Best Management Practices for Liquid Chloride Storage and Pumping Systems

Final Report

CLEAR ROADS

research for winter highway maintenance

Wilfrid Nixon and Associates

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The objective of this project was to examine and document liquid deicing storage and pump systems currently being used by departments of transportation and public works agencies across the country and best practices for managing and maintaining these systems. Using information gathered from surveys and interviews with transportation agencies and vendors, a concise, user-friendly manual was developed documenting liquid deicer storage and pumping system considerations and best practices including planning for success and for proactively maintaining the equipment involved in these systems. Additionally, the manual presents a range of liquid deicer storage and pumping systems ranging from "starting simple" to "more advanced" which include information on typical equipment, system expectations, cost, and personnel and training requirements for each liquid deicer storage and pump system. Findings from this research effort show that there is no one-size-fits-all liquid deicer storage and pumping system in use across multiple transportation agencies. Instead, these systems have been built to fit each agency's needs and funding. However, the best practices and lessons learned from those operating and maintaining these systems can help support other agencies as they look to either maintain their existing equipment or implement new equipment or technology.

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Best Management Practices for Liquid Chloride Storage and Pumping Systems

Final Report

Prepared by:

Karalyn Clouser
Laura Fay
Neil Hetherington
Western Transportation Institute
Montana State University

Marc Valenti
FUSIONE Corporation

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Office of Research & Innovation
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LIST OF ABBREVIATIONS

AASHTO	American Association of State Highway Officials
DOT	Department of Transportation
EMS	Environmental Management System
GPM	Gallons Per Minute
HDPE	High Density Linear Polyethylene
HP	Horsepower
ITD	Idaho Transportation Department
LOS	Level of Service
OEM	Original Equipment Manufacturer
Poly	Polyethylene
SII	Snyder Industries
TRB	Transportation Research Board
UV	Ultraviolet
V	Volts

EXECUTIVE SUMMARY

The objective of this project was to examine and document liquid deicing storage and pump systems currently being used by departments of transportation (DOTs) and public works agencies across the country and best practices for managing and maintaining these systems. The major deliverable of this project, a concise, user-friendly manual, was developed and documents liquid deicer storage and pumping system considerations and best practices including planning for success, proactively maintaining the equipment involved in these systems, and case studies presenting a range of liquid deicer storage and pumping systems from "starting simple" to "more advanced."

To achieve this goal, the research team conducted surveys and in-depth interviews with both transportation agencies and vendors.

The transportation agency survey received a total of 49 responses (covering 27 states across the U.S.), 34 of these respondents provided details on their liquid deicer storage and pumping systems. This included details on the storage tanks, motors, pumps, and other system components, as well as lessons learned and best practices for operating and maintaining these systems. Key lessons learned from the survey responses included an emphasis on the need for a preventative maintenance plan which includes things like periodically inspecting the liquid deicer storage and pumping system, recirculating the system in the off season, keeping the system clean including cleaning and lubricating pumps, and ensuring that all fittings and valves are fitted properly.

In-depth interviews were completed to gather more detailed information beyond the survey responses from the following ten transportation agencies:

- Alaska Department of Transportation and Public Facilities (AK DOT & PF)
- City of Farmington Hills, Michigan
- Iowa Department of Transportation (IA DOT)
- Idaho Transportation Department, Boise (ITD)
- Kansas Department of Transportation (KS DOT)
- Maine Department of Transportation (ME DOT)
- Massachusetts Department of Transportation MassDOT)
- Nebraska Department of Transportation (NDOT)
- Oregon Department of Transportation (OR DOT)
- South Dakota Department of Transportation (SD DOT)

Highlights from the agency interviews covered a variety of best practices including:

- Unique storage solutions to address extreme temperatures. (AK DOT & PF)
- Building designs that allow for drainage, easy clean up, and movement of tanks. (City of Farmington Hills, MI)
- System lifecycle planning will evolve, be flexible. (IA DOT)

- Statewide position for consistent and efficient maintenance and repair of liquid deicer storage and pumping systems. (ME DOT)
- Develop inspection checklists to aid in regular inspection of the system and documentation. (ME DOT, OR DOT)
- Repurposing of train sheds for pump houses. (NDOT)
- Fiberglass tanks do not fail catastrophically. (KS DOT)
- Polyethylene (poly) storage tank condition testing methods including the marker test, light test, baseball bat method, and scraping the tank. (OR DOT, ME DOT)

In addition, the interviews and survey responses helped identify common spare parts that a maintenance garage may want to keep on hand for emergencies. These include spare pumps, fittings, clamps, seals, valves, and hoses.

In addition to the transportation agency interviews, outreach was conducted to vendors and a total of six vendors provided input:

- Assmann & Poly Processing
- Dultmeier
- GVM
- K-Tech Specialty Coatings
- Sno-Biz
- VariTech

The vendors noted that storage tanks can have an expected lifespan of 15 to 20 years and that recirculation of material in the tank is key to keeping material from settling in the tank and causing challenges. Ideally storage tanks would be located indoors or under a cover to reduce ultraviolet (UV) damage and increase the lifespan. Pumps have an expected lifespan of around two years with proper maintenance which should include flushing the pump periodically and inspection seals and bearings.

The data gathered from the agency and vendor interviews and the survey responses was used to develop the best practices manual which highlights system considerations, system maintenance and repairs, and case studies of liquid deicer storage and pumping systems ranging from “starting out” to “more advanced.” In addition to the manual, an example inspection checklist was developed for liquid deicer storage and pump systems with a brine making unit and for those without, a list of recommended parts to keep on hand at the local level and central level, and a safety considerations poster.

Findings from this research effort filled a gap in the literature by documenting current liquid deicer storage and pumping systems and system components used across the United States and best practices and lessons learned from operating these systems.

Findings show that there is no one-size-fits-all liquid deicer storage and pumping system which is in use across transportation agencies. Instead, these systems have been built to fit each agency’s needs and funding. However, the best practices and lessons learned from those operating and maintaining these

systems can help support other agencies as they look to either maintain their existing equipment or implement new equipment or technology.

Best practices identified include:

- Set yourself up for success by planning for your future operational needs.
- Don’t be afraid to start simply and build your system out over time.
- Be proactive rather than reactive to system maintenance by regularly inspecting and maintaining system components.
- Develop an inspection checklist to ensure that all employees are keeping an eye on the system in a regular and consistent manner.
- Keep a stock of supplies on hand for emergencies to avoid potential downtime.
- Don’t forget about the safety of your employees.

1 INTRODUCTION

Liquid deicers, including salt brines and other liquid deicing and anti-icing products, are primarily used to prevent snow and ice from bonding to a roadway, weaken the snow and ice structure on the road, penetrate packed snow, and reduce material scatter. Liquid deicers provide many benefits to winter maintenance agencies including a reduction in solid material use by up to 50%, quicker roadway recover times, and reductions in person and equipment hours (Fay & Clouser, 2020).

Deicer liquids are generally stored in above ground storage tanks with a pump used for chemical circulation and loading of material onto a truck (Federal Highway Administration, 2007). Several state agencies including Michigan, Minnesota, and New Hampshire have published guidelines for deicer production and management which include guidance on deicing liquid storage, however these guidelines do not go into specific storage equipment configurations, components, costs, and other considerations a transportation agency may want to review prior to purchasing or replacing these systems (Michigan Department of Environmental Quality, 2007) (Minnesota Department of Transportation, 2018) (New Hampshire Department of Environmental Services, 2019).

A preliminary literature search found only a few documents available which describe liquid deicer storage equipment in use, associated costs and benefits, and other operational considerations beyond a few state agency guidelines for deicing production and management or storage system manufacturer websites (Minnesota Department of Transportation, 2018) (New Hampshire Department of Environmental Services, 2019). Key documents found in the literature search are highlighted in Table 1.

Table 1. Literature Search Key Findings

Title	Citation	Key Findings
Salt and Brine Storage Guidance for Road Agency Maintenance and Other Facilities (Michigan Department of Environmental Quality, 2007)	Michigan Department of Environmental Quality (2007) Salt and Brine Storage Guidance for Road Agency Maintenance and Other Facilities.	This document provides guidelines for brine storage including above-ground brine storage tanks. Guidelines cover requirements for secondary containment of material, maintenance and inspection, and what to do in case of a spill.
Deicing Production and Storage Tank System Guidelines (Minnesota Department of	Minnesota Department of Transportation (2018) Deicing Production and Storage Tank System Guidelines. Retrieved on January 4, 2023 from: http://www.dot.state.mn.us/maintenanc	This document highlights several best practices and procedures for installation and operation of salt brine and other deicing systems including generator tanks, storage tanks, and automated deicing systems including

Transportation, 2018)	e/files/salt_sustainability/Deicer%20tank%20manual%202018.pdf	recommendations for purchase, siting of tanks, and long-term maintenance and inspection.
Storage and Management of Deicing Materials (New Hampshire Department of Environmental Services, 2019)	New Hampshire Department of Environmental Services (2019) Storage and Management of Deicing Materials Environmental Fact Sheet. Retrieved on January 4, 2023 from: https://www.des.nh.gov/sites/g/files/ehbemt341/files/documents/2020-01/dwgb-22-30.pdf	This fact sheet covers basics on storage and handling of deicing materials, including guidelines on brine storage and management. Of note related to liquid storage tanks, tanks must be designed with materials that are compatible with salt and the system must be designed such that a plumbing failure does not result in release of deicing materials.
Pass the Salt: Efficient Snow and Ice Management (Axiomatic, 2018)	Axiomatic (2018) Pass the Salt: Efficient Snow and Ice Management. Retrieve on January 4, 2023 from: https://www.uvm.edu/seagrant/sites/default/files/uploads/Santoso_GreenSnowProHandouts_sm.pdf	This document highlights winter maintenance best practices including very high-level recommendations on proper material storage based on New Hampshire Department of Environmental Services Guidelines which work to reduce soil and groundwater contamination.
Anti-Icing Equipment Recommendations and Modifications (Iowa Department of Transportation, 2012)	Iowa Department of Transportation (n.d.) Anti-Icing Equipment Recommendations and Modifications. Retrieved on January 4, 2023 from: https://publications.iowa.gov/43131/	This guide documents anti-icing equipment and modifications needed for Iowa DOT's anti-icing program, this included recommendations for storage of anti-icing material. While one storage tank was not recommended over another, the guide provides a basic calculation for determining storage tank needs based on the total lane miles treated (1.5 times the total lane miles to treat times the recommended gallons per lane mile = amount of storage needed).

This project aimed to fill this knowledge gap. The goal of this project was to examine and document liquid deicing storage and pump systems currently being used by departments of transportation (DOTs) and public works agencies across the country and best practices for managing and maintaining these systems.

This report is organized as follows:

Chapter 2: Methodology will describe the work completed for this research effort.

Chapter 3: Survey and Outreach Results will provide a summary of findings from a survey of transportation agencies and outreach to liquid deicer storage and pumping system vendors.

Chapter 4: Follow-Up Interviews will detail findings from follow-up interviews with transportation agencies and liquid deicer storage and pumping system vendors.

Chapter 5: Best Practices Manual will provide a high-level overview of the standalone best practices manual which was developed as a part of this research effort.

Chapter 6: Summary will provide a high-level overview of findings from this research effort and provide recommendations for future research.

The appendices include the survey instrument and detailed responses (Appendix A) and the agency and vendor interview questionnaire and interview summaries (Appendix B).

2 METHODOLOGY

This chapter describes the methods used to develop the survey, interviews, and best practices manual for this research effort.

2.1 SURVEY AND OUTREACH

A survey was conducted to examine and document liquid deicing storage and pump systems currently being used by departments of transportation (DOTs) and public works agencies across the country and identify best practices for managing and maintaining these systems. The survey was developed using Qualtrics, a web-based survey tool to collect information from DOTs and public works agencies. The developed survey was distributed on September 15, 2023 to the Clear Roads Technical Panel and Members states, the American Association of State Highway Officials (AASHTO) Snow & Ice List Serv, the Transportation Research Board (TRB) Winter Maintenance Committee, the American Public Works Association Winter Maintenance Group, and other relevant transportation agencies and organizations. The survey was closed on October 25, 2023.

A summary of the survey results and outreach to liquid deicer storage and pumping system vendors can be found in 3. The survey instrument and detailed survey responses and vendor outreach questionnaire can be found in APPENDIX A – Agency Survey Instrument and Detailed Results.

2.2 INTERVIEWS

Follow-up interviews were conducted to capture additional information beyond the survey responses to create a better understanding of current practices for operating and maintaining liquid deicer storage and pumping systems, including best practices and pitfalls to avoid. The following agencies were targeted for follow-up interviews throughout the months of January and February 2024.

- Alaska Department of Transportation and Public Facilities (AK DOT & PF)
- City of Farmington Hills, Michigan
- Iowa Department of Transportation (IA DOT)
- Idaho Transportation Department, Boise (ITD)
- Kansas Department of Transportation (KS DOT)
- Maine Department of Transportation (ME DOT)
- Massachusetts Department of Transportation MassDOT)
- Nebraska Department of Transportation (NDOT)
- Oregon Department of Transportation (OR DOT)
- South Dakota Department of Transportation (SD DOT)

A list of questions was developed to help guide these interviews. A summary of the agency interview findings is provided in 4. The agency interview questionnaire and detailed interview notes are provided in APPENDIX B – Agency and Vendor Interview Questionnaire and Interview Summaries.

In addition to following up with agencies, several vendors and manufacturers were identified in the survey responses. An outreach questionnaire was developed and sent to all identified vendors and manufacturers. This questionnaire was also sent out to the AASHTO Snow and Ice Listserv to ensure that vendors and manufacturers that were not previously identified could have the opportunity to respond. Follow up interviews were conducted to gain information on equipment installation, equipment considerations, cost, maintenance, and lifecycle.

The following vendors and manufacturers participated in this outreach effort.

- Assmann & Poly Processing
- Dultmeier
- GVM
- K-Tech Specialty Coatings
- Sno-Biz
- VariTech

An overview of the vendor and manufacturer outreach findings is provided in 4. The vendor and manufacturer questionnaire and detailed responses are provided in APPENDIX B – Agency and Vendor Interview Questionnaire and Interview Summaries.

2.3 BEST PRACTICES MANUAL

Using information collected from the literature, survey of transportation agencies, outreach to liquid deicer storage and pumping system vendors, and follow-up interviews a best practices manual was developed which highlights system considerations, best practices for operating and maintaining these systems, and presents a range of liquid deicer storage and pumping systems ranging from “starting simple” to “more advanced.” A high-level overview of the best practices manual is provided in 5The manual was provided as a standalone deliverable which can be downloaded on the Clear Road project website here: https://www.clearroads.org/project/22-02/.

3 SURVEY AND OUTREACH

This chapter provides a high-level overview of the agency survey results. The survey instrument and detailed survey responses, and vendor outreach questionnaire can be found in APPENDIX A – Agency Survey Instrument and Detailed Results

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The research team conducted an online survey of DOTs and public works agencies. Responses were collected from September 15, 2023 to October 25, 2023. The survey was designed to collect information on liquid deicing storage and pump systems currently being used by departments of transportation (DOTs) and public works agencies across the country and to identify best practices for managing and maintaining these systems.

A total of 49 responses were received from 27 states across the U.S. Only 34 respondents provided information on their liquid deicer storage and pumping systems. These respondents ranged from City Public Works Departments to State DOT.

3.1 TANK INFORMATION

The following storage tank manufacturers were identified: Assmann and Poly Processing, Dura-Cast, KBK Industries, Norwesco, Heartland Agricultural, GVM, Snyder Industries (SII), and Varitech. An equipment supplier was also identified, Sprayer Specialty, this supplier carries Norwesco tanks according to their website.

Storage tank capacities ranged from 1,500 gallon to 20,000-gallon tanks. With tank sizes ranging from 8 feet in height to 17 feet in height and ranging from a diameter of 6 feet to 12 feet. The majority of respondents are utilizing polyethylene tanks. Only two respondents (Kansas DOT and North Dakota DOT) are utilizing fiberglass tanks, and both respondents also reported using higher capacity tanks (10,000-to-20,000-gallon tanks).

3.2 MOTORS

The following truck fill motor manufacturers were identified by survey respondents: AMT Pump Company, Baldor Reliance, Belden, Connex, Dayton, Goulds, Leeson, and Marathon. The following equipment suppliers were also identified: Cargill and Dultmeier, and Henderson.

Motor sizes ranged from 3/4 horsepower to 10 horsepower with 5 horsepower motors being the most commonly used. Both single and three phase motors are used. Voltage requirements ranged from 115V to 480V with 220 V being the most commonly used.

3.3 PUMPS

The following truck fill pumps manufacturers were identified by survey respondents: AMT Pump Company, Banjo, Cargill, Dayton, Goulds, MP Pumps, Pacer, and Scots. The following equipment suppliers were identified as selling pumps: Brine Masters, Dultmeier, and Sprayer Specialties.

Pump size ranged from 1/2 horsepower to 10 horsepower or pump discharge ranging from 50 gallons per minute to 750 gallons per minute. Many respondents noted that they use a stainless-steel pump. Several respondents noted that their pump outlet was 2 inches or 3 inches.

Twenty-seven respondents, or about 80%, reported that they have a standard maintenance practice for their liquid deicer storage and pumping system. Fifteen respondents had a standard maintenance practice that included pre-season, mid-season, and post season protocols. Seventeen respondents noted that they had a checklist for inspection of their liquid deicer storage and pumping system, at most agencies this inspection checklist was completed by Snow & Ice Staff.

3.4 LESSONS LEARNED

Respondents were asked to share their best lesson learned from operating their liquid deicer storage and pumping system. Several respondents noted the need to keep the system clean including the need to clean and lubricate pumps or flush out pumps at the end of the season, utilizing fresh water to clean out the system after every use, and using clean salt as debris can cause several issues. One respondent noted that a large opening at the base of the tank was useful for cleaning out the system. Another noted that for spills a more “vaulted” floor is needed to clean. Several respondents also noted the need for consistent preventative maintenance or checks of the system, this included circulating the system during the off season rather than letting it sit. One respondent specified that a lack of a preventative maintenance program was the biggest cause of failure and that implementing a preventative maintenance program helped them grow and improve their operations.

Some respondents noted the need to have a system champion or limit the number of staff who utilize the system in order to ensure that individuals who operate the system have some specialization and operate/maintain the system in a consistent manner.

Other lessons learned include taking the time to ensure that fittings and valves are fitted properly and labeling all lines and valves with the correct flow pattern to quickly isolate a problem if one does occur. One respondent noted that hard lines should be protected from snow sliding off of tanks and that they have found their tanks need to be replaced about every 12 years.

A common modification was some kind of system cover. This included covering the hopper, installing a metal shed over tanks to avoid snow damage, or utilizing indoor tanks to prevent UV damage. However, one respondent noted that while having indoor tanks was a benefit, having the tanks indoors did make replacement more difficult.

3.5 FAILURES AND FIXES

Several respondents noted failures as a result of needing a preventative maintenance plan including the need for keeping the system cleaned and circulated and checking pumps and fittings regularly. Massachusetts DOT specifically noted that adding a preventative maintenance program allowed for growth in operations with minimal failure.

One respondent noted the need for operator training in order to reduce operator errors and another noted assigning personnel to keep the system regularly cleaned and maintained.

Several respondents noted failures in the pump system. One respondent noted a need to switch from a plastic pump to a stainless-steel pump, noting that the plastic pump failed after one year of use. Another respondent noted that changing from flexible lines to rigid lines where possible helped improve flow and durability. Idaho Transportation Department noted that after a tank rupture due to age (20 years), they updated to a scheduled tank replacement after every 12 years.

Maryland DOT SHA noted issues with their system auger jamming during cleanout due to using dirty salt. Because of this issue they now require salt vendors to provide solar salt.

A respondent from the California Department of Transportation noted a challenge with using an integrated system (Accubrine Automated Brine Maker), where if there is a malfunction, they were unable to dispense brine to the truck even when there was material in storage. This required installing a backup truck fill system which would allow them to fill their trucks even if the integrated system is down.

Through the survey responses, a total of 24 vendors and manufacturers were identified (Table 2).

