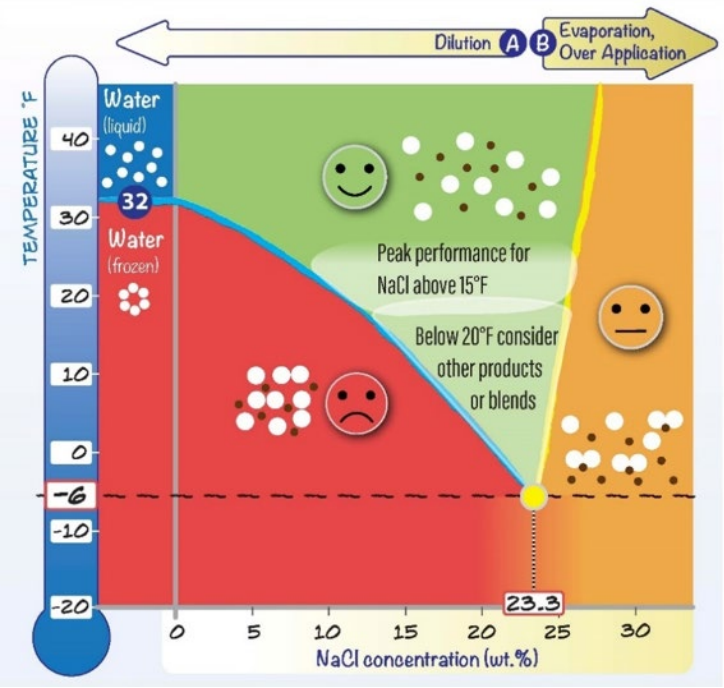
Understanding the Salt Phase Diagram

https://clearroads.org/project/20-02/



WTI-MSU, WSU, Roadtech, Inc.

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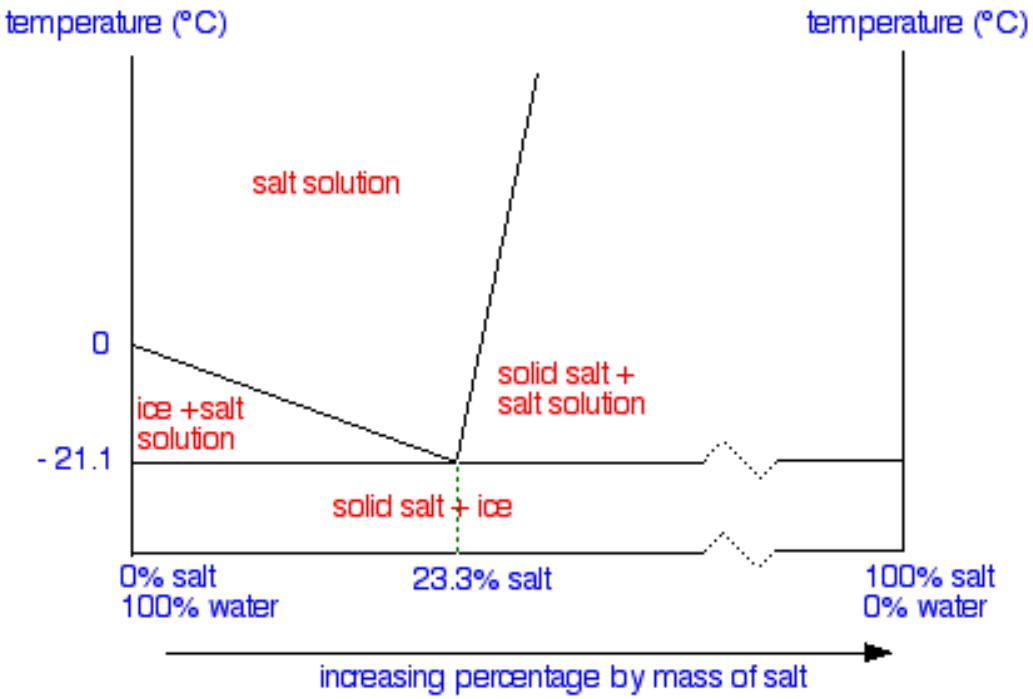
  - Roadtech, Inc.
    - Paul Brown

Why we did the Research



Project Goals

- Develop materials to aid winter maintenance practitioners in making informed decisions on the use of road salts
  - 1 page fact sheet
  - Educational video

Additional Project Work

- Literature Review
- Lab Demonstration
  - Beaker Test
  - Friction/Trafficking Test

Beaker Lab Test Results

- Documented the percentage of ice in salt solutions at varying temperatures
  - Salt brine Solutions: 21%, 22%, 23.3%, 24%, 25%, 26%, 27% and 28% (by weight of aqueous solution).
  - Test temperatures: 32°F (0°C), 30°F (-1.1°C), 25°F(-3.9°C), 20°F(-6.7°C), 15°F(-9.4°C), 10°F(-12.2°C), 5°F(-15°C), 0°F (-17.8°C), and -6°F (- 21.1°C).

