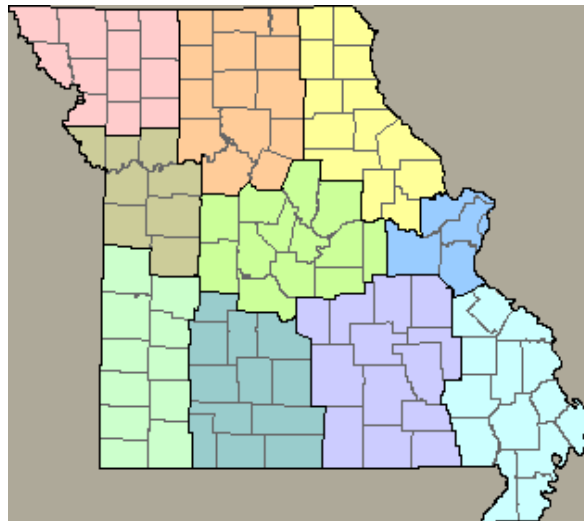




OPERATOR'S GUIDE FOR ANTI-ICING



"The Maintenance Division sets broad policy, shares the best practices, and provides quality assurance for the preservation of the state highway system."

OPERATOR'S GUIDE FOR ANTI-ICING

FOREWORD

Anti-icing is the snow and ice control practice of preventing the development of a bond between snow and/or ice and the pavement surface with the timely application of salt. Applying the right amount of salt at the right time will make our snow removal operations more efficient and produce safer driving conditions during winter storms.

The purpose of this booklet is to provide guidelines for the application of salt to the roadway for a variety of winter storm conditions. The timing and application rates were developed under the SHRP/FHWA Research Program, in which MoDOT participated. Many of our own maintenance personnel who have tested these procedures have found them to be a valuable tool in their winter maintenance operations. The implementation of this technology on a statewide basis will help to produce safer driving conditions on our continuous treatment routes during the winter months.

Jim Carney

Jim Carney
State Maintenance Engineer

OPERATIONS GUIDE FOR MAINTENANCE FIELD PERSONNEL

INTRODUCTION

This is a guide to highway anti-icing operations for maintenance field personnel. Its purpose is to recommend maintenance actions for *preventing* the formation or development of packed and bonded snow or bonded ice on the first priority **continuous treatment routes** during a variety of winter weather events. It is intended to complement the decision-making and management practices of a systematic anti-icing program so that **continuous treatment routes** can be efficiently maintained in the best possible condition.

These guidelines are based on the results of four years of anti-icing field testing conducted by 15 State DOTs, which included MoDOT, and is supported by the Strategic Highway Research Program (SHRP) and the Federal Highway Administration (FHWA). Since then, it has been augmented with many additional years of anti-icing experience in different parts of our state.

Guidance for anti-icing operations is presented in Tables 6 to 11 for six winter weather events. The six events are:

- Light Snow Storm
- Light Snow Storm with Period(s) of Moderate or Heavy Snow
- Moderate or Heavy Snow Storm
- Frost or Black Ice
- Freezing Rain Storm
- Sleet Storm

The tables suggest the appropriate maintenance action to take during initial and follow-up anti-icing operations for a given precipitation or icing event. Each action is defined for a range of pavement temperatures and an associated temperature trend. For some events the operation is dependent not only on the pavement temperature and trend, but also upon the pavement surface or the traffic condition at the time of the action. Many of the maintenance actions involve the application of salt in either a dry solid, pre-wetted or brine (liquid) form. Pre-wetted solid and brine are the two primary forms on which we need to concentrate. Application rates are given for each form where appropriate. **These are suggested rates and should be adjusted, if necessary, to achieve the effectiveness for local conditions.**

Comments and notes are given in each table where appropriate to further guide field maintenance personnel for their anti-icing operations.

GLOSSARY OF TERMS

Black ice. Popular term for a very thin coating of clear, bubble-free, homogenous ice which forms on a pavement with a temperature at or slightly above 32°F when the temperature of the air in contact with the ground is below the freezing-point of water and small slightly supercooled water droplets deposit on the surface and coalesce (flow together) before freezing.

