Winter Maintenance
Snow and Ice Control
– Module 3 –

DEICING, ANTI-ICING, PRE-WETTING, LIQUIDS, AND POST SEASON ACTIVITIES

Delaware
T²/LTAP

PRESENTED BY:

DELAWARE T²/LTAP CENTER

Delaware T^2/LTAP Center

- T^2 Centers or LTAPs located in all 50 states
- Funded by FHWA and state DOTs
- Mission – promote training, tech transfer, research implementation at local level
- Delaware T^2 hosted by University of Delaware, part of Delaware Center for Transportation
- Delaware T^2 funded by FHWA and DelDOT

Delaware T^2/LTAP

University of Delaware

Delaware Center for Transportation

The Preliminaries

Today's Instructor:

- Matheu J. Carter, P.E.
  - Engineering Circuit Rider
  - Back when he actually worked…
    - Heavy construction
    - Design engineer
    - Public works director

- Zoom Meeting is our platform today
  - Potential to be interactive, so join in
  - We will be recording today's session

Extra Credit
Name the Band

The T^2 Center Winter Maintenance Program

What we cover:

- Module 1
  - Introduction to snow and ice control
  - Planning/program development
- Module 2
  - Pre-season activities
  - Plowing
  - Post storm activities
- Module 3
  - Deicing
  - Anti-icing
  - Pre-wetting
  - Liquids
  - Post season activities

Today's stuff

Acknowledgements

Primary references:

- AASHTO Guide for Snow and Ice Control
- APWA, New England Chapter
  - “Plow Power” and “White Gold”
- (former) Salt Institute
- National Local Technical Assistance Program (LTAP)
- Iowa Department of Transportation
- NCHRP
  - Report 526 - Snow and Ice Control: Guidelines for Materials and Methods
  - Report 577 - Guidelines for the Selection of Snow and Ice Control Materials to Mitigate Environmental Impacts

Deicing, Anti-icing, Pre-wetting, and Liquids

ABRASIVES AND FREEZE POINT DEPRESSANTS
CALIBRATE SPREADERS AND OTHER EQUIPMENT
WEATHER INFORMATION
SPECIAL AREAS
RECORDKEEPING
DEALING WITH THE PUBLIC

Abrasives & Freeze Point Depressants

Table 2-1. Snow and ice control materials.

Material Type	Snow and Ice Control Material	Primary Components
Chloride Salts	Sodium Chloride (NaCl)	Na, Cl
	Calcium Chloride ($CaCl_2$)	Ca, Cl
	Magnesium Chloride ($MgCl_2$)	Mg, Cl
Organic Products	Calcium Magnesium Acetate (CMA)	Ca, Mg, $C_2H_3O_2$
	Potassium Acetate (KA)	K, $C_2H_3O_2$
	Agricultural By-Products	Complex sugars
	Manufactured Organic Materials	Varies with product (i.e. glycol, methanol)
Nitrogen Products	Urea	Urea, Ammonia
Abrasive	Abrasives	Varies with th of the mat

NCHRP REPORT 577

Guidelines for the Selection of Snow and Ice Control Materials to Mitigate Environmental Impacts

TRANSPORTATION RESEARCH BOARD, 2007

Table 2-3. Organic products, general properties.

Material	Chemical Formula	Forms used	Optimum Eutectic Temperature °C (°F) @ % Concentration [1]	Common Source(s)	Approximate Annual usage Tonnes (Tons) North America	Median Cost (USD) per Ton (survey of Internet contracts)[2]
Calcium Magnesium Acetate	CaMgAc	Mostly liquid with some solid	-27.5 (-17.5) @ 32.5%	Reaction of Highly Concentrated Acetic Acid with Dolomite Limestone	Not Available	$1280
Potassium Acetate	KAc	Liquid only	-60 (-76) @ 49%	Reaction of Highly Concentrated Acetic Acid with caustic potash (KOH). This reaction produces potassium acetate and water.	Not Available	Not Available
Agricultural By-Products	NA	Liquid only	Usually blended with chloride-based products	Refined from Agricultural base materials	Not Available	Blends
Other Organic Materials	Glycols Methanol	Liquid only	Varies with product	Varies	Not Available	

$62 DE 2019

Table 2-2. Chloride salts, general properties.

Material	Chemical Formula	Forms Used	Optimum Eutectic Temperature °C (°F) @ % Concentration [1]	Common Sources	Approximate Annual usage Tonnes (Tons) North America	Median C t (USD) p Ton (sur y of Inter t contract 2
Sodium Chloride	NaCl	Primarily solid, but increasing use of liquid	-21 (-5.8) @ 23.3%	Mined from natural deposits, solarization of natural brines	21,080,000 (22,291,000) (Salt Institute)	$ 36
Calcium Chloride	$CaCl_2$	Mostly liquid brine, some solid flake	-51 (-60) @ 29.8%	Natural well brines, by-product of the Solvay process	Not Available	$120
Magnesium Chloride	$MgCl_2$	Mostly liquid brine, some solid flake	-33 (-28) @ 21.6%	Solarization of natural brines, natural well brines, by-product of metallurgical process	Not Available	$ 95
Blended Chlorides	Varies with product	Solid and liquid	Varies with product	Natural well brines, solarization of natural brines, mined from natural deposits	Not Available	$142

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- Sand
- Freeze point depressants (FPDs)
  - Rock salt (NaCl)
  - Calcium magnesium acetate (CMA)
  - Magnesium chloride (MgCl)
  - Calcium chloride (CaCl)
  - Potassium acetate (KA)
- Modified salts
  - Magic Salt
  - ClearLane®
  - Ice Ban®
  - Safe-Walk
  - Sugar beet molasses (desugared)
- Brines
- Sand/salt mixtures

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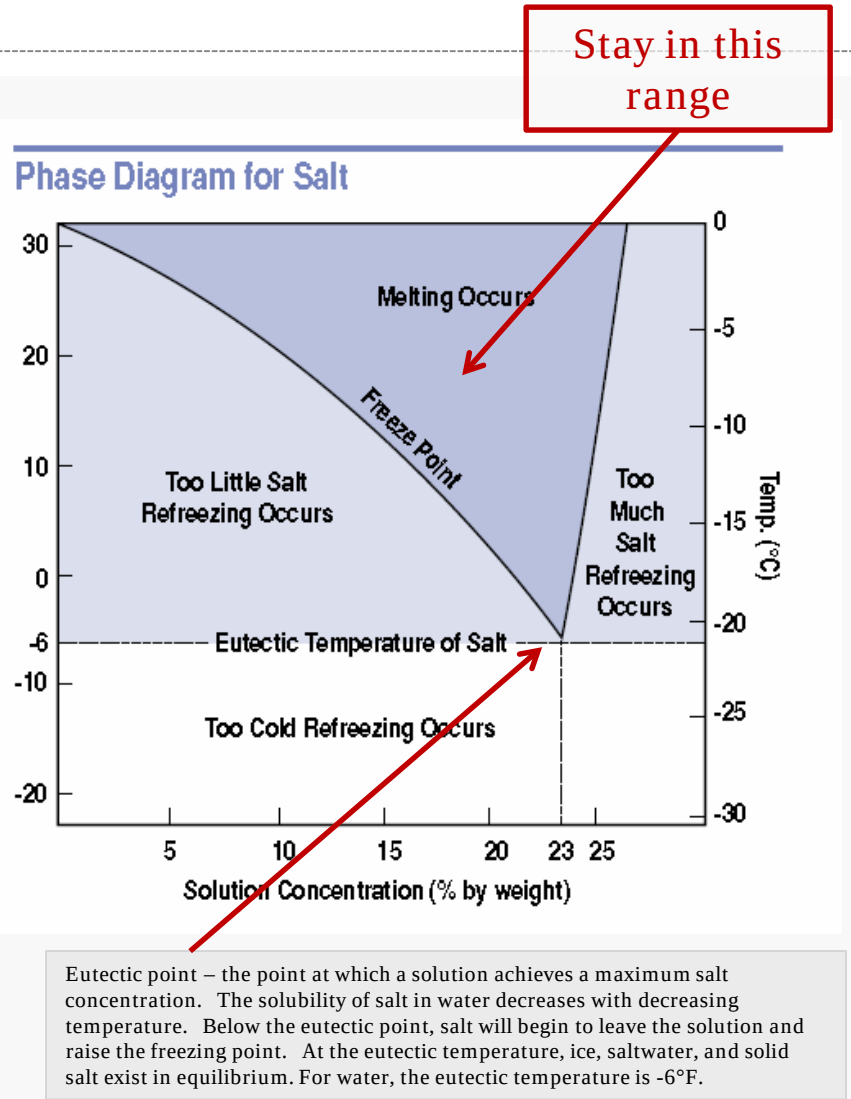
- Storage
  - Solid materials
    - e.g., rock salt
  - Liquid materials
    - e.g., salt brines
      - Commonly includes CaCl, MgCl
    - Most organic products
  - Sand or abrasives

Abrasives & Freeze Point Depressants

- Freeze point depressants
- What's that all about? Let's talk about that
- Chlorides/salts are similar to glycol in your radiator
  - Glycol lowers the freezing point of the water
  - So do salts and it's helpful to think of it that way
- But, absent a leak, the ratio of glycol to water in your radiator stays pretty constant
  - The ratio of chlorides to water start to change from the moment we load salt on the truck
- We're going to talk about this a lot - just remember 23%

Abrasives & Freeze Point Depressants

- Freeze point depressing qualities of brine are important to its use as an anti-icing/deicing agent
- Minimum freeze point of salt brine is -6°F at a concentration of 23.3%.
- Line represents the freeze point of the solution at a given temperature. Dark colored portion in the center of the chart shows the melting range of brine solutions.
- Area to left shows a solution with too little salt; road surface will refreeze unless more salt brine or deicing salt is applied.
- Area to right shows too much salt (more importantly, too little water), and once again the surface will freeze without introduction of more moisture. Additional precipitation and heavy traffic can dilute brine solution allowing the road to refreeze.