Table 2. Identified Vendors and Manufacturers

Vendor/Manufacturer	Supplier vs. Manufacturer (OEM)	Tanks	Motors	Pumps	Fittings/Piping
Ace Roto Mold	OEM	X			
AMT Pump Company	OEM		X	X	
Assmann and Poly Processing	OEM	X			
Baldor Reliance	OEM		X		
Banjo	OEM			X	X
Brine Masters	Supplier			X	
Cargill	Supplier		X	X	
Connex	OEM		X		
Dayton	OEM		X	X	
Dultmeier	Supplier		X	X	
Dura-Cast	OEM	X			

Vendor/Manufacturer	Supplier vs. Manufacturer (OEM)	Tanks	Motors	Pumps	Fittings/Piping
Goulds	OEM		X		
GVM	OEM	X			
Heartland Agricultural	OEM	X			
Henderson	Supplier		X		
KBK Industries	OEM	X			
Leeson	OEM		X		
Marathon	OEM		X		
MP Pumps	OEM			X	
Norwesco	OEM	X			
Pacer Pumps	OEM			X	
Scots	OEM			X	
Snyder Industries	OEM	X			
Sprayer Specialty	Supplier	X		X	

4 FOLLOW-UP INTERVIEWS

This chapter provides a high-level overview of the agency interview and vendor outreach findings. For a more detailed summary of each interview and resources shared from interviewees, see APPENDIX B – Agency and Vendor Interview Questionnaire and Interview Summaries.

4.1 SUMMARY OF AGENCY INTERVIEWS

4.1.1 Storage Tanks

4.1.1.1 Fiberglass vs. Poly Storage Tanks

Most interviewees were using polyethylene (poly) storage tanks, only two interviewees utilized fiberglass storage tanks (Kansas DOT and Nebraska DOT).

The Kansas DOT uses 10,000- and 20,000-gallon fiberglass tanks over poly tanks due to a previous experience with a tank failure. Fiberglass storage tanks will not fail catastrophically due to the fibers in the material, although they may get smaller cracks and seep or leak. The life expectancy of these tanks is around 20 years. Kansas DOT has found the cost to be very competitive with polyethylene tanks, particularly with the tank sizes that they use. Kansas has a local fiberglass tank manufacturer, which is used by the oil industry, that they were able to work with.

The Nebraska DOT utilizes 10,000- and 20,000-gallon fiberglass reinforced tanks from KBK Tanks which is based out of Kansas. Fiberglass tanks were chosen over polyethylene tanks because NDOT found that while they can be more expensive, they were a better return on investment as they held up better over time and had more precise fittings. Whereas when polyethylene tanks age and surplus out, they become brittle and break as they are moved.

4.1.1.2 Storage Tank Age and Tank Replacement

Storage tank lifespans ranged from 13 years to 25 years, with 20 years old being the most common storage tank age. Generally, tanks that are located outdoors have a lower lifespan due to ultraviolet (UV) damage and exposure to harsh winter conditions.

Several interviewees noted having their storage tanks on a replacement plan. Idaho Transportation Department (ITD) District 3 has their storage tanks on a 10-year replacement cycle (closer to 12 years by the time the tank is actually replaced). This replacement plan was implemented after a District had four storage tanks rupture at two separate sites. All tanks were stored outdoors and were south facing, thus they were exposed to a lot of sunlight. Maine DOT purchases around 6 to 9 storage tanks each year; their tanks are replaced on a 20-to-25-year cycle. Maine DOT purchases poly tanks with crosslink construction which helps to prevent the tank from rupturing due to age.

Iowa DOT currently replaces their poly storage tanks as issues arise (e.g., visible cracks). When storage tanks are replaced, Iowa DOT will assess the system footprint and consider whether a 2,500-gallon tank

be replaced with the same tank or should two 2,500-gallon tanks be replaced with a single 5,000-gallon tank. Most of their liquid deicer storage and pumping systems grew from a more grassroots effort, where most locations started small and added storage as needed. Iowa DOT is working to establish an inventory management plan to have tanks on a replacement cycle instead of their current reactionary approach to replacing tanks when the need arises. However, getting the storage tanks on a replacement cycle has been difficult due to the number of tanks, incomplete inventory, the varying age of tanks, the different types of tanks, and the need for funding to get such a system in place. Ideally, they want to be in a position to replace around 10 percent of their tanks each year.

Nearly all interviewees mentioned that when storage tanks reach the end of their lifecycle, they will be cut up and taken to the land fill. Few are repurposing storage tanks, some exceptions included Kansas DOT occasionally reusing tanks at new storage locations when tanks still had some life and Maine DOT who previously gave storage tanks to towns for repurposing (one was used to store water and another was used at a location just starting out with liquid deicers).

4.1.1.3 Inside vs. Outside Storage Tank Placement

Generally, tanks that are located indoors have a greater lifespan due to protection from ultraviolet (UV) damage and weather.

City of Farming Hills, Michigan, Iowa DOT, Maine DOT, and Oregon DOT all had at least some of their storage tanks located indoors. The City of Farmington Hills, Michigan had a “liquids room” addition built onto their maintenance facility in 2015. This addition has concrete flooring with a hardener additive (to help with chloride deterioration). The flooring in this addition is sloped to the east to allow liquids or debris that spill to move down the slope to a pit area that can be pumped out. Iowa DOT noted that they are moving tanks indoors wherever it is practical to reduce UV deterioration of their tanks and to improve working conditions for maintenance staff.

With outdoor tanks, the tank will experience clouding or surface deterioration which causes the tank to become brittle. This becomes an issue when attempting to move the tank and is when tank failure is most likely.

Iowa DOT noted challenges with their indoor storage tanks, where extracting a tank that needs to be replaced can be difficult without disrupting operations.

Around a quarter of Maine DOT’s storage tanks are located indoors. Those that are outdoors tend to have a shorter lifecycle due to UV exposure and weather damage. Oregon DOT has tanks both indoors and outdoors. The western portion of the state gets a lot of rain so they will use coverings (e.g., metal cover, storage sheds) to keep rain from pooling in secondary containment areas, where feasible.

Kansas DOT noted that their fiberglass tanks are all located outdoors and are generally not covered. One district had purchased a tarp to cover their storage tanks due to concerns with UV deterioration. It was noted that fiberglass tanks could be painted to help with UV protection.

Due to extreme temperatures in the winter, Alaska DOT & PF in Fairbanks utilize spray foam with black elastomeric weather-proof coating to insulate and protect their tanks from the elements. This coating was applied in 2015 and has held up well without any required maintenance. With this covering on the tanks, they have not experienced issues with UV damage.

4.1.1.4 Maintenance and Cleaning of Storage Tanks

Most interviewees were using a vactor truck with flexible hosing to flush out and clean storage tanks. Several noted that the debris that comes out of the brine tanks can have the consistency of concrete and be difficult to move.

Both Iowa DOT and South Dakota DOT Sioux Falls Area contract out cleaning of their storage tanks. Iowa DOT contracts the cleaning to an environmental company who utilizes a vacuum excavator to clean the tanks. However, the DOT notes that this cost is high and when considering the cost for cleaning, it could be more effective to buy an oversized tank and plumb it high and leave the debris settled at the bottom, then replace the tank after its lifecycle (e.g., every 15 years). South Dakota DOT Sioux Falls Area shop hires a local septic cleaning company who comes in and uses a vacuum truck to clean out the brine maker. During the winter when they are making a lot of brine, they will schedule this cleaning ahead of time to maintain 24/7 operations.

Kansas DOT noted that a benefit of their fiberglass tanks is that they have a flanged opening near the bottom which allows for cleaning material off the floor of the tank (instead of needing to go through the top). They also have a port at the center of the base of the tank which is used for mixing or recirculation of material. Through this port, three one-inch peri jets are run to the inside bottom of the tank to help circulate material.

Nebraska DOT specifically noted that workers are not sent into the tank for cleaning as this is dangerous. Instead, their fiberglass storage tanks have a large manhole about 4-feet off the ground which can be opened, and pressure washers are used to blow debris off the tanks.

4.1.1.5 Storage Tank Testing Methods

Several interviewees noted that they do not have a specific method to test storage tank condition beyond a visual inspection for cracks and damage.

At Maine DOT their Snow & Ice Supervisor uses some tests to examine the condition of tanks. These include “reading the cracks” and scraping the tank with a screwdriver. If powdery material is scraped off, then the tank may be suffering from deterioration. These tests are done where the tank generally sees the most damage from any UV radiation or weather including at the top of the tank near the dome or the side of the tank more exposed to weather.

Oregon DOT Maintenance Environmental Management System (EMS) developed a manual which includes information on inspecting poly tanks for wear and damage. The guidance notes that common

stress points on stationary tanks include fittings, impact points, near the top, and the “knuckle” (bottom bend). The EMS Manual includes details on three methods to test storage tank conditions.

> The **Black Marker Test** can be used to inspect a specific area on the tank. In this test, a black, water-soluble marker is used to fill in a small area of concern. Before the marker dries, excess ink is wiped off with a cloth. Stress cracks will remain black after the excess ink is wiped off.
>
> The **Light Test** can be used to inspect the entire tank, however, it is not as effective on larger tanks. In this test method, product is removed from the tank and a bridge light is lowered to shine through the tank so that it can be examined for stress points (fine webs or lines).
>
> The **Bat Test** can be used to verify damage to areas identified in other tests. For this method, all product is removed from the tank. A bat is used to strike the area where stress cracks are observed, tank sides, or areas that receive the most sunlight. The tank should flex and rebound. After testing with a bat, the tank should be rechecked for cracking.

The Bat Test was suggested to ITD District 3 by their storage tank manufacturer as a method for testing storage tank condition. The District has not tested the tanks using this method yet. After experiencing storage tank failures, District 3 did forensic work but could not find anything that stood out as to why the tank failed (no dust, powder, or microcracks on the surface).

4.1.1.6 Secondary Containment

Most interviewees noted that they did not have or need secondary containment for their liquid deicer storage and pumping system. For those that did utilize a form of secondary containment, concrete containment walls were common (ITD District 3 and Maine DOT). For those agencies that had secondary containment in place, it was often required by another state agency.

At one location in Nebraska at a DOT facility, storage tanks are located near a retention pond/storage basin (which rarely has standing water) but is primarily used for snow storage and collection of run off. The location could serve as secondary containment if a failure occurred.

For Oregon DOT, secondary containment varies across the state. Oregon DOT utilizes a questionnaire to help prioritize storage locations as high, medium, or low risk for secondary containment based on weather, property features, and whether there are sensitive resources nearby (see Figure 1). Specific guidance is provided on secondary containment from Oregon DOT. Generally, containment must be able to hold 105% of the largest storage tank at the location. Secondary containment can vary from a low berm, to cast-in-place concrete walls, to eco-blocks with a spray-in liner.

RISK ASSESSMENT FOR DEICER TANK LOCATIONS

Instructions

1. Look at the site where the tanks are or will be located.
2. Pick the answer from Box 1 and 2 that best describes the site and surrounding area. Write the number of points that corresponds to the description in the blank column.
3. Add the points from all statements in Box 3 that describes the site. (12 possible points)
4. Add the points for Boxes 1, 2, and 3. Compare total points to the risk level for the site.

LOCATION	DATE	
Box 1- Drainage Around Tank		Points for Box 1
Direct discharge *A large spill would flow into a piped system or a ditch that discharges to surface water or a flood plain*	**7 points**	
Indirect discharge *A large spill would flow across the ground toward surface water*	**3 points**	
Infiltration *A large spill would flow across or sink into the ground*	**1 point**	
Box 2- Presence of Surface Water *(within ¼ mile downslope)*		Points for Box 2
Small freshwater stream, wetland, closed basin, flood plain, or lake	**7 points**	
Large freshwater stream or river	**3 points**	
No fresh surface water	**1 point**	
Box 3- Bonus Points (total the points for all statements that apply to the site)		Points for Box 3
A spill would flow across the ground **and** the adjoining downslope property is agricultural or residential (non-ODOT)	**3 points**	
A spill would flow toward a protected waterbody (e.g. scenic waterway, reservoir, or significant community involvement)	**3 points**	
Property is not owned by ODOT	**3 points**	
A well is located onsite within 250' of tank or the property is located in a wellhead protection zone or groundwater restriction area.	**3 points**	
Risk Level for the Site		**Total Points**
14 - 26 points High	Secondary containment **must** be provided.	
9 - 13 points Medium	Secondary containment should be provided. Evaluate local conditions such as natural barriers and soil.	
2 - 8 points Low	Secondary containment is not required.	

ODOT Maintenance Yard Environmental Management System (EMS) Policy and Procedures Manual
Risk Assessment for Deicer Tank Locations – Version 2 – December 2019 Page 1 of 1

Figure 1. Oregon DOT Risk Assessment for Deicer Tank Locations

4.1.2 Pumps and Motors

4.1.2.1 Pump and Motor Lessons Learned

Several lessons learned specific to pumps and motors were shared throughout the interviews. Generally, it was noted that pumps last on average a couple years. The City of Farmington Hills, Michigan noted that pump failures are generally seen due to seals deteriorating in the pumps and liquids getting into the bearing area.

Kansas DOT originally used covers for the pumps but experienced increased corrosion due to the salty environment. The cover prevented pumps from being washed by rain, thus they have since abandoned covering them.

Nebraska DOT has shifted from mechanical pumps to electric pumps and noted that this was one of the best modifications that they have made to their system. They use old railroad buildings for their pump houses (can insulate and use a pump house heater as needed to prevent freezing). Nebraska DOT has found that electric pumps are easier to clean, pump faster, and remain set up and ready to go in the pump house.

The South Dakota DOT Sioux Falls Area brine making facility uses two different pump manufacturers, a John Blue pump to transfer from the inside to outside storage and to load the tow plow, and a Banjo pump to load trucks. They had previously used stainless steel pumps which lasted around 2 to 3 years, , however they switched to lower cost poly pumps due to the expense of steel pumps. The Sioux Falls Area uses a Lovejoy connection between the pump and motor to save the motor if the seals break and to limit pressure in the pumps. This allows them to swap out pumps easily in case of a failure and has increased the service life of the poly pumps.

4.1.2.2 Maintenance and Cleaning of Pumps and Motors

End of season maintenance for pumps generally included flushing out the pump with water and using a salt neutralizer. As an additional corrosion preventative, Kansas DOT uses RV antifreeze and Massachusetts DOT District 3 uses windshield washer fluid in their pumps during summer storage.

Additional maintenance for pumps and motors included things like restoring paint or taking apart the pump to clean and replace parts. At the end of the season, Nebraska DOT will take trash pumps back to the main shop and take them apart to clean and replace or repair parts. Nebraska DOT noted that electric pumps are easier (compared to mechanical pumps), requiring a wash out, or blow out, and inspection for salt residue or corroded parts.

At Maine DOT, pump and motor setups are mounted onto metal plates that the welding shop created. The Supervisor's maintenance shop has an inventory of these pump and motor setups ready in case of emergency. This allows the Supervisor to efficiently swap out a failing pump or motor then take the broken system back to the maintenance shop for repairs, reducing the need to complete work outside. Repairs will include taking the system apart, repairing broken components, sandblasting, and painting.

The City of Farmington Hills noted that when time allows, they will use a salt neutralizer on the exterior of the motors and restore the paint to protect the exterior of the motor.

4.1.2.3 System Piping

All interviewees were using hard piping for the system and flexible piping from the tank to the truck. Maine DOT previously tried hosing with wire running through it but had issues with those hoses getting run over by the trucks. Once the hose was run over, the wire in it would not allow the hose to bounce back and the wire could puncture the hose causing a leak. They have since switched to flexible hosing which has been more resilient, requiring less replacement. For hoses, Nebraska DOT previously used the cheapest options. Over time with building tank farms and learning what works, they have found that bend radius was important and that mid-price range flexible hoses (composite rubber hoses purchased from Dultmeier) worked best. Nebraska DOT replaces their hoses each year at the end of the winter season.

ITD District 3 found that hard piping needs to be replaced on average every 6 years due to UV damage. They noted that the PVC will start to get a metallic look to it and that is when they know it needs to be replaced. The District has had issues with snow sliding off of the storage tanks and causing damage to the system plumbing. To address this, at a few sites they are using old traffic signs to make A-frame coverings for the plumbing to help shield the system from snow. This covering has the additional benefit of providing some protection from UV damage.

The City of Farmington Hills, Michigan uses air to purge liquids out of their fill point hoses that fill the equipment tanks. This idea was taken from an organics supplier who used air to clean out and purge supply hoses from the truck to the bulk storage tanks. All supply lines to the fill points have one-way valves to prevent back flow of liquids and/or contaminate other liquids while utilizing the air purge system. The DPW notes the air purge system needs to be watched carefully, as too high of air pressure or too much air into the supply tanks can be detrimental to the whole system. Ensure fill tanks have adequate venting to prevent damage to system. The air purge system is very helpful for 2 and 3-inch fill point hoses which can get very heavy when filled with liquids. Typically, operators will use approximately one fourth of the air volume and watch and listen for bubbles to verify the air is all the way through the fill hoses. They will then carefully open the fittings slowly to let the air bleed out of the fill hoses.

4.1.3 Overall System Inspections and Maintenance

Several interviewees noted that they prioritize keeping their system and brine house clean and organized. Most did not have a formal maintenance and inspection checklist that they used, however highlighted the need to have a few maintenance personnel who are trained to operate the system and act as system “champions.” These individuals will regularly check the system for leaks and other issues and can report issues as they occur but will also ensure that maintenance and inspection of the system is done in a consistent manner.

Generally, most interviewees noted that their liquid deicer storage and pumping system is inspected in the spring at the end of the winter season and again in the fall before the winter season.

For Iowa DOT, each garage will conduct an inventory of their liquid deicer storage and pumping system each spring including noting each piece of equipment, its condition, and checking it off on an inventory list. If maintenance is needed, it will be completed during the spring or summer. In the fall, they will complete another inventory and inspection of all equipment including giving the system a once over as things are filled back up, checking for drips or leaks, documenting needed repairs, and planning for maintenance as needed.

ITD District 3 recirculates any material in the storage tanks once a month. They will also complete a basic inspection including checking for any leaks or cracks and conducting a high-level look over of the system. If any issues come up during this inspection, they are reported to the facility manager via email, then the building maintenance crew will complete the repair.

Kansas DOT's end of season maintenance practices generally include draining and cleaning tanks, pumps, motors, and lines, checking valves, cleaning and using RV antifreeze or another rust inhibitor in pumps, and coating electrical connectors with dielectric grease.

Both Maine DOT and Massachusetts DOT District 3 have found that having one person handle repairs and conduct regular maintenance has ensured that their liquid deicer storage and pumping systems are maintained in a consistent manner, have eliminated downtime, and have allowed for growth in operations with minimal failures.

Maine DOT has a statewide Snow & Ice Supervisor who travels around the state managing the repair and maintenance of the liquid deicer storage and pumping systems. This position also handles contracting and purchasing of storage tanks and materials, plumbing on storage tanks, and motor and pump work. In the winter the Snow & Ice Supervisor will travel onsite to repair or replace systems as needed. During the summer, the Supervisor is able to plan out maintenance activities with a goal of visiting each location every other year. Locations are prioritized based on an inspection checklist which is completed by transportation workers at each site. This statewide position is unique, and they have found it reduces the number of people who are repairing and maintaining these systems which can help to ensure things are done in a consistent manner, reduces challenges with necessary tools and parts, and is a good use of time and resources.

Similar to Maine DOT, MassDOT District 3 also has one maintenance person who does repairs and maintains all liquid deicer storage and pumping systems. They have found that the less people touching these systems, the fewer issues they have. This maintenance person will check the liquid deicer storage and pumping systems in the spring and fall. This includes running through a mental checklist – checking hoses, gaskets, and each component of the system as well as checking for leaks. The system filters are checked and replaced if any holes are found. At the end of the winter season, pumps are drained, and then filled with windshield washer fluid as corrosion prevention. Additionally, ball valves are exercised and oiled (every tank has multiple shut off valves to help isolate any issues). Storage tanks are not

drained and washed regularly. The entire routine takes around one hour per system. A single shed is used to house spare parts for repairs. If something goes wrong at a depot, they will call up the maintenance person who will take parts to the depot and complete the repair.

4.1.3.1 Inspection Checklists

Both Maine DOT and Oregon DOT have developed formal documented checklists to inspect their liquid deicer storage and pumping systems.

At Maine DOT the Snow & Ice Supervisor sends out an inspection checklist to each site in April (see Figure 2). Transportation workers at each site will use this inspection checklist to go over the storage and pumping system, note any issues, and send the checklist back to the Supervisor. This inspection checklist includes documenting information about each system component (e.g., storage tank, pump, motor), what liquid is in the tank and how much, check the system for leaks, and generally inspect each component of the system (e.g., hoses, hose clamps, pump, pump cover).

