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Keynote Speaker

How We are Driving Down Salt Use – Advancing Liquids at MnDOT

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Jed Falgren, PE | State Maintenance Engineer

Salt Symposium 2022

DEPARTMENT OF TRANSPORTATION

Keeping the snow off the road

- Greatly expanding use of snow fence
  - Corn rows / round bales
  - Living snow fence
  - Structural snow fence

Mechanical Snow Removal Tools

- Plow Trucks
- Motor graders
- Tow Plows
- Ice Breakers
- Snow Blowers

Step 1: “Keeping it thin”

- Plow during storm events as frequently as possible
- In windy situations our primary tool is scraping
- Reduces bare lane regain time required when storm ends
- Reduces chemical usage

Plows: Blades here, there and everywhere

- Standard Truck has at least 3 blades
  - Front plow
  - Underbody plow (the workhorse)
  - Wing
- Dual wing
- Tow Plow

Ice Breaker

Ice Breaker

Ice Breaker

How do we remove what remains?

Salt

So… How about we…

- Reduce our chloride impact to the environment
- Reduce our material costs? 30% less
- Return our pavements to “normal” more quickly

We can do that!!!

Environmental Impacts of Chlorides

- Chlorides are toxic to aquatic life (EPA)
  - 230 mg/L – long-term
  - 860 mg/L – short-term
- Chloride is a permanent pollutant
- Contaminates groundwater
- Impacts vegetation and wildlife
- Corrodes road surfaces/bridges/buildings/etc.

Source: MPCA

Our Challenge

Get	Make	Figure out	Look
Get the material onto the pavement surface	Make sure it stays there long enough to work	Figure out how much we need for a given circumstance	Look at ways of reducing what we need to achieve our goals

Four pillars of our program

1. Brine Production
2. Liquid Storage and Blending
3. Material application
4. Building and sharing our collective knowledge, understanding

How Much Salt does MnDOT use?

- 220,000 tons per year (Last 11 years)
- Lowest year: 158,000 (2012)
- Highest year: 324,000 (2013)
- Under 200,000 tons in 2021 and 2022

Put water on top of snow and ice… ARE YOU NUTS?!

Moderate/high application rate: 50 gallons per lane mile.

Leaves a layer about .001” thick (in a snowstorm that is putting down a lot more moisture!)

REMEMBER: SALT HAS TO BE IN SOLUTION TO WORK
If we don’t add the water , mother nature will (in time)

Getting Salt to work

- Must be in direct contact with ice.
- Must be in solution (a brine)
- As ice melts it will dilute the brine
- Additional solid salt in the slurry will dissolve and start additional melting
    - More surface area of the salt, the faster it dissolves

Why Use Liquids

- Reduces bounce and scatter when dropping from the truck
- Activates salt
- Reduces Usage
  - Reduced environmental impact
  - Lowers cost
- Can reduce the working temperature (Calcium Chloride)
- Extend the time to remove the snow and ice (Carbohydrates)