Eutectic point – the point at which a solution achieves a maximum salt concentration. The solubility of salt in water decreases with decreasing temperature. Below the eutectic point, salt will begin to leave the solution and raise the freezing point. At the eutectic temperature, ice, saltwater, and solid salt exist in equilibrium. For water, the eutectic temperature is -6°F.

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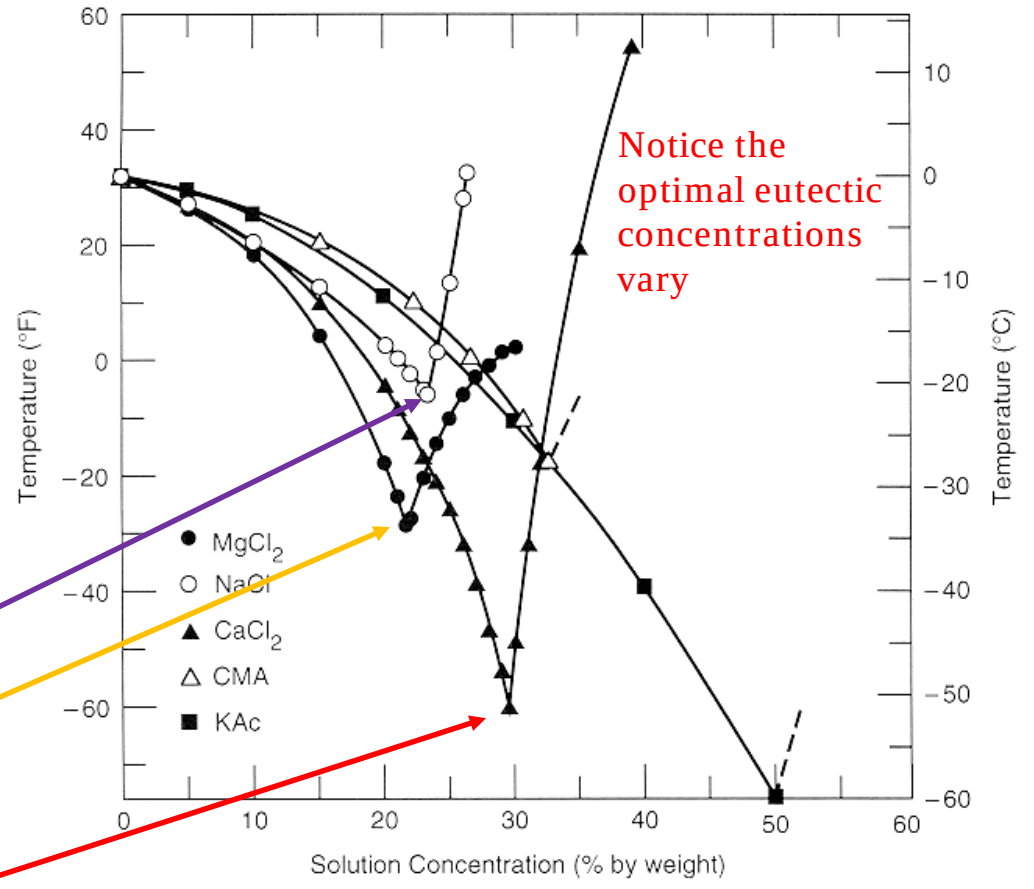
- Eutectic comparisons
  - Sodium chloride (rock salt
  - Calcium magnesium acetate
  - Magnesium chloride
  - Calcium chloride
  - Potassium acetate
- Same kind of curve we just looked at
  - NaCl
  - MgCl

CaCl



Eutectic versus Effective Temperature

- Where theory meets practice…

Chemical	Eutectic (^{0}F)	Effective (^{0}F)
NaCl (sodium chloride)	-6	+15
CaCl (calcium chloride)	-60	-25
MgCl (magnesium chloride)	-28	+5
KCl (potassium chloride)	+13	+25
Kac (potassium acetate)	-76	-15
CMA (calcium magnesium acetate)	-17	+21

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- Application strategies
  - Materials selection
  - Timing
  - Rate
  - Frequency
  - Anti-icing
  - Deicing
  - Pre-wetting
  - Abrasives

Abrasives & Freeze Point Depressants

Table 2-12. Application rates for various snow and ice control strategies.

Strategy/ Method	Materials	Pavement Temperature Ranges[1]	Application Rates[2]
Anti-Icing	Liquid Chemicals, Solid Chemicals, Pre-wet Solid Chemicals	0° C to -12° C (32° F to 10° F)	18-110 Kg /Lane /Km (65 – 400 Lbs / Lane/ Mile)
Deicing	Pre-wet Solid Chemicals, Dry Solid Chemicals	0° C to -18° C (32° F to 0° F)	113 – 400 Kg /Lane /Km (200-700 Lbs / Lane/ Mile)
Abrasives	Pre-wet Abrasives, Dry Abrasives	No limits	225 – 2,700 Kg /Lane /Km (500-6,000 Lbs / Lane/ Mile)
	Abrasive/Salt Mixes	0° C to -18° C (32° F to 0° F)	225 – 2,700 Kg /Lane /Km (500-6,000 Lbs / Lane/ Mile)

Why so different?

Stay tuned…you're going to be amazed!

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- Compare rates

TABLE A-6 Equivalent application rates for five ice control chemicals

Temperature (°F)	NaCl		$CaCl_2$		$MgCl_2$		KAc		CMA	
	100%* Solid lb/LM	23%* Liquid gal/LM	90-92%* Solid lb/LM	32%* Liquid gal/LM	50%* Solid lb/LM	27%* Liquid gal/LM	100%* Solid lb/LM	50%* Liquid gal/LM	100%* Solid lb/LM	25%* Liquid gal/LM
31.5	100	45	109	32	90	31	159	30	159	69
31	100	46	111	32	91	32	161	31	161	72
30.5	100	47	111	33	91	32	155	30	155	71
30	100	48	107	33	94	33	158	31	158	74
29	100	49	109	34	91	33	155	31	155	79
28	100	52	109	34	91	33	152	31	152	81
27	100	54	109	35	90	34	153	31	153	86
26	100	56	104	34	96	36	161	33	161	95
25	100	57	102	34	99	35	167	35	167	108
24	100	61	108	38	102	41	167	35	167	114
23	100	62	112	41	102	41	164	35	164	117
22	100	65	110	41	102	42	160	35	160	121
21	100	68	107	40	101	42	155	35	155	125
20	100	70	108	42	98	42	150	34	150	129
15	100	90	103	44	96	44	142	34	142	170
10	100	120	101	49	95	47	138	35	138	265
5	100	165	104	57	96	51	139	37	139	630

NaCl: Sodium chloride.
$CaCl_2$: Calcium chloride.
$MgCl_2$: Magnesium chloride.
KAc: Potassium acetate.
CMA: Calcium magnesium acetate.

* Typical percent concentrations of the solid and liquid forms with the balance being largely water.

General Notes:

1. The above application rates are normalized to 100 lb/LM of dry solid NaCl. The application rates corresponding to a dry solid NaCl rate other than 100 lb/LM are determined by multiplying the equivalent chemical application rates for a given temperature by the ratio of the desired dry solid NaCl rate to 100 lb/LM. For example, if a 200 lb/LM of dry solid NaCl application rate were recommended at a temperature of 20°F, then switching to a 90 to 92 percent concentration of solid $CaCl_2$ would require a slightly higher application rate of 216 lb/LM.
2. The above application rate data were derived from the freezing point (ice melting) data of the five chemical solutions. As such, the data are more conservative (larger) than field data would suggest for anti-icing operations.

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Salt spreading techniques

Video

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- Deicing
  - Typically, dry NaCl – 100-500 #/lane mile
  - Reactive strategy
  - Chemical applied on top of already bonded snow, ice, frost
  - Solid chemical scattered by traffic can result in significant loss of product without productive effect
  - One study (Montana) – deicing uses 5X chemical vs. anti-icing

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Deicing

Video

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- Anti-icing
  - Proactive strategy
  - Materials applied before snow, ice, frost
  - Prevents bonding of precipitate with the pavement surface, ideally – at a minimum, can weaken the bonds
  - Can be dry or liquid applications
  - Dry applications better where little or no traffic action (sidewalks, parking lots)

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- Anti-icing
  - Tools for brine making
  - Commercial brine makers available
  - Can make your own

Table 2-13. Typical chemical application rates for anti-icing activities at –10°C to –0°C (15°F to 32°F).

Reference	Dry chemical spread rate, kg/lane-km (lb/lane-mi)			
	Light icing	Light snow	Heavy snow	Freezing rain
"Manual of Practice for an Effective Anti-Icing Program" FHWA/CRREL (*2*)	7-36 (25-130)	28 - 55 (100 - 200)	28 - 55 (100 – 200)	21 - 110 (75 – 400)
"Manual of Practice for Anti-Icing of Local Roads" New Hampshire T2 (*8*)	18-36 (65-130)	28 - 55 (100 - 200)	28 - 55 (100 – 200)	21 - 110 (75 – 400)

Hydrometer/Salometer Chart for Salt Brine

% Salt	Hydrometer Specific Gravity	Salometer Using 0-100%
0	1.000	0
1	1.007	4
2	1.014	7
3	1.021	11
4	1.028	15
5	1.036	19
6	1.043	22
7	1.051	26
8	1.059	30
9	1.067	33
10	1.074	37
11	1.082	41
12	1.089	44
13	1.097	48
14	1.104	52
15	1.112	56
16	1.119	59
17	1.127	63
18	1.135	67
19	1.143	70
20	1.152	74
21	1.159	78
22	1.168	81
23	1.176	85
24	1.184	89
25	1.193	93
26	1.201	96
27	-	100

