etc.). It does not replace the other tools, but will enhance them.
Tap into the experience of others	Anti-icing is a relatively new tool. Learn the "easy way" by tapping into the experiences, success, and lessons learned of other anti-icers (Also see page 45 "*Expert Contact List*").

Benefits of Liquid Anti-Icing

Prevention	
Frost Prevention	Frost prevention anti-icing helps prevent frost formation. Applications are typically done on a regular schedule such as Tuesday and Friday. In some conditions, one application can be effective multiple days and prevent or minimize one or two normal frost events. It helps "buy time" at anti-icing locations.
Bond Prevention	The Anti-icing coating layer on pavement surfaces helps prevent snow/ice and snow-pack from bonding to the protected surface.
Friday Applications	Anti-icing on Fridays when there is a chance of frost has proven to benefit weekend road conditions and at the same time reducing needs for overtime.
Improving the condition of and "Buying Time" at Trouble-Spot Locations	
Trouble-Spots	Locations such as hills, curves, …
Higher priority routes	Routes such as hospital routes, school routes, …
Frost Prone locations	Frost-Prone locations such as bridge decks, shaded locations, frost-prone concrete sections, …
Operation Benefits	
Buying Time	By anti-icing in identified frost-prone, trouble-spot and higher priority locations we help improve these locations and "buy time" until the spots can be worked on during the storm.
Multi-Day Effect	See "Frost Prevention" and "Friday Applications" above.
"Anti-Icing Energy" = 1/10 "De-Icing Energy"	Only about 1/10 of the energy is required for preventative anti-icing than reactive de-icing (melting ice/snow-pack).
Immediate Effect	Liquid chemicals immediately form a coating on the roadway compared to solid chemicals that take time and external factors before becoming brine.
Minimizes Wasted Material	Liquid anti-icing applies the liquid directly to the road surface minimizing the chance for loss of materials from the roadway compared to solid chemicals.

Chemicals

Chemical Term Definitions	
Basic	Salt Brine (NaCl). The most commonly used anti-icing chemical. Effective for many events. It is most effective at 20°F and above. If starting a new program, this is a good chemical to start with. Proven to be a chemical that has relatively few application problems (i.e. slippery cases) when principles are followed.
Adhering (Sticky)	Chemicals that adhere to roadway for multiple days if no precipitation.
Depressed Freezing Point	Chemicals with lower freezing points than basic chemicals.
Blends	Blends consist of mixes of two or more of basic, adhering and depressed freezing point chemicals.
Refreeze	This is the term used if an applied road chemical (liquid or diluted solid) freezes. Anti-icing chemicals are mostly water, so they have the potential to freeze as they dilute. Anti-icers have found methods to avoid or minimize this case. Also consider *DOS* and the principle to not over-apply chemical.
Residual	Chemical left on the roadway (adhering chemical). This is usually beneficial for frost prevention. However, caution in areas susceptible to blowing snow. 
Chemical Consistency	Road chemicals include solid and liquid materials, many times in combination (pre-wet solids). Emerging technologies include during-storm liquid use and slurry applications. This guide focuses on liquid chemicals.
Hygroscopic Property (Water Attracting)	The hygroscopic property of a chemical is its ability to “absorb” or take moisture from the air. $CaCl_2$ and $MgCl_2$ are highly hygroscopic. They can draw moisture at a relative humidity of only 35%. $NaCl_2$ is also hygroscopic but needs a relative humidity of approximately 75% to draw moisture. Consider these properties when considering dilution potential. Experience has shown that using the application rates suggested in this guide (**not** overapplying chemical) helps to minimize the chance of chemical residual drawing moisture and dilution-refreeze. Note that it is not uncommon for the relative humidity in Minnesota (winter) to be above 75% meaning that most road chemicals can be hygroscopic. Also note that dew point is usually a better general moisture indicator (see page 9 “Weather Factors”).