Try This at Home

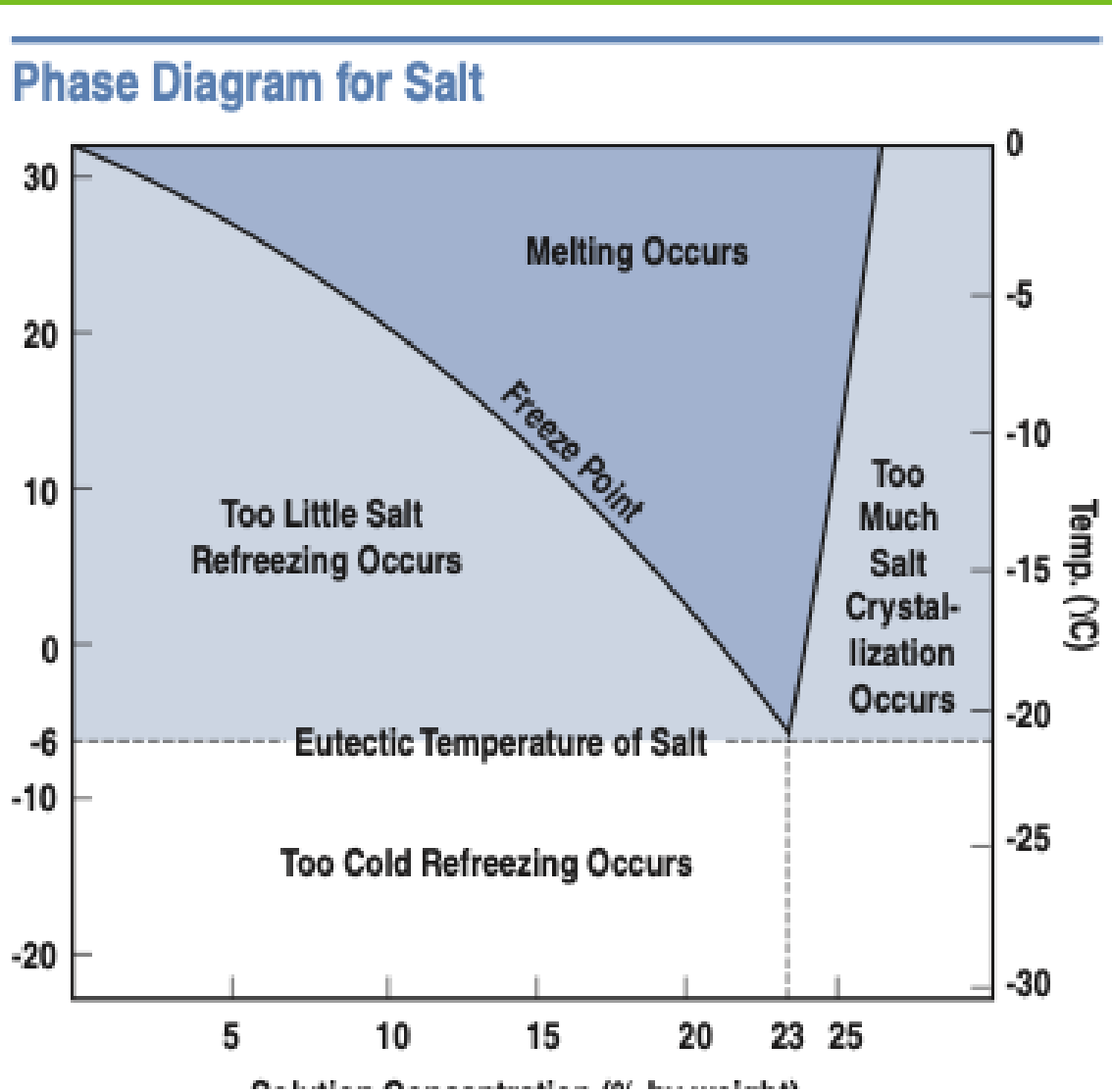
- Cup of salt
- Cup of salt + Brine (add water and let it dissolve some of the salt).

Pour each on the driveway.

Watch the difference

Salt, Concentration, and Temperature

- Salt is less effective at lower temperatures
- Salt dilutes out as more liquid is present (or as more snow is melted)
- We ”want” to be in the part that says “Melting Occurs”



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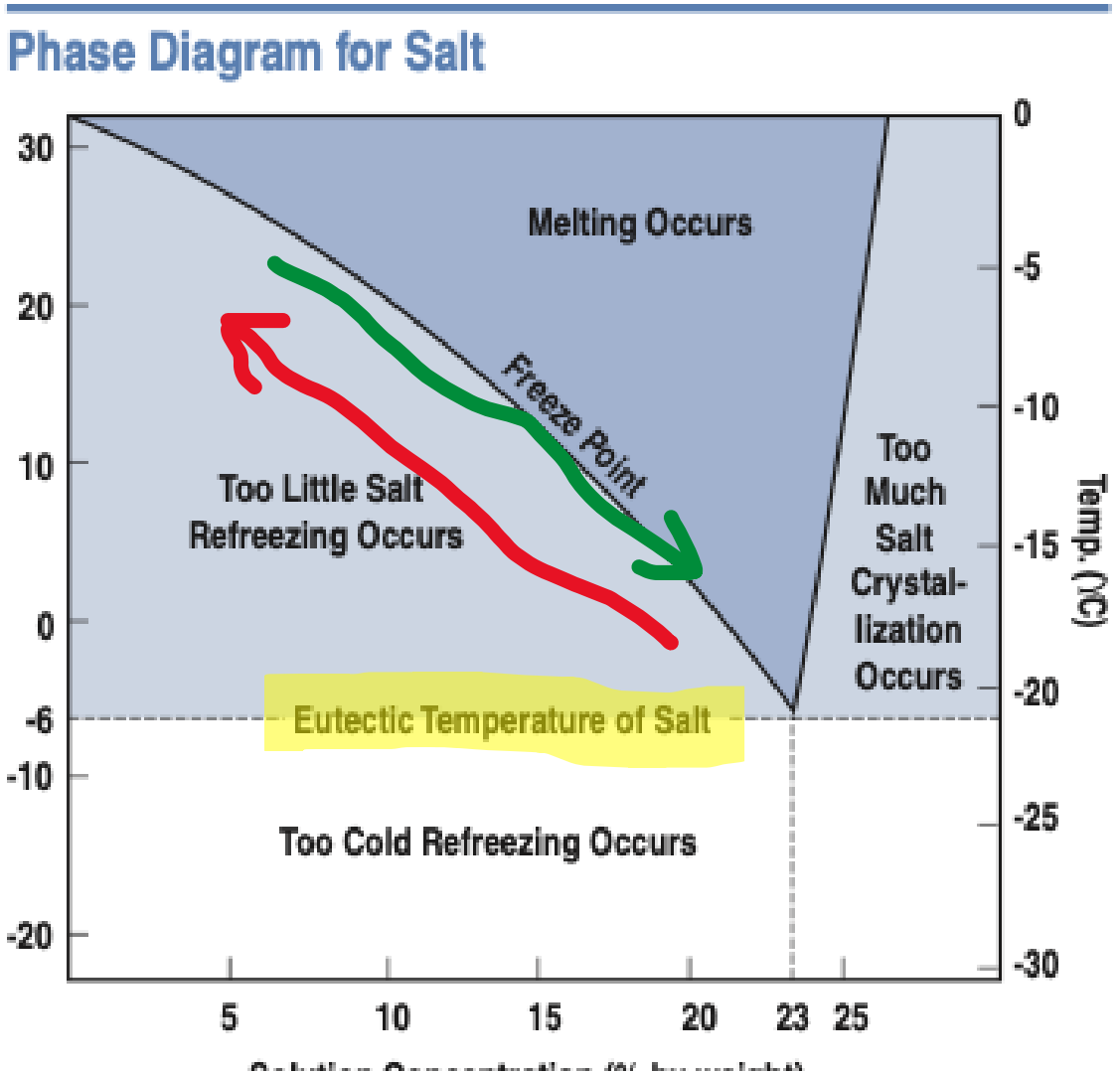


