

Minnesota

Snow and Ice Control

Field Handbook for Snowplow Operators

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# Purpose of this Handbook

The purpose of this field handbook is to help promote the understanding of the tools, best practices, and limitations for snow and ice control. The handbook will also help you under- Less material on stand when to use and when not to use these tools and prac- roads means less tices. In addition, it encourages progressive changes in snow material in lakes and streams.

and ice control practices that will help you reduce salt/sand use and environmental impacts while meeting the safety and mobility needs of roadway users.

Practices such as anti-icing, prewetting, and pretreating are emphasized in this field handbook. Various research projects and reports are cited to support recommended practices. Also included are standard best practices expected in a quality snow and ice control program.

Throughout the field handbook you will find environmental tips shown with this fish symbol . These tips are provided to help you reduce environmental impacts from snow and ice control operations.

A blanket approach will not work for the broad range of conditions Minnesota experiences; different strategies are needed for different regions and different conditions. We encourage you to continue to test, document, and refine the practices from this field handbook.

# Basic Concepts

## **Weather**

Knowing existing and potential weather conditions is very important for a successful snow and ice control operation. Six pieces of information are especially valuable:

1. Start of precipitation
2. Type of precipitation
3. Total precipitation expected/storm intensity
4. Expected event length
5. Wind conditions (speed, gusts, directions)
6. Temperature trend

Monitor the weather closely so that you are available and prepared to act early in storm situations.

## **Weather information sources**

* P hone 511 to get road condition and travel information or visit the Web: www.511mn.org.

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* S ubscribe to a value-added meteorological service (VAMS). These are useful for viewing weather forecasts and pavement temps.
* Check the National Weather Service.
* Check all available weather sources.
* C heck MnDOT’s Road and Weather Information System (RWIS) site: www.rwis.dot.state.mn.us.

### Pavement temPerature

|  |  |
| --- | --- |
| Most weather stations measure temperature and other conditions 30 feet above ground, which means these conditions can differ substantially from pavement temperatures. Thus, use the pavement temperature—not the air temperature—to determine what material to use and the application rate. You’ll notice changes in pavement temperature first on bridge decks and ramps. Pavement temperatures will also be lower in shady areas. | Pavement temperatures can be substantially lower or higher than air temperatures. |

## **Measuring with sensors or RWIS**

There are various ways to measure pavement temperatures: with sensors or with a Road Weather Information System (RWIS).

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## Basic Concepts

Sensors can be hand-held, truck-mounted, or mounted on a structure near a road.

* H and-held infrared laser sensors are pointed at the pavement to get a pavement or surface temperature while your vehicle is stopped or moving slowly.
* T ruck-mounted temperature sensors measure pavement or surface temperatures while your truck is moving. Ideally, every agency should own at least one truck-mounted unit.
* A structure-mounted sensor is non-invasive and provides temperature readings, chemicals present, and grip or friction values.

If you do not have road sensors in your truck or on your roads, you can subscribe to a real-time weather forecasting system. Or, you can look up the road temperature from the closest state highway on RWIS (www.rwis.dot.state.mn.us). This will give you an idea of the local road temperatures. RWIS is a predictive system that consists of a network of towers and temperature sensors embedded in state highways.

### Other tools: MDSS and AVL

* M aintenance Decision Support Systems (MDSS) help transportation agencies make better decisions about their winter maintenance activities by providing reliable weather and road conditions and recommending the most costeffective treatments.
* A utomated Vehicle Location (AVL) systems help support the MDSS by continuously recording plow truck locations and other pertinent information. These data are automatically forwarded to MnDOT maintenance supervisors, who can better respond to any weather related events.

To read more about MDSS/AVL, go to:

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http://ihub/maintenance/mdssavl/index.html http://www.meridian-enviro.com/.

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# Before the Winter

Take some time before the season to plan your routes and learn the plowing policies. A little planning up-front can help you do a more efficient job in keeping the roads safe.

## **Policies**

* M ake sure you have a plowing policy and meet to discuss

Using less salt it. Your level of service may be based on average daily traf- doesn’t have to

fic, environmental concerns, safety, mobility, economics, reduce safety, but and other factors. it does protect our

* Inform your citizens of policies. lakes.
* L earn to record what and how much material you apply on each shift. Be prepared to analyze and make adjustments to your process based on what you learn. **Plan your routes**
* D uring the fall, inspect and make sure ditches, culverts, and surfaces are free from obstructions and ready for the spring melt.
* R emove potential snow traps, such as tall grasses, that will catch and accumulate snow.
* D rive the assigned routes prior to winter to identify critical areas and find the most efficient way to cover the routes.
* I nventory all the areas prone to drifting and have a plan to manage them.
* K now your routes. Plan which way you will start.
* B e flexible. Conditions could change the way you plow your route.
* C onsider implementing a route optimization/decision support tool, such as MDSS or AVL (see page 2).

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## Before the Winter

All good programs include calibration.

If you don’t calibrate your sander, the application

rates will not be accurate.

### calibrate your equiPment

Calibration is an essential procedure to measure the amount of material applied to the roadway at various auger settings in relation to truck speed. No matter how sophisticated or simplified your operations, always calibrate or verify calibration yearly.