Applications

Application Principles	
DOS	Dilution of Solution (DOS) occurs when precipitation dilutes the liquid chemical on the roadway. It reduces the effectiveness of the liquid and if the layer is thick enough can cause refreeze. To minimize DOS, anti-icers do the following: • Apply liquids to the roadway in a thin layer (20 gal/lane-mile is common). This has proven to give the dual benefit of effectiveness and minimization of the chance of refreeze. • Try to avoid anti-icing in extremely cold temperatures. Even if your chemical has a low freezing point, as dilution increases <u>any</u> chemical will become more "water-like" and freezing can occur quickly.
Avoiding Slippery Cases	The following principles have proven effective at avoiding problematic slippery cases (which are rare in anti-icing, but can occur; see guide content for more detail): • Do not over-apply liquids. Only a very thin layer is needed on the pavement. See "*Do Not Over-Apply*" above. • Do not apply any chemical (solid/liquid) to a dry road in an area with anticipated blowing snow conditions. • Be conservative with pavement temperatures. Anti-icing has proven most effective at temperatures above 20°F. Anti-icing should be done with caution with cold forecasted temperatures. (See "Respect Temperatures" principle).
Border Consistency	Experience has shown that maintenance area borders can sometimes be trouble-spots. Anti-icing can help with border consistency. Also see page 57 "*Maintenance Area Border Consistency*".
Knowing Actual Application Rates	It is important to be confident that your actual application rates match your expected application rates (for your anti-icing units). Ensuring this is relatively simple (Also see page 31 "Determining Actual Application Rate").
Do Not Over-Apply	Experience has shown that over-application can cause slippery conditions. Applying the right amount of material has proven to eliminate or minimize the chance of these problems.
Do Not Overlap applications	Avoid overlapping applications which can result in over-application (application rates doubled or more). Consider locations which are more prone to overlap such as ramps.

Special Application Considerations	
Low Application Rates are Most Effective	Low application rates (thin coating) have proven to be most effective for anti-icing (20 gallons/lane-mile). As discussed in this guide, there are several reasons for this. Most important, the relatively low application rates have proven to be effective. Other factors are presented in the "Application Principles" above and throughout this guide. Also, lower rates "minimize" the differences between areas where we have applied anti-icing chemicals and adjacent areas where we have not. Also see the related principle "Knowing Actual Application Rates" above.
1st and 2nd events of the year (or after extended "dry" periods)	Cases have been observed where anti-icing chemicals "scrub" the oils up from the pavement and can worsen the road conditions by making the road slippery. It is suggested that anti-icing be **adjusted** by reducing application rates by ½ for these events.
Pavement Surface Coarseness	You may learn that some roadways in your areas require adjustment of application rates. For example, courser seal-coats typically might require slightly higher rates, and polished concretes might require slightly lower rates.
Multiple Events	If forecasted weather includes multiple events then determine anti-icing needs for both and use the most limiting. For example, for rain followed by snow, the 'rain' event governs our decision. Therefore, we would not anti-ice for this case. Also see page 56 "Special Considerations for Multiple-Day Storms".
Pavement Cross Slope (fast drainage type)	Some roadway cross slopes may be steeper to provide "fast drainage" (i.e. 2.5% as opposed to the standard 2.0%). These may require more frequent applications or you may consider trying an "adhering" chemical type.
Anti-Icing Application Unit Operating Speed	Liquid anti-icing operations are most effective when with an application vehicle unit operating speed of 30 MPH or less. Some anti-icing teams prefer to apply liquids at 20 MPH to 25 MPH. Also see page 39 "Equipment".

Appendix 4 – Special Considerations

Tips if Just Starting Anti-Icing:

If just starting anti-icing, you will find “getting started” suggestions throughout the guide. The following list includes some of these suggestions:

- Start with a “basic” chemical such salt brine
- Start with a smaller or the most readily available anti-icing unit
- Talk to other maintenance shops before starting
- Consider purchasing liquid chemical from nearby maintenance shop

Anti-Icing for 1st Winter Event of Year

The 1st Winter event of the year warrants special consideration. The driving public has not driven on ice/snow for a long time, which may result in increased safety issues. Therefore, it is suggested to monitor weather early in the season and perform anti-icing for the 1st event as outlined in the procedures section.

Note that the procedures section suggests a <u>reduced application rate (1/2)</u> for the 1st event because of potential road surface contamination (oils, etc) that have not yet been “scrubbed off” by snow events. The reduced application rate has proven to eliminate or minimize the chance that the wetted road (by anti-icing chemical) in combination with the oils will not produce a problematic slippery surface.

Special Considerations for Multiple-Day Storms

Often you will have a relatively high level of confidence in weather conditions through a short-duration or single-day storm. This may not be the case with a multi-day storm or blizzard. Experience has shown that these events can start off with air temperatures above 20°F but towards the end of the storm “nose-dive” toward subzero temperatures. This can cause unique challenges in regard to anti-icing.