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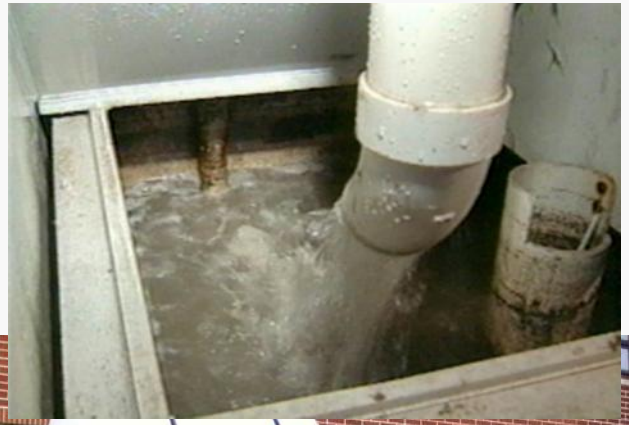
- Anti-icing



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- Brine can
  - Speed up melting
  - Make plowing easier
  - Reduce salt use
- When to/not use
- Special case of CaCl

Video

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- Reactive vs. proactive
- Illustrates
  - Anti-icing
  - Deicing
- Anti-icing not the best answer at all times

Video

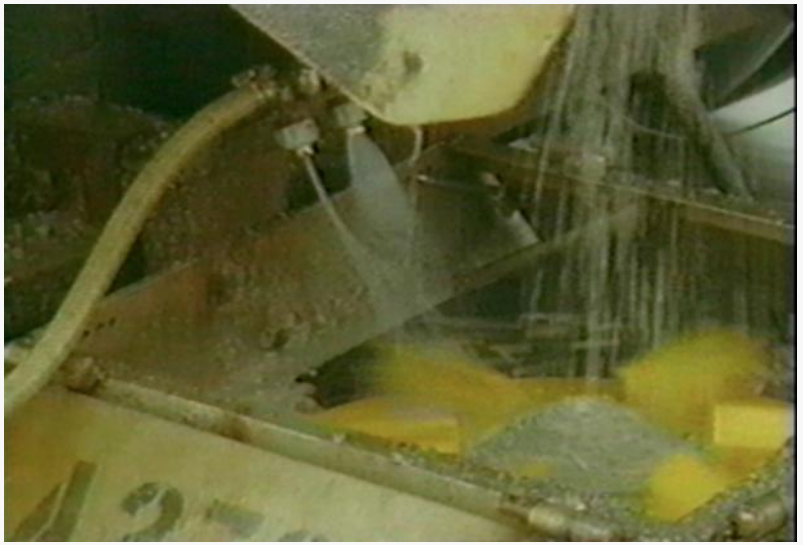
Abrasives & Freeze Point Depressants

- Pre-wetting
  - Injecting/spraying liquid chemical to solids
  - Enhance effectiveness and reduce material loss
  - Applied to chemical (i.e., NaCl), can expedite formation of brine; once brine formed, more likely to stay on roadway
  - Danish study – 90% retention of salt from brine
  - Applied to abrasives, adds weight, cushions impact, may help material stick to roadway
  - Montana study – prewetting abrasives can reduce application by 50% in cold temperatures