During the spring and summer months, each shop will complete a building inspection every month. This inspection includes taking time to recirculate any liquids in the storage tanks, work ball valves and spray with fluid film, check for any leaks, and check for any rust. If anything is rusted, they are supposed to clean it with a wire brush.

Recirculation of tanks is expected to vary depending on the size of the pump, the procedure includes several calculations to determine how long product should be circulated.

Formula: # of gallons in the tank/pump gallons per minute

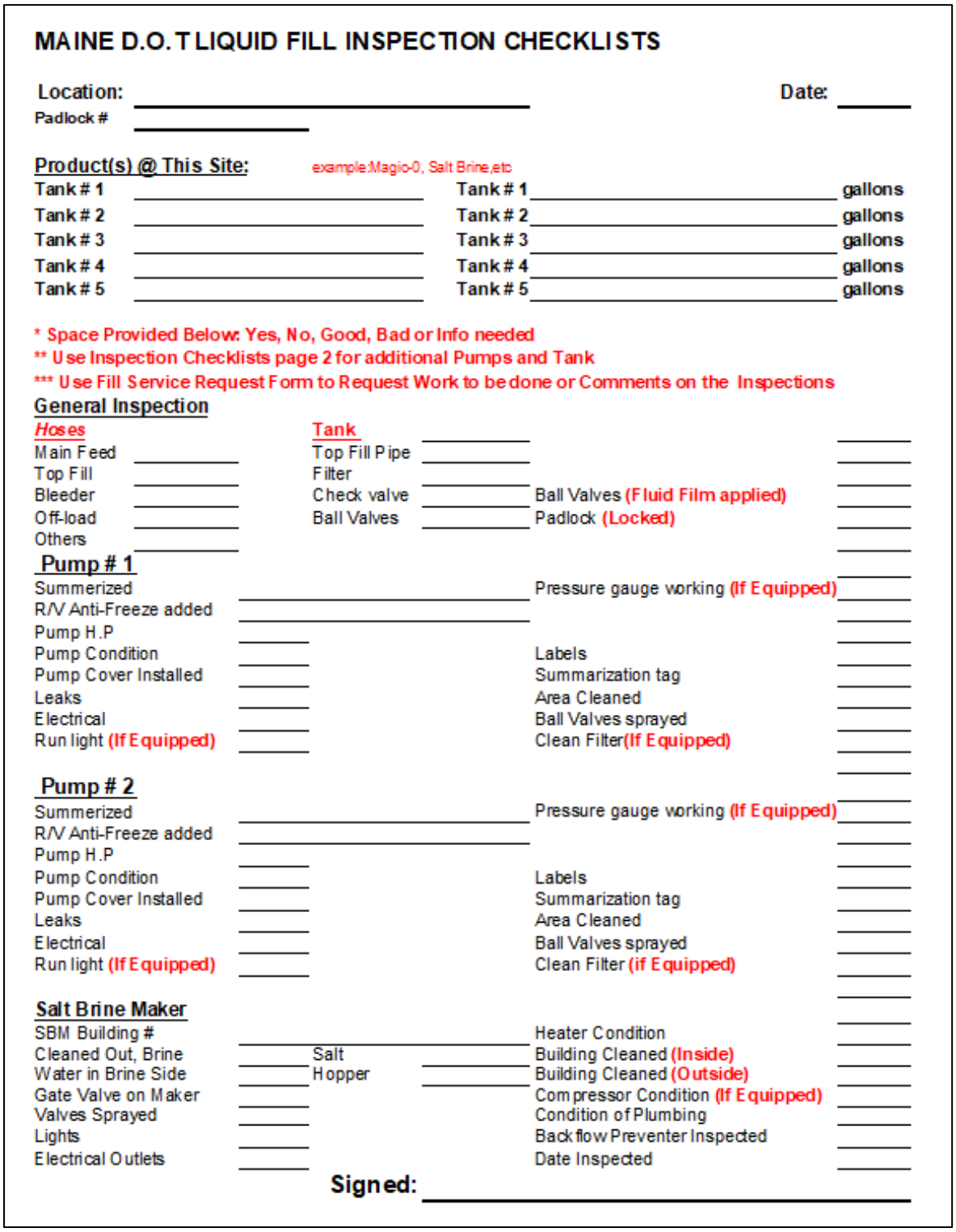
- *It is then recommended that an additional 15 minutes is added to ensure proper mixing.*

Size	Gallons Per Minute
¾ HP Motor/Pump	30 GPM
1.5 or 2 HP Motor/Pump	55 GPM
5 HP Motor/Pump	100 GPM

Once the Supervisor receives these checklists, they can prioritize locations that need attention during the summer months.

The checklist, shown in Figure 2, was developed by the Snow & Ice Supervisor and has been modified over time as systems have changed. Each site is audited every three years. As a part of this auditing process the auditor will ask to see all of the inspection checklists.

Figure 2. Maine DOT Inspection Checklist



MAINE D.O.T LIQUID FILL INSPECTION CHECKLISTS

Location: _____ **Date:** _____

Padlock # _____

Product(s) @ This Site: example:Magic-0, Salt Brine,etc

Tank # 1		Tank # 1	gallons
Tank # 2		Tank # 2	gallons
Tank # 3		Tank # 3	gallons
Tank # 4		Tank # 4	gallons
Tank # 5		Tank # 5	gallons

* Space Provided Below: Yes, No, Good, Bad or Info needed
** Use Inspection Checklists page 2 for additional Pumps and Tank
*** Use Fill Service Request Form to Request Work to be done or Comments on the Inspections

General Inspection

Hoses		Tank			
Main Feed		Top Fill Pipe			
Top Fill		Filter			
Bleeder		Check valve		Ball Valves (Fluid Film applied)	
Off-load		Ball Valves		Padlock (Locked)	
Others					

Pump # 1

Summerized		Pressure gauge working (If Equipped)	
R/V Anti-Freeze added			
Pump H.P			
Pump Condition		Labels	
Pump Cover Installed		Summarization tag	
Leaks		Area Cleaned	
Electrical		Ball Valves sprayed	
Run light (If Equipped)		Clean Filter(If Equipped)	

Pump # 2

Summerized		Pressure gauge working (If Equipped)	
R/V Anti-Freeze added			
Pump H.P			
Pump Condition		Labels	
Pump Cover Installed		Summarization tag	
Leaks		Area Cleaned	
Electrical		Ball Valves sprayed	
Run light (If Equipped)		Clean Filter (if Equipped)	

Salt Brine Maker

SBM Building #				Heater Condition	
Cleaned Out, Brine		Salt		Building Cleaned (Inside)	
Water in Brine Side		Hopper		Building Cleaned (Outside)	
Gate Valve on Maker				Compressor Condition (If Equipped)	
Valves Sprayed				Condition of Plumbing	
Lights				Backflow Preventer Inspected	
Electrical Outlets				Date Inspected	

Signed: _____

***MaineDOT* LIQUID FILL INSPECTION CHECKLISTS**

Type in Space Provided Below: Good, Bad, Yes, No or Info needed

Pump # 3

Summerized		Pressure gauge working (If Equipped)	
R/V Anti-Freeze added			
Pump H.P			
Pump Condition		Labels	
Pump Cover Installed		Summarization tag	
Leaks		Area Cleaned	
Electrical		Valves Sprayed	
Run light (If Equipped)			

Pump # 4

Summerized		Pressure gauge working (If Equipped)	
R/V Anti-Freeze added			
Pump H.P			
Pump Condition		Labels	
Pump Cover Installed		Summarization tag	
Leaks		Area Cleaned	
Electrical		Valves Sprayed	
Run light (If Equipped)			

General Inspection Tank #1

Tank			
Tank Top Fill			
Tank Hose		Valves (Fluid Film Applied)	
Padlock		Labels	
Valve		Check valve (If Equipped)	

General Inspection Tank #2

Tank			
Tank Top Fill			
Tank Hose		Valves (Fluid Film Applied)	
Padlock		Labels	
Valve		Check valve	

General Inspection Tank #3

Tank			
Tank Top Fill			
Tank Hose		Valves (Fluid Film Applied)	
Padlock		Labels	
Valve		Check valve	

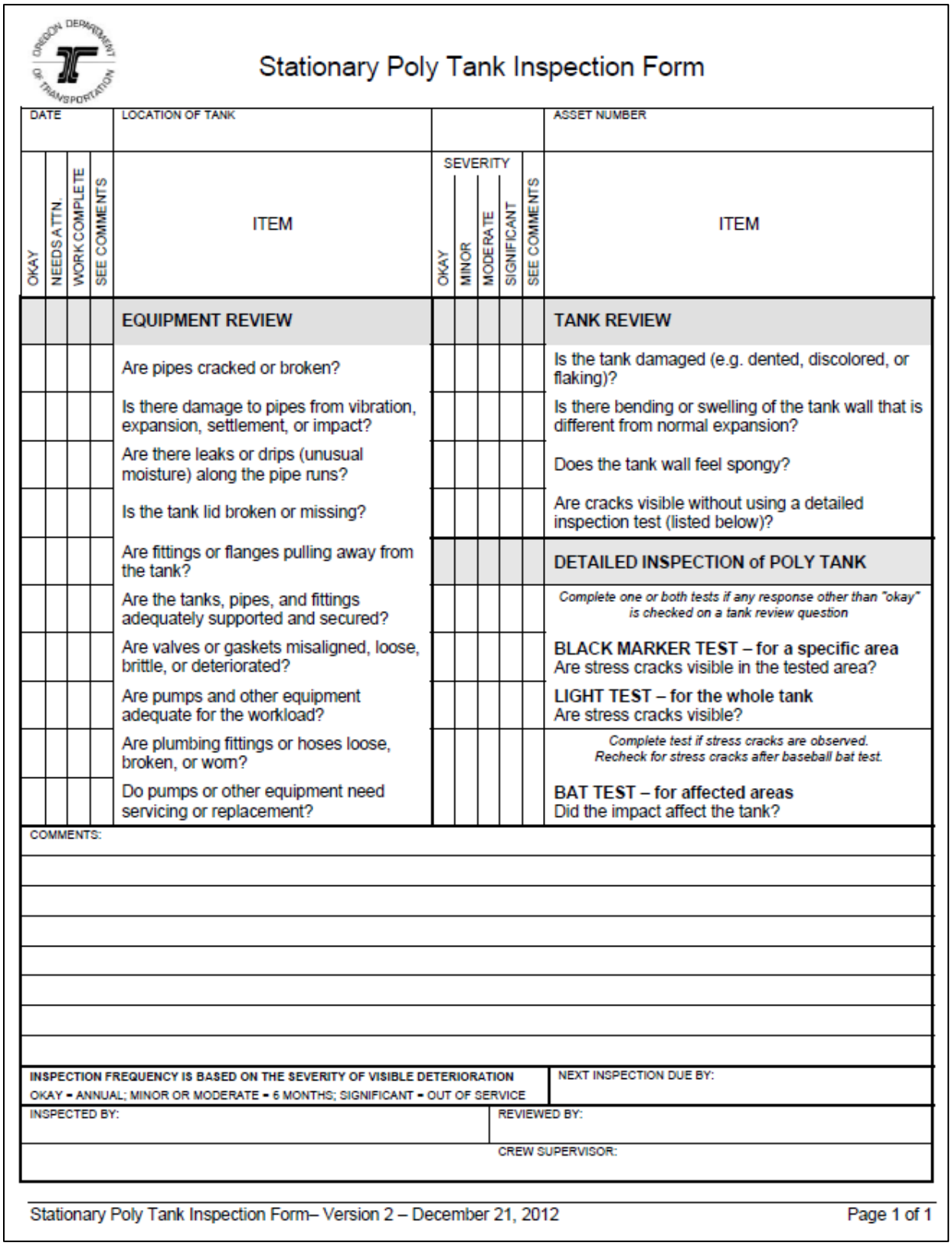
General Inspection Tank #4

Tank			
Tank Top Fill			
Tank Hose		Valves (Fluid Film Applied)	
Check valve		Labels	
Valve		Padlock	

Signed _____

Oregon DOT has developed a poly storage tank inspection form which requires workers to examine tanks for cracks or other damage and examine other equipment including piping, fittings, pumps, and hoses (see Figure 3). Additionally, they have a monthly maintenance field audit form which is used to document any issues or major changes (see Figure 4).

Figure 3. Oregon DOT Inspection Checklist



Stationary Poly Tank Inspection Form

DATE | LOCATION OF TANK | ASSET NUMBER

OKAY	NEEDS ATTN.	WORK COMPLETE	SEE COMMENTS	ITEM	SEVERITY: OKAY	MINOR	MODERATE	SIGNIFICANT	SEE COMMENTS	ITEM
				EQUIPMENT REVIEW						**TANK REVIEW**
				Are pipes cracked or broken?						Is the tank damaged (e.g. dented, discolored, or flaking)?
				Is there damage to pipes from vibration, expansion, settlement, or impact?						Is there bending or swelling of the tank wall that is different from normal expansion?
				Are there leaks or drips (unusual moisture) along the pipe runs?						Does the tank wall feel spongy?
				Is the tank lid broken or missing?						Are cracks visible without using a detailed inspection test (listed below)?
				Are fittings or flanges pulling away from the tank?						**DETAILED INSPECTION of POLY TANK**
				Are the tanks, pipes, and fittings adequately supported and secured?						*Complete one or both tests if any response other than "okay" is checked on a tank review question*
				Are valves or gaskets misaligned, loose, brittle, or deteriorated?						**BLACK MARKER TEST – for a specific area** Are stress cracks visible in the tested area?
				Are pumps and other equipment adequate for the workload?						**LIGHT TEST – for the whole tank** Are stress cracks visible?
				Are plumbing fittings or hoses loose, broken, or worn?						*Complete test if stress cracks are observed. Recheck for stress cracks after baseball bat test.*
				Do pumps or other equipment need servicing or replacement?						**BAT TEST – for affected areas** Did the impact affect the tank?

COMMENTS:

INSPECTION FREQUENCY IS BASED ON THE SEVERITY OF VISIBLE DETERIORATION
OKAY = ANNUAL; MINOR OR MODERATE = 6 MONTHS; SIGNIFICANT = OUT OF SERVICE

NEXT INSPECTION DUE BY:

INSPECTED BY:

REVIEWED BY:

CREW SUPERVISOR:

Stationary Poly Tank Inspection Form– Version 2 – December 21, 2012 Page 1 of 1

Figure 4. Oregon DOT Monthly EMS Field Audit Form

MONTHLY MAINTENANCE EMS FIELD AUDIT

Yard **Date**

Notify the Maintenance and Operations Branch of significant changes (e.g. install a new tank, modify drainage, change water treatment systems, put in a building, or build a wash rack)

OPERATIONAL AREAS – including fuel stations, service bays, wash areas, mixing areas, and loading/unloading areas

1	Are operations only occurring in established areas?	☐ Yes	☐ No	☐ NA
2	Are areas free of visual evidence (e.g. product or absorbent) of spills, tracking, or leaks?	☐ Yes	☐ No	☐ NA
3	Are spill kits or granular absorbents accessible and adequately stocked?	☐ Yes	☐ No	☐ NA
4	Are posted warning signs and operating instructions legible?	☐ Yes	☐ No	☐ NA
5	Are fuel dispensers and other delivery/distribution systems in good repair?	☐ Yes	☐ No	☐ NA
6	Are delivery/distribution lines closed or capped when not in use?	☐ Yes	☐ No	☐ NA
7	Are drip buckets and drain pans either a) actively in-use or b) closed and labeled?	☐ Yes	☐ No	☐ NA
8	Are efforts to keep potential pollutants out of stormwater well maintained?	☐ Yes	☐ No	☐ NA

Notes:

TANKS, TOTES, and STORAGE AREAS –storage areas include storage bays, pole buildings, cargo containers, closets, bulk storage, parked slip-ins, and onsite stockpiles

9	Are storage areas tidy (e.g. clean, organized, random containers put away)?	☐ Yes	☐ No	☐ NA
10	Does each container, tank, and tote have a visible, intact, and legible label?	☐ Yes	☐ No	☐ NA
11	Are containers, tank, and totes closed (e.g. lids on, covers shut, boxes tops folded)?	☐ Yes	☐ No	☐ NA
12	Are tanks, totes, and containers undamaged - in good repair?	☐ Yes	☐ No	☐ NA
13	Are surfaces free of product and has saturated absorbent been picked up?	☐ Yes	☐ No	☐ NA
14	Are supports to minimize stress on fittings and tanks in-place and in good condition?	☐ Yes	☐ No	☐ NA
15	Can empty containers be visually identified from full ones?	☐ Yes	☐ No	☐ NA
16	Is secondary containment available for products stored near sensitive resources?	☐ Yes	☐ No	☐ NA
17	Is secondary containment currently in use – are containers on/in containment?	☐ Yes	☐ No	☐ NA
18	Are containers stored indoors or covered if stored outdoors?	☐ Yes	☐ No	☐ NA
19	Are gas cans, flammable liquids, and aerosols stored in flammable cabinets where needed?	☐ Yes	☐ No	☐ NA
20	Are storage areas secured –additional actions aren't needed to discourage vandalism?	☐ Yes	☐ No	☐ NA
21	Are products usable, current, and wanted?	☐ Yes	☐ No	☐ NA
22	Is there sufficient available capacity in tanks and containers used to store wastes?	☐ Yes	☐ No	☐ NA

Notes:

MONTHLY MAINTENANCE EMS FIELD AUDIT

Yard _____ Date _____

	DRAINAGE –outfalls, ditches, catch basins, floor drains, pit drains, wash drains, oil/water separators, swales			
23	Are catch basins and outfalls free of visible pollutants (e.g. sheen, sediment, and trash)?	☐ Yes	☐ No	☐ NA
24	Is the ground/floor/pavement around catch basins free of spills?	☐ Yes	☐ No	☐ NA
25	Is the volume of sediment in catch basins and sumps below the outflow pipe?	☐ Yes	☐ No	☐ NA
26	Is erosion or sediment control installed where needed?	☐ Yes	☐ No	☐ NA
27	Are water treatment measures in good working order?	☐ Yes	☐ No	☐ NA
28	Do water treatment and control measures appear maintained?	☐ Yes	☐ No	☐ NA
Notes:				

	SECONDARY CONTAINMENT And Monitoring Equipment – including deicer bunkers, salt sheds, lined ponds, fuel delivery containment, berms, double-walled tanks, and spill pallets.			
29	Is secondary containment free of product and spills?	☐ Yes	☐ No	☐ NA
30	Is the area around the containment free of product and evidence of spills?	☐ Yes	☐ No	☐ NA
31	Are drainage control valves and drain mats accessible and operational?	☐ Yes	☐ No	☐ NA
32	Are drainage control valves closed while providing containment?	☐ Yes	☐ No	☐ NA
33	Is the space between the walls of double-walled tanks free of liquids?	☐ Yes	☐ No	☐ NA
34	Are tank gauges or monitoring systems operational?	☐ Yes	☐ No	☐ NA
35	Does secondary containment appear to be intact/undamaged?	☐ Yes	☐ No	☐ NA
Notes:				

		Annual or Routine practices that were completed this month – varies by site	
☐ Yes	☐ NA	Completed the Stationary Poly Tank Inspection. (annual)	Notes:
☐ Yes	☐ NA	Inspected poly tanks at secondary site that does not need monthly audits.	
☐ Yes	☐ NA	Determined containment is water-tight. (annual) ☐ bulk fuel delivery ☐ deicer ☐ salt ☐ lined pond ☐ other	
☐ Yes	☐ NA	Visually inspected the septic system and drainfield. (annual)	
☐ Yes	☐ NA	Tested the emergency shut-off for the fuel tank. (annual)	
☐ Yes	☐ NA	Completed SPCC training / spill response briefing. (annual)	
☐ Yes	☐ NA	Completed UIC training. (annual – if facility has drywells)	
☐ Yes	☐ NA	Repaired or responded to fluid level monitoring or leak detection equipment. ☐ fuel ☐ deicer ☐ other	
☐ Yes	☐ NA	3rd party tank inspection: ☐aboveground ☐underground	
☐ Yes	☐ NA	Cleaned drains: ☐wash bay ☐stormwater ☐other	
☐ Yes	☐ NA	Cleaned /maintained sediment control, containment, or water treatment: ☐ oil/water separator ☐ swale/pond ☐ catch basins insert ☐ carbon/media barrels ☐ swept parking lot ☐ other	

The answers on this audit are True and Complete to the best of my ability.