If anti-icing for these types of events, you should be confident that you are able to plow the sections of road where you applied liquid chemical within a reasonable time.

If it is expected that it may be difficult to keep up with plowing of some roadways during the multi-day event, those locations should not be anti-iced. The chemicals will do their job and cause a weak bond and keep the snow/surface interface moist. However, if this moist layer is not plowed for a prolonged period, as dilution occurs, this layer may freeze causing a potential thick bonded layer. Falling temperatures exasperate this problem. In certain cases, experience has shown, that if the bond is thick enough it may take many days or longer and increasing temperatures to remove it.

Maintenance Area Border Trouble-Spots

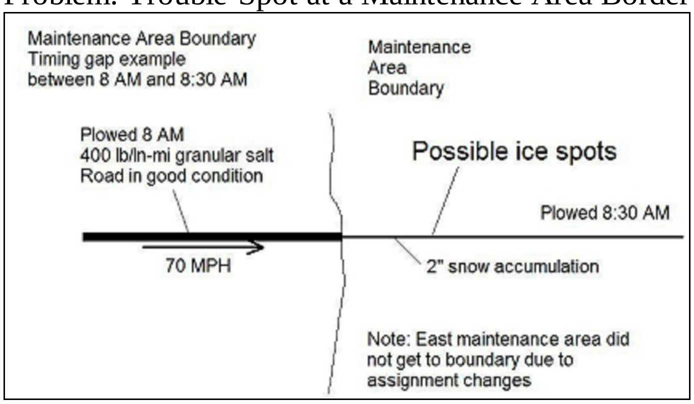
Experience has shown that maintenance area borders can in some cases be "trouble-spots" because of variations in operation timing, methods, and chemical application rates between adjacent areas.

There can be a period of time where there is a transition from plowed (bare lane) to unplowed (snow accumulation) roadway.

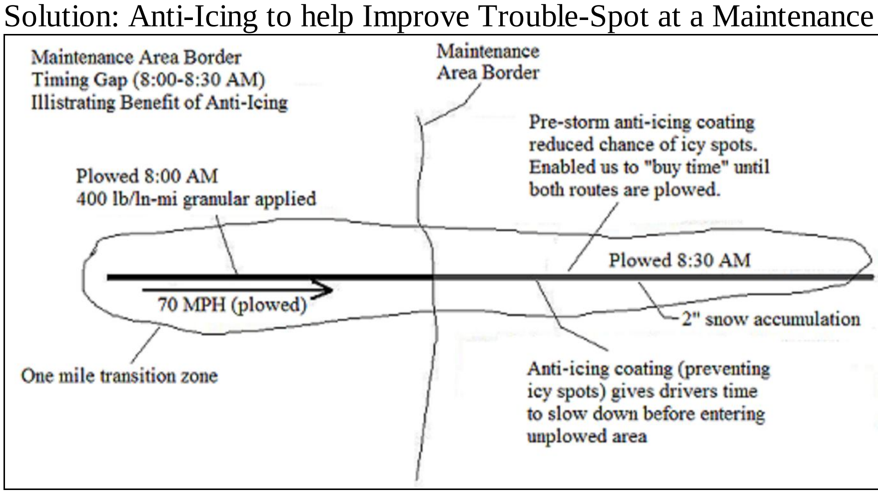
Coordinate with adjacent maintenance areas to try to match operation timing, methods, and chemical application rates as closely as possible.

Anti-icing this "transition zone" can help drivers transition between the areas. A low application rate of 20 gallons/lane-mile or less is suggested. The low rate minimizes the difference at the end of the transition zone (especially for unplowed routes). *See the sketches below* that show how pre-storm anti-icing can help to "buy time" and improve a trouble-spot border.

Problem: Trouble-Spot at a Maintenance Area Border



Solution: Anti-Icing to help Improve Trouble-Spot at a Maintenance Area Border



Adjustments for Blowing Snow Conditions

This section describes different approaches that you may want to consider for blowing snow conditions. Pre-storm anti-icing is often “avoided” when there is the potential for blowing snow.

This is very limiting in geographic areas that are generally open and flat.

There are approaches (adjustments) that have been used successfully to perform more anti-icing in these types of geographic areas.

Experience has shown that areas with blowing snow conditions warrant special consideration and adjustments of your anti-icing program. Open areas (susceptible to blowing snow) were identified in the previous sections.

This section outlines suggested adjustments of anti-icing procedures for blowing snow conditions. Also see page 11 “Wind and Blowing Snow”.