* B ecause spreaders vary, calibrate each truck. Re-calibration is required if changes are made to the hydraulic system, if the augers have extensive wear or are resurfaced or replaced, or a different material is used.
* F ollow the manufacturer’s guidelines for calibration, and contact the manufacturer for training.
* C alibrate separately for salt/sand mix vs. salt or sand only.
* D etermine flow rate or calibrate liquid application systems at the same time as the dry systems.
* R emember: The auger plate must be in place during calibration. You are not calibrating the truck properly if the material is gravity-flowing.
* For manual sander controls, place a chart in your truck to see how much material is applied at each setting, at various speeds.
* There are two types of automatic sander controllers. Open-loop controllers monitor only truck speed during operation; closed-loop controllers monitor both truck speed and spreader discharge.

Calibration resources:

* C lear Roads has links to manufacturers’ calibration instructions and a comprehensive calibration guide: http:// clearroads.org/researchprojects/05-02calibration.html • MnDOT also has calibration instructions: www.dot.state .mn.us/maintenance/training.
* F or sander calibration training, contact the Minnesota Circuit Training and Assistance Program (CTAP) instructor at www.mnltap.umn.edu/about/programs/ctap.

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* F or liquid calibrations, see the *MnDOT Anti-icing Guide* at www.dot.state.mn.us/maintenance/training.

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# Before the Storm

## **anti-icing**

Anti-icing can be a cost-effective strategy that optimizes chemical usage. It is a proactive approach that should be first in a series of strategies for most winter storms. By applying chemical freeze-point-depressant materials before a storm, you can prevent snow and ice from bonding to the pavement.

For guidance on which anti-icing chemical is most cost effective for your agency/location, see the MnDOT Cost Benefit Analysis Tool. For guidance on how to begin or expand an anti-icing program, see the *MnDOT Anti-Icing Guide*. Both can be found at www.dot.state.mn.us/maintenance/training.

## **Clear Roads online cost-benefit analysis toolkit**

Anti-icing can provide significant cost, safety, and environmental benefits. To help determine cost savings, use the Clear Roads toolkit available at www.clearroads.org (click on re- search projects).

Anti-icing can reduce airborne

## **Guidelines for anti-icing** dust and salt

* Anti-icing is often effective for heavy frosts. particulates.
* A nti-icing works best when combined with accurate road weather information.
* B ecause motorists have difficulty perceiving how slippery light freezing drizzle and light frost can be, early application is important in these conditions.
* L iquids are the most efficient and may be applied days in advance of an event, but the closer to the event start time, the better, as tire action and wind wear away material.
* Similar applications of pretreated salts will also work. Use the lowest possible setting, less than 100 lbs/two-lane mile; apply as close to the start of event as possible.
* See the Application Rate Guidelines on page 16 of this field handbook.

### *What to do*

* A pply liquids only with stream nozzles to maintain some bare pavement between sprayed areas to reduce slipperiness. Fan spray is not recommended.
* S chedule applications on bridge decks and critical areas if

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## Before the Storm Before the Storm

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| --- | --- | --- |
|  |  | temperature and conditions could produce frost or black ice. |
| Use wisely. Chlorides can increase the salinity of soil, which can lead to compaction and erosion. |      | * C onsider spot-applications on hills, curves, and intersections if predicted conditions warrant.
* U se appropriate chemical for your pavement temperature range. See the chart on page 19 of this field handbook.
* A pply an anti-icing product during non-rush-hour traffic periods.
* W hen frost on the shoulder starts to move into the travel lanes, reapply anti-icing product.
 |

### *What not to do*

* D on’t anti-ice under blowing conditions, in areas prone to drifting, and anywhere else you would refrain from using salt. Be aware of areas that are prone to wind issues.
* R eapplication isn’t always necessary if there is still a residual. The residual effect can remain for up to five days after application if precipitation or traffic wear-off does not dilute the initial application.
* R emember that the surface can refreeze when precipitation or moisture in the air dilutes the chemical.
* D on’t apply MgCl2 or CaCl2 to a warm road (above 28˚ F pavement temperature). It can become slippery and cause crashes!
* D on’t apply before predicted rain.
* F or the first application or after a prolonged dry spell, apply liquids at half the rate (not half the concentration). On dry roads, liquids tend to mix with oil from vehicles and cause slippery conditions.
* O ver-application of liquid chemicals may make the road become slippery. Less is better. Always follow manufacturers’ application recommendations.

### Equipment

 • S ee the *MnDOT Anti-Icing Guide*: www.dot.state.mn.us/maintenance/training.html

#### Pretreating and PreWetting salt and sand

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Dry material bounces or blows off the road, so everyone If you must use should be either pretreating or prewetting dry material. Liq- dry material, follow uids also increase salt’s effectiveness by jump-starting the best practices to

melting process. Depending on the liquid used, it may lower reduce bounce salt’s effective working temperature. and scatter.

Because pretreating and prewetting cause material to stick to the road, 20 to 30 percent less material is used—saving money and reducing environmental impacts.

### Guidelines for pretreating

Pretreating is mixing a liquid into the stockpile of salt or sand before it is applied. Unlike prewetting, it does not require Chemicals equipment changes and requires no new capital investment leaching from

a stockpile into for equipment. You can also switch from dry application to groundwater is a wet application immediately—just turn down the application common problem. rate.

#### Salt stockpile

* T reat the salt stockpile with a liquid deicing chemical. It may be purchased pretreated or mixed on site by the vendor or your crew.
* W hen treating the stockpile at the shop, apply at 4 to 6 gallons/ton. Salt must be very dry for the chemical to stick.
* B ecause leach risk at a stockpile is increased, store it covered on an impervious pad.