Brine. Water saturated with common salt (NaCl), also liquid salt or liquid chemical.

Continuous Treatment Routes. All National Highway System (NHS) routes, all remaining arterial (RA) routes, and all collector routes over 1700 AADT. These routes receive a continuous application of snow and ice control treatments over the entire length of the route.

Dew Point. The temperature at which a vapor begins to condense.

Freezing rain. Super-cooled droplets of liquid precipitation falling on a surface whose temperature is below or slightly above freezing, resulting in a hard, slick, generally thick coating of ice commonly called glaze or clear ice. Non-super-cooled raindrops falling on a surface whose temperature is well below freezing will also result in glaze.

Frost. Also called hoarfrost. Ice crystals in the form of scales, needles, feathers or fans deposited on surfaces cooled by radiation or by other processes. The deposit may be composed of drops of dew frozen after deposition and of ice formed directly from water vapor at a temperature below 0°C (32°F) (sublimation).

Light Snow. Snow falling at the rate of less than 1/2 in. per hour; visibility is not affected adversely.

Moderate or heavy snow. Snow falling at a rate of 1/2 in. per hour or greater; visibility may be reduced.

Pre-treatment. This is the practice of applying salt brine at 44 gallons per lane mile to dry pavement prior to the winter event, or the application of pre-wetted salt to the surface prior to snow and ice bonding to the pavement.

Pre-wetting. Pre-wetting is the practice of applying salt brine to dry salt before it is placed on the pavement, and should be done at 10 to 15 gallons per ton. Liquid calcium chloride may be used for pre-wetting salt at temperatures below 15° F.

Sleet. A mixture of rain and of snow which has been partially melted by falling through an atmosphere with a temperature slightly above freezing.

Slush. Accumulation of snow which lies on an impervious base and is saturated with water in excess of its freely drained capacity. It will not support any weight when stepped or driven on but will "squish" until the base support is reached.

Spread Rate. The salt application rate in either the solid or liquid form. For solid applications it is simply the weight of the salt applied per lane mile. For liquid applications it is the volume (gallons) of brine applied per lane mile.

Table 1. How to Use Liquid Anti-Icers

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

Temperature Degrees F.	One Pound of Salt (Sodium Chloride)
30	46.3 lbs of ice
25	14.4 lbs of ice
20	8.6 lbs of ice
15	6.3 lbs of ice
10	4.9 lbs of ice
5	4.1 lbs of ice
0	3.7 lbs of ice
-6	3.2 lbs of ice

Table 2. Equivalent Salt Spread Rates

Solid or Pre-wetted Solid (Lbs/Ln.mi.)	Salt Brine (23% Concentration NaCl) (Gal/Ln. mi.)
25	11
50	22
75	33`
100	44
125	55
150	65
200	87

Table 3. Pure salt concentration and corresponding specific gravity
(measured by a hydrometer) at 59°F

Percent salt	Specific gravity at 59°F	Percent of saturation	*Weight of salt lb/gal
0	1.000	0	0
5	1.035	20	0.43
6	1.043	24	0.52
7	1.050	28	0.61
8	1.057	32	0.71
9	1.065	36	0.80
10	1.072	40	0.90
11	1.080	44	0.99
12	1.087	48	1.00
13	1.095	52	1.10
14	1.103	56	1.29
15	1.111	60	1.39
16	1.118	63	1.49
17	1.126	67	1.60
18	1.134	71	1.71
19	1.142	75	1.81
20	1.150	79	1.92
21	1.158	83	2.03
22	1.166	87	2.14
23	1.175	91	2.26
24	1.183	95	2.37
25	1.191	99	2.45
25.2	1.200	100	

***Note:** Weight of commercial salt required = (weight of pure NaCl from table) ÷ (purity in percent)

Table 4. Gradation of salt specified by ASTM D 632 & MoDOT.