Name **Date** **Title**

Signature

Monthly Maintenance EMS Field Audit – Version 4 – December 2019 Page 2 of 2

4.1.3.2 Parts Kept on Hand for Emergencies

Each interviewee mentioned that they keep at least some parts on hand for emergencies. These part lists varied by organization and whether that organization had easier access to parts depending on their location. Specifically, ITD District 3 and South Dakota DOT Sioux Falls Area mentioned that parts are easily accessible.

Generally, spare pumps, fittings, clamps, seals, valves, and hoses were common parts to keep on hand for emergencies. Massachusetts DOT noted that they also keep rebuild kits for their pumps and motors on hand.

The City of Farmington Hills, Michigan specifically noted that an agency should consider keeping any other replacement parts that they have struggled to obtain in the past (e.g., supply chain or delivery challenges).

Alaska DOT&PF in Fairbanks mentioned keeping arctic-grade fuel hose on hand, which is unique due to the extreme temperatures they experience.

Iowa DOT keeps spare pumps on hand at the maintenance district level (their DOT has six districts statewide) where garages can request items as they are needed for repairs. At the garage level they will keep sections of hose, valves, pipes, and fittings. Similarly, Idaho District 3 keeps a central storage of parts as needed for repairs. At Maine DOT and Massachusetts DOT where they have one position who will maintain the liquid deicer storage and pumping systems for their region, these locations also have more centralized storage of parts for emergencies. The Maine DOT statewide Snow & Ice Supervisor position comes with a ¾ ton pickup truck that has parts and equipment ready for repairs, additionally they have a maintenance shop where repairs can be completed.

4.1.4 Other Considerations

4.1.4.1 Training

Most training to operate these systems is done as on-the-job training. As part of their winter operations training, the City of Farmington Hills, Michigan will conduct a walkthrough and train individuals on how to use truck fill points. Few have developed specific training materials related to liquid deicer storage and pumping systems.

A few interviewees noted that they have had product vendors come out and conduct training as part of the system implementation.

Kansas DOT has an Equipment Users Handbook which includes guidelines, checklists, and procedures to ensure that employees are properly operating and maintaining equipment. This handbook includes winter operations and end of season shutdown procedures for brine equipment, storage tanks, and pumps.

Nebraska DOT has implemented operator training for all workers (even for long-time workers). This training is done in a more ad hoc manner, covering how the field office wants them to operate the liquid deicer storage and pumping system including how to turn it on/off, how the pumps work, how to fill the truck, and how to bring material into the pumps. In some areas, the system will have one pipeline which requires multiple materials to go through, so training will focus on how to handle multiple materials on one pipeline. No formal training materials have been developed. Instead, training is based on a playlist of talking points. The training content may vary slightly depending on the field office but overall should cover the same content.

Nebraska DOT suggested a best practice is to bring everyone into a room (e.g., system operators, supervisors) and discuss what has worked and how previous problems have been solved. This could help to document experiences and how to operate and maintain these systems over time.

4.1.4.2 Cleaner Salt

Several interviewees utilize mined salt in their brine operations and noted struggles with insoluble/debris/fines/sand falling out of suspension in their salt brine, even if the liquids are filtered. On some occasions the debris was from the delivery truck not being adequately cleaned out before the salt was loaded (e.g., corn, husks, etc.). This results in a lot of buildup in the bottom of the storage tanks and brine maker which can be difficult to clean out. Several interviewees highlighted a desire to try solar salt because it is cleaner and would cut down on cleaning and increase productivity. For the City of Farmington Hills, Michigan they currently can make around 4,000 to 5,000 gallons of salt brine an hour, however they estimate that this could increase to 6,000 to 7,000 gallons of salt brine an hour with cleaner salt. Iowa DOT noted that solar salt is a lot more expensive which is a limiting factor. The South Dakota DOT Sioux Falls Area is considering switching from a mined rock salt to cleaner brining salt (which is currently used in Western South Dakota). This switch is expected to reduce the amount of system cleaning needed to roughly once per season.

Oregon DOT Portland Metro Area maintenance yard is pilot testing the use of salt brine this winter season. The yard is using a Cargill Accubrine system and solar salt to manufacture brine. To date, they have seen little to no issues with debris build-up in their system.

4.1.5 Key Takeaways from Agency Interviews

These interviews resulted in several key takeaways.

- Facilities
    - Start simple and don’t get overwhelmed.
    - System lifecycle planning will evolve, be flexible.
    - Extreme temperatures result in the need for unique storage solutions.
    - Consider building designs that allow for drainage, easy clean up, and movement of tanks.
    - Locating storage tanks indoors can protect from UV deterioration but can cause challenges when storage tanks need to be replaced.

- Maintenance and Cleaning
    - Keep your facility clean.
    - Dirty salt results in more tank cleanup.
    - Use air to clean and purge the liquid out of hoses to reduce hose weight.
    - Develop a schedule for system inspection.
    - Develop a handbook to document system guidelines, checklists, and procedures to ensure that employees are properly operating and maintaining equipment.
    - Consider having a statewide position for maintenance and repair of liquid deicer storage and pumping systems.
    - Develop an inspection checklist to aid in regular inspection of the system and documentation.
    - Spare pumps, fittings, clamps, seals, valves, and hoses were common parts to keep on hand for emergencies.
- Storage Tanks
    - Consider a storage tank replacement program to reduce catastrophic failures.
    - Fiberglass tanks do not fail catastrophically and can be competitively priced compared to poly tanks, especially at larger capacities.
    - Storage tanks with a port at the center of the tank to assist with circulation of material.
    - Test tank condition by “reading the cracks” and scraping the storage tank.
    - Triage process to determine secondary containment needs based off weather, property features, and whether there are sensitive resources nearby. Check with relevant state agencies to determine if secondary containment is required.
- Pumps and Motors
    - End of season cleaning with water and use of a corrosion preventative was common.
    - Pump and motor setups mounted onto metal plates allow for efficient replacement.
    - Repurposing of train sheds for pump houses.
    - System plumbing coverings to protect plumbing from snow damage using old traffic signs.
- Training
    - Regular training for operators who will use the liquid deicer storage and pumping system.
    - Group meetings help the DOT learn what works, what didn’t, and how problems are solved.
    - Limiting staff for brine making can reduce operator error.

In addition, several resources and documents were shared by these agencies as a part of the interview process. A full list of these resources can be found in APPENDIX B – Agency and Vendor Interview Questionnaire and Interview Summaries.

4.2 SUMMARY OF VENDOR OUTREACH

4.2.1 Assmann & Poly Processing

- Poly tanks

- Secondary containment options

Assmann & Poly Processing is a liquid storage tank manufacturer. They offer high-density cross-linked polyethylene (HDXLPE) and linear polyethylene. Storage tanks are available in capacities ranging from 40 to 12,500 gallons. Tanks were noted as being lower cost than fiberglass reinforced polyethylene (FRP) or fiberglass tanks. Assmann & Poly Processing provides a 5-year warranty on their tanks. Typical life expectancy is around 15 to 20 years.

These tanks have UV ray protection mixed into the storage tank material which helps reduce UV damage. Locating the tanks indoors or outside under shade is ideal and can help improve the life cycle of the tank.

Assmann & Poly Processing has some unique manufacturing characteristics compared to other storage tank manufacturers. Their tanks have a uniform wall thickness throughout the entire tank, whereas other manufacturers tend to have a tapered wall thickness (tanks are thicker at the bottom and taper up) which can make the tank most susceptible to damage. Assmann & Poly Processing uses ambient air-cooling to finish their tanks, which helps to reduce stress fracturing.

They have both single wall and double walled tanks available. They also offer a few options for secondary containment including containment basins with 110% capacity of the storage tank that the storage tank sits in. These basins are made of polyethylene.

The suggested typical maintenance routine is draining and cleaning the tank at least once a year. Tanks should be washed out with water. They also recommend conducting a visual inspection to check for cracks or leaking fittings as often as once per month.

Assmann & Poly Processing did not mention any availability or supply chain challenges, orders are generally received within 4 to 6 weeks of being ordered.

4.2.2 Dultmeier

- Poly tanks
- Pumps

Dultmeier supplies systems, equipment, and suppliers for liquid deicing and dust control applications, including all components of liquid deicer storage and pumping systems. Dultmeier has several polyethylene storage tank options ranging in capacity from 250 gallons to over 15,000 gallons. Polyethylene storage tanks life expectancy is expected to differ based on conditions (e.g., UV exposure), but estimated life expectancy is 10 to 12 years. The recommended optimal location is on a level concrete pad either inside or outside, however storing inside or in the shade does increase the life cycle.

Dultmeier storage tanks are not double-walled, and they do not provide other forms of secondary containment. They do not recommend repurposing storage tanks.

They recommend a typical storage tank maintenance routine include changing out gaskets in fittings every 3 years or sooner as leaks occur. Storage tanks should be cleaned out using a tank rinse nozzle.

Dultmeier storage tank orders are generally received six weeks after the order is placed. A forklift is used to set the tanks in place.

Dultmeier also has several pumps available in both single and three phase configurations with capacities ranging from 1 to 1,700 gallons per minute (GPM). Pumps can be located outdoors. They recommend replacing pumps every two years or when they start to leak. Pump orders are generally received 3 to 4 weeks after the order is placed.

Dultmeier notes they have not experienced compatibility issues with brine or chlorides; however, they have had issues with petroleum-based products.

4.2.3 GVM

- Poly tanks
- Pumps

GVM offers an inventory of liquid deicer equipment. High density polyethylene resin (HDPE) liquid deicer storage tanks from Norwesco. Storage tanks are available in capacities ranging from 35 to 20,000 gallons. Norwesco tanks are vertical tanks with tie-down slots. They have built-in graduated gallon indicators, an offset fill-opening, and a self-vented lid. Tanks can be configured with any size polyethylene or stainless-steel fitting. Life expectancy is expected to be longer for tanks stored indoors.

Depending on the storage tank type purchased, these tanks carry a three-to-five-year warranty from date of manufacture. Should a defect appear within the warranty period, Norwesco will supply a new, equivalent tank replacement. Norwesco's liability is limited to the value of the tank itself and specifically excludes the cost of installation and/or removal or consequential damages.

These tanks are not double-walled and GVM does not offer any other form or suggestions for secondary containment.

GVM does not provide specific information on storage tank maintenance. However, for testing storage tank condition, they recommend examining the tank for fissures or hairline cracks (e.g., crazing). They recommend specifically looking for crazing on the dome of the tank where sunlight exposure is most intense. These fine cracks will become more intense and visible as time goes on and will become stress cracks. GVM also suggested that the baseball bat test is another good method as the tank resilience will be immediately obvious. A tank beyond its life expectancy will sound dull when struck and could crack as a result. To avoid tank failures, GVM recommends checking early and be safe versus losing valuable chemicals and incurring cleanup expense. When a tank is determined to be unsafe or you know it is getting old, it is best to make it a non-drinking water only tank.

GVM is a supplier for Banjo and Pacer pumps. They suggest that pumps can be located either indoors or outdoors, but electrical pumps located outdoors should be covered. It is recommended to flush the pump after every use to maintain the longevity of the pump seals. GVM does have a team that can walk through how a unit should be plumbed and recommend plumbing/piping that would be ideal for each unique set up.

GVM noted no availability or supply chain issues for storage tanks or pumps. The equipment is delivered by truck. At least two personnel are needed to do the installation. Larger storage tanks may require additional equipment (e.g., a crane) to set the tank in place.

4.2.4 K-Tech Specialty Coatings

- Asphalt products
- Deicing products

K-Tech Specialty Coatings is a supplier of asphalt products and deicer products (primarily Beet Heet). K-Tech noted that they serve around 500 locations in 15 states and have seen significant issues with liquid deicer storage and pumping systems. Issues noted included utilizing pumps with a capacity greater than 150 gallons per minute on systems with a one-inch fill hose which causes foam. K-Tech highlighted that recirculating deicer material is key. This is especially true for deicers consisting of multiple chloride and organic components because these products have differing weights (densities) which if not circulated will fall out of suspension and stratify, creating sludge build up in the storage tank. Calcium chloride, magnesium chloride, and sugar will travel downward, whereas sodium chloride, potassium chloride, and water will travel upward. Lack of circulation can result in an agency pulling only a portion of what should be a deicer mixture (e.g., pulling heavier components at the start of the season then later pulling lighter components).

Recirculation is needed from bottom to the top of the storage tank. However, this can cause foaming issues. K-Tech recommends using a “cascading vortex” design to reduce the foaming issue. For storage tanks with an upper port installed, this design recommends a 3- to 4-foot-long downspout be installed inside the storage tank with a 45-degree elbow aimed so that it cascades deicer down the sidewall of the tank and creates a vortex inside the tank (see Figure 5). This downspout should not be installed all the way to the bottom of the tank as this will just recirculate material at the bottom. For new storage tanks, K-Tech recommends installing an upper port about 3 to 4 feet from the top of the tank and installing a 90-degree elbow inside the tank aimed down at 45-degrees to create the same effect.

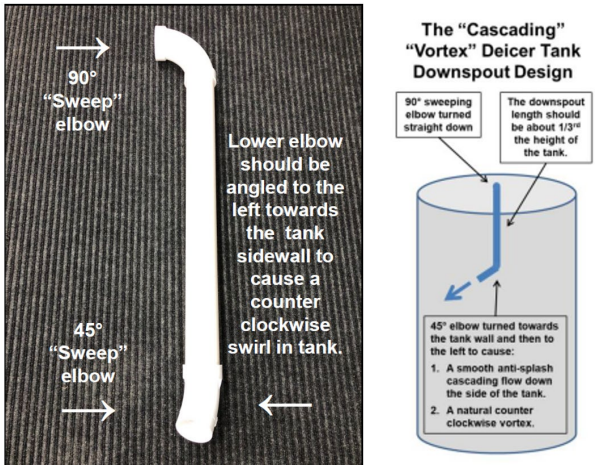


Figure 5: Cascading Vortex Design

4.2.5 Sno-Biz

- Deicing products
- Poly and Fiberglass tanks
- Secondary containment options
- Pumps
- Brine making equipment

Sno-Biz is a supplier of snow and ice control materials and equipment including liquid storage tanks, pumps, and brine makers. Sno-Biz offers fiberglass storage tanks from KBK Industries and HDPE tanks from Camion/Enduraplas).

Poly tanks from Camion/Enduraplas tanks cost around $1.00 to $1.75 per gallon of storage capacity rated at 1.9 specific gravity. These tanks are available up to 10,400 gallons of capacity. Tank-flange outlets are 3-inch bolted polyethylene or stainless-steel threaded fittings, generally an output at the bottom and an input/recirculation fitting 2 to 3 inches from the bottom of the tank and 45-degrees from the drain fitting. These storage tanks are expected to have a lifespan of 15 to 20 years and have a 10-year warranty. Tanks should be located on a level concrete pad either indoors or outdoors, however tanks located indoors are expected to have a longer lifespan.

The KBK fiberglass tanks are available at larger capacities (from 15,000 gallons) on special order.

The tanks Sno-Biz offers are single wall tanks and help provide solutions for secondary containment depending on the needs of the customer.

They suggest that tanks should be inspected for crazing and/or cracking by shining a light through the tank wall on an annual or bi-annual basis. For cleaning, they recommend power washing and using a vacuuming system. In addition, they recommend using cleaner materials like solar salt. Materials should be recirculated periodically. Sno-Biz notes that personnel should not enter the tank.

Sno-Biz offers several pumps. A Camion single phase, 5 horsepower/230-volt pump which has a capacity of 120 gallons per minute (GPM). The life expectancy of these pumps is two years with proper maintenance. They also have a Henderson three phase, 5 horsepower, 208/240-volt pump with a wash down motor and cast stainless steel design. These pumps have a variable flow ranging from 20 to 200 GPM. The life expectancy of these pumps is 2 to 5 years with proper maintenance.

Sno-Biz generally recommends that pumps should be indoors or covered.

Sno-Biz has the Henderson brine maker products which do have stack blending capability for up to four products in real-time. The design is modular, it comes with a two-product stack capability which can be increased to four products. Remote inventory options can be added to the machine which allows the customer or dealer to remotely troubleshoot issues and collect use information.

Sno-Biz did not note any supply or availability issues.

4.2.6 VariTech

- Poly tanks
- Tank fittings
- Secondary containment options
- Pumps
- Motors
- Brine making equipment

VariTech offers high density linear polyethylene (HDPE) and cross-linked polyethylene storage tanks. These tanks are a lower cost option when compared to fiberglass or stainless-steel options. Storage tanks are available up to 18,800 gallons in capacity. The tank-flange outlets are available as PVC/CPVC double flange fittings which utilize two 150-pound flanges along with encapsulated bolts. VariTech has both poly and stainless-steel fittings available. Storage tanks can be placed either outdoors or indoors, it is suggested that they are located on a flat and clean level surface that fully supports the tank.

VariTech does have double-walled storage tanks available. They recommend a dike containment system, which are available for purchase, however, the common method is to pour concrete walls for the storage tank to sit in.

They noted that customers have repurposed tanks for other liquids. VariTech recommends making sure the tank is compatible with the liquid to be stored and is thoroughly cleaned before switching out the material stored.

VariTech does not have a suggested maintenance routine. If the storage tanks need to be cleaned, they recommend warm water and mild detergent.

VariTech has a wide range of pump and motor combinations. Electrical options available include 115-, 208-, 230-, or 480-volt service, single or three phase power, with pump capacities ranging from 50 to

over 500 GPM. Cost varies significantly depending on pump housing material (cast iron, bronze, stainless steel) and the motor size needed. They suggest that if pumps are located outdoors that they have some sort of protective cover. Life expectancies range from 5 to 10 years depending on how well they are maintained. VariTech recommends that seals and bearings should be inspected at the end of each season.

VariTech does offer guidance on system piping which differs based on customer needs. Typical installation for liquid deicer storage and pumping systems uses wire-reinforced EPDM rubber hose with FRP poly fittings (e.g., Banjo fittings). Schedule 80 PVC can be used however it is generally more expensive, and replacement parts can be more difficult to find.

VariTech brine makers use real-time blending. The system is modular. Both the Smart Transfer System and Blend Boss system can be added to virtually any liquid storage system on the market. Remote inventory monitoring will be available for use during the 2024-2025 winter season.

Depending on the equipment ordered, a loader, boom truck, or crane may be needed to transport and set the equipment in place. Pumping systems can be moved with a forklift and shifted into position by hand. VariTech did not note any availability issues.

4.2.7 Key Takeaways from Vendor Outreach

This outreach resulted in several key takeaways.

- Storage Tanks
    - Storage tanks have an expected lifespan of 15 to 20 years.
    - Cascading vortex design to reduce deicer material settling and stratifying.
    - Recirculation of material in the tanks is key!
    - Reading the cracks, tank lighting, and the baseball bat method are recommended tank condition testing methods.
    - Locating storage tanks indoors or undercover can reduce UV damage and increase storage tank lifespan.
- Pumps/Motors
    - Pumps have an expected lifespan of up to 2 years with proper maintenance.
    - Suggested maintenance for pumps includes flushing the pump periodically and inspecting seals and bearings.
    - Recommended to keep pumps/motors either indoors or utilize some form of covering.

In addition, several resources and documents were shared as a part of the outreach process. A full list of these resources can be found in APPENDIX B – Agency and Vendor Interview Questionnaire and Interview Summaries.

5 BEST PRACTICES MANUAL

Information gathered from the literature, the agency and vendor interviews, and the survey responses was utilized to develop a concise, user-friendly manual documenting liquid deicer storage and pumping system considerations and best practices. The manual presents a selection of liquid deicer storage and pumping systems ranging from "starting simple" to "more advanced."

The manual is organized as follows:

- **Liquid Deicer Storage and Pump System Considerations**: This section highlights general considerations for both storage tanks and truck fills, including typical forms of secondary containment.
- **Equipment and Replacement Program**: This section describes the general life span of both storage tanks and truck fills.
- **Maintenance and Inspection**: This section includes best practices for routine maintenance and inspection, including an example inspection checklist, a suggested list of supplies to keep on hand for emergencies, storage tank condition testing methods, and safety considerations.
- **Case Studies: System Options from Starting Out to More Advanced:** Information is provided on typical equipment, system expectations, cost, and personnel and training requirements for each liquid deicer storage and pump system option. This section also includes ideas for "next steps" to improve your liquid deicer storage and pump system.