How cold will Salt still melt ice?

Chemical	Eutectic Temp °C	Eutectic Temp °F	Conc. % by weight
NaCl (salt) sodium chloride	-21	-6	23
CaCl calcium chloride	-51	-60	30
MgCl magnesium chloride	-33	-28	22
KCl potassium chloride	-11	+13	20
KAc potassium acetate	-60	-76	49
CMA calcium magnesium acetate	-27	-17	32
Urea	-12	+10	33

Thoughts about Salt, Temperature *and TIME*

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 blow away before it melts anything.
5	4.1 lbs of ice	
0	3.7 lbs of ice	
-6	3.2 lbs of ice	

Application Rate Guidelines

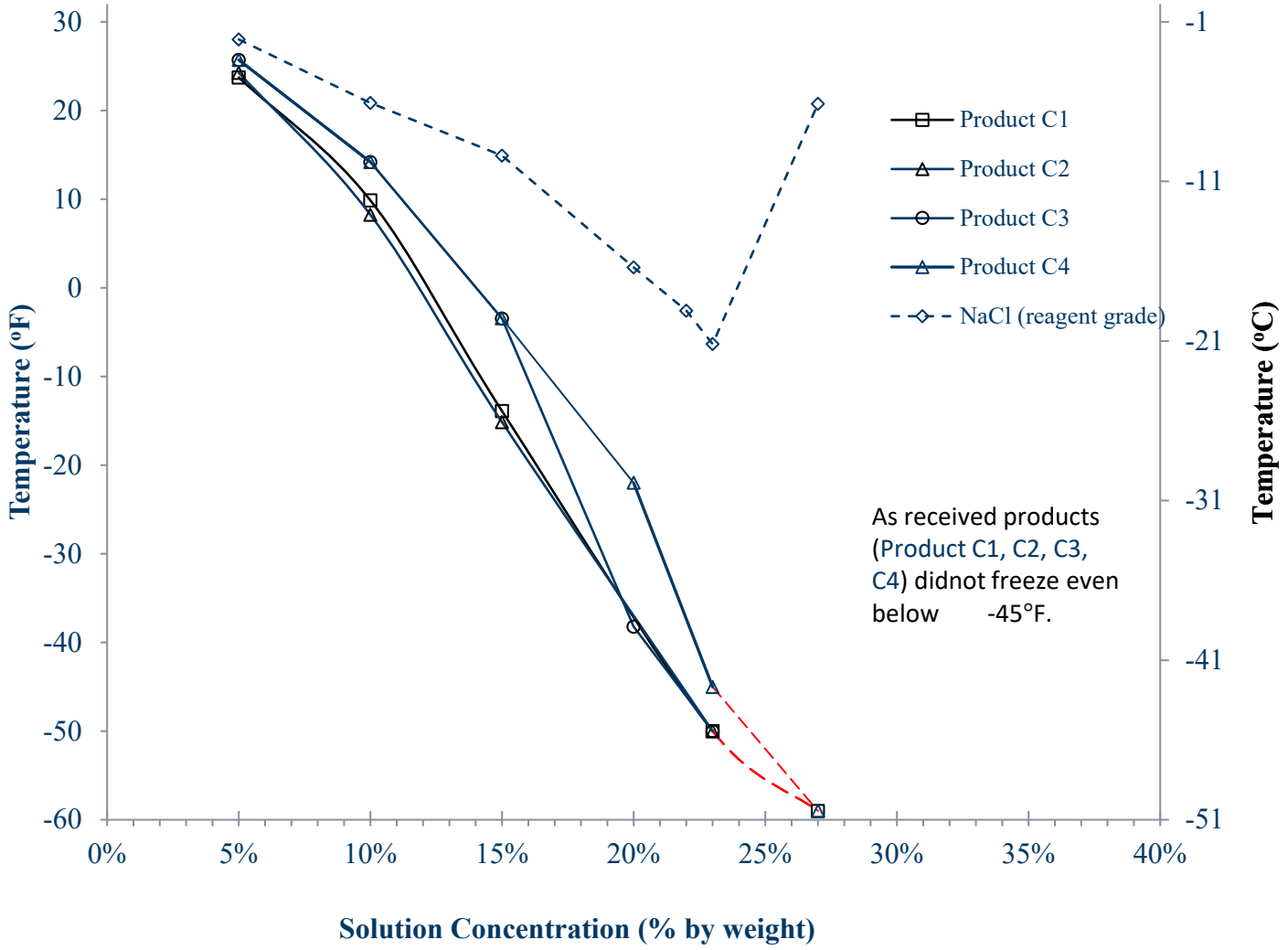
It is not cost-efficient to apply salt (sodium chloride) at pavement temperatures less than 15° F.