#### Sand stockpile

* P retreat the stockpile to keep it flowable.
* A pply to stockpile at 4 gallons of salt brine/ton sand.
* S tore the stockpile *under cover.*

6 7

Apply wisely. We will never have a

chance to recover the chlorides applied.

### Guidelines for prewetting

Prewetting is adding a liquid to the salt as it is being applied— either at the spinner or through a soaker pipe in the auger box—to help it stick to the road better. Although prewetting requires some equipment changes, it provides flexibility to switch the chemical makeup depending on conditions.

* S alt brine, calcium, magnesium chlorides, and acetates may be used as prewetting agents.
* Th e usual application rate is 8 to 14 gallons/ton for salt brine.
* P rewetting with other chemicals at the spinner can help reduce the application rate.
* B elow 15˚ F, salt brine becomes less effective; below 0˚ F, it may freeze hoses and valves.
* Salt brine should be mixed at 23.3%.
* V erify concentration of liquids you’re using:

 Salt brine: 23.3%

 CaCl₂: 29.8%

 MgCl₂: 21.6%

 CMA: 32.5%

 KAC: 49%

* M nDOT completed the laboratory phase of a research project in 2012 comparing the ice-melting capacity and the cost-benefit of various pre-wetting chemicals. A second phase of this project, testing of chemicals on actual road surfaces, will begin in 2013. Information is available at www.dot.state.mn.us/maintenance/training.
* Super-saturated salt or slurry is a method in which a high volume of liquid is added to the granular salt. Two 400-gallon tanks, located within the box, pump brine at roughly 90 pounds of liquid/210 pounds of salt, resulting in a salt slurry that activates very rapidly.

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# During the Storm

## **deicing**

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Deicing is a reactive operation in which a deicer is applied to the top of an accumulation of snow, ice, or frost that is already bonded to the pavement surface.

Removing ice that has already bonded to the pavement can be difficult, and removing it mechanically can damage equipment and roads. Generally, enough ice must be melted chemically to break the bond between the ice and the pavement, which requires larger quantities of chemical than anti-icing.

* U se an appropriate amount of salt. Most oversalting can be prevented by using calibrated, speed-synchronized spreaders and good judgment in selecting application rates and truck speed.
* I t is not necessary to melt all the snow or ice on the road with salt. This is an overuse of materials. Apply just enough to loosen the bond between the road and the ice so it can be plowed off.
* S ee the Application Rate Guidelines on pages 17–19 of this handbook.
* D ilution of Solution (see page 15) also applies to deicing.

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Use cautiously.

Many chemicals contain trace

metals including cyanide, arsenic, lead, and mercury.

The goal is not to melt everything. The goal is to penetrate through the ice and snow and break the bond so the

pavement can be plowed.

## During the Storm **using abrasives**

|  |  |
| --- | --- |
| Winter abrasives use has been documented as an air pollution concern.If you use a 50/50 salt/sand mix, you’re generally either half right or  | Use winter sand and other abrasives when temperatures are too cold for deicing chemicals to be effective. But be aware that sand does not melt anything. It provides temporary traction, and only when it is on top. Sand also clogs sewers, ditches, and streams. As a result, avoid sand use as much as possible. A salt/sand mix is generally not recommended. Salt reduces the effectiveness of sand, and sand reduces the effectiveness of salt. However, a salt/sand mix may be helpful in limited situations such as a freezing rain event where the salt is washed away quickly. A 25 to 50 percent sand/salt mix has been documented as effective in increasing friction by sticking the sand to the surface, like sandpaper.* U se abrasives in slow-moving traffic areas such as intersections and curves.
* I f your purpose is melting, use salt only.
* S alt is ineffective in cold weather, so use sand or an alternative chemical.
* S and is not cheap when you consider the handling, cleanup, and disposal costs.
 |
| half wrong. Using a • S weep up sand frequently, after each event if feasible. salt/sand mix leads to overapplication of both materials. **standard Practices*** K now the pavement temperatures and trends to help you use the right application at the right time. Generally use less chemical when temperatures are rising and more when they are falling.
* D on’t apply dry salt (sodium chloride) at below 15˚ F pavement temperature. It will not melt fast enough to help and it will blow off the road into the ditch.
* B elow 20˚ F, switch to other tools like CaCl2 and MgCl2 at curves, hills, and intersections to obtain maximum melting. If unavailable, use sand for traction.
* A djust your spinner speed to the lowest setting possible,

Sand that washes except at intersections.into a stream • D on’t let the traffic dictate your speed. Drive at the slowor lake may est possible speed—17 to 25 mph—to keep material on the smother some road. small aquatic • O n high-speed roads, apply deicers in the center of the organisms. road or high side of the curve. |

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* S et spinners lower to the ground or use a chute to reduce bounce and scatter. See www.dot.state.mn.us /maintenance/training.html and www.mnltap.umn.edu/ Never use calcium about/programs/opera/fact/documents/washingtoncad. chloride to open pdf for chute-building instructions. drains—it is

extremely toxic to

* T urn off auger when stopped, even briefly. aquatic systems.