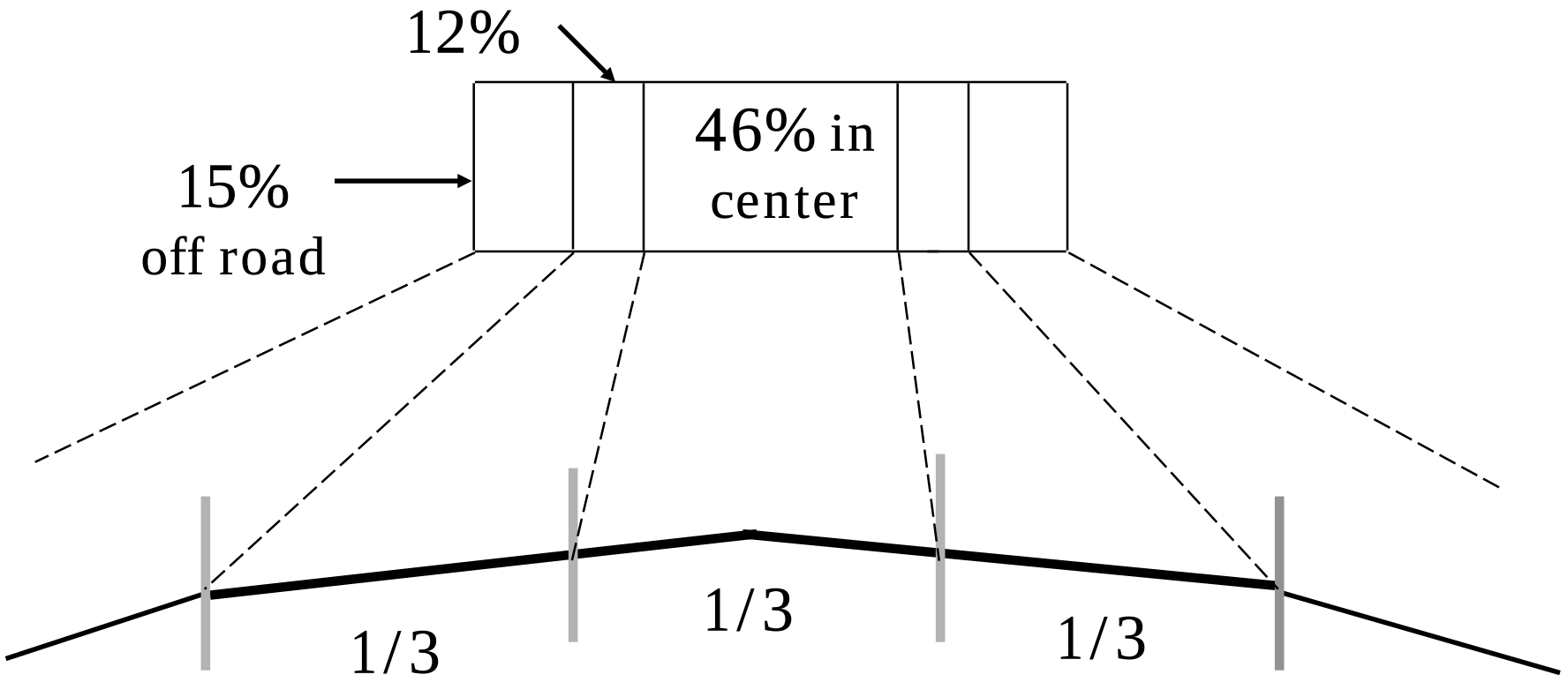

hydrometer

Abrasives & Freeze Point Depressants

- Pre-wetting

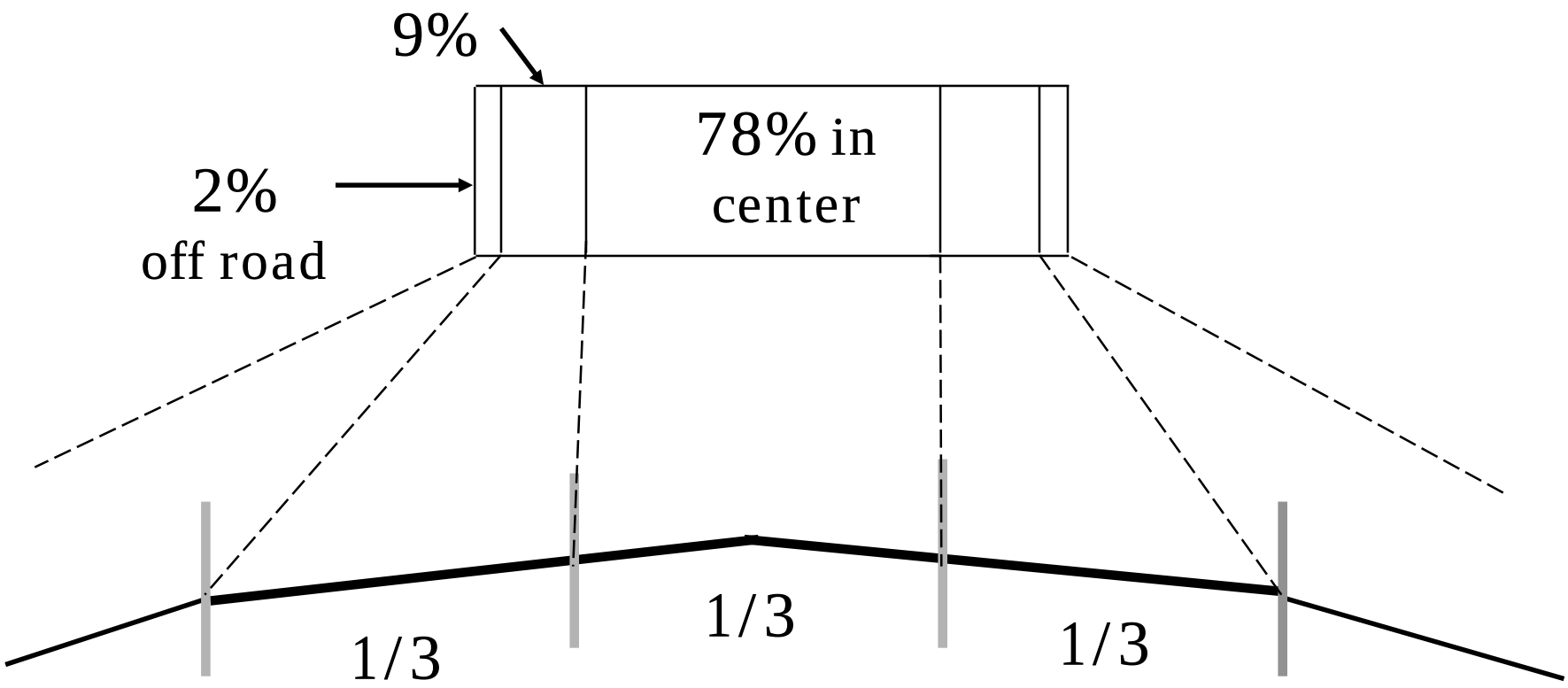


Typical Scatter of Road Salt



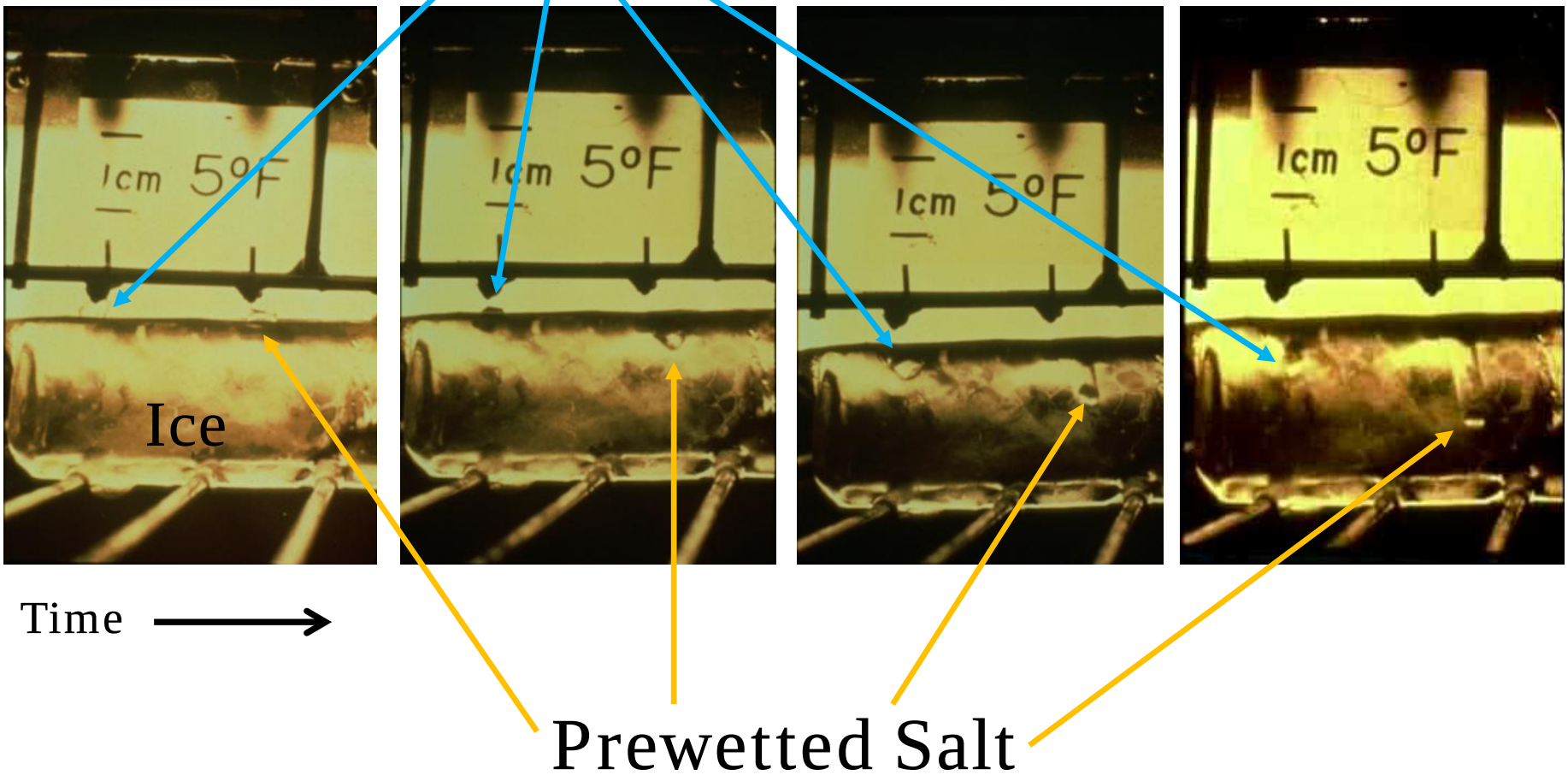
100% salt spread in center 1/3 of road

Typical Scatter of Prewetted Road Salt



100% prewetted salt spread in center 1/3 of road

Efficiency of Prewetted Road Salt



Abrasives & Freeze Point Depressants

- Watch how little salt bounce/scatter
- Illustrates how little salt relative to surface area of the roadway
- Watch at end – how's our 23% holding up?

Video

Abrasives & Freeze Point Depressants

- Advantages of prewetting salt
  - Reduced salt usage
  - Reduced cost of deicing materials
  - Reduced labor costs
  - Increased deicing efficiency and faster melting action
  - Increased safety to motorists

Abrasives & Freeze Point Depressants

- Liquid storage
  - Inside, outside
  - Underground, above
  - Secondary containment
  - Corrosion resistant materials
    - Polyethylene
    - Stainless steel
    - Glass fiber
  - Corrosion inhibitors, agitation, circulation, filtration

Abrasives & Freeze Point Depressants

- Dry abrasives/chemical mixes
  - Common, popular strategy
  - Typically, 1:1 mixture of abrasive and salt
  - Has not been found to be as cost-efficient as chemicals only
  - Less effective at reducing accidents

Abrasives & Freeze Point Depressants

- Abrasives
  - Sanding – strategy of choice for many agencies
  - Visible, low cost to manage friction
  - But placed dry, only short term friction effect
  - Roadway speeds >30 mph, little benefit
  - Particle size matters
    - Natural sand – 10% retention
    - Manufactured coarse sand – 50%
  - Insurance claims and env impacts with sand

Table 2-15. Abrasive use.

Road Type	Use of Dry Abrasives
Freeways	Inappropriate
Rural roads, paved	Inappropriate
Rural roads, gravel	Only on low speed sections (perhaps hills and curves)
Rural intersections	Only on low speed approach length of gravel roads
High speed urban roads	Inappropriate
Low speed urban roads	Only in certain locations and when snowpack will persist
Urban intersections	Only when snowpack will persist

Abrasives & Freeze Point Depressants

- Application strategies – analyses
  - Idaho DOT study
  - Tradition methods (deicing, NaCl, abrasives) replaced with liquid anti-icing on US 12
  - Sharp reductions in labor, abrasives, and accidents

Table 2-17. Idaho results.

	Average Annual Labor Hours	Average Annual Abrasives Used	Average Annual Accidents
Before 1997	650	1475 cu. M	16.2
1997-2000 Period	248	247 cu. M	2.7
Percent Reduction	*62%*	*83%*	*83%*

Abrasives & Freeze Point Depressants

- Application strategies – analyses
  - Colorado DOT study
  - Tradition methods (deicing, NaCl, abrasives) replaced with liquid anti-icing
  - Focus – particulate matter reduction

Table 2-18. Colorado DOT materials use from 1992 to 2000.

Year	Sand (tons/mile)	Salt (NaCl) (tons/mile)	Liquid Deicer (gallons/mile)
1992	0.25	1.1	<0.5
1993	0.20	0.9	<0.5
1994	0.17	1.3	<0.5
1995	0.29	0	<0.5
1996	0.19	0	1
1997	0.23	0	3
1998	0.17	0	5
1999	0.09	0	8
2000	0.04	0	11

Abrasives & Freeze Point Depressants

- Sand stockpile treatment
  - Abrasives or chemicals treated to avoid clumps
  - “Frost proofing”
  - Clumping makes materials difficult to handle and apply
  - Typically, liquid or solid chlorides added at 5% (by weight)
  - Solid chemicals tend to attract moisture – causing lumps and workability problems
    - “Frost proof” with small amount of liquid chemical with a lower eutectic temperature

Abrasives & Freeze Point Depressants

- Impact on the environment

Table 6-1. Generalized potential environmental impairment related to common snow and ice control chemicals.

Environmental Impact	Road Salt (NaCl)	Calcium Chloride ($CaCl_2$)	Magnesium Chloride ($MgCl_2$)	Acetates (CMA and KA)	Organic Biomass Products	Abrasives
Water Quality/ Aquatic Life (Section 3.4)	Moderate: Excessive chloride loading, metal contaminants; ferrocyanide additives.	Moderate: Excessive chloride loading; heavy metal contamination.	Moderate: Excessive chloride loading; heavy metal contamination.	High: Organic content leading to oxygen demand.	High: Organic matter leading to oxygen demand; nutrient enrichment by phosphorus and nitrogen; heavy metals.	High: Turbidity; increased sedimentation.
Air Quality (Section 3.8)	Low: Leads to reduced abrasive use.	Low: Leads to reduced abrasive use.	Low: Leads to reduced abrasive use.	Low: Leads to reduced abrasive use.	Low: Leads to reduced abrasive use.	High: Fine particulate degrades air quality.
Soils (Section 3.5)	Moderate/High: Sodium accumulation breaks down soil structure and decreases permeability and soil stability; potential for metals mobilization.	Low/Moderate: Improves soil structure; increases permeability; potential for metals mobilization.	Low/Moderate: Improves soil structure; increases permeability; potential for metals mobilization.	Low/Moderate: Improves soil structure; increases permeability; potential for metals mobilization.	Low: Probably little or no effect; limited information available.	Low: Probably little or no effect.
Vegetation (Section 3.7)	High: Spray causes foliage damage; osmotic stress harms roots; chloride toxicosis.	High: Spray causes foliage damage; osmotic stress harms roots; chloride toxicosis.	High: Spray causes foliage damage; osmotic stress harms roots; chloride toxicosis.	Low: Little or no adverse effect; osmotic stress at high levels.	Low: Probably little or no effect.	Low: Probably little or no effect.
Animals (Section 3.9)	Low: Sodium linked to salt toxicosis and vehicle kills; magnitude unclear.	Low: Probably little or no effect.	Low: Probably little or no effect.	Low: Probably little or no effect.	Low: Probably little or no effect; limited toxicity information available.	Low: Probably little or no effect.