Adding sugar??

- Slows the refreezing of ice as temps drop or brine dilutes
- Try at home…
  - Diet Coke / Coke in the freezer – use with caution ;-)
  - Or just by a Coke slush at McDonalds (can’t buy Diet Coke Slush)
- BEET HEET

Enhanced performance with Carbohydrates

Agra-based products **Significantly lowered** the freezing point of water compared to NaCl.



A hypothetical benefit of Carbohydrates

Viscosity

From Wikipedia, the free encyclopedia

The **viscosity** of a fluid is the measure of its resistance to gradual deformation by shear stress or tensile stress.[1] For liquids, it corresponds to the informal concept of "thickness"; for example, honey has higher viscosity than water.[2]

Viscosity is a property of the fluid which opposes the relative motion between the two surfaces of the fluid that are moving at different velocities. In simple terms, viscosity means friction between the molecules of fluid. When the fluid is forced through a tube, the particles which compose the fluid generally move more quickly near the tube's axis and more slowly near its walls; therefore some stress (such as a pressure difference between the two ends of the tube) is needed to overcome the friction between particle layers to keep the fluid moving. For a given velocity pattern, the stress required is proportional to the fluid's viscosity.

A fluid that has no resistance to shear stress is known as an *ideal* or *inviscid* fluid. Zero viscosity is observed only at very low temperatures in superfluids. Otherwise, all fluids have positive viscosity and are technically said to be viscous or viscid. A fluid with a relatively high viscosity, such as pitch, may appear to be a solid.

Viscosity (dynamic)

A simulation of liquids with different viscosities. The liquid on the right has higher viscosity than the liquid on the left.

Common symbols	η, μ
Derivations from other quantities	$\mu = G \cdot t$

Ag-based products tend to be more viscous and stickier than salt brine, mag, etc.

Enhanced Performance

- What does viscosity have to do with deicing?

Agro-based products with higher viscosity than salt brine may have slower **grain boundary penetration** than the salt brine with lower viscosity.

https://cleaninup.com/2013/02/26/science-for-kids-capillary-action/

Enhanced Performance

- *Products with higher viscosity may have more product remain on the pavement surface resulting in reduction in bond strength between ice and pavement surface.*

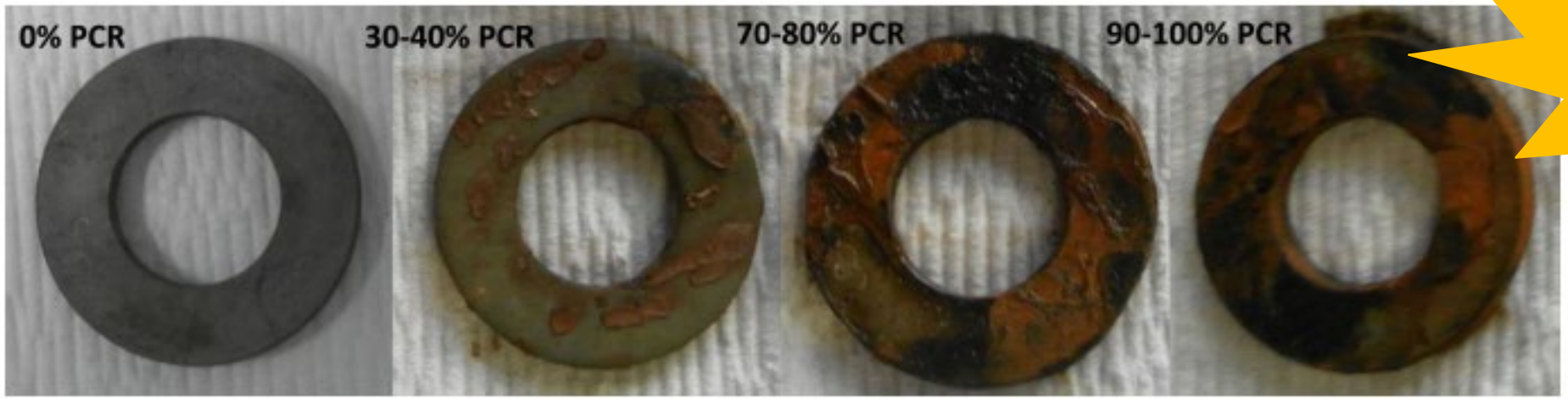
<u>How does this impact us?</u>

- **Black Ice treatment**
- **Serve as pretreatment**
- **Reduce amount of next application**

Enhanced Performance

- But wait there's more….