### Loading/hauling

* S et up and load under cover and on a level surface wherever possible.
* M aintain loading area. Keep it clear and smooth.
* D on’t overload. Avoid spilling on units.
* W atch for co-workers/pedestrians in or near the loading area.
* Good housekeeping and material storage recommendations are at www.dot.state.mn.us/maintenance/training. When slush begins

to stiffen and

### Effective use of plows kicks to the rear

Plow to remove snow and loose ice before deicing applica- from vehicle tires, tions. If snow accumulates before or after applications, plow- it’s time to plow

ing directly before your next application will minimize prod- and then reapply uct dilution. chemical.

* P low first before applying deicers to avoid dilution of the salt.
* C oordinate plowing activities to eliminate windrows at intersections and prevent plowing off another operator’s material.
* R emove snow from roads as quickly as possible to reduce compaction; use of underbody blades helps remove compacted or slushy snow.
* M ake use of carbide, flexible, or rubber-encapsulated plow blade edges. For research information on cutting edges, see www.clearroads.org/research-projects /07-01carbideinsert.html.
* A djust blade angle to maximize cutting efficiency or snow throwing capabilities.

### Public safety/operator safety Once chlorides

* P erform your required CDL pre- and post-trip inspections. enter the ground or
* M ake sure you’re mentally and physically prepared to surface water, they drive. never go away.
* O bey traffic laws. Use the seat belt. Clean lights and windows frequently.

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## During the Storm

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| --- | --- | --- |
|  |   | • F low with traffic as much as possible. Avoid sudden moves.  |
| Make sure a shield is in place to control the application or you’ll overapply salt. |         | Be alert to all surroundings.* D emonstrate courtesy toward other drivers and pedestrians.
* B e aware of spinner discharge at all times.
* A void pushing snow over bridge rails and onto roads below.
* B e alert to hazards such as downed power poles, stop lights, overhead structures, power lines, etc.
* K now the height of your truck box. Raise box only to move material to the back of the box. When raising the box, be certain no overhead obstacles are present.
* B e aware of changing braking abilities from a loaded box to an empty one.
* K eep others informed of changing conditions.
* A ssist/report stranded motorists as necessary.
 |

### Snow cloud

Be aware of wind conditions and potential problems. Snow clouds can form during any plowing operation. A very slight snow cloud can temporarily block out any lighting configuration and increase chances of being hit from the rear.

* R educe your speed to minimize snow clouds.
* D on’t plow just to plow. If shoulder plowing isn’t necessary when the wind is blowing, don’t do it.
* I f you have created a snow cloud, do not brake or slow down—just lift plow and wing.

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# After the Storm

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Begin cleanup operations once the roads are clear to the prescribed level of service. Then, evaluate what was done, how well it worked, and what could be changed to improve operations.

* R emove snow from bridge walls to prevent ramping, and clear snow from crosswalks to allow pedestrian access. Americans with Disabilities Act (ADA) access must also be considered. For further guidance on cleanup prioritization, see www.dot.state.mn.us/maintenance/manual

.html.

* A ccurately record your material use at the end of your shift (see below).
* A ttend a post-storm meeting in the shop to evaluate your operations.
* L ook for opportunities to try new and improved practices.
* C lean and check all equipment.
* R eport any hazards such as low-hanging branches, raised utilities, or other potential problems.
* A t the end of the season, clean and maintain the truck, tanks, brine-making systems, and pumps according to manufacturer specifications.
* P lace all piles on an impervious pad and cover them. This includes salt and salt/sand mixes.

**standard Practices**

## **Documenting and charting**

Good documentation helps you use less material, reduce costs and environmental impacts, and run a more effective snow and ice control program. Unless you document and chart, you can’t measure what you are doing.

* T rack your material use.
* U nderstand the storm conditions and the target level of service for each route.
* R efine your procedures and material use based on observations.
* S hare observations to improve operations and learn from each other.
* U se forms like those shown in the appendix of this field handbook to record and track your work and observations.

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You can’t manage what you don’t measure.

Some fish species are affected by impaired water,

which is equivalent to about 1 to 1.5 tablespoons of

salt in 5 gallons of water.

## After the Storm

* C omplete forms at the end of your shift.
* T urn in documentation forms to your supervisor.
* U se Clear Roads online cost benefit analysis toolkit (2012) to examine costs and benefits of new and existing prac-

tices, equipment, and operations at http://clearroads.org /research-projects/08-02costbenefitanalys.html.

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### Fine-tuning your program

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| Calibrate YearlyUse Application Rate Guidelines (pages 15-18) and Best PracticesCheck Weather and Pavement ConditionsTrack and Evaluate TreatAdjust Rates and Methods |

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# Application Rate Guidelines

Develop your own application rates using the guidelines on pages 15–18 as a starting point and modify them incremental- ly over time to fit your needs. You can summarize information Salt spray gathered from your truck logs into application rates for your damages roadside area. Be aware, though, that rate charts vary greatly. Make it vegetation. a goal to apply only as much material as needed to keep the roads safe. You can reduce rates by following anti-icing and other strategies covered in this field handbook. **guidelines for determining aPPlication rates**

* S and/salt mix isn’t advised but may help in some situations such as freezing rain.
* A lways plow before applying chemical.
* G enerally the first pass will require an application rate at the higher end of the range, with subsequent passes requiring less and less.
* O n long routes where you’ll only be able to make one pass, you may have to apply more material than what’s recommended in the charts.
* H igh traffic volume will work salt into the snow and aid in melting—so use a lower rate.
* H igher traffic speeds will blow salt off the road and hinder melting—so increase use of prewetted materials.
* U se sand for short-term traction only. It will never melt anything.
* I t is usually not cost-efficient to apply salt (sodium chloride) at pavement temperatures below 15˚ F. **dilution: the cause of refreeze**

An ice control product will work until product dilution causes the freeze point of the brine to equal the pavement temperature. At this point, the material will stop melting and you may experience refreeze if pavement temperatures are dropping.