Beaker Test Lab Results

		A			B			C			D			E			F			G			H		
	Concentrations	21 wt. %			22 wt. %			23 wt. %			24 wt. %			25 wt. %			26 wt. %			27 wt. %			28 wt. %		
32 F	Ice Formation	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
	Precipitating	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	✓	✓	✓	✓	✓	✓	✓	✓	✓
25 F	Ice Formation	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	✓	✓	✓	✓	✓	✓
	Precipitating	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	✓	✓	✓	✓	✓	✓	✓	✓	✓
20 F	Ice Formation	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	✓	✓	✓	✓	✓	✓
	Precipitating	×	×	×	×	×	×	×	×	×	×	×	×	✓	×	×	✓	✓	✓	✓	✓	✓	✓	✓	✓
15 F	Ice Formation	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Precipitating	×	×	×	×	×	×	×	×	×	×	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
10 F	Ice Formation	×	×	×	×	×	×	×	×	×	×	×	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Precipitating	×	×	×	×	×	×	×	×	×	×	×	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
5 F	Ice Formation	×	×	×	×	×	×	×	×	×	×	×	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Precipitating	×	×	×	×	×	×	×	×	×	✓	×	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
0 F	Ice Formation	×	×	×	×	×	×	×	×	×	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Precipitating	×	×	×	×	×	×	×	×	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
-6 F	Ice Formation	×	×	×	×	×	×	×	×	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Precipitating	×	×	×	×	×	×	×	×	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Beaker Test Lab Results

- Test Temperature: 32°F

F

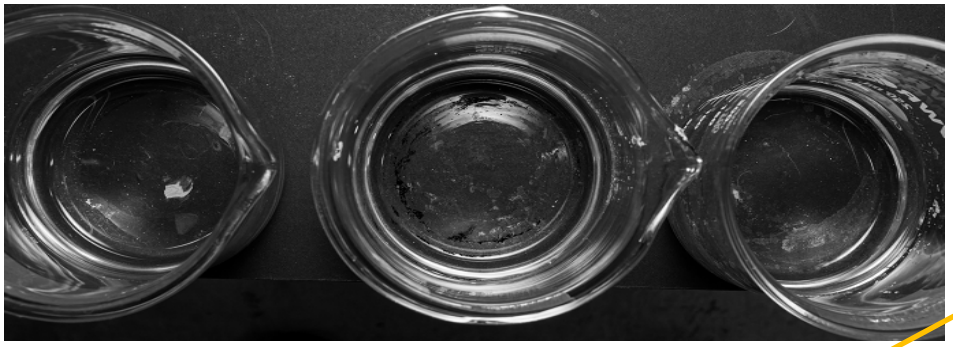
G

H

Beaker Test Lab Results

- Test Temperature: 25°F

F



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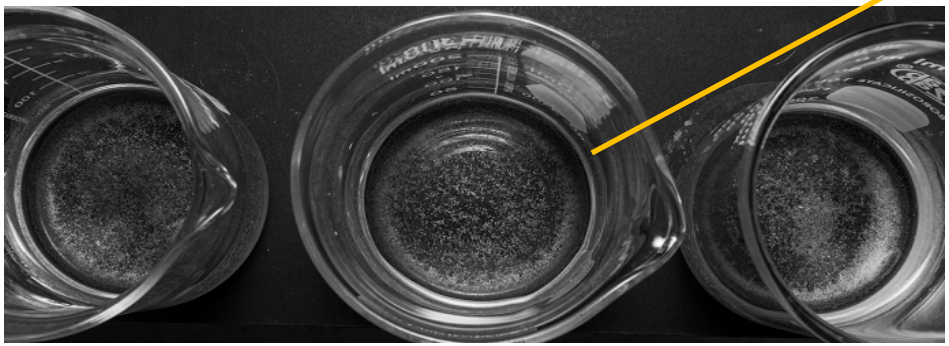

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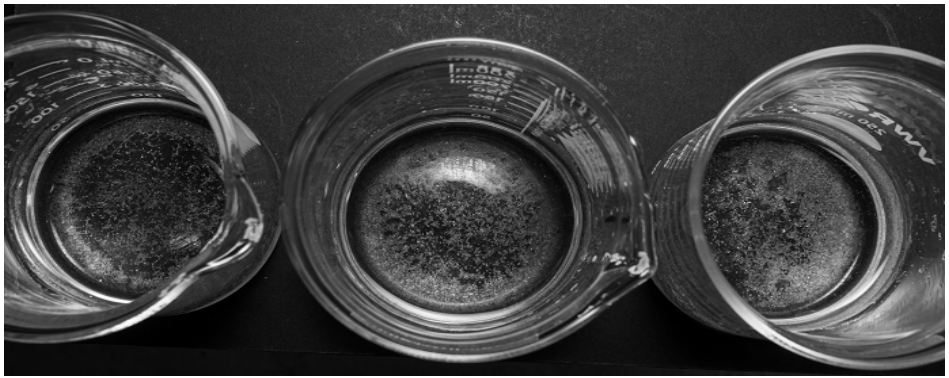
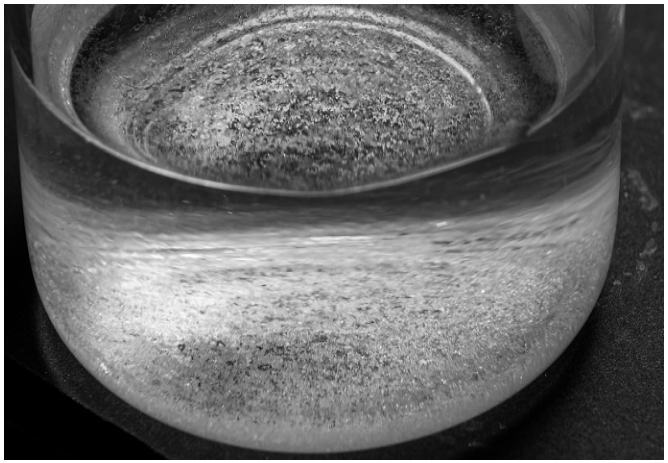
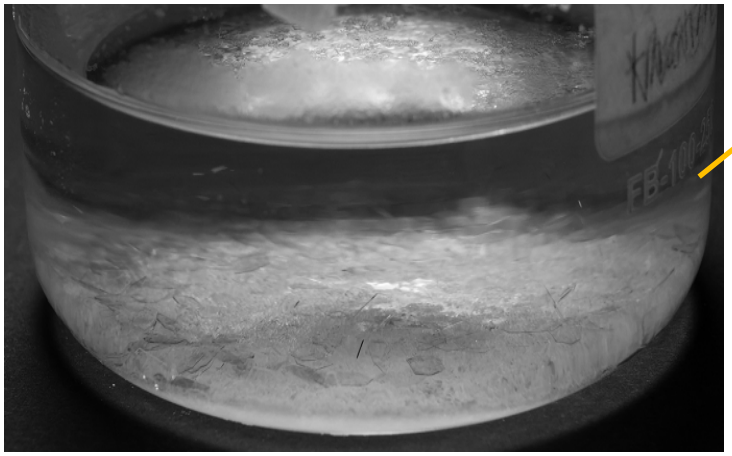