Ag-based product show much lower corrosion rates to carbon steel.



Less Corrosive

Reduced corrosion rates

Deicer	Original state	PNS Dipping Test		Electrochemical Test		
		Average Corrosion Rate (MPY)	Percentage Corrosion Rate (%)	E_{corr} (mV, SCE)	I_{corr} (μA/cm^2)	Average Corrosion Rate (MPY)
3% Product A1	Solid	50.5	82.0	-683.0	7.2	32.8
3% Product A2	Solid	46.2	74.1	-709.0	8.3	37.8
3% Product B1	Liquid	42.8	80.2	-508.0	5.4	24.6
3% Product B2	Liquid	15.1	30.8	-656.0	8.5	38.8
3% Product B3	Liquid	20.3	34.0	-704.0	7.6	34.7
3% Product B4	Liquid	29.5	52.9	-638.0	11.3	51.5
3% Product C1	Liquid	16.8	31.2	-556.0	6.3	28.7
3% Product C2	Liquid	18.1	38.7	-521.0	4.5	20.5
3% Product C3	Liquid	21.2	45.4	-685.0	8.9	40.6
3% Product C4	Liquid	14.3	30.6	-524.0	5.5	26.2
	Solid	56.3	100	-751.0	12.8	58.4
	Liquid	5.0	0	-	-	-

How many gallons of liquid does MnDOT Use?

- 2012-2017 approx. 3.1 M gallons
- 2018 – 5.3 M
- 2019 – 5.8 M
- 2020 – 6.5 M
  - 212,000 tons of Salt in 2020
- 2021 – 6.6 M
  - 159,000 tons of Salt in 2021 (25% less)

This year …

8.1 M gallons

189,000 tons

Now to the road: Breaking the Bond

- Salt is not used to melt ALL the snow and ice. Just BREAK the bond
  - Plows on truck are primary tool.
  - De-icer makes plowing more efficient
  - Less snow and ice left behind

In a perfect world… “May only take 25% of the salt if we could prevent the bond in the first place”

Terminology of Treatment Types

1. Anti-icing – sometimes referred to as pre-treating – Liquid Only
2. De-icing /Pre-wetting – applying liquids to solids before placement on surface or roadway
   - In stockpile (pre-treated salt)
   - At discharge
3. High Volume Output
   - High amounts of liquids combined with some solids – Slurry / Shake and Bake
   - Direct Liquid Application instead of solids for de-icing – high amounts of liquids