Sieve size	Weight % passing		MoDOT
	ASTM Gr. 1	ASTM Gr. 2	
3/4 in.	...	100	...
1/2 in.	100	...	100
3/8 in.	95 -100	...	95 -100
No. 4	20-90	29-100	15-95
No. 8	10-60	10-60	5-65
No. 30	0-15	0-15	0-15

Note: ASTM Gr. 1 is the most commonly used gradation in the U.S.

Table 5. Proportions for preparing sodium chloride solution from commercial grade salt (i.e., up to 5 percent impurities).

%NaCl actual	Weight NaCl		Crystallization temperature °F	Weight per unit volume of solution lb/gal
	per volume solution lb/gal	per volume water lb/gal		
10	0.9	0.8	20	8.95
15	1.4	1.3	12	9.28
20	1.9	1.7	0	9.6
23*	2.3	1.9	-6	9.76
25	2.5	2.1	16	10.3

*Note. This is the approximate eutectic composition, i.e., the composition that results in the lowest temperature at which a solution can exist while remaining completely liquid.

First Priority Continuous Treatment Routes

Table 6: Weather Event: Light Snow Storm.

PAVEMENT TEMPERATURE RANGE AND TREND	INITIAL OPERATION				SUBSEQUENT OPERATIONS			COMMENTS
	Pavement surface at time of initial operation	Maintenance action	Salt Spread Rates		Maintenance action	Salt Spread Rates		
			Pre-wetted solid salt (lb/l _n -mi)	Brine (gal/l _n -mi)		Pre-wetted solid salt (lb/l _n -mi)	Brine (gal/l _n -mi)	
Above 32°F, steady or rising	Dry, wet, slush or light snow cover	None, see comments			None, see comments			1) Monitor pavement temperature closely for drops toward 32°F and below 2) Treat icy patches if needed with pre-wetted solid salt at 100 lb/lane-mi; plow if needed
Above 32°F, 32°F or below is imminent; ALSO 15 to 32°F, remaining in range	Dry Wet, slush, or light snow cover	Apply brine or pre-wetted solid salt Apply liquid or solid salt	100 100	44 44	Plow as needed; reapply liquid or solid chemical when needed	100 200	44	1) Applications will need to be more frequent at lower temperatures and higher snowfall rates 2) It is not advisable to apply a straight brine at the indicated spread rate when the pavement temperature drops below 20°F 3) Do not apply brine onto heavy snow accumulation or packed snow
0 to 15°F, remaining in range	Dry, wet, slush, or light snow cover	Apply pre-wetted solid chemical	200		Plow as needed; reapply pre-wetted solid chemical when needed	200		1) Abrasives may be added to the salt to enhance traction at colder temperatures 2) Liquid calcium chloride may be used for pre-wetting solid salt at colder temperatures
Below 0°F, steady or falling	Dry or light snow cover	Plow as needed			Plow and apply salt/abr. mix as needed			1) If pavement becomes slick apply salt/abrasive mix to enhance traction. Salt will have limited melting power in this temperature range. 2) Pre-wet salt/abrasive mix with liquid calcium chloride.

Notes: SALT APPLICATIONS. (1) Time initial and subsequent chemical applications to **prevent** deteriorating conditions or development of packed and bonded snow. (2) Apply salt ahead of traffic rush periods occurring during storm.
PLOWING. If needed, **plow before salt applications** so that excess snow, slush, or ice is removed and pavement is wet, slushy, or lightly snow covered when treated.

First Priority Continuous Treatment Routes

Table 7. Weather Event: Light Snow with Period(s) of Moderate or Heavy Snow.