This process is *Dilution of Solution*.

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How long an application will last depends on five factors: pavement temperature, application rate, precipitation, beginning concentration, and chemical type. These factors explain why one application rate will not fit all storm events.

* I f your equipment is unable to deliver material at lower rates, consider exchanging the 9-inch-diameter auger for either a 6-inch or 9-inch special auger to deliver about two-thirds less material/revolution.

**Anti-icing Application Rate Guidelines**

These guidelines are a starting point. Reduce or increase rates incrementally based on your experience.

|  |  |  |  |
| --- | --- | --- | --- |
| Condition |  | Gallons/Lane Mile | Other Products |
| CaCl2 | MgCl2 | Salt Brine |
| 1. Regularly scheduled applications | 15 – 25 | 15 – 25 | 20 – 40 | Follow manufacturers’ recommendations. |
| 2. Prior to frost or black ice event | 15 – 25 | 15 – 25 | 20 – 40 |
| 3. Prior to light or moderate snow | 15 – 25 | 15 – 25 | 20 – 50 |

## **Pounds of Ice Melted Per Pound of Salt**

|  |  |  |
| --- | --- | --- |
| Pavement Temp. ˚F | One Pound of Salt (NaCl) melts | Melt Times  |
| 30 | 46.3 lbs of ice | 5 min. |
| 25 | 14.4 lbs of ice | 10 min. |
| 20 | 8.6 lbs of ice | 20 min. |
| 15 | 6.3 lbs of ice | 1 hour |
| 10 | 4.9 lbs of ice | Dry salt is ineffective and will  |
| 5 | 4.1 lbs of ice | blow away before it melts anything. |
| 0 | 3.7 lbs of ice |  |
| -6 | 3.2 lbs of ice |  |

At temps below 15 degrees, it may be more cost-effective to use a chemical other than NaCl.

See research at www.dot.state.mn.us/maintenance/training

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##  Application Rate Guidelines

### Deicing Application Rate Guidelines

**24’ of pavement (typical two-lane road)**

These rates are not fixed values, but rather the low end of a range to be selected and adjusted by an agency according to its local conditions and experience.

|  |  |
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|  | Lbs/ two-lane mile |
| Pavement Temp. (˚F) and Trend ( ) | Weather Condition | Maintenance Actions  | Salt Prewetted/Pretreated With Salt Brine | Salt Prewetted/Pretreated With Other Blends | Dry Salt\* | Winter Sand (abrasives) |
| >30°  | Snow | Plow, treat intersections only | 80 (40/lane mile) | 70 | 100\* | Not recommended |
|  | Frz. rain | Apply chemical | 80 – 160 | 70 – 140 | 100 – 200\* | Not recommended |
| 30°  | Snow | Plow & apply chemical | 80 – 160 | 70 – 140 | 100 – 200\* | Not recommended |
|  | Frz. rain | Apply chemical | 150 – 200 | 130 – 180 | 180 – 240\* | Not recommended |
| 25 - 30˚  | Snow | Plow & apply chemical | 120 – 160 | 100 – 140 | 150 – 200\* | Not recommended |
|  | Frz. rain | Apply chemical | 150 – 200 | 130 – 180 | 180 – 240\* | Not recommended |
| 25 - 30˚  | Snow | Plow & apply chemical | 120 – 160 | 100 – 140 | 150 – 200\* | Not recommended |
|  | Frz. rain | Apply chemical | 160 – 240 | 140 – 210 | 200 – 300\* | 400 |
| 20 - 25˚  | Snow or frz. rain | Plow & apply chemical | 160 – 240 | 140 – 210 | 200 – 300\* | 400 |
| 20 - 25˚  | Snow | Plow & apply chemical | 200 – 280 | 175 – 250 | 250 – 350\* | Not recommended |
|  | Frz. rain | Apply chemical | 240 – 320 | 210 – 280 | 300 – 400\* | 400 |
| 15 - 20°   | Snow | Plow & apply chemical | 200 – 280 | 175 – 250 | 250 – 350\* | Not recommended |
|  | Frz. rain | Apply chemical | 240 – 320 | 210 – 280 | 300 – 400\* | 400 |
| 15 - 20°  | Snow or Frz. rain | Plow & apply chemical | 240 – 320 | 210 – 280 | 300 – 400\* | 500 for frz. rain |
| 0 to 15˚  | Snow | Plow, treat with blends, sand hazardous areas | Not recommended | 300 – 400 | Not recommended | 500 – 750 spot treat as needed |
| < 0˚ | Snow | Plow, treat with blends, sand hazardous areas  | Not recommended | 400 – 600\*\* | Not recommended | 500 – 750 spot treat as needed |

\*Dry salt is not recommended. It is likely to blow off the road before it melts ice.

\*\*A blend of 6 – 8 gal/ton MgCl2 or CaCl2 added to NaCl can melt ice as low as -10˚.