Buildings and Brine Making Equipment - ~~$25 M~~ ~$15M

Cargill

VARITECH INDUSTRIES

Brine Storage and Blending - $10 M

Upgrade Application Equipment - $10 M

Slurry System with In-Box Side Mount Tanks

Saturated salt with an “oatmeal” like consistency

Anti-icing / Pretreating

Pre-Wet / Slurry Equipment

Anti-icing / Pretreating

Mixing liquid near discharge / chutes

Tow plow – added liquid availability

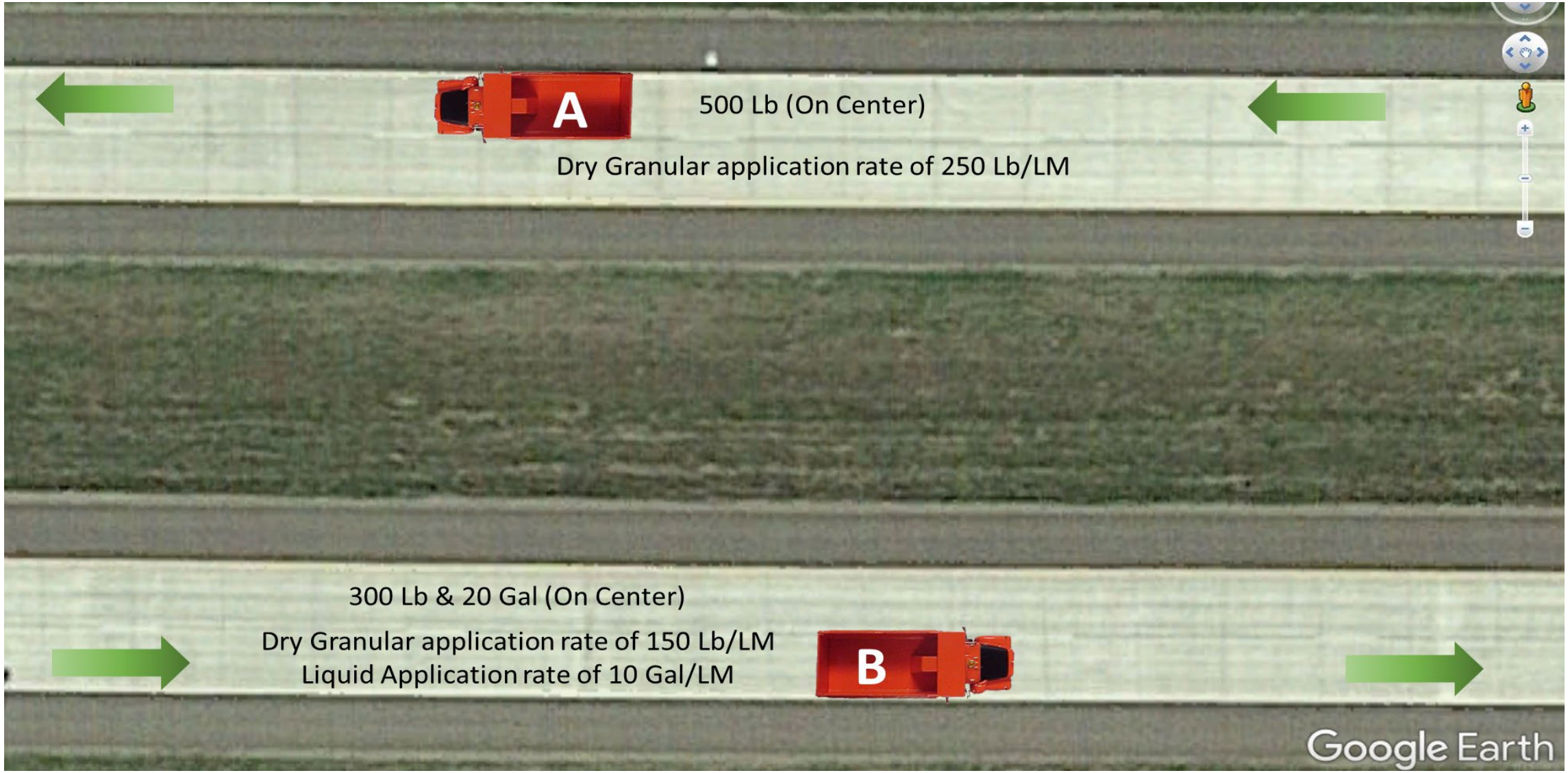
Tow plow – as an anti-icing unit

Direct liquid application

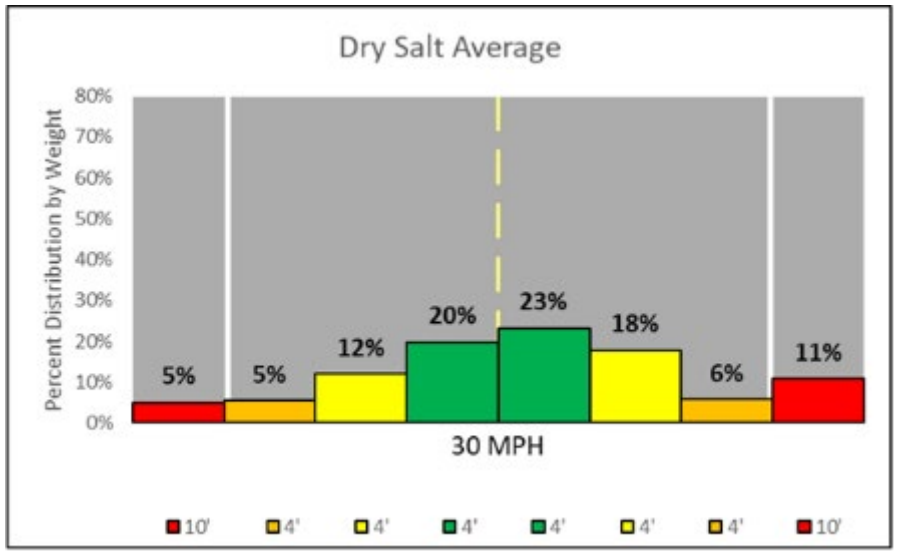
Also working on MDSS model

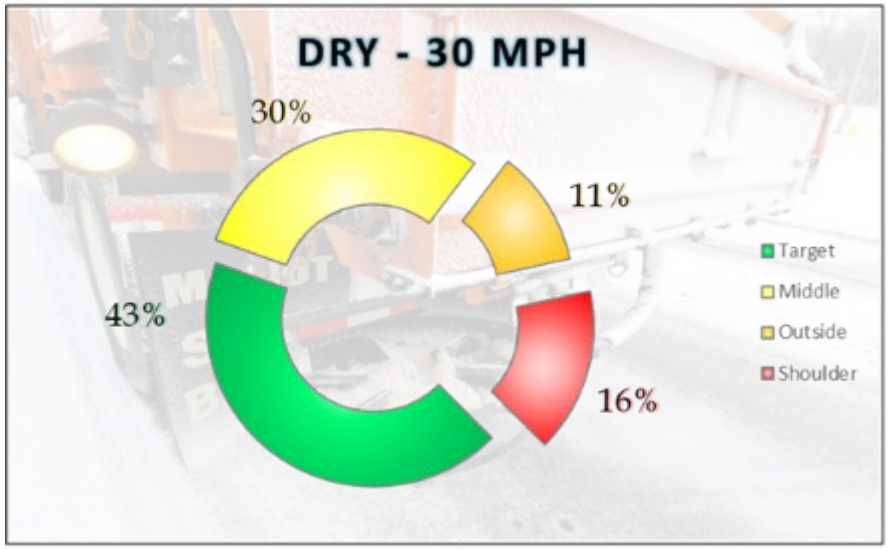
Controled Test Environment – Camp Ripley

Design

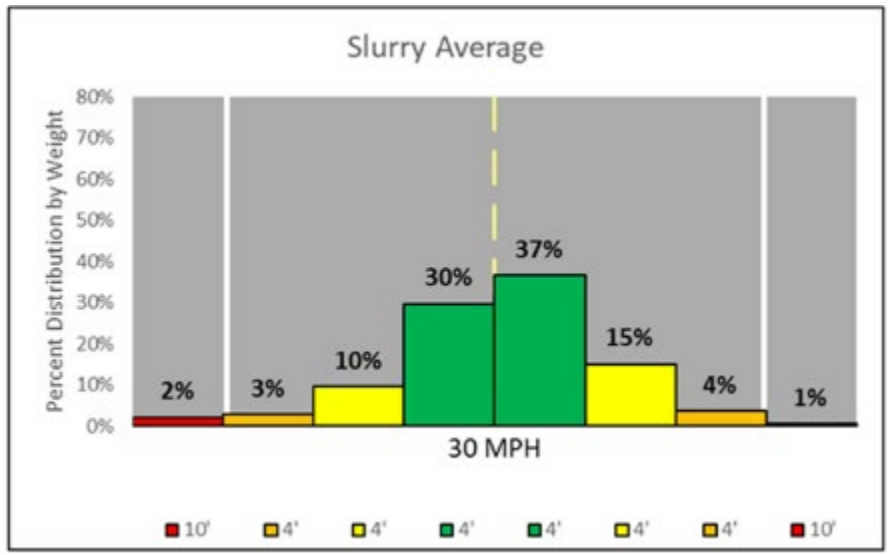

A
500 Lb (On Center)