PAVEMENT TEMPERATURE RANGE AND TREND	INITIAL OPERATION				SUBSEQUENT OPERATIONS				COMMENTS	
	Pavement surface at time of initial operation	Maintenance action	Salt spread rates		Maintenance action	Salt spread rates				
			Pre-wetted solid salt (lb/l _n -mi)	Brine (gal/l _n -mi)		Pre-wetted solid salt (lb/l _n -mi)		Brine (gal/l _n -mi)		
						Light snow	Heavier snow	Light snow		Heavier snow
Above 32°F, steady or rising	Dry, wet, slush or light snow cover	None, see comments			None, see comments					1) Monitor pavement temperature closely for drops toward 32°F and below 2) Treat slick patches if needed with pre-wetted salt at 100 lb/lane-mi or brine 44 gal/l _n -mi; plow if needed
Above 32°F, 32°F or below is imminent; ALSO 20 to 32°F, remaining in range	Dry Wet, slush, or light snow cover	Apply brine or pre-wetted salt Apply brine or pre-wetted salt	100 100	44 44	Plow as needed; reapply brine or pre-wetted solid salt when needed	100 100	200 250	44 44	88 88	1) Applications will need to be more frequent at lower temperatures and higher snowfall rates 2) Do not apply brine onto heavy snow accumulation or packed snow 3) After heavier snow periods and during light snow fall, reduce salt rate to 100 lb/lane-mi or 44 gal/l _n -mi brine; continue to plow and apply salt as needed
10 to 20°F, remaining in range	Dry, wet, slush, or light snow cover	Apply pre-wetted salt	200		Plow as needed; reapply pre-wetted solid salt when needed	200	250			1) Reduce salt rate to 200 lb/lane-mi after heavier snow periods and during light snow fall; continue to plow and apply salt as needed 2) Liquid calcium chloride may be used for pre-wetting salt at colder temperatures.
Below 10°F, steady or falling	Dry or light snow cover	Plow as needed			Plow and apply salt/abrasive mix as needed					1) As pavement becomes slick apply salt/abrasive mix to enhance traction. Salt will have limited melting power at this temperatures

Notes: SALT APPLICATIONS. (1) Time initial and subsequent salt applications to *prevent* deteriorating conditions or development of packed and bonded snow. (2) **Anticipate increases in snowfall intensity. Apply higher rate treatments prior to or at the beginning of heavier snowfall periods to prevent development of packed and bonded snow.** (3) Apply salt ahead of traffic rush periods occurring during storm.

PLOWING. If needed, *plow before salt applications* so that excess snow, slush, or ice is removed and pavement is wet, slushy, or lightly snow covered when treated.

First Priority Continuous Treatment Routes

Table 8. Weather Event: Moderate or Heavy Snow Storm.

PAVEMENT TEMPERATURE RANGE AND TREND	INITIAL OPERATION				SUBSEQUENT OPERATIONS			COMMENTS
	Pavement surface at time of initial operation	Maintenance action	Salt spread rates		Maintenance action	Salt spread rates		
			Pre-wetted solid salt (lb/l _n -mi)	Brine (gal/l _n -mi)		Pre-wetted solid salt (lb/l _n -mi)	Brine (gal/l _n -mi)	
Above 32°F steady or rising	Dry, wet, slush or light snow cover	None, see comments			None, see comments			1) Monitor pavement temperature closely for drops toward 32°F and below 2) Treat slick patches if needed with pre-wetted salt at 100 lb/lane-mi or with brine at 44 gal/l _n -mi; plow if needed
Above 32°F, 32°F or below is imminent; ALSO 30 to 32°F, remaining in range	Dry	Apply brine or pre-wetted solid salt	100	44	Plow accumulation and reapply brine or solid salt as needed	100	44	1) If the desired plowing/treatment frequency cannot be maintained, the spread rate can be increased to 200 lb/lane-mi to accommodate longer operational cycles 2) Do not apply brine onto heavy snow accumulation or packed snow
	Wet, slush, or light snow cover	Apply brine or pre-wetted solid salt	100	44				
20 to 30°F remaining in range	Dry	Apply brine or pre-wetted solid salt	150-200	65-87	Plow accumulation and reapply brine or solid salt as needed	200	87	1) If the desired plowing/treatment frequency cannot be maintained, the spread rate can be increased to 400 lb/lane-mi to accommodate longer operational cycles 2) Do not apply brine onto heavy snow accumulation or packed snow
	Wet, slush, or light snow cover	Apply brine or pre-wetted solid salt	150-200	65-87				
10 to 20°F, remaining in range	Dry, wet, slush, or light snow cover	Apply pre-wetted solid salt	200		Plow accumulation and reapply brine or solid salt as needed	250		1) If the desired plowing/treatment frequency cannot be maintained, the spread rate can be increased to 500 lb/lane-mi to accommodate longer operational cycles 2) Liquid calcium chloride may be used for pre-wetting salt at colder temperatures
Below 10°F, steady or falling	Dry or light snow cover	Plow as needed			Plow accumulation as needed	250		1) As pavement becomes slick apply salt/abrasive mix to enhance traction. Salt will have limited melting power in this temperature range.