Abrasives & Freeze Point Depressants

- Chloride impact on concrete
  - Known to adversely affect concrete (roadways, sidewalks, bridge decks)
    - Physical deterioration of surface – scaling
    - Chemical reactions of salt/paste/aggregates – paste degrades
    - Diffusion of chloride ions – corrosion of reinforcing steel
  - Degree – some disagreement in the literature
  - CMA, urea, KA, glycols
    - Research of their impacts on concrete is limited
    - Primary use is to limit corrosion of aircraft parts, so they're probably kinder to steel reinforcing
    - Still, they're expensive
  - Moral? Use less when you can

Abrasives & Freeze Point Depressants

- Impact on concrete

Table 6-3. Generalized potential corrosion impairment related to common snow and ice control chemicals.

Environmental Impact	Road Salt (NaCl)	Calcium Chloride ($CaCl_2$)	Magnesium Chloride ($MgCl_2$)	Acetates (CMA and KA)	Organic Biomass Products	Abrasives
Atmospheric Corrosion to Metals (General)	High: Will initiate and accelerate corrosion.	High: Will initiate and accelerate corrosion; higher potential for corrosion related to hygroscopic properties	High: Will initiate and accelerate corrosion; higher potential for corrosion related to hygroscopic properties	Low/moderate: Potential to initiate and accelerate corrosion due to elevated conductivity.	Low: Potential to initiate and accelerate corrosion due to elevated conductivity claims of mitigation of corrosion require further evaluation.	Low: Probably little or no effect
Concrete Matrix (Section 4.1)	Low/moderate: Will exacerbate scaling; low risk of paste attack.	Low/moderate: Will exacerbate scaling; low risk of paste attack.	Moderate/high: Will exacerbate scaling; risk of paste deterioration from magnesium reactions.	Moderate/high: Will exacerbate scaling; risk of paste deterioration from magnesium reactions	Low: Probably little or no effect.	Low: Probably little or no effect
Concrete Reinforcing (Section 4.1)	High: Will initiate corrosion of rebar.	High: Will initiate corrosion of rebar.	High: Will initiate corrosion of rebar, evidence suggests $MgCl_2$ has highest potential for corrosion of chloride products	Low: Probably little or no effect.	Low: Probably little or no effect; claims of mitigation of corrosion require further evaluation	Low: No Effect

Abrasives & Freeze Point Depressants

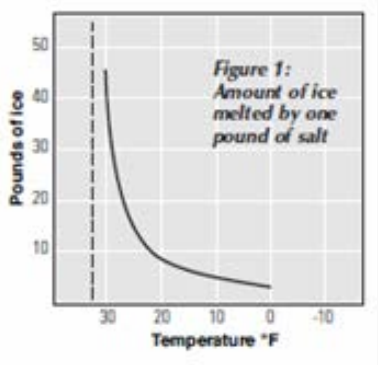
- A couple of cautions
- Calcium Chloride - CaCl
  - Hygroscopic – absorbs moisture from the air
  - If left as a residual on the road, moist air can actually create ice
- Urea - $(NH_2)_2CO$
  - Synthesized from natural gas
  - 46% nitrogen – it's basically fertilizer
  - Less effective than NaCl – eutectic point is 12.2°F
    - Do you recall what the eutectic point for rock salt was?
  - Excessive use can burn roadside vegetation and cause algal blooms in receiving waters

Abrasives & Freeze Point Depressants

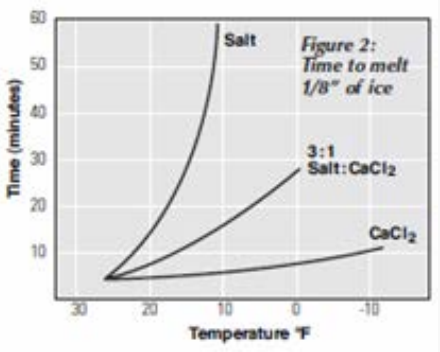
- Temperature
  - What do we think of when we say temperature?
    - Air temperature?
  - What about other temperature information?
    - Pavement surface temperature?
    - Subsurface temperature?
  - Each of these temperatures (and other information) can affect the formation of ice on the roadways and the plowing/deicing/anti-icing techniques that will be most effective

Abrasives & Freeze Point Depressants

- Salt (NaCl)
  - Meaning, sodium chloride (rock salt, road salt)
  - Our most common “freeze point depressant”



  - At 30˚F (pave temp), 1# salt melts 40# ice
  - At 20˚F (pave temp), 1# salt melts 8# ice



  - Salt melts ice as low as -6˚F (pave temp)
  - But below ~15˚F (pave temp) effect of salt greatly reduced
  - Most managers limit use of salt when temps are 20˚F and falling

Abrasives & Freeze Point Depressants

- So…
  - Not too much moisture and not too little – got to keep concentration near optimal – pre-wetting can help
    - One way or another, you have to establish a brine on the surface
  - Not too cold –NaCl just sits there below -6˚F (pave temp)
- So…
  - Below ~ 15˚F (pave temp) or so, have to think about whether salt is doing much good at the moment
  - Below ~ 5-10˚F (pave temp), hang it up, or go to sand, or apply brine, or go to calcium chloride (CaCl) or magnesium chloride (MgCl)
- Regardless…
  - Knowing just the air temperature doesn't help you as much as also knowing the pavement temperature

Temperature and Ice Forming

- Air temperature does not correlate to pavement temperature, generally
  - So, the "current temperature" (at least, by itself) doesn't tell snowfighters what they really want to know
  - Frigid December day, subfreezing air temps – pavement and subsurface can be substantially warmer, deicing efforts are light, and use of chemicals can be minimized
  - Mild early March night – air temps may be above freezing, the surface and subgrade temps can frustrate deicing efforts
- Pavement and subsurface temperatures can help optimize use of chemicals/abrasives and improve performance

Temperature and Ice Forming

- If the pavement is at 32˚F or below and there is precipitation, ice is a given; beyond that it gets trickier
- In the fall, subsurface temps are warmer, which tends to keep pavement temps warmer, even when the air temp is lower
- In the spring (depending upon what winter has wrought) subsurface temps are generally low, providing little protection for the pavement against ambient temps – may even contribute to lower pavement temps than even the ambient air
- Sun has strong influence

Temperature and Ice Forming

- Black Ice
  - Forms when the air temp is below freezing but warmer than the pavement temp (e.g., air at 30˚F and pavement at 26˚F)
    - When more likely to see black ice? Later in the winter, right?
  - Moisture rapidly freezes and creates a thin layer of ice that may be transparent on the roadway
  - Rain or snow not necessary – just need subfreezing pavement, slightly warmer air temps, and elevated humidity
  - Look for times when the dew point and air temp converge
    - Air can no longer hold the moisture – condenses on the pavement
    - May not be noticed by motorists until too late – hence, very dangerous condition
    - Tends to be spotty – crops up here and there
    - Watch bridges in particular

Abrasives & Freeze Point Depressants

Table 8. Weather event: light snow storm.

PAVEMENT TEMPERATURE RANGE, AND TREND	INITIAL OPERATION				SUBSEQUENT OPERATIONS			COMMENTS
	pavement surface at time of initial operation	maintenance action	dry chemical spread rate, kg/lane-km (lb/lane-mi)		maintenance action	dry chemical spread rate, kg/lane-km (lb/lane-mi)		
			liquid	solid or prewetted solid		liquid	solid or prewetted solid	
Above 0°C (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 0°C (32°F) and below 2) Treat icy patches if needed with chemical at 28 kg/lane-km (100 lb/lane-mi); plow if needed
Above 0°C (32°F), 0°C (32°F) or below is imminent;	Dry	Apply liquid or prewetted solid chemical	28 (100)	28 (100)	Plow as needed; reapply liquid or solid chemical when needed	28 (100)	28 (100)	1) Applications will need to be more frequent at lower temperatures and higher snowfall rates 2) It is not advisable to apply a liquid chemical at the indicated spread rate when the pavement temperature drops below -5°C (23°F) 3) Do not apply liquid chemical onto heavy snow accumulation or packed snow
ALSO **-7 to 0°C (20 to 32°F)**, remaining in range	Wet, slush, or light snow cover	Apply liquid or solid chemical	28 (100)	28 (100)				
-10 to -7°C (15 to 20°F), remaining in range	Dry, wet, slush, or light snow cover	Apply prewetted solid chemical		55 (200)	Plow as needed; reapply prewetted solid chemical when needed		55 (200)	If sufficient moisture is present, solid chemical without prewetting can be applied
Below -10°C (15°F), steady or falling	Dry or light snow cover	Plow as needed			Plow as needed			1) It is not recommended that chemicals be applied in this temperature range 2) Abrasives can be applied to enhance traction

Notes

CHEMICAL APPLICATIONS. (1) Time initial and subsequent chemical applications to *prevent* deteriorating conditions or development of packed and bonded snow. (2) Apply chemical ahead of traffic rush periods occurring during storm.

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

http://www.fhwa.dot.gov/reports/mopeap/eapcov.htm

Abrasives & Freeze Point Depressants

Table 9. Weather event: light snow storm 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	dry chemical spread rate, kg/lane-km (lb/lane-mi)		maintenance action	dry chemical spread rate, kg/lane-km (lb/lane-mi)				
			liquid	solid or prewetted solid		liquid		solid or prewetted solid		
						light snow	heavier snow	light snow	heavier snow	
Above 0°C (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 0°C (32°F) and below 2) Treat icy patches if needed with chemical at 28 kg/lane-km (100 lb/lane-mi); plow if needed
Above 0°C (32°F), 0°C (32°F) or below is imminent; *ALSO* **-4 to 0°C (25 to 32°F)**, remaining in range	Dry	Apply liquid or prewetted solid chemical	28 (100)	28 (100)	Plow as needed; reapply liquid or solid chemical when needed	28 (100)	55 (200)	28 (100)	55 (200)	1) Applications will need to be more frequent at lower temperatures and higher snowfall rates 2) Do not apply liquid chemical onto heavy snow accumulation or packed snow 3) After heavier snow periods and during light snow fall, reduce chemical rate to 28 kg/lane-km (100 lb/lane-mi); continue to plow and apply chemicals as needed
	Wet, slush, or light snow cover	Apply liquid or solid chemical	28 (100)	28 (100)						
-10 to -4°C (15 to 25°F), remaining in range	Dry, wet, slush, or light snow cover	Apply prewetted solid chemical		55 (200)	Plow as needed; reapply prewetted solid chemical when needed			55 (200)	70 (250)	1) If sufficient moisture is present, solid chemical without prewetting can be applied 2) Reduce chemical rate to 55 kg/lane-km (200 lb/lane-mi) after heavier snow periods and during light snow fall; continue to plow and apply chemicals as needed
Below -10°C (15°F), steady or falling	Dry or light snow cover	Plow as needed			Plow as needed					1) It is not recommended that chemicals be applied in this temperature range 2) Abrasives can be applied to enhance traction

Notes

CHEMICAL APPLICATIONS. (1) Time initial and subsequent chemical 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 chemical ahead of traffic rush periods occurring during storm.