Dry Granular application rate of 250 Lb/LM
300 Lb & 20 Gal (On Center)
Dry Granular application rate of 150 Lb/LM
Liquid Application rate of 10 Gal/LM
B
Google Earth

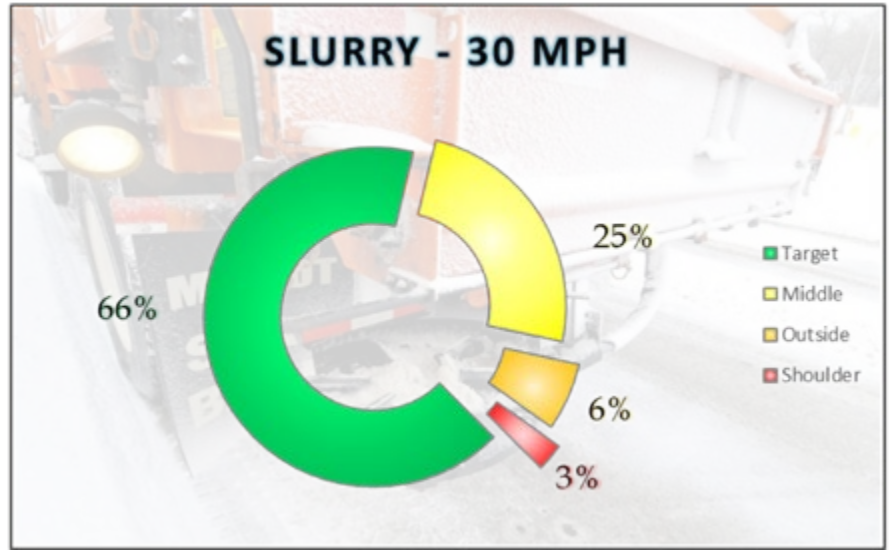
Salt Scatter Result Recap – Summer testing





Illustrates an estimated **30%** Reduction





Camp Ripley Winter Test

- Validated summer test impressions performed on the same track.
- The slurry track utilized **31 percent less salt** than the rock salt track. **345 lbs/mi vs 500 lbs/mi**
- The slurry track returned to a bare lane condition **30% faster** than the rock salt track. **77 min vs 110 min**
- ***Reduced cost and environmental impact while improving mobility and safety!***

Gallons per Ton: A key predictor of success?