Notes: SALT APPLICATIONS. (1) Time initial and subsequent salt applications to *prevent* deteriorating conditions or development of packed and bonded snow--**timing and frequency of subsequent applications will be determined primarily by plowing requirements.** (2) Apply salt ahead of traffic rush periods occurring during storm. **PLOWING.** *Plow before chemical applications* so that excess snow, slush, or ice is removed and pavement is wet, slushy, or lightly snow covered when treated.

First Priority Continuous Treatment Routes

Table 9. Weather Event: Frost or Black Ice.

PAVEMENT TEMPERATURE RANGE AND TREND	TRAFFIC CONDITION	INITIAL OPERATION			SUBSEQUENT OPERATIONS			COMMENTS
		Maintenance action	Spread rates		Maintenance action	Spread rates		
			Pre-wetted solid salt (lb/l _n -mi)	Brine (gal/l _n -mi)		Pre-wetted solid salt (lb/l _n -mi)	Brine (gal/l _n -mi)	
Above 32°F steady or rising	Any level	None, see comments			None, see comments			1) Monitor pavement temperature closely; begin treatment if starts to fall to 32°F and below and is at or below dew point
28 to 32°F , remaining in range or falling to 32°F or below, <i>and</i> equal to or below dew point	Traffic rate less than 100 vehicles per hr	Apply brine or pre-wetted solid salt	25-65	11-28	Reapply pre-wetted solid salt as needed	25-65		1) Monitor pavement closely; if pavement becomes wet or if thin ice forms, reapply salt at higher indicated rate. 2) Do not apply brine on ice so thick that the pavement cannot be seen
	Traffic rate greater than 100 vehicles per hr	Apply brine or pre-wetted solid salt	25-65	11-28	Reapply brine pre-wetted solid salt as needed	25-65	11-28	
20 to 28°F , remaining in range <i>and</i> equal to or below dew point	Any level	Apply brine or pre-wetted solid salt	65-130	28-57	Reapply brine pre-wetted solid salt as needed	65-130	28-57	1) Monitor pavement closely; if thin ice forms, reapply salt at higher indicated rate 2) Applications will need to be more frequent at higher levels of condensation; if traffic volumes are not enough to disperse condensation, it may be necessary to increase frequency 3) It is not advisable to apply a brine at the indicated spread rate when the pavement temperature drops below 20°F
10 to 20°F , remaining in range <i>and</i> equal to or below dew point	Any level	Apply pre-wetted solid salt	130-200		Reapply pre-wetted solid salt as needed	130-200		1) Monitor pavement closely; if thin ice forms, reapply salt at higher indicated rate 2) Applications will need to be more frequent at higher levels of condensation; if traffic volumes are not enough to disperse condensation, it may be necessary to increase frequency
Below 10°F , steady or falling	Any level	Apply abrasives			Apply abrasives as needed			1) Monitor pavement closely, salt will have limited melting power in this temperature range. 2) Liquid calcium chloride may be used for pre-wetting salt/abrasive mix at colder temperatures.

Notes: TIMING. (1) Conduct initial operation in advance of freezing. Apply brine up to 3 hr in advance. Use longer advance times in this range to effect drying when traffic volume is low. Apply pre-wetted solid salt 1 to 2 hr in advance. (2) In the absence of precipitation, brine at 33 gal/lane-mi has been successful in preventing bridge deck icing when placed up to 4 days before freezing on higher volume roads and 7 days before on lower volume roads.