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

Abrasives & Freeze Point Depressants

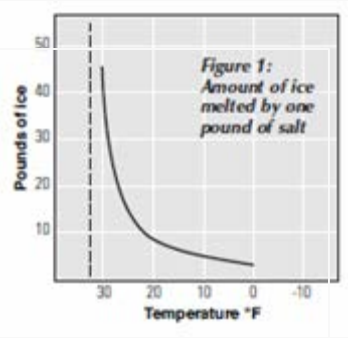
Table 12. Weather event: freezing rain storm.

PAVEMENT TEMPERATURE RANGE, AND TREND	INITIAL OPERATION		SUBSEQUENT OPERATIONS		COMMENTS
	maintenance action	chemical spread rate, kg/lane-km (lb/lane-mi)	maintenance action	chemical spread rate, kg/lane-km (lb/lane-mi)	
Above 0°C (32°F), steady or rising	None, see comments		None, see comments		1) Monitor pavement temperature closely for drops toward 0°C (32°F) and below 2) Treat icy patches if needed with prewetted solid chemical at 21-28 kg/lane-km (75-100 lb/lane-mi)
Above 0°C (32°F), 0°C (32°F) or below is imminent	Apply prewetted solid chemical	21-28 (75-100)	Reapply prewetted solid chemical as needed	21-28 (75-100)	Monitor pavement temperature and precipitation closely
-7 to 0°C (20 to 32°F), remaining in range	Apply prewetted solid chemical	21-70 (75-250)	Reapply prewetted solid chemical as needed	21-70 (75-250)	1) Monitor pavement temperature and precipitation closely 2) Increase spread rate toward *higher indicated rate* with decrease in pavement temperature or increase in intensity of freezing rainfall 3) Decrease spread rate toward *lower indicated rate* with increase in pavement temperature or decrease in intensity of freezing rainfall
-10 to -7°C (15 to 20°F), remaining in range	Apply prewetted solid chemical	70-110 (250-400)	Reapply prewetted solid chemical as needed	70-110 (250-400)	1) Monitor precipitation closely 2) Increase spread rate toward *higher indicated rate* with increase in intensity of freezing rainfall 3) Decrease spread rate toward *lower indicated rate* with decrease in intensity of freezing rainfall
Below -10°C (15°F), steady or falling	Apply abrasives		Apply abrasives as needed		It is not recommended that chemicals be applied in this temperature range

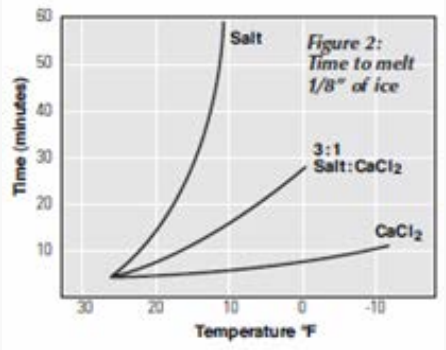
Notes

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

Spreading Abrasives and Chemicals



- Control the rate
  - Manager should adjust with conditions
- Control the distribution patterns
  - For 2-lane, 2-way traffic (including most urban streets), most effective technique (for dry or pre-wetted material) is to spread across the middle 2/3; let the cross slope and traffic distribute
- Give it time to work
  - As temp drops, more time needed
  - Don't just plow it back off five minutes later



Spreading Abrasives and Chemicals

- Multi-lane highways – apply nearly full width
- Parking areas – spread evenly
- Hills/curves/intersections – higher application rate
- Bridges – higher application rate
- Banked curves – apply on high side
- High winds – dry material may not stick

Spreading Abrasives and Chemicals

- Special areas
  - At-grade railroad crossings
  - Interchanges
  - Super-elevated curves
  - Steep grades
  - Deep cuts
  - Shaded areas
  - Drainage
    - Poor drainage/trapped areas
    - Closed drainage
    - Open drainage

Weather Basics

- Back to the weather
  - Plows at the ready and nice piles of salt and sand are important
  - Well trained and organized crews are essential
  - Safety must always be on everyone's mind
  - And…

  - Weather information is an important tool in your arsenal, too
    - Weather Channel – www.weather.com
    - NOAA National Weather Service - http://www.weather.gov/
    - NOAA local forecasts - http://www.erh.noaa.gov/phi/
    - DelDOT interactive weather - http://www.deldot.gov/traffic/map.ejs

Weather Basics

- Snow
  - Ice crystals form gangs way up high and float down innocently
  - Sustained snowfall requires constant inflow of moisture
- Ice
  - Moisture gets on stuff that's cold – nobody likes that
- Black ice
  - Forms when the air temp is below freezing but warmer than the pavement temp (e.g., air at 30˚F and pavement at 26˚F)
  - Look for when the dew point and air temp converge - air can no longer hold the moisture – condenses on the pavement
- Sleet
  - Cold, deep layer of air at surface cause raindrops as they descend
- Freezing rain
  - Water droplets fall from above-freezing layer to below-freezing layer

Weather Basics

- Weather information to watch
  - Temperatures
    - Air
    - Pavement
    - Subsurface
  - Dew point
  - Wind
    - Speed
    - Direction
- Where do we find it
  - Weather Channel/weather.com
  - NOAA
  - DelDOT
  - On-site weather station
  - Finger in the air?

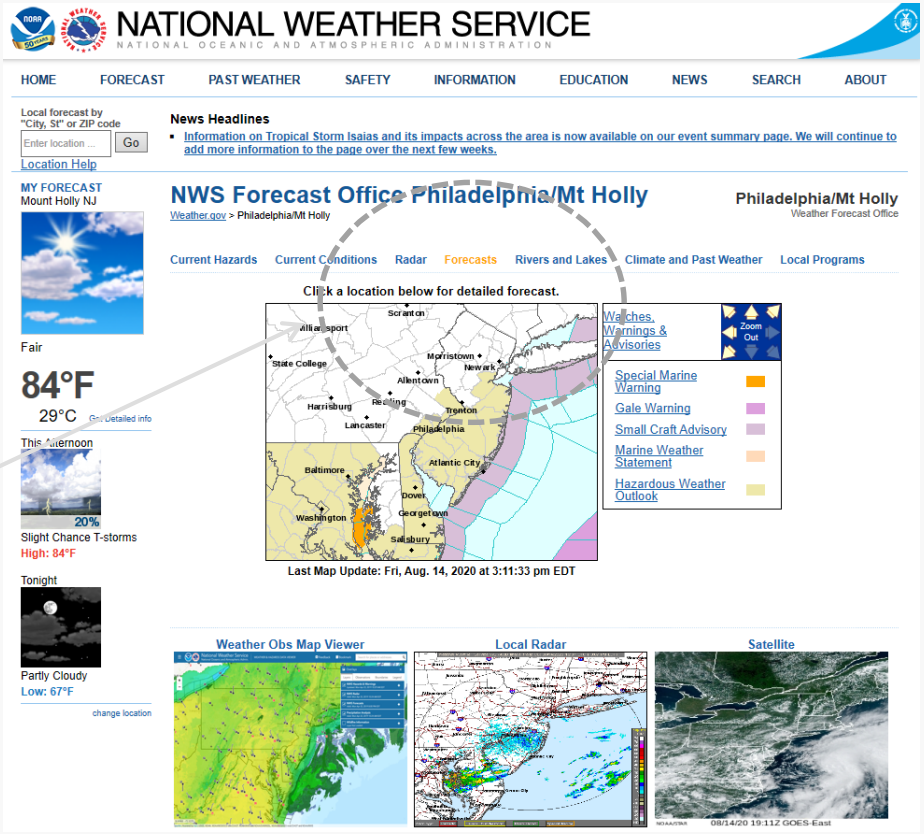
Weather Basics

- Recognizing what has happened, what is happening, and what is likely to happen…
  - Snow
  - Ice
  - Black ice
  - Sleet
  - Freezing rain

- Helps guide us what to do at any given point in the storm
  - Start treatment
  - Change treatments
  - Stop
  - Pause

NOAA NWS

- Tons of information as storms approach
- Click on your location on most maps and you'll get very localized information
- Local text forecasts written largely laymen terms
- Area forecast discussion