Beaker Test Lab Results

- Test Temperature: 20°F

G



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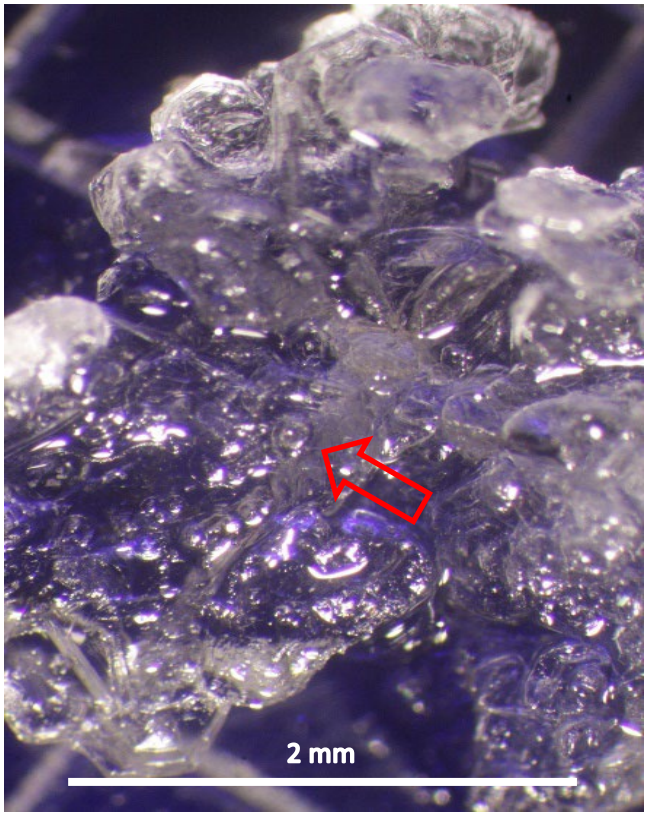
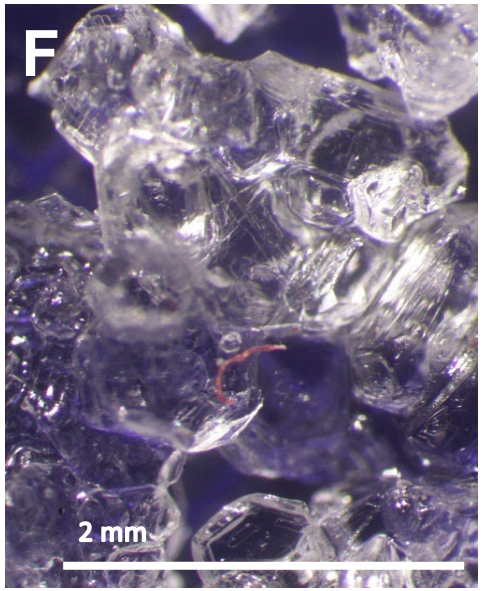
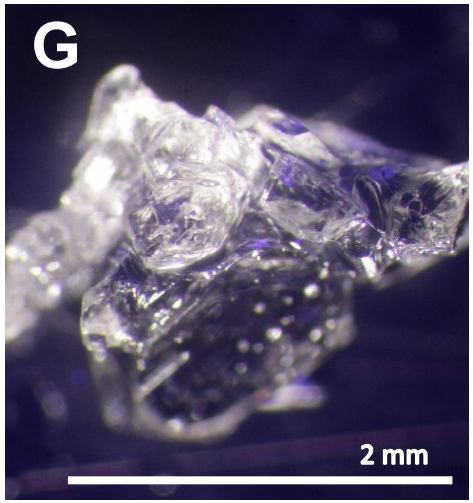
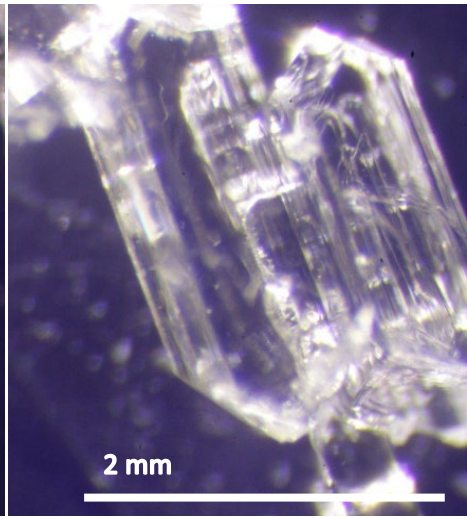