First Priority Continuous Treatment Routes

Table 10. Weather Event: Freezing Rain Storm.

PAVEMENT TEMPERATURE RANGE AND TREND	INITIAL OPERATION		SUBSEQUENT OPERATIONS		COMMENTS
	Maintenance action	Salt spread rate (lb/l _n -mi)	Maintenance action	Salt spread rate (lb/l _n -mi)	
Above 32°F, steady or rising	None, see comments		None, see comments		1) Monitor pavement temperature closely for drops toward 32°F and below 2) Treat icy patches if needed with pre-wetted solid chemical at 75-100 lb/lane-mi
Above 32°F, 32°F or below is imminent	Apply pre-wetted solid chemical	75-100	Reapply pre-wetted solid chemical as needed	75-100	Monitor pavement temperature and precipitation closely
20 to 32°F, remaining in range	Apply pre-wetted solid chemical	75-250	Reapply pre-wetted solid chemical as needed	75-250	1) Monitor pavement temperature and precipitation closely 2) Increase spread rate toward <i>higher indicated rate</i> with decrease in pavement temperature or increase in intensity of freezing rainfall 3) Decrease spread rate toward <i>lower indicated rate</i> with increase in pavement temperature or decrease in intensity of freezing rainfall
10 to 20°F, remaining in range	Apply pre-wetted solid chemical	250-400	Reapply pre-wetted solid chemical as needed	250-400	1) Monitor pavement temperature and precipitation closely 2) Increase spread rate toward <i>higher indicated rate</i> with increase in intensity of freezing rainfall 3) Decrease spread rate toward <i>lower indicated rate</i> with decrease in intensity of freezing rainfall
Below 10°F, steady or falling	Apply abrasives		Apply abrasives as needed		It is not recommended that chemicals be applied in this temperature range

Notes: SALT APPLICATIONS. (1) Time initial and subsequent chemical applications to *prevent* glaze ice conditions. (2) Apply chemical ahead of traffic rush periods occurring during storm.

First Priority Continuous Treatment Routes

Table 11. Weather Event: Sleet Storm.

PAVEMENT TEMPERATURE RANGE AND TREND	INITIAL OPERATION		SUBSEQUENT OPERATIONS		COMMENTS
	Maintenance action	Dry chemical spread rate (lb/ln-mi)	Maintenance action	Salt spread rate (lb/ln-mi)	
Above 32°F, steady or rising	None, see comments		None, see comments		1) Monitor pavement temperature closely for drops toward 32°F and below 2) Treat icy patches if needed with pre-wetted solid chemical at 125 lb/ln-mi
Above 32°F, 32°F or below is imminent	Apply pre-wetted solid chemical	125	Reapply pre-wetted solid chemical as needed	125	Monitor pavement temperature and precipitation closely
28 to 32°F, remaining in range	Apply pre-wetted solid chemical	125-325	Reapply pre-wetted solid chemical as needed	125-325	1) Monitor pavement temperature and precipitation closely 2) Increase spread rate toward <i>higher indicated rate</i> with increase in sleet intensity 3) Decrease spread rate toward <i>lower indicated rate</i> with decrease in sleet intensity
10 to 28°F, remaining in range	Apply pre-wetted solid chemical	250-400	Reapply pre-wetted solid chemical as needed	250-400	1) Monitor pavement temperature and precipitation closely 2) Increase spread rate toward <i>higher indicated rate</i> with increase in sleet intensity 3) Decrease spread rate toward <i>lower indicated rate</i> with decrease in sleet intensity
Below 10°F, steady or falling	Plow as needed		Apply abrasives as needed		1) It is not recommended that chemicals be applied in this temperature range (2) Abrasives can be applied to enhance traction

Notes: SALT APPLICATIONS. (1) Time initial and subsequent salt applications to *prevent* the sleet from bonding to the pavement. (2) Apply salt ahead of traffic rush periods occurring during storm.