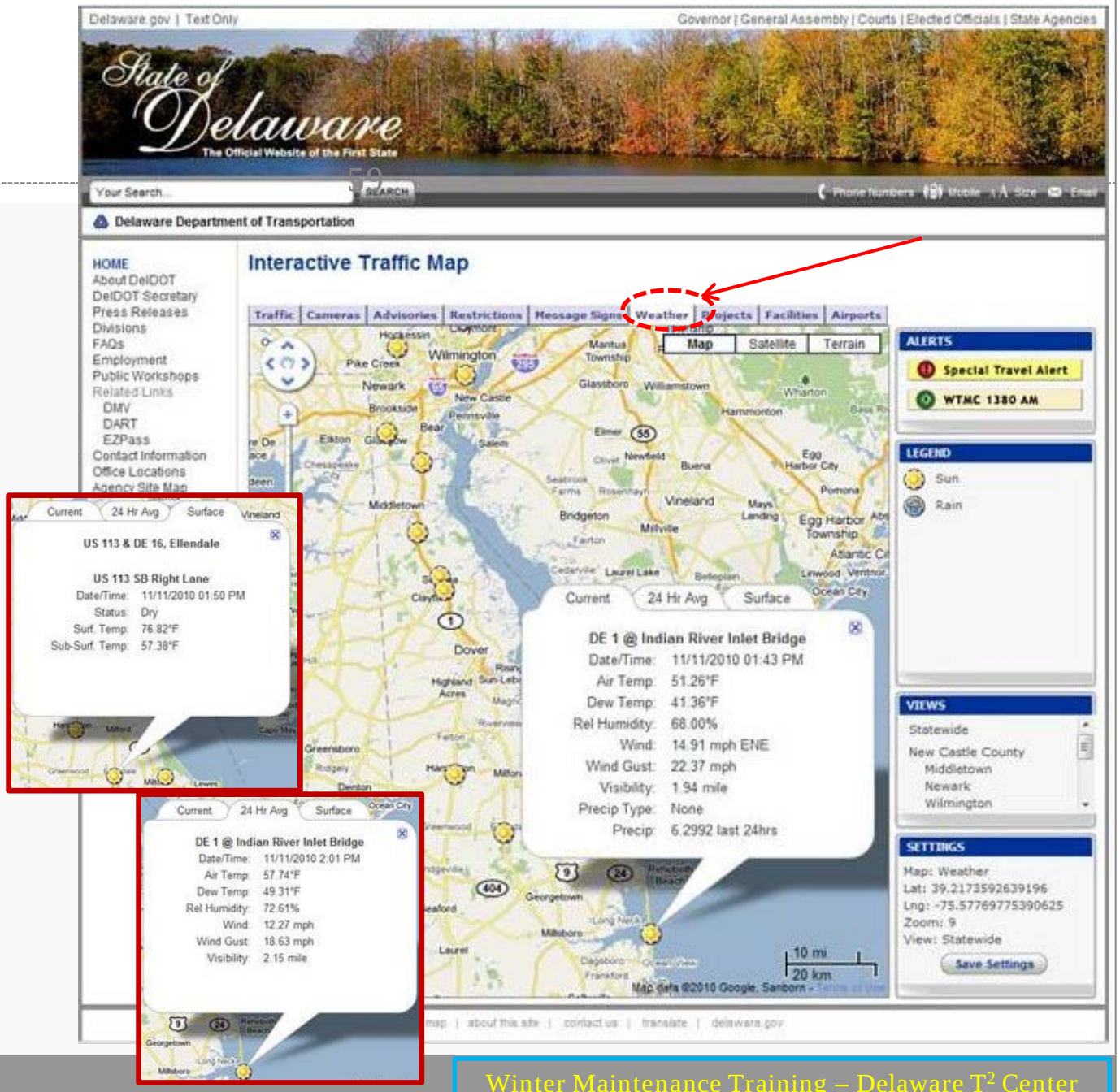


DelDOT Weather

- Live, interactive map
- ~30 locations

- Air temps
- Pave temps
- Sub-surface temps

- Humidity
- Dew point
- Wind



Vehicle-Based Weather Equipment

- Systems like these can give you real time, local information
  - Air temp
  - Surface temp
  - Relative humidity
  - Dew point

Some Weather Scenarios

- From the Salt Institute
- Don't be shocked if there's an emphasis on salt use
- Nonetheless, these can be good starting guides

Pounds of Ice Melted Per Pound of Salt

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

Application of Salt

Rate of Application Per Two-Lane Mile	Coverage Per Cu. Yd. of Salt Per Two-Lane Mile
800 lb	2 1/2
700 lb	2 3/4
600 lb	3
500 lb	4
400 lb	5
300 lb	6
200 lb	10

Note: Salt meeting ASTM Specification D632 weighs approximately 80 lb per cubic foot.

Stormfighting Guidelines

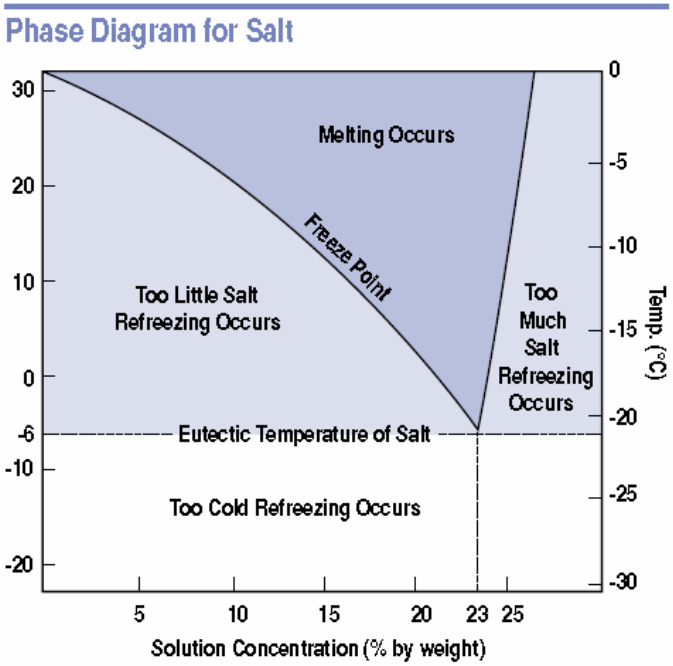
The following chart is a guideline to combat various types of storms. Local conditions and policies will be the final determining factor.

Condition 1 **Temperature** Near 30 **Precipitation** Snow, sleet or freezing rain **Road Surface** Wet	If snow or sleet, apply salt at 500 lb per two-lane mile. If snow or sleet continues and accumulates, plow and salt simultaneously. If freezing rain, apply salt at 200 lb per two-lane mile. If rain continues to freeze, re-apply salt at 200 lb per two-lane mile. Consider anti-icing procedures.
Condition 2 **Temperature** Below 30 or falling **Precipitation** Snow, sleet or freezing rain **Road Surface** Wet or Sticky	Apply salt at 300-800 lb per two-lane mile, depending on accumulation rate. As snowfall continues and accumulates, plow and repeat salt application. If freezing rain, apply salt at 200-400 lb per two-lane mile. Consider anti-icing and deicing procedures as warranted.
Condition 3 **Temperature** Below 20 and falling **Precipitation** Dry Snow **Road Surface** Dry	Plow as soon as possible. Do not apply salt. Continue to plow and patrol to check for wet, packed or icy spots; treat them with heavy salt applications.
Condition 4 **Temperature** Below 20 **Precipitation** Snow, sleet or freezing rain **Road Surface** Wet	Apply salt at 600-800 lb per two-lane mile, as required. If snow or sleet continues and accumulates, plow and salt simultaneously. If temperature starts to rise, apply salt at 500-600 lb per two-lane mile, wait for salt to react before plowing. Continue until safe pavement is obtained.
Condition 5 **Temperature** Below 10 **Precipitation** Snow or freezing rain **Road Surface** Accumulation of packed snow or ice	Apply salt at rate of 800 lb per two-lane mile or salt-treated abrasives at rate of 1500 to 2000 lb per two-lane mile. When snow or ice becomes mealy or slushy, plow. Repeat application and plowing as necessary.

Note: The light, 200 lb application called for in Condition 1 and 2 must be repeated often for the duration of the condition.

Worst Case Weather Scenarios

- Excessive amounts water/ice
- Blizzard conditions
- Intense snowfall, wind, very cold temperatures
- Chemicals can become quickly diluted (remember the phase diagram?)
- Abrasives can be washed away or buried



Worst Case Weather Scenarios

- Blizzard with very low, sustained temps going in and coming out of storm…
  - Plowing alone may be best option – hold off on chemicals and abrasives
  - If post storm conditions are still favorable to icing, consider abrasives along with chemicals to buy time for them to work or for warmer conditions
- Blizzard with warmer temps going in and coming out of storm…
  - Consider ice control chemical before storm or early on
  - Plow mostly without salt or sand
  - Deice at end of storm

Worst Case Weather Scenarios

- Rapidly accumulating freezing rain…
  - Apply solid ice control chemicals at high rate on high side wheel path of each lane
  - Attempt to achieve at least one wheel path with sufficient friction to stop and steer
  - Watch for rapidly changing conditions
- Falling/blowing snow, near zero visibility (white out)
  - Get vehicles and equipment well off road, keep emergency lights active, communicate with operations base
  - Extra caution in operational yards as well
  - Wait it out – conditions may only be temporary
  - Operating in these conditions is a danger to everyone

Taking Calls

- No test of government is more important to a citizen than the manner in which his or her request or complaint is handled

Taking Calls

- Request / Complaint Handling Procedure:
  - Receiving calls
    - Courtesy
    - Write it down – thoroughly
  - Prompt investigation & correction
    - Get the information to the right personnel
    - Request timeline for reporting back
  - Follow-up procedure for tracking
  - Response back to resident before checking off
    - Keep record of call and resolution, including times
    - Note satisfaction (or lack thereof) from caller

Crashes

- Take and keep photos of road conditions before and after crashes
- What can we tell from them?
- Driver error?
- Poor road conditions?