- Gallons of Liquid/Ton of Salt Used

	A	B	C	D	E	F	G	H	I	J	K
1	Category	(All)									
2	Sub Category	(All)									
3	District Name	(Multiple Items)									
4	Source Type Name	(All)									
5											
6		**Column Labels**									
7	**Values**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
8	Sum of Gal Liq (total)	2,093,473	4,044,007	3,322,808	2,766,145	3,090,519	3,446,226	5,338,843	5,779,602	6,548,628	6,594,519
9	Sum of Tons Salt (total)	158,081	324,473	280,215	181,022	174,602	201,636	263,713	256,399	212,378	159,103
10	Sum of Liq/Salt ratio	13	12	12	15	18	17	20	23	31	41
11											

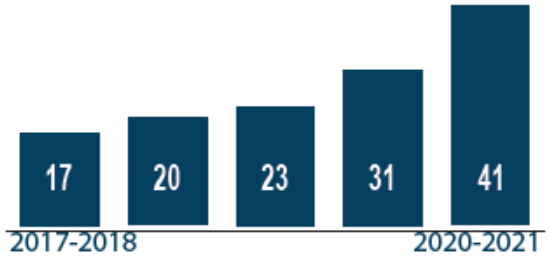
Gallons per Ton: By District

	A	B	C	D	E	F	G	H	I	J	K
1	Category	(Multiple Items)									
2	Sub Category	(All)									
3	Resource Name	(All)									
4											
5	**Sum of Liq/Salt ratio**	**Column Labels**									
6	**Row Labels**		**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
7	D1-Duluth		7	7	10	9	10	10	15	14	32	38
8	D2-Bemidji		9	8	11	10	9	14	19	21	22	19
9	D3-Baxter		19	15	16	22	17	21	27	34	38	41
10	D4-Detroit Lakes		18	16	27	33	39	62	86	106	188	176
11	D6-Rochester		12	12	16	15	17	19	16	24	33	37
12	D7-Mankato		25	31	35	37	46	49	46	86	97	131
13	D8-Willmar		19	17	18	20	21	22	22	22	25	45
14	Metro District		7	7	8	13	11	12	12	14	16	19
15	**Grand Total**		**12**	**12**	**15**	**18**	**17**	**20**	**23**	**31**	**41**	**44**
16												

Gallons per Ton: Setting a goal

	A	B	C	D	E
1	Past				
2	Baseline ratio	13	gals/ ton		
3	Basline salt usage	221,000	tons		
4	Baseline liquid	2,873,000	gallons		
5					
6	Future				
7	Estimate Liquid target	30,000,000	gallons		
8	Est salt savings at goal	30%			
9	Estimated Salt usage target	154,700	tons		
10	Target ratio	194	gal/ton	Use 200??	
11					
12					
13	Salt savings / ratio point	366	tons per year	Use 350??	
14					
15					

Performance Measures Modification

Measures	Target	Result & Score	Trend	Analysis
Reduction in Total Chlorides - Ratio of liquid to solid de-icing chemicals applied to the roadway for snow and ice control	200 gal of liquid/ ton of solid (2027)	41 gal/ton (20-21) ▲		MnDOT research has shown that at rates greater than 100 gal/ton a 25% reduction in total chlorides can be realized. Greater liquid use will also result in quicker clearance times.

Gallons per Ton: Setting a goal

- Is 200 gals per ton achievable??
- The following truck stations have exceeded 200 gals/ton for the entire season in 2021 and/or 2022
  - D4 - Alexandria, Appleton, Evansville, Moorhead and Morris
  - D7 – Mankato, Mapleton, Storden, Wells and Windom

Thank you!

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Gallons per Ton: Camp Ripley

Salt Application Rate (lbs)	Liquid Application Rate (Gallons)												
	2	5	10	15	20	25	30	35	40	45	50	55	60
50	80	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400
100	40	100	200	300	400	500	600	700	800	900	1000	1100	1200
150	27	67	133	200	267	333	400	467	533	600	667	733	800
200	20	50	100	150	200	250	300	350	400	450	500	550	600
250	16	40	80	120	160	200	240	280	320	360	400	440	480
300	13	33	67	100	133	167	200	233	267	300	333	367	400
350	11	29	57	86	114	143	171	200	229	257	286	314	343
400	10	25	50	75	100	125	150	175	200	225	250	275	300
450	9	22	44	67	89	111	133	156	178	200	222	244	267
500	8	20	40	60	80	100	120	140	160	180	200	220	240
550	7	18	36	55	73	91	109	127	145	164	182	200	218
600	7	17	33	50	67	83	100	117	133	150	167	183	200
650	6	15	31	46	62	77	92	108	123	138	154	169	185
700	6	14	29	43	57	71	86	100	114	129	143	157	171
750	5	13	27	40	53	67	80	93	107	120	133	147	160
800	5	13	25	38	50	63	75	88	100	113	125	138	150