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##  Application Rate Guidelines

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| BEFORE & DURING SHIFT, CONSULT RWISTM BEFORE APPLYING *ANY* CHEMICALS OR MATERIALS! |
| Pre-wet Material Chart | Application Rate Recommendation Chart |
| Pavement Temp | Weather Conditions | Pounds Per Two (2) Lane Mile | Actions & Application Recommendation |
| 100% Salt | 50% Salt | Stock Pile |
| Above 30˚  | Snow | 150-300 | Not Recommended | Not Recommended | Plow, Treat Hazards ONLY |
| Freezing Rain | 150-300 | Not Recommended | Not Recommended | Apply As Needed |
| Snow | 200-400 | Not Recommended | Not Recommended | Plow & Apply As Needed |
| Freezing Rain | 200-400 | Not Recommended | Not Recommended | Apply As Needed |
| 25˚ to 30˚  | Snow | 200-400 | Not Recommended | Not Recommended | Plow & Apply As Needed |
| Freezing Rain | 200-400 | Not Recommended | Not Recommended | Apply As Needed |
| Snow | 300-500 | Not Recommended | Not Recommended | Plow & Apply As Needed |
| Freezing Rain | 300-500 | 500-750 | Not Recommended | Apply As Needed |
| 20˚ to 25˚  | Snow/ Frz Rain | 300-500 | 500-750 | Not Recommended | Plow & Apply As Needed |
| Snow | 300-500 | Not Recommended | Not Recommended | Plow & Apply As Needed |
| Freezing Rain | 400-500 | 500-750 | Not Recommended | Apply As Needed |
| 15˚ to 20˚  | Snow | 300-500 | Not Recommended | Not Recommended | Plow & Apply As Needed |
| Freezing Rain | 400-500 | 500-750 | Not Recommended | Apply As Needed |
| Snow/ Frz Rain | 400-500 | 500-750 | Not Recommended | Plow & Apply As Needed |
| Below 15˚ | Snow | Not Recommended | Not Recommended | 500-750 | Plow, Treat Hazards w/ Stockpile |
| FROST: 15˚ & RISING: TREAT BY ANTI-ICING (Brine 20-40 G/LM) or 15˚ & FALLING: 100% SALT @ 150 #/LM |
| WIND CONDITIONS: PLOW, TREAT (TROUBLE SPOTS ONLY!) WITH 50/50 @ 300#/LM OR STOCKPILE @ 200-400 #/LM |
| IF EVENT/SHIFT TEMPERATURES WILL *RISE*, USE SALT INSTEAD OF SAND (& vise versa as temps fall) |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Temperature | Maintenance Action | Spinner Speed | Salt % | Pounds Per Lane Mile |
| 30 | Light sleet, light rain, or light snowfall stopped. | low | 100% | 100 to 200 |
| Light freezing rain or light snow continuing. | 150 to 300 |
| 25 | Heavy freezing rain, sleet, or snowfall continuing. | low | 100% | 200 to 400 |
| Light snowfall continues at 1/8” to 1/4” per hour. | low | 100% | 150 to 300 |
| 20 | Heavy snowfall, repeat salting at lower rate. | low | 100% | 200 to 350 |
| Light snow falling at trace to 1/4” accumulation. | 150 to 300 |
| 15 | Light snowfall continues at 1/8” to 1/4” per hour. | low | 100% | 200 to 300 |
| Heavy snowfall, repeat salting at lower rate. | off | 80% |
| 10 | Snow stopped and sun is going to come out. | low | 100% | 200 to 300 |
| Light snowfall continuing or sun is going to come out. | 80% | 200 to 300 |
| 5 to 10 | Light snowfall continuing or sun is going to come out. | low | 70% | 150 to 300 |
| Light snowfall at trace to 1/4” accumulation. | 25% | 200 to 400 |
| 0 to -15 | Light snowfall at trace to 1/4” accumulation. | low | 25% | 400 to 600 |
| Light snowfall at trace to 1/4” accumulation. |
| 0 to -15 | Snow stopped and roads have hard pack. | off | 25% | 400 to 600 |
| Snow stopped and roads have hard pack. |
|  | \*Concentrate salt with low spinner speed \*Rates are per lane |  |  |

The following are examples of application rate charts used in Minnesota.

Use a higher % of sand in cold temps or use 200 to 400 lbs treated salt below 15 temp

Rates are for units with salt settings of 100, 150, 200, 250, 300, 350, 400, 450, 500, 600.

Credit: Anoka County Highway Department

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Materials and Quality Control

**Chemical Melting Temperatures**

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Multiple products can be used in a snow and ice control program. This chart helps you choose the correct product and apply it at the correct times. For further guidance on blending chemicals, see the *MnDOT Anti-Icing Guide*: www.dot.state.mn.us/maintenance/training. For a list of vendor contacts and chemicals available on the Minnesota Approved Products list, see the MnDOT *Winter Chemical Catalog* at www.dot.state.mn.us/maintenance/training.