In addition to the best practices manual several standalone items were developed which include:

- **Liquid Deicer Storage and Pumping System Inspection Checklists:** Two inspection checklists were developed (one for systems with a brine unit and one for those without one) that walks users through each piece of the systems and provides examples of things to look for.
- **The "911 Box"**: Which is a list of recommended parts and supplies to keep on hand at both the local depot level and the central maintenance facility level.
- **Safety Considerations Flyer**: This flyer describes several safety items to consider when working with liquid deicer storage and pumping systems including personal protective equipment to keep on hand, lock out/tag out, pinch points, lifting and handling, systems under pressure, sharp edges, slippery conditions, and confined spaces.

The best practices manual and the standalone items are available on the Clear Roads project website: https://www.clearroads.org/project/22-02/

6 SUMMARY

This report presents information on liquid deicer storage and pumping systems including system components and the best practices and lessons learned from operating these systems. A survey of both transportation agencies and vendors was used to identify equipment and maintenance and operations practices. From this survey a list of vendors was identified. Outreach to these vendors and follow up interviews were conducted to learn additional information beyond the survey responses. The data gathered from the agency and vendor interviews and the survey responses was used to develop the best practices manual which highlights system considerations, system maintenance and repairs, and case studies of liquid deicer storage and pumping systems ranging from “starting out” to “more advanced.”

Findings from this research effort filled a gap in the literature by documenting current liquid deicer storage and pumping systems and system components used across the United States and best practices and lessons learned from operating these systems.

Findings show there is no one-size-fits-all liquid deicer storage and pumping system which is in use across transportation agencies. Instead, these systems have been built to fit each agency’s needs and funding. However, the best practices and lessons learned from those operating and maintaining these systems can help support other agencies as they look to either maintain their existing equipment or implement new equipment or technology.

Best practices identified include:

- Set yourself up for success by planning for your future operational needs.
- System lifecycle planning will evolve, be flexible.
- Don’t be afraid to start simply and build your system out over time.
- Be proactive rather than reactive to system maintenance by regularly inspecting and maintaining system components.
- Develop an inspection checklist to ensure that all employees are keeping an eye on the system in a regular and consistent manner.
- Keep a stock of supplies on hand for emergencies to avoid potential downtime.
- Don’t forget about the safety of your employees.

Throughout the research process, research needs and knowledge gaps were identified which can help advance this field by supporting a better understanding of how transportation agencies are operating and maintaining these systems and their lessons learned which can help other agencies as they look to potentially implement new equipment or technology.

- **Technology Transfer**: Throughout the survey and interview process, several agencies mentioned the desire to learn about how others operate and maintain liquid deicer storage and pumping systems. Particularly how other agencies have solved (or attempted to solve) the challenges that arise. This highlights a need to prepare training materials related to the findings of this research effort, support presentation of these materials at state and local conferences and trainings and

consider the establishment of a working group or roundtable which would meet regularly to share experiences and learn from peers.

- **The "No Tank" Option**: While this research effort was focused on liquid deicer storage and pumping systems, another option an agency may want to consider is skipping the storage tanks altogether and having a direct truck fill from the brine system. This option helps eliminate some of the challenges with the purchase and maintenance of equipment like truck fill stations and tanks. However, using this system is only possible if the brine system can manufacture brine at a rate that is within standard truck fill rates (50 GPM to 100 GPM). If this option is used, consideration of the brine manufacturing production capability, water source and demand from the truck fleet is required. For smaller agencies and or satellite depots, the "no tank" option could work if the brine system and water source meet the performance requirements of the OEM.

- **Synthesis of Brine Making Unit Best Practices**: This would include a similar examination of brine making units themselves and the best practices and lessons learned from operating and maintaining these systems. When conducting interviews for this research effort, several interviewees noted that they monitor and maintain their salt brine manufacturing system in addition to the truck fills and tank farms. An examination similar to this research effort would allow agencies to share their brine manufacturing system best practices and for the development of a manual and operations and maintenance plan for those that consider the entire operation one big piece of equipment which includes the brine manufacturing unit, truck fills, and storage tanks.

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APPENDIX A – AGENCY SURVEY INSTRUMENT AND DETAILED RESULTS

SURVEY INSTRUMENT

This survey has been created to help support Clear Roads and its member states in their understanding of liquid deicer storage and pump systems currently in use by departments of transportation and public works agencies across the country and the identification of best practices to manage and maintain these systems. Information gathered in the survey will be used to develop a manual which will present a range of liquid deicer storage and pump systems which can serve as a guide for agencies considering purchasing or replacing these systems.

Please note that this survey questionnaire will ask questions to obtain specific information about your liquid deicer storage and pumping system including the tanks, pumps, and motors. It may be helpful to gather information on your system prior to starting the survey.

Participation in this survey is voluntary and you may skip any question you do not want to answer and/or you can stop at any time. Proceeding with this survey indicates your consent to participate. The survey should take about 15 minutes. Any questions or comments can be directed to Karalyn Clouser of WTI/MSU at karalyn.clouser@montana.edu.

Thank you for your time.

General Information

1. Please provide the following information about your organization.
   - Organization:
   - Location:

2. Do you use liquid deicers in your winter maintenance activities?
   - Yes
   - No → If no is selected, end the survey.

3. Do you manufacture or purchase and store liquid deicers on site? (check all that apply)
   - ☐ Manufacture
   - ☐ Purchase
   - ☐ Other (please specify):

4. Are you blending liquid deicers with other liquid additives?
   - Yes
   - No

5. Please describe how you are blending liquid deicers with other liquid additives.

6. How much liquid deicer do you use each winter season?

- 0-100k gallons
- 100k – 250k gallons
- 250k-1M gallons
- 1M+ gallons

Liquid Deicer Storage and Pumping System

Please provide the following information on your liquid deicer storage and pumping system.

7. Please describe your liquid deicer storage tanks including tank manufacturer(s), tank material(s) (e.g. fiberglass, polyethylene, etc.), and tank size(s) (e.g., gallons, height, diameter, etc.).

8. Please describe your truck fill motor including motor manufacturer(s), motor size(s) (in HP), RPM, and electrical voltage requirements.

9. Please describe your truck fill pump including pump manufacturer(s), pump size(s) (in HP), and pump discharge(s) (in GPM).

10. Does your Truck Fill Pump have Variable Flow Capability?

- Yes
- No

11. Is your truck fill pump stand alone or part of a salt brine system?

- Stand Alone
- Salt Brine System

12. Please describe your liquid deicer storage and pumping system piping and fittings (e.g., hard vs. soft).

13. Can your truck fill station capture gallons of product dispensed?

- Yes
- No

14. Can your truck fill station maintain a database of product dispensed?

- Yes
- No

15. Can your truck fill station keep a real-time tank level of available inventory?

- Yes
- No

Maintenance

16. Do you have a standard maintenance practice for your liquid deicer storage and pumping system?
    - Yes
    - No → If No is selected, skip to Question 18.

17. Does your standard maintenance practice include pre-season, mid-season and/or post-Season protocols? (check all that apply)
    - ☐ Pre-Season
    - ☐ Mid-Season
    - ☐ Post-Season
    - ☐ Other (please specify):

18. Is there a checklist for inspection of the system?
    - Yes
    - No → In No is selected, skip to Question 20.

19. Who completes the inspection checklist? (check all that apply)
    - ☐ Snow & Ice Staff
    - ☐ Fleet/Mechanic
    - ☐ Other (please specify):

20. Who is responsible for the maintenance of such systems? (check all that apply)
    - ☐ Snow & Ice Staff
    - ☐ Fleet/Mechanic
    - ☐ Other (please specify):

21. Are there common parts failing, annually (i.e., tanks, pumps, hoses, etc.; please list)?

22. Are there particular parts that are kept on the shelf for emergencies (please list)?

Lessons Learned

23. What is the best lesson learned from operating your liquid deicer storage and pumping system?

24. What is the best modification/upgrade/improvement that you have done to your system?

25. What is the biggest failure from operating such a system? How was it fixed?

Follow-Up

26. Would you be willing to participate in a follow up conversation about your liquid deicer storage and pumping system?

- Yes
- No → If no is selected, end the survey.

27. Please provide the following contact information.

- Name:
- Email Address:

We thank you for your time spent taking this survey.

You may also take the survey online using the link or QR code below:

https://montana.qualtrics.com/jfe/form/SV_brw5FWw6wc0xgr4

TRANSPORTATION AGENCY SURVEY – DETAILED SURVEY ANALYSIS

This survey saw a total of 49 responses from 27 states across the U.S. (see Figure 6). Respondents were asked whether their organization utilized liquid deicers in their winter maintenance operations. One respondent (Town of Sturbridge, Massachusetts) noted that they did not utilize liquid deicers. Since this survey was interested in understanding liquid deicer storage and pumping systems and practices, this respondent was thanked for their time and exited from the survey.

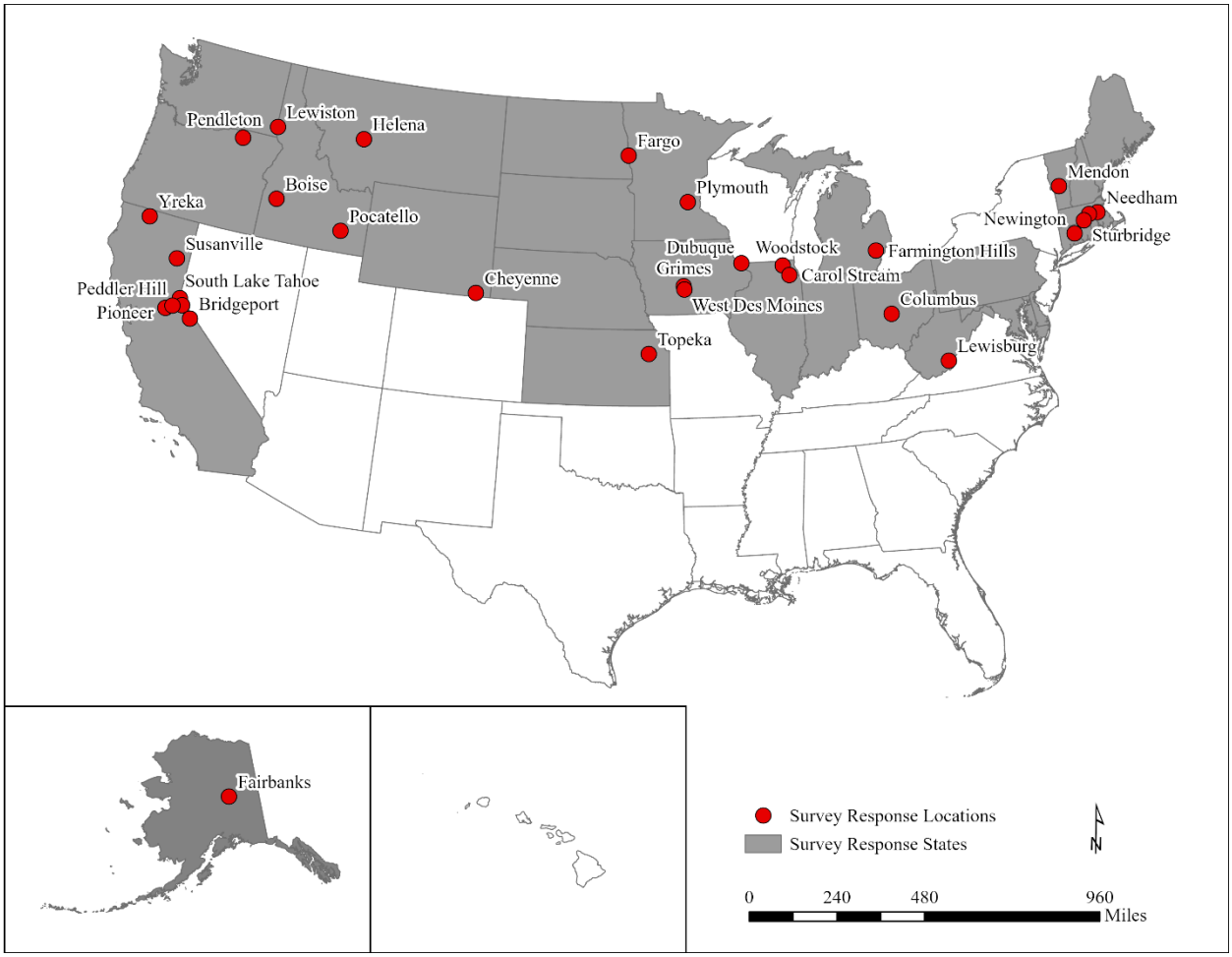

Figure 6. Survey Respondent Locations

Use of Liquid Deicer Products

Respondents were then asked whether they manufacture or purchase and store liquid deicers on site (see Figure 7). Most respondents (~49%) were both manufacturing their liquid deicers and purchasing and storing them on site. Around 40% of respondents were manufacturing their liquid deicers. Only five respondents (~11%) were purchasing and storing liquid deicers.

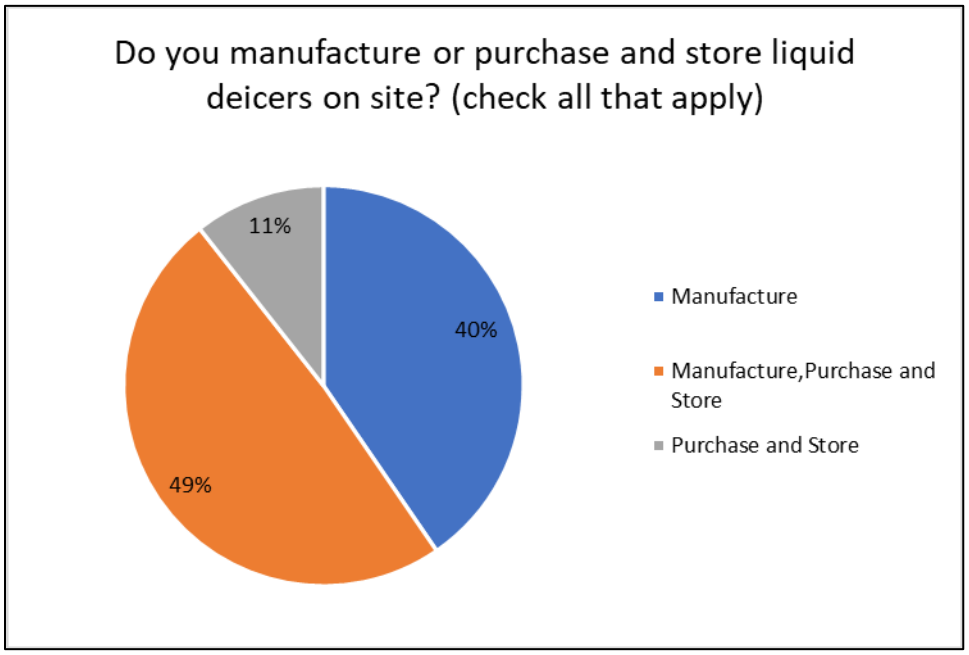

Figure 7. Percent of Respondents Who Manufacture or Purchase and Store Liquid Deicers On Site

Respondents were then asked whether they were blending liquid deicers with other liquid additives. Twenty-seven respondents (~57%) reported that yes, they were blending liquid deicers with liquid additives. These respondents were asked a follow up question to describe how they were blending; 21 respondents provided details (see Table 3).

Several respondents were utilizing some form of automated brine making system. Two respondents (Alaska DOT&PF and Maine DOT) noted that they use a Cargill Accubrine system to automatically manufacture and store brine. One respondent (City of Grimes, IA) uses an automated blending system from Brine Masters. Finally, one other respondent (MDOT SHA) also noted using an automated blending module as a part of their brine production system but did not specify which system they used.

Other blending methods noted included mixing liquids at the truck using two storage tanks, tank to tank mixing of liquids, and adding liquid additives at the storage tank and circulating the resulting liquid.

Table 3. Liquid Deicer Blending Methods

Organization	Location	Are you blending liquid deicers with other liquid additives?	Please describe how you are blending liquid deicers with other liquid additives.
Alaska Department of Transportation & Public Facilities	Fairbanks, AK	Yes	We use a **Cargill AccuBrine NextGen** system to manufacture & store brine, and also to **blend the additives with the brine as the truck is loaded**
City of Dubuque Iowa	Dubuque, IA	Yes	Normally with calcium chloride but will add an agricultural product at times
City of Grimes IA, Public Works	Iowa	Yes	**Automated blending system purchased from Brine Masters**
Carol Stream IL Public Works	Village of Carol Stream, IL	Yes	Normal operations consist of 80% brine - 20% organic
Kansas Department of Transportation	Topeka, KS	Yes	**Mix in truck Tank from two storage tanks**
Massachusetts Department of Transportation	Massachusetts	Yes	We currently blend MgCl with salt Brine to create a Blended Brine solution for use during roadway pretreatment operations
Massachusetts Department of Transportation	Massachusetts	Yes	Combining Liquid MgCl with Salt Brine for a Blended Brine solution used for pretreatment
Needham MA Department of Public Works	Needham, MA	Yes	Purchase premixed brine and beet juice
Maryland Department of Transportation, State Highway Administration	Maryland	Yes	**Using blending modules that are part of the Brine Production Units**.

Organization	Location	Are you blending liquid deicers with other liquid additives?	Please describe how you are blending liquid deicers with other liquid additives.
Maine Department of Transportation	Maine	Yes	With the use of **Accubrine Automated Brine Mixers**, as well as **tank to tank mixing** with a timeframe for circulation to achieve a mix of 70/30%(70 =salt brine/30=Magic -0)
City of Farmington Hills, MI	Farmington Hills, MI	Yes	We typically blend manufactured sat brine and beet juice for various functions such as Pre-wetting, Ant-Icing and DLA. We also use a small % of Calcium at 32% in the winter as well as 38% in the summer for dust control on gravel roads and shoulders.
City of Plymouth, MN	Plymouth, MN	Yes	**Blend at the truck**
Montana Department of Transportation	Helena, MT	Yes	**Mixed at time of production at our 5 manufacturing facilities.**
North Dakota Department of Transportation	Fargo, ND	Yes	80% Brine / 20 % Geomelt
Nebraska Department of Transportation	Nebraska	Yes	Beet Juice is blended with NaCl brine in ratios up to 50/50 for prewetting solid rock salt. 10 % $MgCl_2$ is blended with NaCl for direct liquid application. brine
New Hampshire Department of Transportation	New Hampshire	Yes	We mix 80% brine with 20% Mag. We do this by **adding Mag into a tank of brine and circulating it**.
City of Columbus OH Department of Public Service	Columbus, OH	Yes	Our **truck loading systems blend them as they load**.
Ohio Department of Transportation	Columbus, OH	Yes	Brine with Beet Heet and Brine/Beet Heet/Calcium Chloride
South Dakota Department of Transportation	Central Office, SD	Yes	We normally blend 20-30% of our liquid additives to 70-80% sodium chloride brine. Additives we currently use is

Organization	Location	Are you blending liquid deicers with other liquid additives?	Please describe how you are blending liquid deicers with other liquid additives.
			AMP, Ice B Gone Magic, Beet Heat Mn. We also use Mag Chloride which is purchased and hauled directly to our requested locations. Mag is used straight as a prewet method during extremally cold temperatures.
South Dakota Department of Transportation	Central Office, SD	Yes	**Based on quantity needed, salt brine and additive are added to a separate tank and mixed before delivery**.
Wyoming Department of Transportation	Cheyenne, WY	Yes	Mix salt brine with Beet 55 at a 30% (Beet 55) mix

Respondents were asked how much liquid deicer their organization uses each winter season. The amounts of 0 to 100,000 gallons of liquid deicer and over 1,000,000 gallons of liquid deicer were the most commonly chosen response (32% of respondents) (see Table 4 and Figure 8).