Record Keeping

- Storm information
  - Snow, ice, sleet, freezing rain, black ice?
  - What was the storm sequence – i.e., freezing rain started at 4 a.m., changed to wet snow at 5:30, changed to rain at noon…
  - Day of week, holidays, etc.
  - Other weather conditions (temps, sunshine, clouds, dew points, winds)
- Manpower and equipment status
  - Beginning of storm, throughout
  - Reasons for gaps (vacation, waiting on parts, funding)
  - Auxiliary personnel or equipment used
- Notable problems/obstructions/interference

Record Keeping

- Performance
  - Miles plowed (and/or material applied) per hour, possibly broken down by route and/or road type
  - Times when various roads were made passable
  - Abrasives and chemicals used (tonnage, per route)
  - Cutting edges consumed
  - Percentage of time LOS met
  - Crashes (fatal, non-fatal, pedestrians, property damage only)
- Feedback
  - Number of phone calls from public, elected officials
  - Public comment at meetings
  - News articles, letters to editors

Record Keeping

- Storm record

Weather and Pavement Condition Sheet

Weather Data	Date 2002	1/16	1/16	1/16	1/16	1/16	1/16	1/16			
	Time	1100	1200	1300	1400	1500	1600	1700			
	Forecast (F) or Actual (A)	A	F	F	F	F	F	F			
	Precipitation Type	OS[1]	OS[1]	OS[1]	PS[2]	None	None	None			
	Precipitation Intensity (H, M, or L)	M	L	L	L	–	–	–			
	Percent Clouds	100	100	100	100	90	70	50			
	Cloud Density (H, M, or L)	H	H	M	M	L	L	L			
	Radiational Effects (0, + or –)	0	0	0	0	+	0	–			
	Air Temperature (°F)	25	25	25	24	23	22	21			
	Air Temperature Trend (0, + or –)	0	0	–	–	–	–				
	Wind Velocity (mph)	6	7	8	8	9	10	12			
	Wind Direction	SE	S	SSW	SSW	W	W	NW			
	Relative Humidity (%)										
	Dewpoint (°F)										
Pavement Condition Data	Pavement Temperature (°F)	28	28	27	27	26	26	25			
	Pavement Temperature Trend (0, + or –)	0	–	0	–	0	–				
	Treatment Cycle Time (hr)	2.0									
	Traffic Speed (mph)	50									
	Traffic Volume (vph)	100									
	Slush, Loose Snow, or Packed Snow in Wheelpath (Yes or No)	No									
	Ice Pavement Bond (Yes or No)	No									
Text Forecast and Other Operational Data											

[1] Ordinary snow.
[2] Powder snow.

Figure B-1. Completed Form 1—Example weather and pavement condition worksheet.

Agency_____ Date_____
Route_____ Operator_____

Date		1/16/02									
Time		1100									
Dilution Potential	Precipitation and Trend (L, M, or H)	M									
	Cycle Time (0, +1, or +2)	1									
	Wheel Path Condition (0 or +1)	0									
	Traffic (0 or +1)	0									
	Adjusted (do not exceed H)	H									
Pavement Temperature (°F) and Trend		28									
Ice/Pavement Bond (Yes or No)		No									
Recommended Treatment		190 lb/LM of solid sodium chloride									

Figure B-2. Completed Form 2—Example snow and ice control treatment design worksheet.

Record Keeping

- Storm record
- Other checklists can be found in the Snowfighter's Handbook

STORM RECORD

Salt Institute

Storm No:		Sec:		Div:		Date:	
1. Time	**AM**	**PM**	**Day of Week**	**2. Location**		**Miles**	
Storm Started				From:			
Storm Ended				To:			
Road Cleared							
3. Description							
Dry Snow		Temp		Wind			
Wet Snow		Max:	Min:	Direction:	Velocity	MPH	
Sleet		Depth of Snow		Visibility			
Freezing Rain		Avg (in)	Drifts (ft)	Good:	Fair:	Poor:	

4. Procedures				**5. Results**			
	No of Apps	Time			Excellent	Good	Poor
Salt		From:	To:	Salt			
Plowing		From:	To:	Plowing			
Abrasives		From:	To:	Abrasives			

6. Labor, Equipment & Materials

Personnel	Reg Hrs.	O.T. Hrs.	Total	Equip. No.	Type	Hours	Material (TONS)
							Salt
							Abrasives
Total							

Comments:

Completed by: _____
Name, Title

Safety

- Don’t miss a chance to remind
- Establish a safety culture from the top down
- For you, your crews, pedestrians, motorists, visitors to operational centers and yards…
- Kids in snow banks, sledding, throwing snow balls
- Even the delinquents

- Day versus night operations
- Rest…eat…drink (water) – don’t over-do it
- Know when to cease operations temporarily

Post Season Activities

INVENTORY EQUIPMENT AND MATERIALS
CLEAN AND REPAIR EQUIPMENT
STORE EQUIPMENT
REVIEW OF PERFORMANCE AND SAFETY STATISTICS
BRIEF ELECTED OFFICIALS AND BEAN COUNTERS
PLAN FOR REPLENISHMENT OF MATERIALS
ROAD AND SHOULDER REPAIRS
ASSESS THE SEASON
CALIBRATE PLAN ACCORDINGLY

Post Season Activities

- Spring is coming
- You're unhooking plows and spreaders
- You're thinking about summer maintenance activities (and baseball and crab feasts and so on)

- Hold on there – just a few things to do before we turn our backs on another winter season

Post Season Activities

- Equipment
  - Thoroughly clean
    - Get the salt off
    - And the other gunk, too
    - Clean equipment easier to inspect, also
  - Repair and maintain
    - Thorough inspection
    - Grease
    - Repair, replace broken chains, wear points, cutting edges
  - Inventory
    - Got everything you started with?
  - Identify replacements

Post Season Activities

- Cleaning/repairing equipment is essential prior to storage

Post Season Activities

- Store equipment
  - Hang spreaders if you can
  - Store plows up out of the dirt
  - Keep hydraulic connections free of debris
  - Ensure that attachments are marked/numbered for easy association with its master vehicle

Post Season Activities

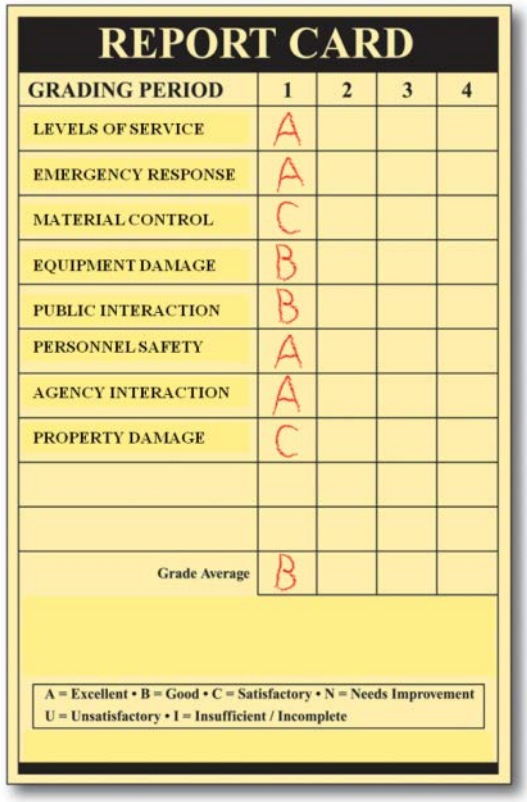
- Good storage locations and facilities are an asset

Post Season Activities

- Materials
  - Inventory
  - Dress up piles (and ensure they are covered and protected)
  - Identify quantities needed for next season
  - Make arrangements with suppliers
    - Short supplies next winter?
    - Early bird gets the worm

Post Season Activities

- Review performance standards
  - Levels of Service
  - Safety goals
  - Budget
  - Met? Exceeded? Fell short?
  - Extenuating circumstances?
- Be brutally honest with yourself and crews

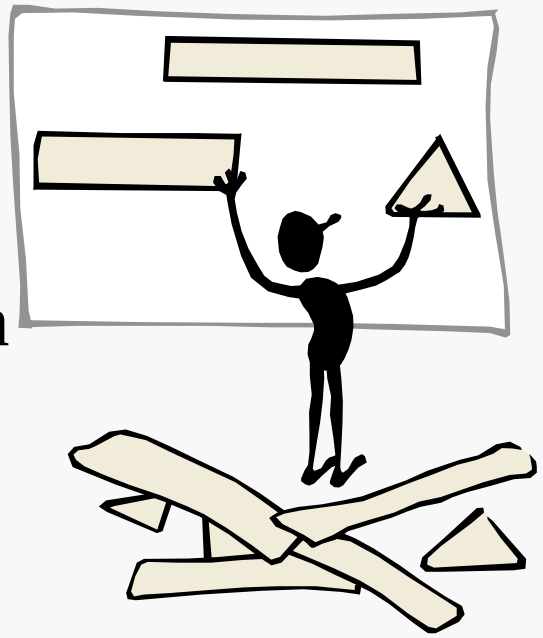


Post Season Activities

- Assess the season
  - What went well
  - What didn't
  - Why
  - Obstacles
  - Manpower
  - Equipment
  - Materials
  - Outside forces, interlopers
  - Contractors, vendors
  - Things to improve

Post Season Activities

- Things that went well
  - Can we repeat them?
- Things that went…poorly
  - Can we eliminate them?
  - Minimize them?
  - Avoid them?
- Revise the Snow and Ice Control Plan
  - Tweak
  - Rearrange
  - Calibrate



Post Season Activities

- Brief stakeholders
  - Elected officials
  - Public
  - Bean counters
- Written reports
- Presentations
- Press releases
- Interviews
- Admit shortcomings, oversights
- Show achievements

Post Season Activities

- Repair the roads
  - Permanent pothole repair
  - Water and ice damage
  - Shoulder repairs
  - Guardrail
  - Signs and sign posts
  - Pavement markings
  - Stormwater inlet grates
  - Drainage ditches and culverts
  - Manhole covers
  - …

Post Season Activities

- Repair the roads

Post Season Activities

- Inspect roadway safety features

Post Season Activities

- Roadside hardware can be easily damaged over winter by plows or vehicular accidents

Post Season Activities

- Drainage facilities are essential in preventing water damage to our roads

Post Season Activities

- Post-winter cleanup is essential to our roads, streets, bridges, drainage systems…essential to our total transportation infrastructure

Post Season Activities

- And forget about snow and ice…
- Until later in the summer
- When it's time to get suited up all over again

Okay, Who Was That Band?

Eric Idle (Monty Python), reflected on the band's name in a 1999 performance:

"I once wrote a sketch about rock musicians, and I was trying to think of a name that would be so silly nobody would ever use it, or dream it could ever be used. So I wrote the words 'Toad the Wet Sprocket.' And a few years later, I was driving along the freeway in LA, and a song came on the radio, and the DJ said, 'that was by Toad the Wet Sprocket,' and I nearly drove off the freeway."

Need More?

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