|  |  |  |
| --- | --- | --- |
| Chemical | Lowest Practical Melting Temperature | Concentration |
| \*NaCl (Sodium Chloride)—Delivered as solid rock salt; also can be made into a brine. The basis of most deicing materials. Very corrosive. Inexpensive. | 15˚ F | 23.3% |
| \*MgCl2 (Magnesium Chloride)—Delivered as flakes, pellets, or liquid. Often used to wet NaCl crystals to increase adherence to road and reduce melting points. Corrosive. Higher cost. | -10˚ F | 27 to 30% |
| \*CaCl2 (Calcium Chloride)—Delivered as flakes, pellets, or liquid. Powerful deicer but extremely corrosive. Sometimes used incorrectly to open storm drains. Higher cost. | -20˚ F | 30% |
| CMA (Calcium Magnesium Acetate)—Delivered as a powder, crystals, pellets, or liquid. Liquid CMA is used mainly on automated bridge deicing systems. Noncorrosive, biodegradable. Sometimes added to sodium chloride as a corrosion inhibitor. Alternative for areas where chloride use must be limited. Higher cost. | 20˚ F | 32% |
| KAc (Potassium Acetate)—Delivered as a liquid. Used on automated bridge deicing systems. Use for anti-icing, deicing, and prewetting. Non-corrosive, biodegradable. Alternative for areas where chloride use must be limited. Higher cost. | -15˚ F | 50% |
| Winter Sand/Abrasives—Winter sand is sand treated with brine or another blend. It is often used as an abrasive for low-temperature conditions when chemicals are not effective. Sand provides temporary traction and only works when it is on top of the ice. | Never melts—traction only |  |
| Other Blends—Proprietary-purchased blends or blended in-house. | Varies | Varies |

\*Liquid chlorides are available with corrosion inhibitors.

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### Material Conversions

The following quick reference table and the formulas below will help you convert between tons and cubic yards. Weights will vary depending upon moisture content.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| S | and |  | S | alt |
| Yards | Tons | Yards | Tons |
| 1 | 1.4  | 1 | 1.1  |
| 2 | 2.8  | 2 | 2.2  |
| 3 | 4.2 | 3 | 3.2 |
| 4 | 5.6 | 4 | 4.3 |
| 5 | 7.0 | 5 | 5.4 |
| 6 | 8.4 | 6 | 6.5 |
| 7 | 9.8 | 7 | 7.6 |
| 8 | 11.2 | 8 | 8.6 |
| 9 | 12.6 | 9 | 9.7 |
| 10 | 14.0 | 10 | 10.8 |
| 11 | 15.4 | 11 | 11.9 |
| 12 | 16.8 | 12 | 13.0 |
| 13 | 18.2 | 13 | 14.0 |
| 14 | 19.6  | 14 | 15.1 |
| 15 | 21.0  | 15 | 16.2 |
| 16 | 22.4 | 16 | 17.3 |
| 17 | 23.8 | 17 | 18.4 |
| 18 | 25.2 | 18 | 19.4 |
| 19 | 26.6 | 19 | 20.5 |
| 20 | 28.0 | 20 | 21.6 |

1. To convert tons of clean sand to cubic yards: #tons divided by 1.4 = cubic yards
2. To convert cubic yards of clean sand to tons: #cubic yards multiplied by 1.4 = tons
3. To convert tons of winter sand to cubic yards: #tons divided by 1.37 = cubic yards
4. To convert cubic yards of winter sand to tons: #cubic yards multiplied by 1.37 = tons
5. To convert tons of straight salt to cubic yards: #tons divided by 1.08 = cubic yards
6. To convert cubic yards of straight salt to tons:

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#cubic yards multiplied by 1.08 = tons

## Materials and Quality Control

### materials testing

It is important to understand how deicing chemicals will react on the roadway. Therefore, a guide for testing the effectiveness of chemicals was developed. See the Clear Roads report at http://clearroads.org (click on research projects, completed projects).

Test your materials to ensure that they are delivered as or- Protect our dered and will perform as needed. Refer to your contract or roadside Material Safety Data Sheet (MSDS) for specific gravity. vegetation.

Chlorides can

**Testing liquids** damage vegetation

* B efore unloading the tanker truck, use a clean container to at concentrations obtain a small sample (about 2 cups). greater than 70
* M easure the specific gravity or percent saturation using a ppm (about 1/3 hydrometer or salimeter. teaspoon of salt in

5 gallons). • M ake sure you have the correct hydrometer for your material.

* S alt brine should have a salimeter reading of 85% or a hydrometer reading of 1.176, which equates to 23.3% salt in the brine.
* I f the specific gravity is not within specifications, don’t unload, and notify your supervisor.

### Testing sand

* C onduct a visual inspection of the material to make sure it is clean.
* N ote that each user has its own specifications based on available materials.

### Testing solid salt

* M ake sure someone is present to watch the load being dumped and observe if it is wet.
* T est salt for moisture content. You are looking for a moisture content of less than or equal to 1.5%. (Check your agency’s specification.)

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***How to measure the moisture content of rock salt:***

 •Supplies:

 -A calibrated scale, triple beam, or digital accurate to 0.1 grams

 -A microwave with maximum wattage of 1,200. Higher power may be too hot and make salt pop, compromising weight of sample.

 -A sample of salt (about 1 cup). Ensure it is a good representation of the pile.

 •Process:

1. Weigh sample before cooking, record weight on worksheet
2. Cook, once salt is dry weigh again, record dry weight
3. Do calculations on the worksheet

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### Salt Moisture Worksheet

(with scale zeroed out to account for container)

Date:

Company:

P.O. #:

Ticket #:

|  |  |
| --- | --- |
| A. Weight of wet salt | Moisture Calculations: |
| B. Weight of dry salt | C ÷ A x 100 = % moisture |
| C. Weight loss (A-B) | Remarks: |
| Tested by:  |  |
|  |  |

For complete instructions, go to www.dot.state.mn.us/maintenance/training. html.