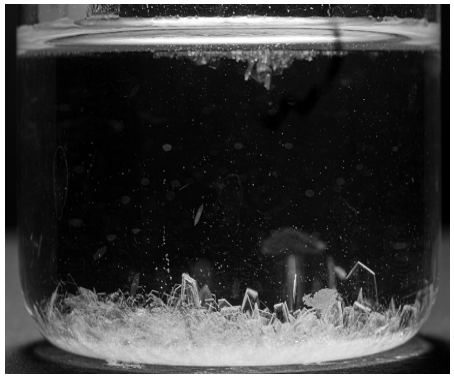
Beaker Test Lab Results

- Test Temperature: 10°F



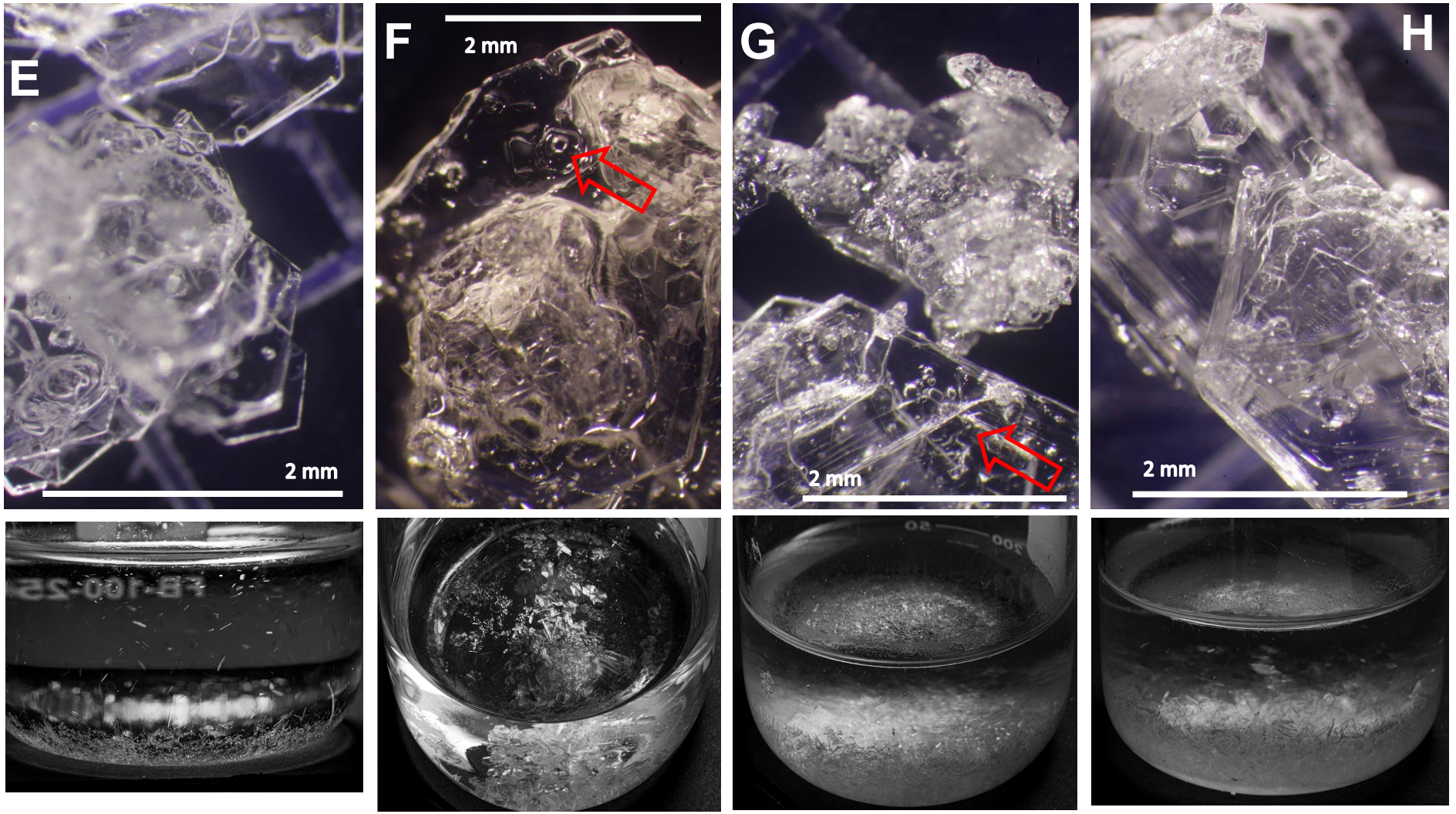






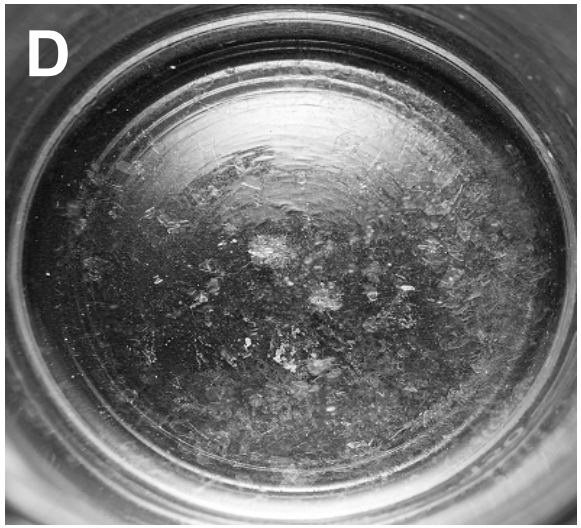
Beaker Test Lab Results

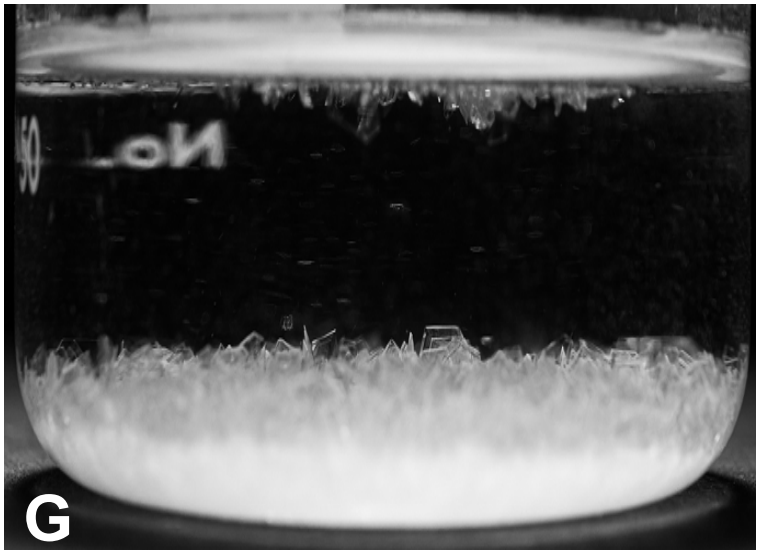
- Test Temperature: 0°F

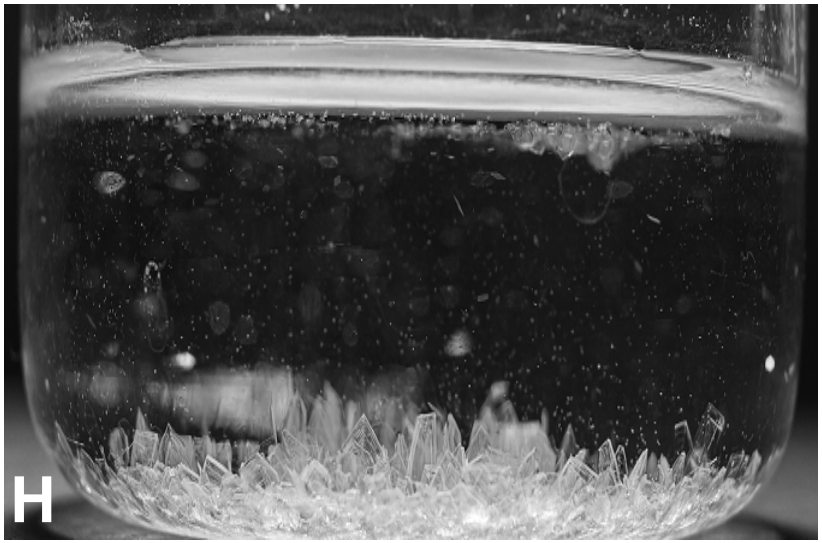


Beaker Test Lab Results

- Test Temperature: -6°F







Beaker Test Lab Results

- General Findings