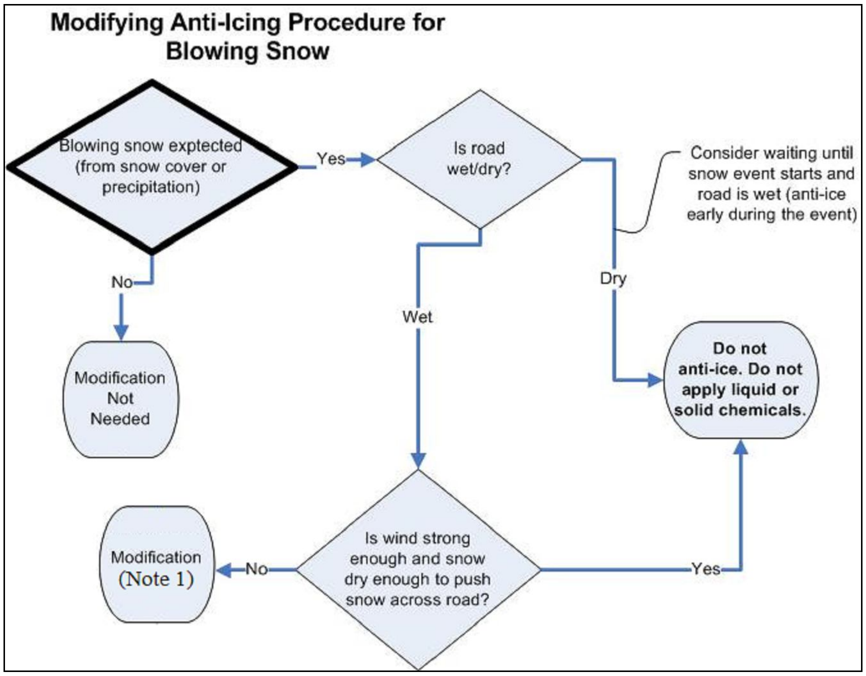
The following charts and tables will help you adjust your anti-icing program for blowing snow conditions.

Timing becomes more important in blowing snow conditions (ie performing anti-icing closer to the start of the snow event or even early during the snow event. Some experts use a rule-of-thumb to not apply any chemical (solid/liquid) to a dry road if blowing snow conditions are expected.

Anti-icing in open areas under blowing snow conditions can make the road conditions worse. This occurs when a liquid chemical makes the road “wet”. This wet road then can 'catch' the blowing snow. Even solid chemicals can catch some of the blowing snow, which then forms liquid brine on the pavement, making the road wet, and catching more snow.

When identifying open areas, experience has shown that bridge decks should be handled on a case-by-case basis. Some bridge decks do not receive blowing snow, in other cases they do. It is a good idea to chart the bridges.

Frost events occur less frequently in areas prone to high winds (there will be exceptions as weather events can be unpredictable).



Adjustments of Anti-Icing Procedures For Blowing Snow Conditions
(Also see page 9 "Weather Factors")

Anti-Icing Action	Description
Condition - No snow cover or snow cover is not prone to blowing1[1] *Event* - Significant snow event[2,6] *Event Probability* - High[3]	*Technique: Anti-icing with favorable snow cover* Apply anti-icing chemicals within 24 hours of forecasted event (best practice is as close to event as possible) or early/during event when road has little or no snow accumulation[4]
Condition - Snow cover is prone to blowing[1] *Event* - Significant snow event[2,6] that will likely produce snow-pack or bonding problems[5] *Event Probability* - *Wait until storm starts.*	*Technique: Anti-icing after storm starts (*early-during-storm) Apply anti-icing chemicals within early period of snow event before significant accumulation or onto clean (plowed) road. Pros • Can help produce a weak snow/ice bond allowing easier plowing during the event and for post storm cleanup. Produces • High level of confidence that we will not have post-storm residual in blowing snow.