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# Bibliography and Additional Resources

Amsler Sr., D. E. “Are You Using the Right Amount of Ice Control Chemical?” *Salt & Highway Deicing,* vol. 40, no. 2, summer 2004.

Blackburn, R., et al. *Snow and Ice Control: Guidelines for Materials and Methods*. National Cooperative Highway Research Program Report 526, 2004. Washington, D.C.: Transportation Research Board. www.TRB.org

Blackburn, R., D. Amsler, and K. Bauer. *Guidelines for Snow and Ice Control.* Presented at 10th AASHTO/TRB Maintenance Management Conference, Duluth, MN, July 2003. http://maintenance.transportation.org/Documents/Final%20 Report%2020-07%20Task%20250.pdf

Circuit Training and Assistance Program (CTAP). *CTAP Calibration Procedures Manual.* 2000-2001. www.mnltap.umn.edu/ctap

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Clear Roads Calibration Guide. http://clearroads.org

/researchprojects/05-02calibration.html

Federal Highway Administration. *Manual of Practice for an Effective Anti-icing Program: A Guide for Highway Winter Maintenance Personnel.* 1996. www.fhwa.dot.gov/reports/mopeap /eapcov.htm

Minnesota Department of Transportation http://www.dot.state.mn.us/maintenance/training.html

Nixon, W.A. “Snow-How.” *Snow & Ice Manager,* January 2004. Primedia Business Magazines and Media. www.grounds-mag.com

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## Bibliography and Additional Resources

University of New Hampshire Technology Transfer Center. *Manual of Practice*. [www.t2.unh.edu/pubs/manofpractice\_1.pdf](http://www.t2.unh.edu/pubs/manofpractice.1.pdf)

Utah LTAP Center. *Manual of Practice for an Effective Anti-icing Program: A Guide for Highway Winter Maintenance*. www.utaht2

### .usu.edu training and technical assistance

* The Circuit Training and Assistance Program (CTAP), a joint program of MnDOT and the Minnesota Local Technical Assistance Program (LTAP), brings training to your doorstep. For workshop registration visit www.mnltap.umn.edu/ctap.
* Minnesota LTAP offers a series of workshops around the state on a variety of topics. Visit [www.mnltap.umn.edu](http://www.mnltap.umn.edu/).
* MnDOT Winter Maintenance Coordinator: 651-366-3586.

### other Web resources

* Iowa Department of Transportation. *Anti-icing Equipment Manual* (with drawings for shop-made equipment). www. dot.state.ia.us/maintenance/manuals/equip/intro.htm
* Minnesota Department of Transportation. *Guide to FieldTesting Deicing and Anti-Icing Chemicals*. [www.dot.state. mn.us/maint/research/chemical/chem\_](http://www.dot.state.mn.us/maint/research/chemical/chem)evaluation\_guide. pdf
* Pacific Northwest Snowfighters. [www.wsdot.wa.gov/partners/pns/default.htm](http://www.wsdot.wa.gov/partners/pns/default.htm)
* Salt Institute.
* *Practical Guide for Storing and Handling Deicing Salt*. [www.saltinstitute.org/snowfighting](http://www.saltinstitute.org/snowfighting)
* Calibration Instructions (with downloadable Excel worksheet) [www.saltinstitute.org/snowfighting/6-calib.html](http://www.saltinstitute.org/snowfighting/6-calib.html)

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* Clear Roads Pooled-Fund Project. www.ClearRoads.org

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## Appendix

Example Daily Salt/Sand Use Ticket ..................................A-2

Example Loader Ticket: Daily Salt/Sand Issued ..................A-3

Example Documentation Form For Anti-Icing ......................A-4

Bare Lanes Data Collection Sheet .....................................A-5

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| Appendix | **Example Daily Salt/Sand Use Ticket** | **Example Loader Ticket: Daily Salt/Sand Issued** | Appendix |
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|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Operator |  |  | Shift |  | Date |  |
| Truck No. |  |  | Capacity |  |  |  |
| Weather |  |  |  |  | Temp. |  |
| Stockpile | Route | Yards Sand | Yards Salt | Yards Used | Yards Returned | Liquid Gallons |
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| **TOTALS** |  |  |  |  |  |  |

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| --- | --- | --- | --- |
| Operator ShiftLoader No. Capacity of Bucket |  | Date |  |
| Stockpile | Truck # | Yards Sand | Yards Salt | Stockpile | Truck # | Yards Sand | Yards Salt |
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| **TOTALS** |  |  |  |  |  |  |

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| --- | --- | --- | --- |
| Appendix | **Example Documentation Form For Anti-Icing** | **Bare Lanes Data Collection Sheet** | Appendix |
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|  |  |
| --- | --- |
| Anti-icing Route Data Form |  |
| Truck Station:Date: |  |
| Air Temp. | Pavement Temp. | Relative Humidity | Dew Point | Sky |
| Reason for applying:Route:Chemical:Application Time:Application Amount:Observation (1st day):Observation (After event):Observation (Before next application):Name: |  |

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|  |  |  |  |
| --- | --- | --- | --- |
| Event Began |  | Event Ended | Event Type |
| Date | Time | Date Time | (snow, rain, both, drifting) |
| Description | Route # | Bare Lanes Lost | Bare Lanes Regained |
|  |  | Date | Time | Date | Time |
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