  - There is an optimal range for salt concentration in Winter Management Operations.
  - As temperatures decreased ice formed in more solutions
  - Ice crystal formation and salt precipitation was not observed at the macro scale for solutions A (21 wt.%), B (22 wt.%), or C (23.3 wt.%)

*Takeaway – More NaCl is not better!

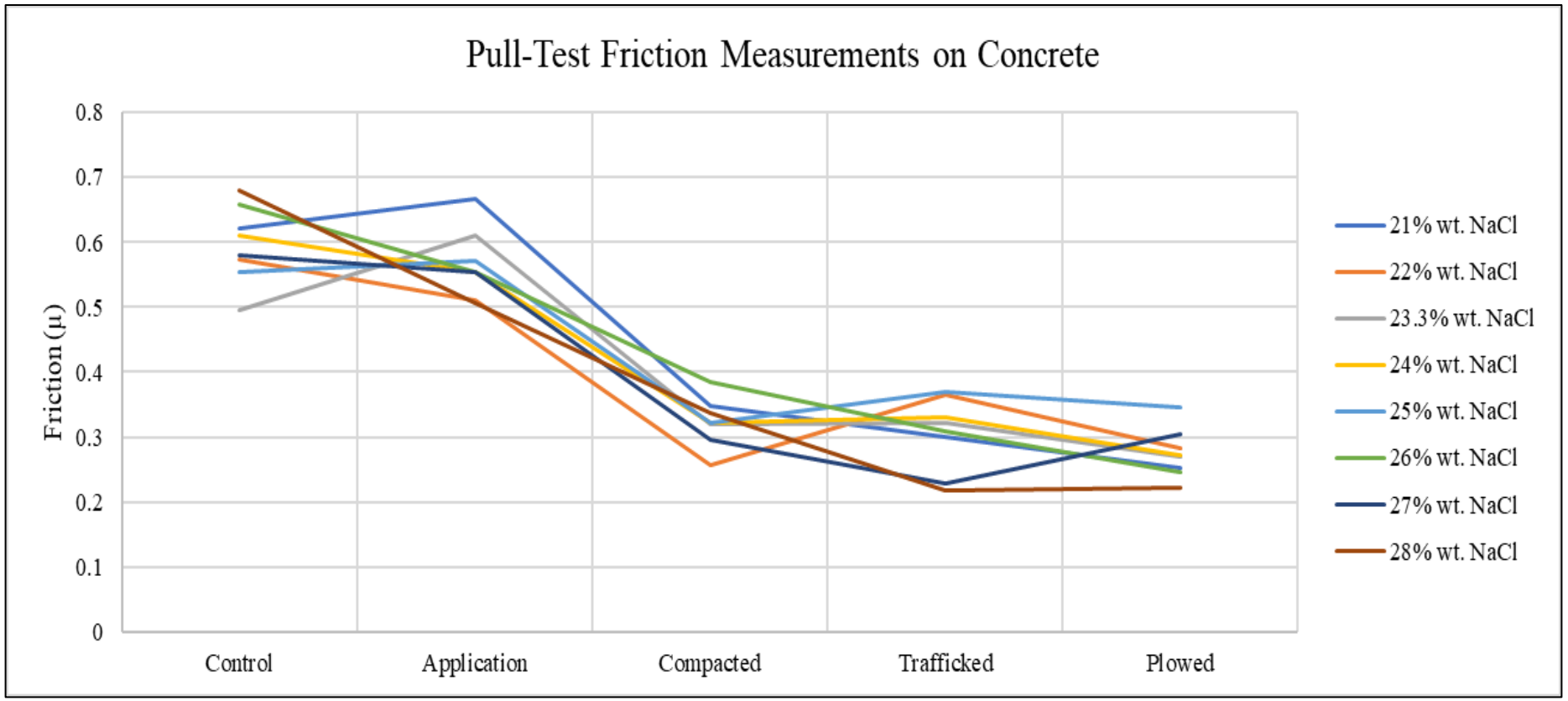
  - On average ~ 18% of the weight of the solutions were ice crystals/precipitated salt.