<table>
<tr>
<td><u>Condition</u> - Snow cover is prone to blowing[1]
<u>Event</u> - Significant snow event[2,6] that will likely produce snow-pack or bonding problems[5]
<u>Event Probability</u> – High[3]
<u>Other</u> – Time application so there is not blowing snow onto chemically wet road between application time and event start time. As close to event as possible is best practice.</td>
<td><u>Technique:</u> Anti-icing before storm starts (pre-storm)
Apply anti-icing chemicals before and as <u>close to the event</u> as possible
<u>Pros</u>
• Can help produce a weak snow/ice bond allowing easier plowing during the event and for post storm cleanup. Produces
• High level of confidence that we will not have post-storm residual in blowing snow
• Often easier operationally as the shift working before the event can do the anti-icing</td>
</tr>
<tr>
<td colspan="2">Notes
1 – Assess snow cover. Crusty snow cover will produce the least blowing snow, and loose snow the most. Dryer snows tend to produce more blowing than wetter. (also a function of the expected wind strengths in your area).
2 – A <u>significant snow event</u> is defined as an event that will “use up” all of the chemical applied to the road so that there is <u>not</u> undesired chemical residual left on the road after the storm (in area with blowing snow). 3 – A high probability (level of confidence) in a forecast will be based on your confidence in your forecasting tools. A rule-of-thumb is that a high level of confidence is often associated with a prediction chance of 70%/80% or higher, and within 16 hours of the event.
4 – Best to apply chemical onto road with no or little snow accumulation of <u>½ inch or less</u>. Note that that this technique allows anti-icing be performed early in the storm before plowing or onto a cleaned/plowed road during the storm
5 – Snowfall events that will likely produce snow-pack or bonding problems include evens with sufficient moisture (i.e. cold and dry snowfall events will have less chance of producing these issues. This will be a judgment call you will make utilizing your forecasting tools and experiences with local weather).
6 - Also consider forecasted maximum wind speeds maximum during the event. If forecasted wind speeds are 15 MPH between the time you expect to apply chemical and when you think event will be over and cleanup completed, it is suggested not to anti-ice in open areas; strong winds in some cases can help to 'clear' a relatively dry road.</td>
</tr>
</table>

Also consider such innovations as “Living Snow Fences”, which have proven to reduce blowing snow. Each will have to be assessed to determine if they provide “protection” from blowing snow.

Appendix 5 – Blank Forms

The following pages include handy quick forms for anti-icing.

Samples for using the forms can be found in the guide.

Also see page 46 “Conversions”.

Anti-Icing Locations Form

(F) Locations Prone to Frost	**(T) Trouble-Spots**	**(H) Higher Priority Routes**
B = Bridge Deck C = Concrete Section S = Shaded Area *(enter more below)*	M = Maintenance Area Border I = Intersection A = Known Accident Area R = Ramp H = Hill U = Curve T = Town in Rural Route *(enter more below)*	H = Hospital Route V = Higher Volume Route O = School Routes *(enter more below)*

Plow Route[1]	Anti-Icing Location	Type	Open[2]	Length (miles)	Notes

Notes
1) Optionally, prioritize anti-icing locations
2) Yes if location is in “open area” that is susceptible to blowing snow (when blowing snow conditions exist)
3) See samples in guide content

Anti-Icing Strategy Form

Maintenance Area:	Year:
Event Types:	
Chemicals and Application[1]	Criteria (triggering anti-icing)[1]
Schedule/Timing	Blowing Snow Adjustment[3]
Notes 1) See information in guide to help determine strategies	

Determining Actual Application Rate Quick Form

Anti-Icing Unit Description			
Anti-Icing Unit Speed		MPH	
Place collection bucket(s) below discharge nozzles			
Start timer and fill buckets (T)		minutes	
Determine volume[1] (V)		gallons	If weighing buckets, see "Conversion Tips" below
Calculate flow rate (V/T)		gpm	
Look up application rate[2] using flow rate (gpm) and vehicle speed (MPH)		gplm	Also see page 47 "Application Rate Lookup Table"
Notes: 1. CAUTION - Never lift more weight than the maximum weight allowed by your governing safety regulations. 2. gplm = gallons/lane-mile			

Storm Taper Log Form

Location

Date	Time	Note	Storm Description

Road Snow and Ice Control Action Log

Route Description:

Sketch:

				Chemical Treatment		Road Condition			
Date	**Time**	**Plow?**		**Liquid or Solid (L or S)**	**Rate (1) (gal or lbs per lane-mile)**	**Snow Depth (2) (inches)**	**Snow- pack / Bonding**	**Slippery Conditions (spots)**	**Notes**

Action Summary:

Chemical Usage Summary:

Road Conditions Summary (Observed):

Notes

1) For chemical types used on routes, see "Route and treatment description(s)" at top of this page
2) Snow depth: snow accumulation on roadway

Snowfighting Story Log

Location
Time Period **By**

Summary	Sketch