Table 4. Amount of Liquid Deicer Used Each Winter Season

How much liquid deicer do you use each winter season?	Total Respondents	Percent of Respondents
0 - 100,000 gallons	15	32%
100,000 - 250,000 gallons	6	13%
250,000 - 1,000,000 gallons	11	23%
Over 1,000,000 gallons	15	32%
Grand Total	47	100.0%

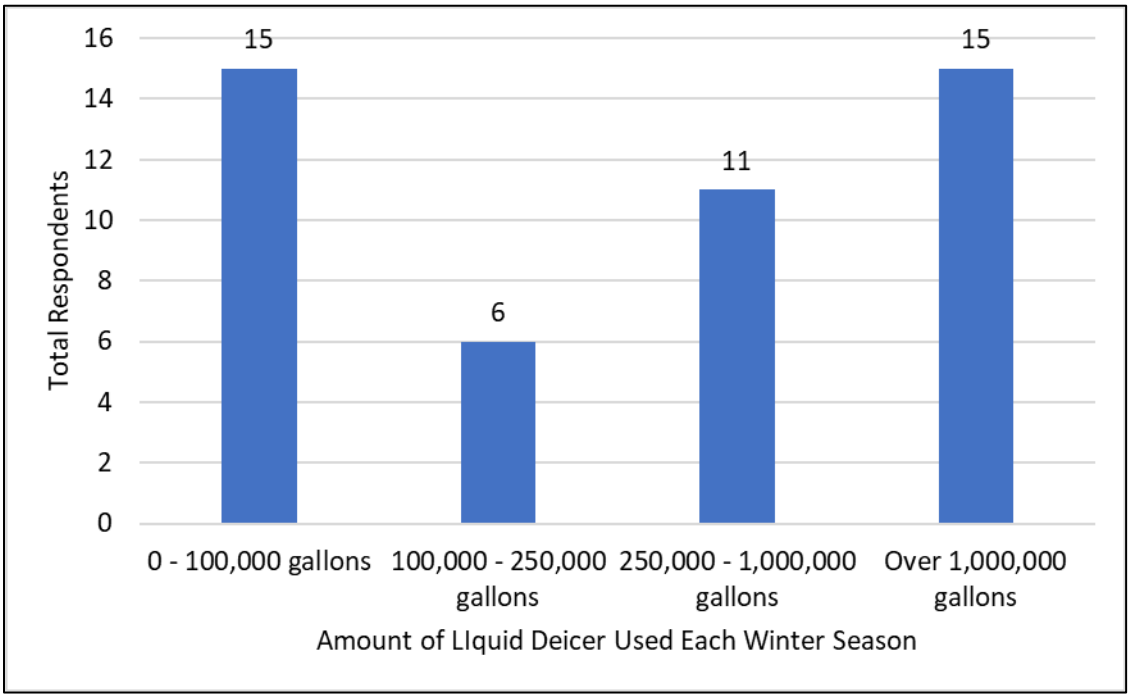

Figure 8. Amount of Liquid Deicer Used Each Winter Season

Liquid Deicer Storage and Pumping System

Respondents were then asked several questions related to their liquid deicer storage and pumping system components. Fifteen respondents ended the survey at this point. The remaining sections of this appendix are based on the remaining 34 respondents (see Figure 9).

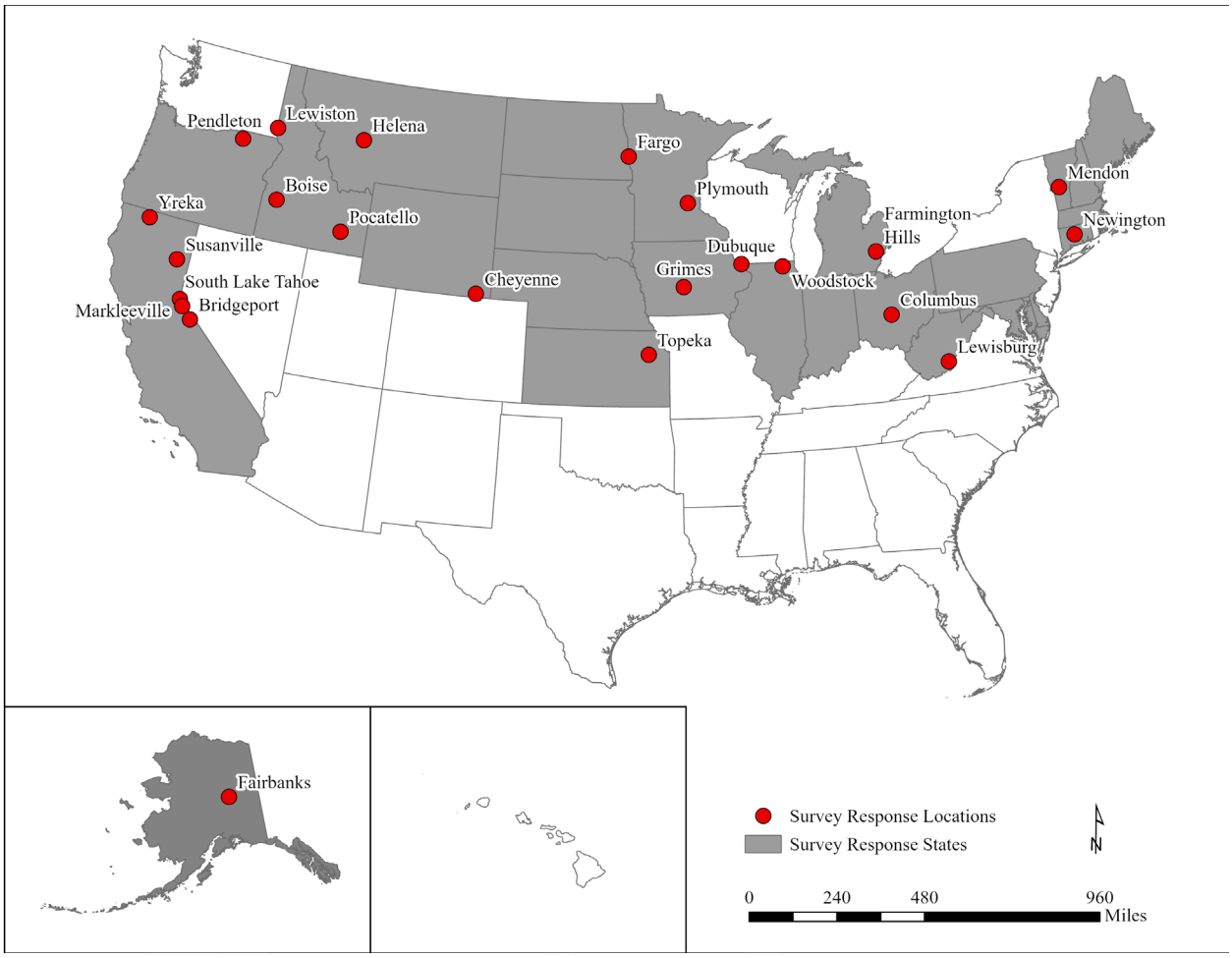

Figure 9. Remaining Survey Respondent Locations

Storage Tanks

Thirty-two respondents provided details on their liquid deicer storage and pumping system tanks (see Table 5). Respondents provided information on a variety of storage tanks from the following manufacturers: Assmann and Poly Processing, Dura-Cast, KBK Industries, Norwesco, Heartland Agricultural, GVM, Snyder Industries (SII), and Varitech. An equipment supplier was also identified, Sprayer Specialty, this supplier carries Norwesco tanks according to their website.

Storage tank capacities ranged from 1,500 gallon to 20,000-gallon tanks. With tank sizes ranging from 8 feet in height to 17 feet in height and ranging from a diameter of 6 feet to 12 feet. The majority of respondents are utilizing polyethylene tanks. Only two respondents (Kansas DOT and North Dakota DOT) are utilizing fiberglass tanks. Both of these respondents also reported using higher capacity tanks (10,000-to-20,000-gallon).

Montana DOT provided several additional characteristics for their tanks including that the tank be:

- " Linear polyethylene resin construction
    - Suitable for 1.67 specific gravity, 14 lb. per gallon material
    - Minimum of 2 tie down lugs
    - Tank to have a 16" manway with a 4" center lid located on the top of the tank
    - Tank to be fitted with a minimum of one (1) 3" stainless steel female threaded outlet
    - Minimum 3 year warranty
- Tank color will be available in blue or white. The color of the tank will be specified at the time of the order."

Table 5. Liquid Deicer Storage and Pumping System - Tank Details

Organization	Location	Number of Tanks	Tank Capacity	Tank Size	Tank Material	Tank Type	Tank Manufacturer
Alaska Department of Transportation & Public Facilities	Fairbanks, AK	4	5,000 gallon	102" diameter	Polyethylene	Vertical	
California Department of Transportation - Caltrans	Susanville CA		10,000 gallon	141" diameter, 160" height	Polyethylene	Single-Wall	Norwesco
California Department of Transportation - Caltrans	District 9, Bridgeport, CA		5,000 gallon		Polyethylene		
California Department of Transportation - Caltrans	South Lake Tahoe, CA		5,000 gallon	12'x9'	Polyethylene		SII
California Department of Transportation - Caltrans	Woodfords Maintenance Station, Markleeville, CA		6,000 gallon	11' height, 11' diameter	Polyethylene		
California Department of Transportation - Caltrans	Yreka, CA		10,000 gallon		Polyethylene		
Connecticut Department of Transportation	Newington, CT		6,500 gallon	200" height, 108" diameter	Polyethylene		Snyder Industries
Delaware Department of Transportation	Delaware		5,000 gallons - 10,000 gallons 20,000 gallons		Polyethylene Fiberglass		Various manufacturers
City of Dubuque Iowa	Dubuque, IA	3	5,000 gallon		Polyethylene	Double Wall	Various manufacturers

Organization	Location	Number of Tanks	Tank Capacity	Tank Size	Tank Material	Tank Type	Tank Manufacturer
City of Grimes IA, Public Works	Iowa	3 1	2,500 gallon 5,000 gallon		Polyethylene		Sprayer Specialty
Iowa Department of Transportation	Iowa		2,500 gallon - 9,000 gallon	Varies - Diameter 6' to 10', Height 7' to 17'	Polyethylene		
Idaho Transportation Department	Lewiston, ID		10,000 gallon	18' x 11.5'	Polyethylene		
Idaho Transportation Department	Pocatello, ID		10,000 gallon	159" Height, 141" Width		Vertical	Norwesco
Idaho Transportation Department	Boise Area, ID		10,000 gallon	14' Height, 12' Width	Polyethylene		Norwesco Heartland Agricultural
McHenry County IL Department of Transportation	Woodstock IL	10	15,500 gallon		Polyethylene		
Indiana Department of Transportation	Indiana		10,500 gallon	169" Height, 142" Diameter	Polyethylene	Rotational Molded HDPE	Snyder Industries
Kansas Department of Transportation	Topeka, KS		10,000 and 20,000 gallon		Fiberglass		KBK Industries (Rush Center, KS)
Massachusetts Department of Transportation	Massachusetts		5,000 gallon 10,000 gallon	12'8" Height, 8'6" Base 13' Height, 11'10" Base	Polyethylene		Snyder Industries (SII)

Organization	Location	Number of Tanks	Tank Capacity	Tank Size	Tank Material	Tank Type	Tank Manufacturer
Maryland Department of Transportation, State Highway Administration	Maryland		6,000 gallon 10,000 gallon	11.5' Height, 9.9' Diameter 13' Height, 11.74' Diameter	Polyethylene		Norwesco, GVM
Maine Department of Transportation	Maine		5,500 gallon	141" Height, 120" Diameter	Polyethylene		Assmann and Poly Processing
City of Farmington Hills, MI	Farmington Hills, MI	10 2 2	6,000 gallon 3,500 gallon 3,000 gallon		Polyethylene		Norwesco, Schneider [Synder]
City of Farmington Hills, MI	Farmington Hills, MI		3,000 gallon - 6,000 gallon		Polyethylene		Schneider [Synder]
City of Plymouth, MN	Plymouth, MN	2 2	5,500 gallon 2,000 gallon		Polyethylene		Varitech
Montana Department of Transportation	Helena, MT		10,000 gallon minimum	175" Height ± 10%, 142" Diameter ± 10% Tank to have a 16” manway with a 4” center lid located on the top of the tank	Polyethylene (Linear polyethylene resin construction)	• Suitable for 1.67 specific gravity, 14 lb. per gallon material • Minimum of 2 tie down lugs • Tank to be fitted with a minimum of one (1) 3” stainless steel female threaded outlet • Minimum 3 year	

Organization	Location	Number of Tanks	Tank Capacity	Tank Size	Tank Material	Tank Type	Tank Manufacturer
						warranty • Tank color will be available in blue or white. The color of the tank will be specified at the time of the order.	
North Dakota Department of Transportation	Fargo, ND		16,000 gallon		Fiberglass		
New Hampshire Department of Transportation	New Hampshire		1,500 gallon - 5,000 gallon	Varies			Various Brands
City of Columbus OH Department of Public Service	Columbus, OH		5,500 gallon - 10,000 gallon		Polyethylene		Norwesco
Oregon Department of Transportation	Pendleton, OR	4	10,000 gallon	13' Height, 35' Diameter			Unknown
Pennsylvania Department of Transportation	Pennsylvania		5,000 gallon - 10,000 gallon		Polyethylene		Various manufacturers

Organization	Location	Number of Tanks	Tank Capacity	Tank Size	Tank Material	Tank Type	Tank Manufacturer
South Dakota Department of Transportation	Central Office, SD		7,000 gallon - 10,000 gallon		Polyethylene		Dura-Cast, Ace Roto Mold
Agency of Transportation State of Vermont - Operations/Maintenance	District 3, Mendon, VT (Southwest Region)		3,000 gallon - 6,000 gallon	8' to 14' Height, 8' Diameter	Polyethylene		
West Virginia Division of Highways - District 9	Lewisburg, WV		5,000 gallon		Polyethylene		

Truck Fill Motors

Twenty-nine respondents provided details on their liquid deicer storage and pumping system truck fill motors (see Table 6). Information was provided on several truck fill motors from the following manufacturers: AMT Pump Company, Baldor Reliance, Belden, Connex, Dayton, Goulds, Leeson, and Marathon. The following equipment suppliers were also identified: Cargill and Dultmeier, and Henderson.

Motor sizes ranged from 3/4 horsepower to 10 horsepower with 5 horsepower motors being the most commonly used. Both single and three phase motors are used. Voltage requirements ranged from 115V to 480V, with 220 V being the most commonly used.

Table 6. Truck Fill Motor Details

Organization	Location	Motor Size (Horsepower)	Motor RPM	Electrical Voltage Requirements	Motor Characteristics	Motor Manufacturer
Alaska Department of Transportation & Public Facilities	Fairbanks, AK	7.5 HP	3,525 RPM	208-230/460 volts		AMT Pump Company
California Department of Transportation - Caltrans	Susanville CA	3 HP	3,450 RPM	230 V A/C		Dayton
California Department of Transportation - Caltrans	District 9, Bridgeport, CA	5 HP		208V		Accubrine
California Department of Transportation - Caltrans	South Lake Tahoe, CA	3 HP		220V		
California Department of Transportation - Caltrans	Woodfords Maintenance Station, Markleeville, CA	5 HP	2,900 RPM	240 Ac, 3 Amps, 3 Phase		AMT Pump Company
California Department of Transportation - Caltrans	Yreka, CA					Accubrine
Connecticut Department of Transportation	Newington, CT	3 HP	3,450 RPM	220/230V, Single Phase		
Delaware Department of Transportation	Delaware	10 HP		230/460V, 3 Phase 480V	AMT 4261-98	AMT Pump Company
City of Dubuque Iowa	Dubuque, IA				Blending System	Cargill
City of Grimes IA, Public Works	Iowa	5 HP	2,860 RPM	230V		

Organization	Location	Motor Size (Horsepower)	Motor RPM	Electrical Voltage Requirements	Motor Characteristics	Motor Manufacturer
Iowa Department of Transportation	Iowa				Pumps are driven with electric motors hooked to PVC cased pumps with PVC impellers.	
Idaho Transportation Department	Lewiston, ID	5 HP	3,450 RPM	240V		Chem Flo
Idaho Transportation Department	Pocatello, ID	10 HP	3,500 RPM	220V		Various Manufacturers
Idaho Transportation Department	Boise Area, ID				Tank fill is performed by vendor.	
McHenry County IL Department of Transportation	Woodstock IL	5 HP (x1 motor) 3 HP (x2 motors) 1 HP (x2 motors)		480V		Baldor Reliance
Indiana Department of Transportation	Indiana	3 HP			184TC Frame, Stainless Steel, Three Phase	Connex
Kansas Department of Transportation	Topeka, KS	2-5 HP		230V		Lesson Belden
Massachusetts Department of Transportation	Massachusetts	3 HP	2,300 RPM	220W		Baldor Reliance, Marathon

Organization	Location	Motor Size (Horsepower)	Motor RPM	Electrical Voltage Requirements	Motor Characteristics	Motor Manufacturer
Maine Department of Transportation	Maine	3/4, 1.5, 2, and 5 HP		220-250V	20-30 Amp All weather Quick Disconnect Plugs	Baldor, Dayton, Leeson
City of Farmington Hills, MI	Farmington Hills, MI	10 HP (x1 motor) 5 HP (x2 motors)				Henderson
City of Farmington Hills, MI	Farmington Hills, MI				Stacked Fill Point System - Approximately 7 Years Old	Henderson
Montana Department of Transportation	Helena, MT	Variable Sizes				
North Dakota Department of Transportation	Fargo, ND	1/2 HP		220V		
City of Columbus OH Department of Public Service	Columbus, OH	5 HP 3 HP	3,470 RPM 3,500 RPM	230/460V 230V	Four Sites Also Have 2 Cargill Blend V2 Truck Loading Systems Per Site	Baldor Reliance Goulds
Oregon Department of Transportation	Pendleton, OR	7.5 HP	3,450 RPM	230V, 3 Amps, Single Phase		Baldor Reliance
Pennsylvania Department of Transportation	Pennsylvania	1.5 HP	3,450 RPM	220V		Dayton
South Dakota Department of Transportation	Central Office, SD	5 HP		230/460V		Dultmeier

Organization	Location	Motor Size (Horsepower)	Motor RPM	Electrical Voltage Requirements	Motor Characteristics	Motor Manufacturer
Agency of Transportation State of Vermont - Operations/Maintenance	District 3, Mendon, VT (Southwest Region)			115V or 230V, 28.5 Amps Start Up, 14.5 Amps Running	Three Phase	

Truck Fill Pumps

Thirty respondents provided details on their liquid storage and pumping system truck fill pumps (see Table 7). Information was provided for truck fill pumps from the following manufacturers: AMT Pump Company, Banjo, Brine Masters, Cargill, Dayton, Dultmeier, Goulds, MP Pumps, Pacer, Scots, and Sprayer Specialties.

Pump size ranged from 1/2 horsepower to 10 horsepower or pump discharge ranging from 50 gallons per minute to 750 gallons per minute. Many respondents noted that they use a stainless-steel pump. Several respondents noted that their pump outlet was 2 inches or 3 inches. Some agencies have a large horsepower pump with high volume capacity (300 GPM+) to load larger tanks.

A few noted that their pump was a part of their brine system. There are multiple OEM Salt Brine Companies that incorporate a truck loading option that can pump up to 300 GPM, directly from the brine system.

One respondent from Maryland DOT SHA noted that their contract requires that the brine application trucks have a similar pump discharge size as their storage and pumping system equipment so that they can act as a backup if the pump goes down.