Friction/Trafficking Testing Lab Results

- Measured pavement friction following application of salt brine at varying concentrations
  - concrete and asphalt pavements
  - salt solution concentrations (21%, 22%, 23.3%, 24%, 25%, 26%, 27%, 28%)
    - applied as anti-icers at 45 gal/l-m
  - Test temperature: 15°F

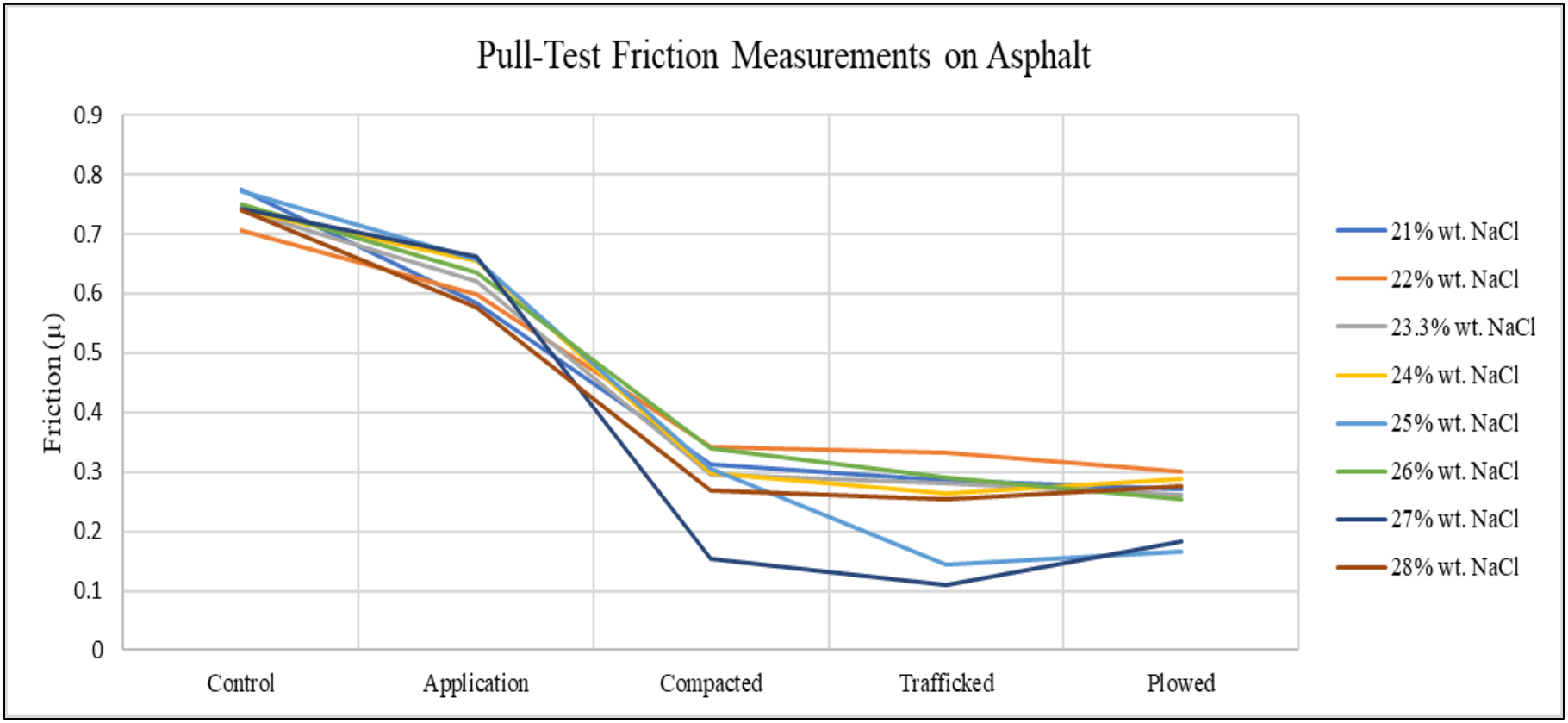
Friction/Trafficking Testing Lab Results

- Friction – pull-test



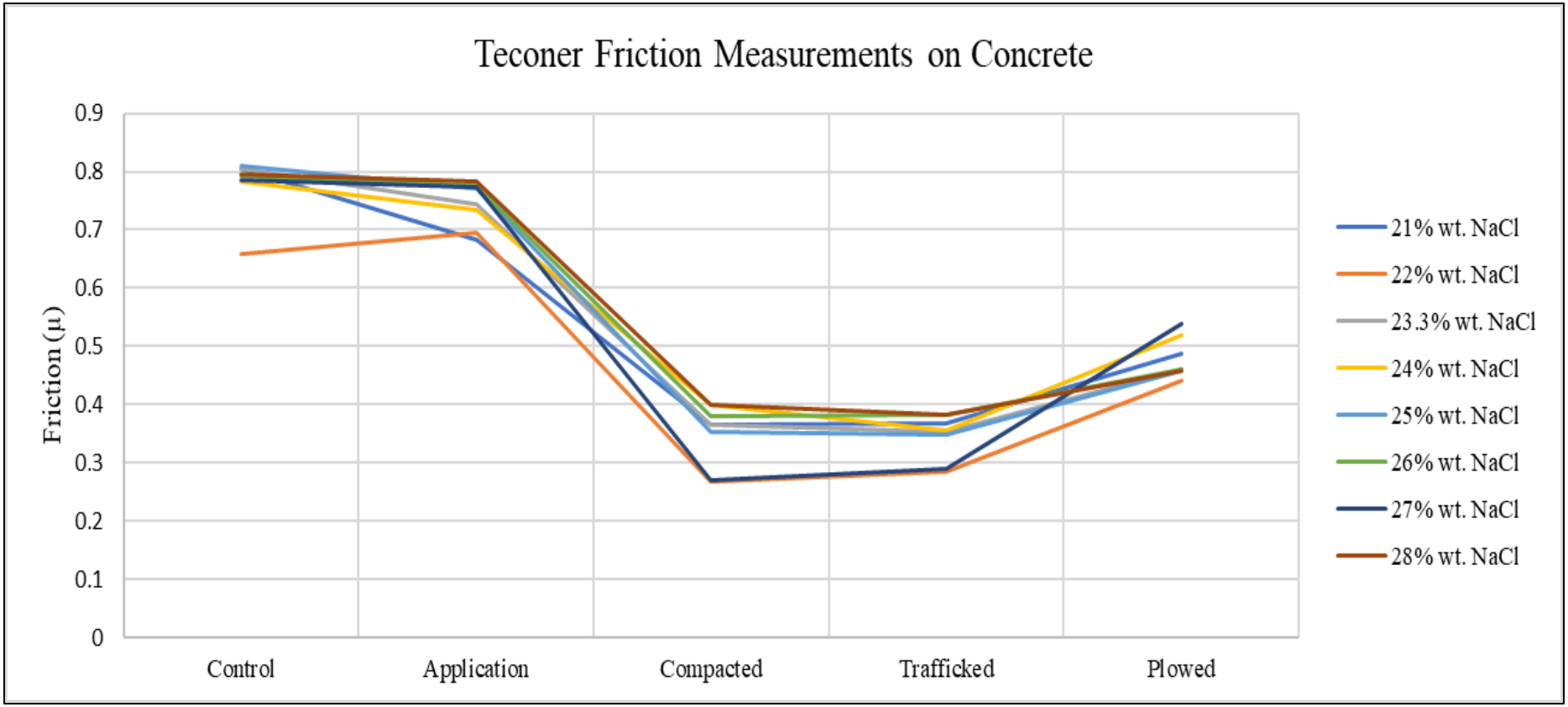
Friction/Trafficking Testing Lab Results

- Friction – pull-test



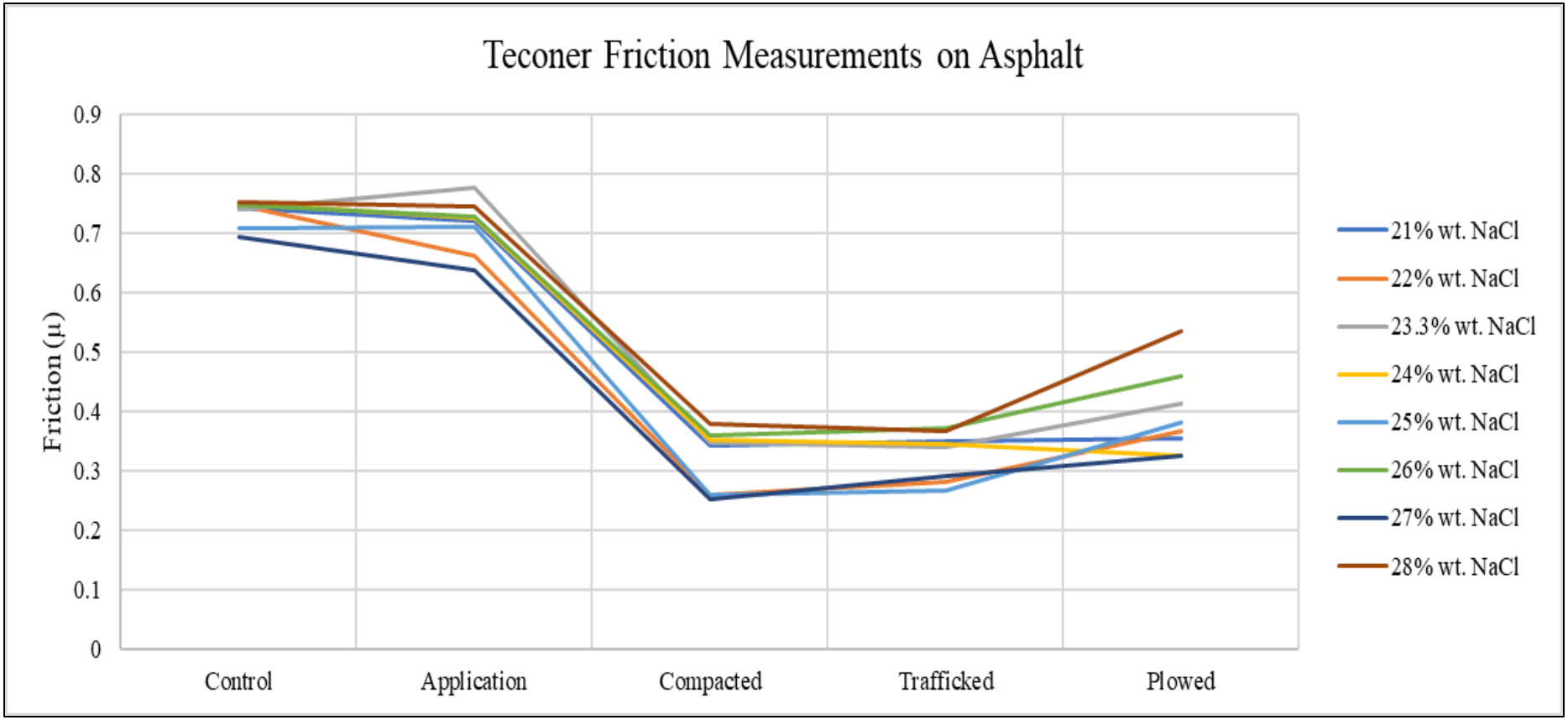
Friction/Trafficking Testing Lab Results

- Friction – Teconer Sensor



Friction/Trafficking Testing Lab Results

- Friction – Teconer Sensor



Friction/Trafficking Testing Lab Results

- Summary of Findings
  - The Teconer sensor provided a more consistent and robust friction data set for analysis, compared to the pull-test friction values.
    - Pull-test – limited data, triplicates
    - Teconer – continuous measurement every second
  - A significant difference in plowed friction values was observed between the concrete and asphalt pavements from the pull-test and Teconer sensor results.