Table 7. Truck Fill Pump Details

Organization	Location	Pump Size (HP)	Pump Discharge (GPM)	Pump Characteristics	Pump Manufacturer
Alaska Department of Transportation & Public Facilities	Fairbanks, AK		300 GPM	Stainless Steel, Direct Coupled to the Truck Fill Motor	AMT Pump Company
California Department of Transportation - Caltrans	Susanville CA		150 GPM	Closed Impeller, Stainless Steel, Mounted Directly to the Electric Motor	Dayton
California Department of Transportation - Caltrans	District 9, Bridgeport, CA	5 HP	50 GPM		
California Department of Transportation - Caltrans	South Lake Tahoe, CA		50-100 GPM	Part of Brine System	
California Department of Transportation - Caltrans	Woodfords Maintenance Station, Markleeville, CA		200 GPM		AMT Pump Company
California Department of Transportation - Caltrans	Yreka, CA			Part of Accubrine Automated Brine Maker	Accubrine
Connecticut Department of Transportation	Newington, CT		100 GPM	Stainless Steel, 2" Inlet/Outlet	
Delaware Department of Transportation	Delaware	10 HP		3" Suction and Discharge	AMT Pump Company
City of Dubuque Iowa	Dubuque, IA			Part of Cargill Blending System	Cargill

Organization	Location	Pump Size (HP)	Pump Discharge (GPM)	Pump Characteristics	Pump Manufacturer
City of Grimes IA, Public Works	Iowa			Part of Brine Masters - Continuum TF-XR Truck Fill Station	Brine Masters
Iowa Department of Transportation	Iowa		100 GPM	PVC Cased Pumps with PVC Impellers, 2" Discharge, Some are 3" Discharge	Dultmeier, Sprayer Specialties
Idaho Transportation Department	Lewiston, ID	5 HP	750 GPM		
Idaho Transportation Department	Pocatello, ID			3" Cast Iron Pump	Various Manufacturers
Idaho Transportation Department	Boise Area, ID		340 GPM	Banjo 1800 Series, 3"	Banjo
McHenry County IL Department of Transportation	Woodstock IL		80-150 GPM		
Indiana Department of Transportation	Indiana			Stainless Steel, Silicon Carbide Seals	
Kansas Department of Transportation	Topeka, KS		110 GPM	Stainless Steel, 2" Pump	Banjo
Massachusetts Department of Transportation	Massachusetts				MP Pumps
Maryland Department of Transportation, State Highway Administration	Maryland		200 GPM	Our contracts require that the brine application trucks have similar GPM pump sizes on the	

Organization	Location	Pump Size (HP)	Pump Discharge (GPM)	Pump Characteristics	Pump Manufacturer
				equipment. This is used as a backup if our pumps go down.	
Maine Department of Transportation	Maine	3/4, 1.5, 2, and 5 HP	100 GPM (1.5 and 2 HP Pumps) 145 GPM (5 HP Pumps)		Dayton, Scots
City of Farmington Hills, MI	Farmington Hills, MI				MP Pumps
Montana Department of Transportation	Helena, MT			2" to 3" Camlock Discharge Hose	
North Dakota Department of Transportation	Fargo, ND	1/2 HP			
City of Columbus OH Department of Public Service	Columbus, OH		300 GPM (AMT Pumps) 64 GPM (Goulds)		Accubrine, AMT, Goulds
Oregon Department of Transportation	Pendleton, OR		280 GPM	Pacer pump SE3LL CSS, 3" Inlet, 3" Outlet	Pacer Pump
Pennsylvania Department of Transportation	Pennsylvania		100 GPM	1.5" Discharge, 2" Intake	Dayton

Organization	Location	Pump Size (HP)	Pump Discharge (GPM)	Pump Characteristics	Pump Manufacturer
South Dakota Department of Transportation	Central Office, SD	5 HP	750 GPM		Dultmeier
Agency of Transportation State of Vermont - Operations/Maintenance	District 3, Mendon, VT (Southwest Region)		80-90 GPM		

Respondents were then asked whether the truck fill pumps had variable flow capabilities. Variable flow pumps allow the user to change the flow rate of the liquid. Just over a third of respondents (~37%) had a pump with variable flow capabilities. These included pumps from AMT Pump Company, Brine Masters, MP Pumps, and Pacer Pumps. Detailed information on these pumps is provided in Table 8.

Table 8. Pumps with Variable Flow Capabilities

Organization	Location	Liquid Deicer Storage and Pumping System - Truck Fill Pump(s)	Does your truck fill pump have variable flow capacity?
Alaska Department of Transportation & Public Facilities	Fairbanks, AK	The truck fill pump is an AMT stainless steel centrifugal 300 gpm pump direct coupled to the truck fill motor	Yes
California Department of Transportation - Caltrans	Woodfords Maintenance Station, Markleeville, CA	Same as above, 200 GPM.	Yes
City of Grimes IA, Public Works	Iowa	Brine Masters truck fill -- Continuum™ TF-XR Truck Fill Station	Yes
Idaho Transportation Department	Lewiston, ID	5 HP Pumps, 240V 3450 RPM Triple Phase Power, 750 gallon/minute	Yes
McHenry County IL Department of Transportation	Woodstock IL	All pumps are MP pumps ran by motors listed above. capable of pumping 80-150 gallons a minute.	Yes
Maryland Department of Transportation, State Highway Administration	Maryland	Not sure of the pump size, but I know our brine makers have pumps that are rated to 200 GPM. Our contracts require that the brine application trucks have similar GPM pump sizes on the equipment. This is used as a backup if our pumps go down.	Yes
City of Farmington Hills, MI	Farmington Hills, MI	#3 - MP pumps (HP etc. will be supplied & GPM will be supplied if needed)	Yes
City of Farmington Hills, MI	Farmington Hills, MI	Can get after doing some homework, we have 3 fill points for liquids	Yes
City of Plymouth, MN	Plymouth, MN		Yes
Montana Department of Transportation	Helena, MT	Variable size with 2-3" camlock discharge hose	Yes
Oregon Department of Transportation	Pendleton, OR	Pacer pump SE3LL CSS, 3" inlet, 3" outlet, 280 GPM	Yes
West Virginia Division of Highways - District 9	Lewisburg, WV		Yes

Then, respondents were asked whether their truck fill pump was stand alone or part of a salt brine system. Most respondents (~61%) reported using a stand-alone truck fill pump system. For the thirteen respondents that were using a salt brine system, reported systems include Cargill's Accubrine brine makers.

Piping and Fittings

Respondents were asked to provide details on their liquid deicer storage and pumping system piping and fittings. Thirty-two respondents provided details (see Table 9).

The majority of respondents utilize a combination of both hard and soft piping and fittings, with several respondents noting that tank lines were all hard piped and the lines from the pump to the truck are flexible. Fittings were generally described as rigid plastic, stainless steel, or brass. Several respondents noted that they use Banjo Corporation fittings and valves.

Table 9. System Piping and Fitting Details

Organization	Location	Piping and Fitting	Piping	Fittings
Alaska Department of Transportation & Public Facilities	Fairbanks, AK	Hard Plastic	Hard plastic lines	Plastic (Banjo Brand) - Fittings and Valves
California Department of Transportation - Caltrans	Susanville CA	Both (hard and flexible)	2" soft plastic corrugated hose	2" rigid plastic "Banjo" quick coupler fittings held together with stainless steel hose clamps
California Department of Transportation - Caltrans	Yreka, CA	Both (hard and flexible)	Soft plumbing	Hard fittings
California Department of Transportation - Caltrans	South Lake Tahoe, CA	Soft/Flexible	Flexible hose	
California Department of Transportation - Caltrans	Woodfords Maintenance Station, Markleeville, CA	Both (hard and flexible)		
California Department of Transportation - Caltrans	District 9, Bridgeport, CA	Soft/Flexible		
Connecticut Department of Transportation	Newington, CT	Soft/Flexible	Soft, polypropylene	

Organization	Location	Piping and Fitting	Piping	Fittings
Delaware Department of Transportation	Delaware	Both (hard and flexible)	Hard connected with manifold. Manifold to the trucks and tanks are flexible lines (3" minimum).	
City of Dubuque Iowa	Dubuque, IA	Both (hard and flexible)		
City of Grimes IA, Public Works	Iowa	Both (hard and flexible)	Combination of flexible and hard hoses	Hard fittings
Iowa Department of Transportation	Iowa	Both (hard and flexible)	The main truck usually has multiple 2" flex lines feeding from the storage tanks to the main truck that then carries the liquid to the pumps. 2" and/or 3" flex line is used again from the electric pumps to fill the brine trailers or prime tanks on the vehicle. The main truck is usually made from at least 12 PVC pipe.	
Idaho Transportation Department	Pocatello, ID	Hard	Gray ABS plastic piping	Gray ABS fitting and valves
Idaho Transportation Department	Boise Area, ID	Both (hard and flexible)	All lines to the pump are hard lines. Lines from pump to truck are flexible.	3" Camlock
Idaho Transportation Department	Lewiston, ID	Soft/Flexible	3" flexible PVC piping	3" Camlock connections

Organization	Location	Piping and Fitting	Piping	Fittings
McHenry County IL Department of Transportation	Woodstock IL	Hard	Tanks are all hard piped	Banjo valves
Indiana Department of Transportation	Indiana	Pipe Trunk Lines are run to storage tanks and pumping systems. Hose connections are also used for final connections to devices that have vibration and movement from expansion and contractions.		
Kansas Department of Transportation	Topeka, KS	Both (hard and flexible)	2" plumbing PVC and tank recirculation, 2" flex hose to fill the truck	Stainless steel flanges to connect to the tank
Massachusetts Department of Transportation	Massachusetts	Both (hard and flexible)	2" flexible suction hose, 2" flexible discharge hose (fill hose), and 1" flexible discharge hose (fill hose)	All fittings and valves are brass
Maine Department of Transportation	Maine	Both (hard and flexible)	All pump stations are designed using EPDM all weather hose, 100 PSI, -40F to +140F, as well as gray SCH 80 PVC pipe.	Gray SCH 80 PVC pipe fittings, also Banjo polypropylene pipe fittings.
City of Farmington Hills, MI	Farmington Hills, MI	Indoor vaulted floor for containment as well as any spills in garage fill point		

Organization	Location	Piping and Fitting	Piping	Fittings
		areas tied to sanitary system		
City of Farmington Hills, MI	Farmington Hills, MI	Both (hard and flexible)	Majority are schedule 80 piping with 2" and 3" bumblebee style hoses at the end point before camlocking onto equipment tanks.	Camlock
City of Plymouth, MN	Plymouth, MN	Both (hard and flexible)		
Montana Department of Transportation	Helena, MT	Hard	Plastic, stainless steel, and flexible wire reinforced suction/discharge lines	2-3" Camlocks
North Dakota Department of Transportation	Fargo, ND	Both (hard and flexible)	Combination hard stainless and flexible HD hose	
Nebraska Department of Transportation	Nebraska	Both (hard and flexible)	Hard pipes for much of the plumbing, soft hoses for dispensing	
New Hampshire Department of Transportation	New Hampshire	Soft/Flexible		

Organization	Location	Piping and Fitting	Piping	Fittings
City of Columbus OH Department of Public Service	Columbus, OH	Both (hard and flexible)	Combination of schedule 80 PVC and corrugated flexible tubing	Valves and fittings are banjo
Oregon Department of Transportation	Pendleton, OR	Both (hard and flexible)	Flexible line from pump to truck fill	Hard plumbing from tanks to pump
Pennsylvania Department of Transportation	Pennsylvania	Both (hard and flexible)	Hard PVC and soft silicon/rubber reinforced hose	
South Dakota Department of Transportation	Central Office, SD	Both (hard and flexible)	EPDM/polyethylene blend 2" (bumblebee)lines	2" Banjo fittings
Agency of Transportation State of Vermont - Operations/Maintenance	District 3, Mendon, VT (Southwest Region)	Soft/Flexible	Soft flex hose 2"	Camlock couplers - all fixed fittings are threaded and taped PVC with shark bite couplers on hose connections with stainless steel hose clamps.
West Virginia Division of Highways - District 9	Lewisburg, WV	Hard		

Product Inventory Capabilities

Respondents were asked a series of questions on additional truck fill station capabilities. In particular, questions related to whether their system could capture data related to product use including whether their truck fill station could capture gallons of product dispensed, maintain a database of product dispensed, and whether it could keep a real-time tank level of available product (see Table 10).

Twenty-five respondents had a truck fill station with at least one product monitoring capability (see Figure 10). Fifteen respondents (~44%) had a truck fill station with all three capabilities.

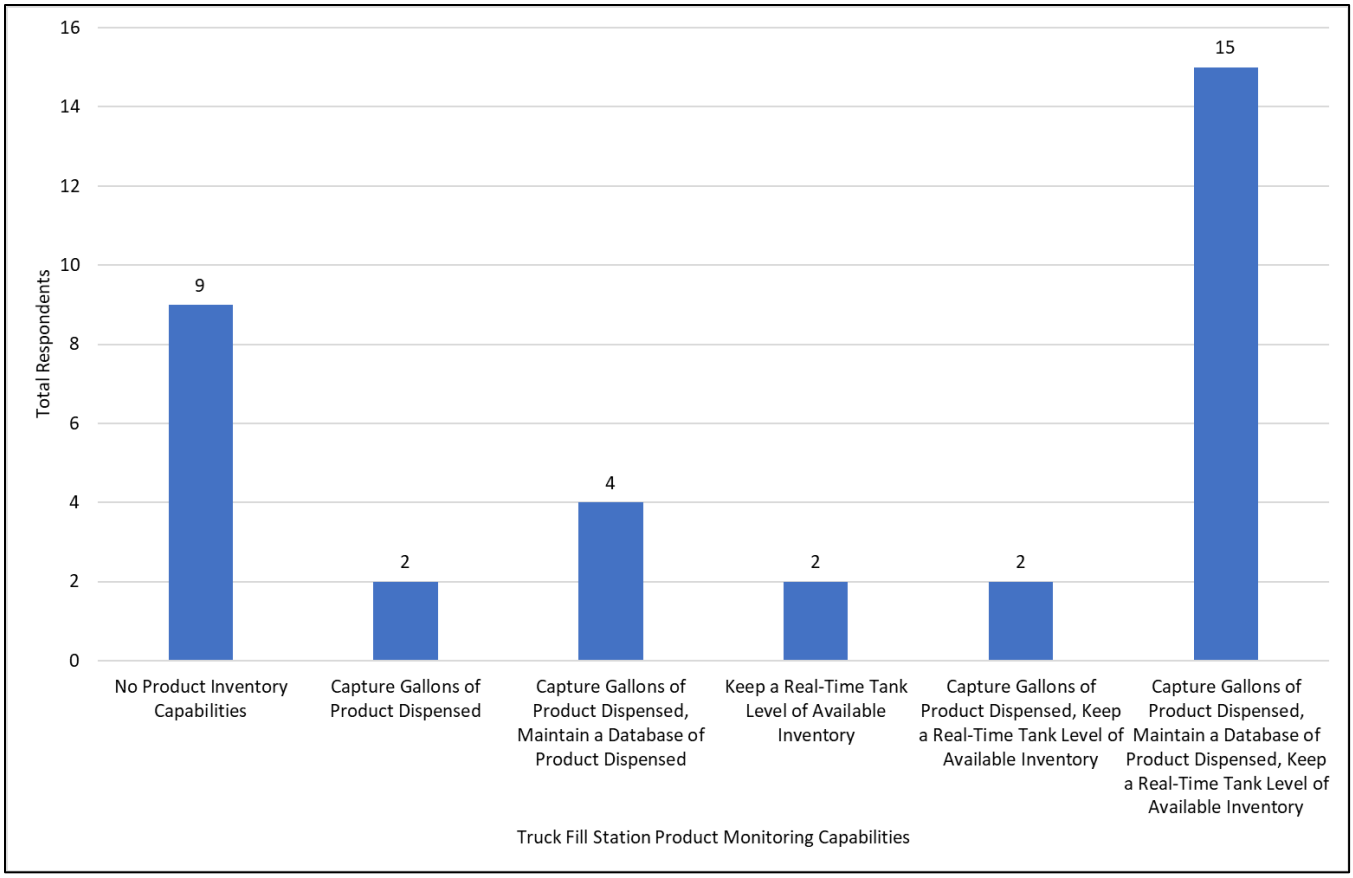

Figure 10. Total Respondents by Truck Fill Station Capabilities

Table 10. Truck Fill Station Product Inventory Capabilities

Organization	Location	Can your truck fill station capture gallons of product dispensed?	Can your truck fill station maintain a database of product dispensed?	Can your truck fill station keep a real-time tank level of available inventory?
Alaska Department of Transportation & Public Facilities	Fairbanks, AK	Yes	Yes	Yes
California Department of Transportation - Caltrans	District 9, Bridgeport, CA	Yes	Yes	Yes
California Department of Transportation - Caltrans	South Lake Tahoe, CA	Yes	Yes	Yes
California Department of Transportation - Caltrans	Woodfords Maintenance Station, Markleeville, CA	Yes	Yes	Yes
California Department of Transportation - Caltrans	Yreka, CA	Yes	Yes	Yes
California Department of Transportation - Caltrans	Susanville CA	No	No	No
Connecticut Department of Transportation	Newington, CT	Yes	Yes	Yes
Delaware Department of Transportation	Delaware	No	No	No
City of Dubuque Iowa	Dubuque, IA	Yes	Yes	Yes
City of Grimes IA, Public Works	Iowa	Yes	Yes	Yes
Iowa Department of Transportation	Iowa	No	No	No
Idaho Transportation Department	Lewiston, ID	Yes	Yes	No
Idaho Transportation Department	Pocatello, ID	No	No	No
Idaho Transportation Department	Boise Area, ID	No	No	No
McHenry County IL Department of Transportation	Woodstock IL	Yes	Yes	Yes
Indiana Department of Transportation	Indiana	Yes	Yes	Yes
Kansas Department of Transportation	Topeka, KS	No	No	No

Best Management Practices for Liquid Chloride Storage and Pumping Systems

Organization	Location	Can your truck fill station capture gallons of product dispensed?	Can your truck fill station maintain a database of product dispensed?	Can your truck fill station keep a real-time tank level of available inventory?
Massachusetts Department of Transportation	Massachusetts	No	No	No
Maryland Department of Transportation, State Highway Administration	Maryland	Yes	Yes	Yes
Maine Department of Transportation	Maine	No	No	Yes
City of Farmington Hills, MI	Farmington Hills, MI	Yes	Yes	No
City of Farmington Hills, MI	Farmington Hills, MI	Yes	Yes	No
City of Plymouth, MN	Plymouth, MN	Yes	Yes	Yes
Montana Department of Transportation	Helena, MT	Yes	Yes	No
North Dakota Department of Transportation	Fargo, ND	Yes	Yes	Yes
Nebraska Department of Transportation	Nebraska	No	No	Yes
New Hampshire Department of Transportation	New Hampshire	No	No	No
City of Columbus OH Department of Public Service	Columbus, OH	Yes	Yes	Yes
Oregon Department of Transportation	Pendleton, OR	Yes	Yes	Yes
Pennsylvania Department of Transportation	Pennsylvania	No	No	No
South Dakota Department of Transportation	Central Office, SD	Yes	No	No
Agency of Transportation State of Vermont - Operations/Maintenance	District 3, Mendon, VT (Southwest Region)	Yes	No	Yes
West Virginia Division of Highways - District 9	Lewisburg, WV	Yes	No	Yes
Wyoming Department of Transportation	Cheyenne, WY	Yes	No	No

Maintenance of Liquid Deicer Storage and Pumping Systems

Respondents were then asked a series of questions related to how they inspect and maintain their liquid deicer storage and pumping systems. Twenty-seven respondents (~79%) reported that they have a standard maintenance practice for their liquid deicer storage and pumping system.

Those twenty-seven respondents were asked whether that standard maintenance practice included pre-season, mid-season, and/or post season protocols. Most respondents (~56%) had a standard maintenance practice that included pre-season, mid-season, and post season protocols (see Figure 11). The second most commonly reported maintenance practice was for both pre-season and post-season (~26% of respondents). Maine DOT added that "70/30 mix and straight Magic-0 is circulated every thirty days so crew members [can] look over [the] pump stations for any issues and report [them] to [the] Snow and Ice Supervisor".