Conclusions

- Salt-phase diagrams are a great information source for studying the chemistry of sodium chloride solutions (brines) and provide key information such as the eutectic point and solubility limit.
- Phase diagrams aid in making informed decisions on deicer type and deicer blend compositions according to needs (e.g., temperature).

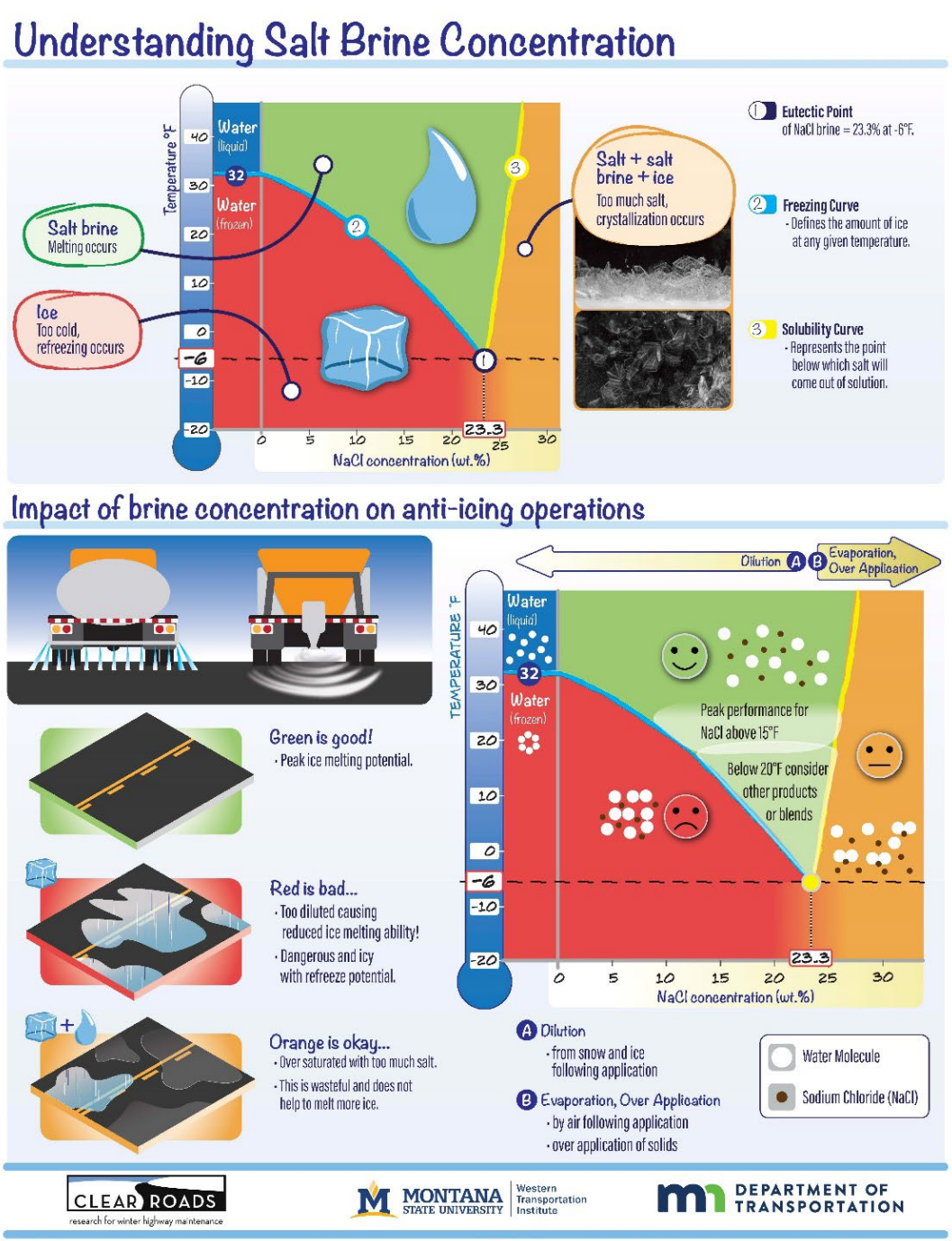
Conclusions

- Results from the lab testing produced great images and video of ice, salt crystal formation, and potentially dihydrate salt in solution.
- Bubbles present in the ice crystals, potentially filled with salt brine, may indicate that the solid phase of ice crystals and salt crystals is not pure, and phases can co-exist.
- Therefore, ice formed in the presence of the salt brine may be weaker than ice formed only in presence of pure water.

Conclusions

- Pavement friction values following the application of salt brine at various concentrations varied by:
  - pavement type
  - salt concentration
  - friction measurement technique
  - snow density
  - humidity

One-Page Fact Sheet



Understanding the Salt Phase Diagram - Educational Video

- https://clearroads.org/project/20-02/

Final Report & Webinar

- The final report and webinar recording of the final report presentation can be found:

https://clearroads.org/project/20-02/

Questions

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