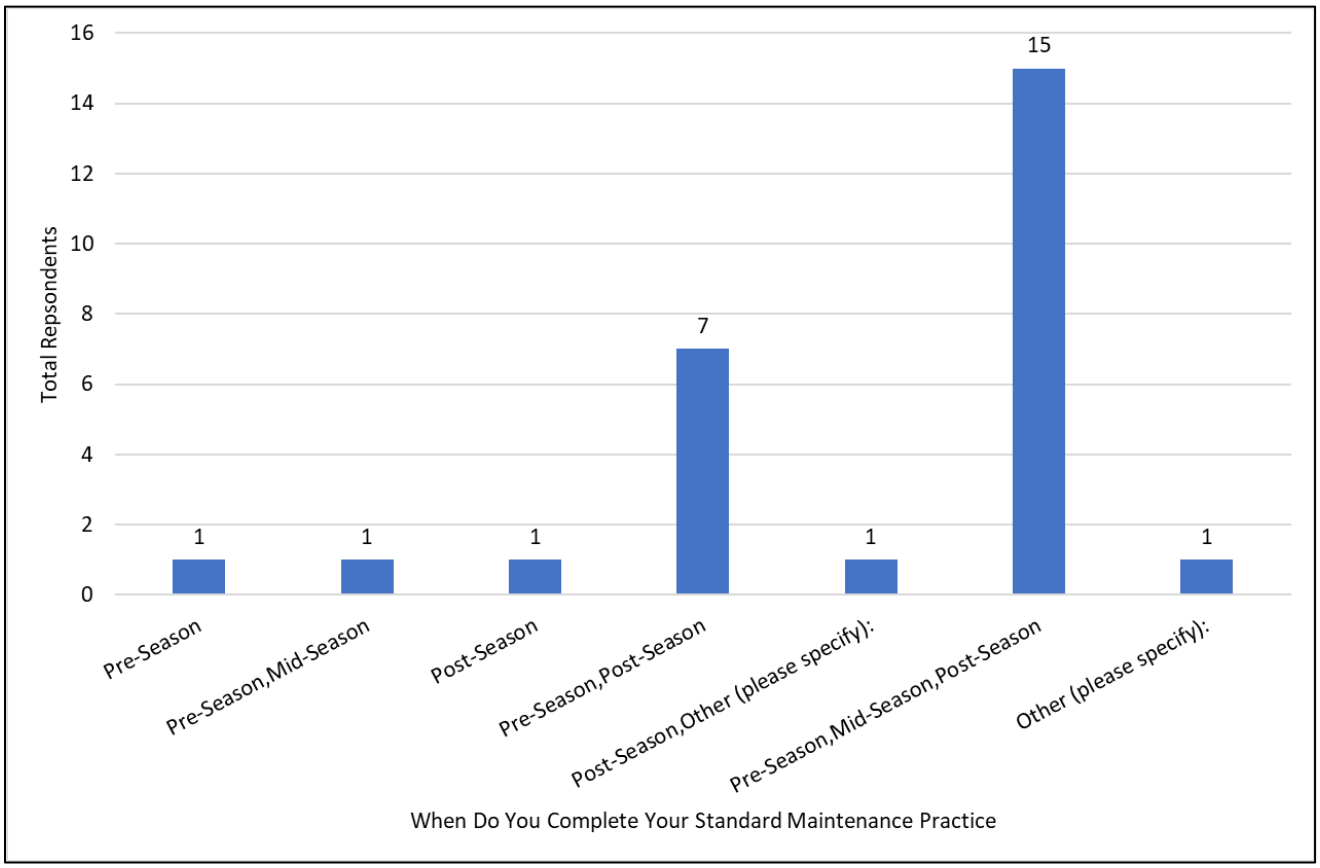

Figure 11. Total Respondents by Standard Maintenance Practice Timing

Half of respondents (17 respondents) noted that they had a checklist for inspection of their liquid deicer storage and pumping system. At most agencies this inspection checklist was completed by Snow & Ice Staff. Eight respondents noted that the inspection checklist was completed by another person within the agency. These responses included tech staff, facilities maintenance, and vendors (see Table 11).

Table 11. Liquid Deicer Storage and Pumping System Inspection Checklist Responsibilities

Organization	Location	Who completes the inspection checklist? (check all that apply) - Selected Choice	Who completes the inspection checklist? (check all that apply) - Other (please specify): - Text
Delaware Department of Transportation	Delaware	Fleet/Mechanic	
Alaska Department of Transportation & Public Facilities	Fairbanks	Snow & Ice Staff	
California Department of Transportation - Caltrans	Susanville CA	Snow & Ice Staff	
City of Dubuque Iowa	Dubuque, Iowa	Snow & Ice Staff	
Iowa Department of Transportation	Iowa	Snow & Ice Staff	
Idaho Transportation Department	Pocatello	Snow & Ice Staff	
Massachusetts Department of Transportation	Massachusetts	Snow & Ice Staff	
South Dakota Department of Transportation	Central Office	Snow & Ice Staff	
Oregon Department of Transportation	Pendleton, OR	Snow & Ice Staff, Fleet/Mechanic	
Agency of Transportation State of Vermont - Operations/Maintenance	District 3 Mendon, VT. Southwest Region	Snow & Ice Staff, Fleet/Mechanic, Other (please specify):	Tech staff
McHenry County IL Department of Transportation	Woodstock IL	Snow & Ice Staff, Other (please specify):	Facilities Maintenance
Maine Department of Transportation	Maine	Snow & Ice Staff, Other (please specify):	Any crew members
California Department of Transportation - Caltrans	South Lake Tahoe	Other (please specify):	Vendor
California Department of Transportation - Caltrans	Woodfords Maintenance Station, Markleeville, CA, 96120	Other (please specify):	Supervisor
Indiana Department of Transportation	Indiana	Other (please specify):	Facilities Department
City of Columbus OH Department of Public Service	Columbus Ohio	Other (please specify):	Building Maintenance
Pennsylvania Department of Transportation	Pennsylvania	Other (please specify):	Maintenance Repairman

Respondents were asked who was responsible for the maintenance of their liquid deicer storage and pumping system. Snow and Ice Staff most commonly handle this (42%) (see Figure 12). Seven

respondents noted that another staff member was responsible for maintenance. Answers included vendors, building crew, a supervisor, and building maintenance (see Table 12). Maine DOT reported that they have two statewide maintenance personnel who are responsible for maintenance and repair of their liquid deicer storage and pumping systems statewide.

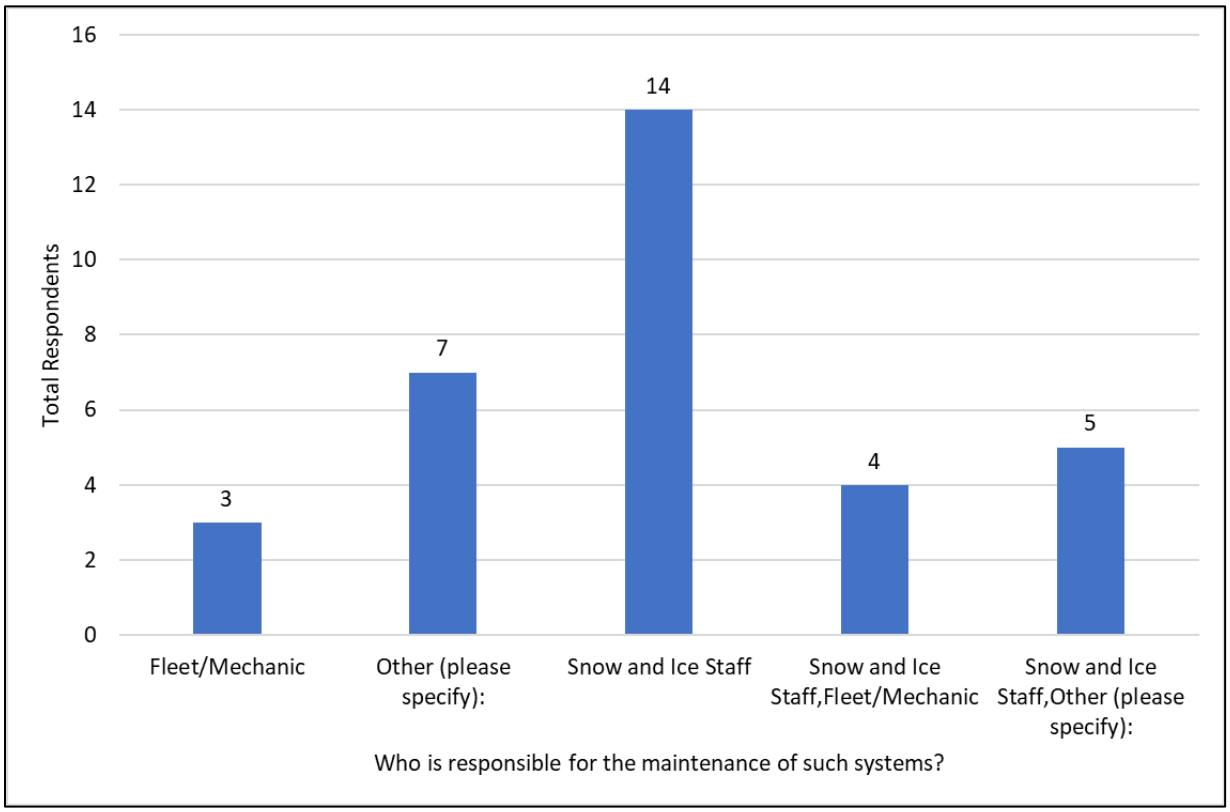

Figure 12. Who is responsible for the maintenance of your liquid deicer storage and pumping system?

Table 12. Other Staff Members Responsible for Maintenance

Organization	Location	Who is responsible for the maintenance of such systems? (check all that apply) - Selected Choice	Who is responsible for the maintenance of such systems? (check all that apply) - Other (please specify): - Text
Alaska Department of Transportation & Public Facilities	Fairbanks	Snow and Ice Staff, Other (please specify):	Cargill technicians as required
California Department of Transportation - Caltrans	Woodfords Maintenance Station, Markleeville, CA	Snow and Ice Staff, Other (please specify):	Supervisor

Organization	Location	Who is responsible for the maintenance of such systems? (check all that apply) - Selected Choice	Who is responsible for the maintenance of such systems? (check all that apply) - Other (please specify): - Text
McHenry County IL Department of Transportation	Woodstock IL	Snow and Ice Staff, Other (please specify):	Facilities Maintenance
Indiana Department of Transportation	Indiana	Snow and Ice Staff, Other (please specify):	Facilities Department
City of Farmington Hills, MI	Farmington Hills, MI	Snow and Ice Staff, Other (please specify):	Vendors when needed
Idaho Transportation Department	Lewiston	Other (please specify):	Maintenance/Operations Personnel
Idaho Transportation Department	Boise Area	Other (please specify):	Building Crew
Maine Department of Transportation	Maine	Other (please specify):	Statewide Snow and Ice Crew comprised of two employees that service the whole state
Nebraska Department of Transportation	Nebraska	Other (please specify):	Maintenance Personnel (mechanics, maintenance workers and supervisors)
City of Columbus OH Department of Public Service	Columbus Ohio	Other (please specify):	Building maintenance
Pennsylvania Department of Transportation	Pennsylvania	Other (please specify):	
Wyoming Department of Transportation	Cheyenne	Other (please specify):	Local shop Foreman

Respondents were then asked whether their liquid deicer storage and pumping system had common parts that were failing (see Table 13). Pumps and fittings were the most commonly noted items that experienced failure. Two agencies (Maryland DOT SHA and South Dakota DOT) both noted specific failures with Banjo fittings. One respondent specifically noted that non-brass parts tend to fail more often than others. Several respondents also noted failures of hoses and connections. One respondent noted failure of hard line connections when snow slid off tanks. Another noted needing to replace their hoses annually to bi-annually and one noted challenges with hoses being driven on.

Table 13. Common Parts Experiencing Failure

Organization	Location	Are there common parts failing, annually (i.e., tanks, pumps, hoses, etc.; please list)?
California Department of Transportation - Caltrans	D9 Bridgeport, Ca	Nothing failing consistently if anything it would be small micro wires breaking due to vibration
California Department of Transportation - Caltrans	Woodfords Maintenance Station, Markleeville, CA	One end cap on the brine system has failed twice in 10 years. Simple repair and no spillage occurs.
California Department of Transportation - Caltrans	South Lake Tahoe	Pipe and fittings
Delaware Department of Transportation	Delaware	Hoses
City of Dubuque Iowa	Dubuque, Iowa	Normally pump related failure
Iowa Department of Transportation	Iowa	Pumps are very common replacement items.
Idaho Transportation Department	Lewiston	Hoses every year or two depending on location. Motors and pumps vary from 5 to 15 years
Idaho Transportation Department	Boise Area	Leaks on hard line connections. Snow sliding off tanks can break hard lines. Coupler between pump and electric motor.
Idaho Transportation Department	Pocatello	Pump heads. Sight Glasses need Cleaned on a regular basis.
Kansas Department of Transportation	Topeka Kansas	Pumps and Hoses. Can send you a list.
Massachusetts Department of Transportation	Massachusetts	Cam lock fittings, clamps, shutoff valves (handles), fill nozzles. Essentially all non-brass parts tend to fail more often than any other.
Maryland Department of Transportation, State Highway Administration	Maryland	Salinity Meters, Festo block failures, banjo fittings, flexible hoses, etc.
Maine Department of Transportation	Maine	Bearings in the pumps fail often, hoses last for a long time if they're not driven on, motors are very rarely replaced. Site tubes may last 2 years, they corrode fast due to sunlight and liquid
City of Farmington Hills, MI	Farmington Hills, MI	Occasionally pumps and seals, have had some hose failures.

Organization	Location	Are there common parts failing, annually (i.e., tanks, pumps, hoses, etc.; please list)?
City of Farmington Hills, MI	Farmington Hills, MI	Occasional hose breaking, pump seals periodically need replaced etc.
Montana Department of Transportation	Helena, Montana	After a certain number of years in service, we have seen failures of tanks, pumps, and hoses with not set pattern.
Nebraska Department of Transportation	Nebraska	Pumps and hoses regularly need replaced
New Hampshire Department of Transportation	New Hampshire	Pumps and fittings
City of Columbus OH Department of Public Service	Columbus Ohio	Occasionally a pump or flow meter
Pennsylvania Department of Transportation	Pennsylvania	Pumps, hoses, fittings
South Dakota Department of Transportation	Central Office	Pumps and Banjo 2'' fittings have the most failures I am told.
Agency of Transportation State of Vermont - Operations/Maintenance	District 3 Mendon, VT. Southwest Region	Pumps - hoses, valves, and fittings
West Virginia Division of Highways - District 9	Lewisburg, WV	pumps
Alaska Department of Transportation & Public Facilities	Fairbanks	No
California Department of Transportation - Caltrans	Yreka, CA	No
City of Grimes IA, Public Works	Iowa	We have not had any failures in the yrs of operation
McHenry County IL Department of Transportation	Woodstock IL	As of now, No
Indiana Department of Transportation	Indiana	N/A
City of Plymouth, MN	Plymouth, MN	No
North Dakota Department of Transportation	Fargo	Not Really
Oregon Department of Transportation	Pendleton, OR	No

A follow up question asked respondents if they kept particular parts on the shelf for emergencies (see Table 14). Similar to the list of commonly failing parts, respondents were keeping pumps, hoses, and fittings on the shelf in case of emergency. Other mentioned parts include valves, rubber gaskets for fittings, and clamps. Again, Maine DOT noted that they have two state personnel who maintain and repair liquid deicer storage and pumping systems statewide. It was noted that these statewide personnel have a workshop where all repairs are done to motors and pumps.

Table 14. Parts Kept In Case of Emergency

Organization	Location	Are there particular parts that are kept on the shelf for emergencies (please list)?
Alaska Department of Transportation & Public Facilities	Fairbanks	We have spare pumps, fittings, and hoses on the shelf for emergencies
California Department of Transportation - Caltrans	Woodfords Maintenance Station, Markleeville, CA	Yes. I keep (2) 3" end caps in stock.
California Department of Transportation - Caltrans	South Lake Tahoe	Pipe and fittings
California Department of Transportation - Caltrans	D9 Bridgeport, Ca	Flex hose, clamps, manual valves, fittings
California Department of Transportation - Caltrans	Susanville CA	Fittings and hoses
California Department of Transportation - Caltrans	Yreka, CA	Rubber gaskets for quick coupler fittings, Quick coupler fittings, Extra hose
Delaware Department of Transportation	Delaware	Hoses and fittings
City of Dubuque Iowa	Dubuque, Iowa	Extra pump
Iowa Department of Transportation	Iowa	Pumps
Idaho Transportation Department	Boise Area	Tanks Valves, connectors, T fittings.
Idaho Transportation Department	Lewiston	Clamps and extra hoses
Idaho Transportation Department	Pocatello	Pump heads, impeller repair kits.
McHenry County IL Department of Transportation	Woodstock IL	Clamps, fittings, and filters
Massachusetts Department of Transportation	Massachusetts	All aforementioned parts as well as hoses and gaskets and filter screens and a motor rebuild kit.
Maryland Department of Transportation, State Highway Administration	Maryland	See above.
City of Farmington Hills, MI	Farmington Hills, MI	Hoses, valves, Banjo connections, Pumps, Motors etc.

Organization	Location	Are there particular parts that are kept on the shelf for emergencies (please list)?
City of Farmington Hills, MI	Farmington Hills, MI	Yes, hoses, camlocks and motors, pumps etc.
City of Plymouth, MN	Plymouth, MN	Pump, hoses, fitting, clamps
Montana Department of Transportation	Helena, Montana	Usually kept spare loading hoses and one pump per division.
Nebraska Department of Transportation	Nebraska	Valves and hoses
City of Columbus OH Department of Public Service	Columbus Ohio	Pump and motor assemblies, pressure switches, flow meters
Oregon Department of Transportation	Pendleton, OR	Just fittings so we can hook to all types of trucks
Pennsylvania Department of Transportation	Pennsylvania	Yes, pumps, hoses, fittings
South Dakota Department of Transportation	Central Office	Our shops keep spare pumps, hoses, cam-loc fittings and connectors on hand for quick repairs.
Agency of Transportation State of Vermont - Operations/Maintenance	District 3 Mendon, VT. Southwest Region	Pumps, hoses, valves, and an assortment of all fittings - kept in inventory
West Virginia Division of Highways - District 9	Lewisburg, WV	Pumps
Maine Department of Transportation	Maine	Maine has designated positions for 2 individuals that travel the state doing repairs, they have their own workshop where all repairs are done to motors and pumps
City of Grimes IA, Public Works	Iowa	NA
Indiana Department of Transportation	Indiana	Unsure
Kansas Department of Transportation	Topeka Kansas	No
North Dakota Department of Transportation	Fargo	No
New Hampshire Department of Transportation	New Hampshire	No
Wyoming Department of Transportation	Cheyenne	No, purchase as needed

Lessons Learned

In the last section of the survey, respondents were asked a series of questions related to lessons learned and best practices identified from operating their liquid deicer storage and pumping systems.

First, respondents were asked to share their best lesson learned from operating their liquid deicer storage and pumping system. Twenty-nine respondents shared lessons learned (see Table 15).

Several respondents noted the need to keep the system clean including the need to clean and lubricate pumps or flush out pumps at the end of the season, utilizing fresh water to clean out the system after every use, and using clean salt as debris can cause several issues. One respondent noted that a large opening at the base of the tank was useful for cleaning out the system. Another noted that for spills a more "vaulted" floor is needed to clean. Several respondents also noted the need for consistent preventative maintenance or checks of the system, this included circulating the system during the off season rather than letting it sit.

Some respondents noted the need to have a system champion or limit the number of staff who utilize the system in order to ensure that individuals who operate the system have some specialization and operate/maintain the system in a consistent manner.

Other lessons learned include taking the time to ensure that fittings and valves are fitted properly and label all lines and valves with the correct flow pattern to quickly isolate a problem if one does occur. One respondent noted that hard lines should be protected from snow sliding off of tanks and that they have found their tanks need to be replaced about every 12 years.

Table 15. Lessons Learned from Liquid Deicer Storage and Pumping System Operations

Organization	Location	What is the best lesson learned from operating your liquid deicer storage and pumping system?
Alaska Department of Transportation & Public Facilities	Fairbanks	Keep it **clean**
California Department of Transportation - Caltrans	South Lake Tahoe	Works well
California Department of Transportation - Caltrans	D9 Bridgeport, Ca	Try to remember to **exercise system periodically** in the off season
California Department of Transportation - Caltrans	Susanville CA	Keep **clean salt**
California Department of Transportation - Caltrans	Yreka, CA	Take your time and make sure all **fittings and valves are positioned properly**
California Department of Transportation - Caltrans	Woodfords Maintenance Station, Markleeville, CA	Do consistent **ongoing maintenance and checks**

Organization	Location	What is the best lesson learned from operating your liquid deicer storage and pumping system?
Delaware Department of Transportation	Delaware	Remove and **clean/lubricate pumps at the end of each season**. store pumps indoors in off season
City of Dubuque Iowa	Dubuque, Iowa	Have a few **dedicated champion** to operate and maintain the system
City of Grimes IA, Public Works	Iowa	This is a great way to keep track of the liquid material used in snow and ice operations
Iowa Department of Transportation	Iowa	**End of season pump flush**
Idaho Transportation Department	Boise Area	Main tanks need to be replaced every 12 years. **Hard lines need to be protected from snow sliding off tanks.**
Idaho Transportation Department	Pocatello	Use better, **cleaner salt for system**. Debris causes all kinds of issues.
McHenry County IL Department of Transportation	Woodstock IL	Ensure all liquids are mixed, made and stored properly.
Indiana Department of Transportation	Indiana	Keep the tanks **circulated during the offseason**
Kansas Department of Transportation	Topeka Kansas	**Fiberglass Tanks are safer**. Large opening at base for cleanout
Massachusetts Department of Transportation	Massachusetts	**Preventive maintenance is the key to success**.
Maryland Department of Transportation, State Highway Administration	Maryland	**Fresh water clean out** after every use is a must.
Maine Department of Transportation	Maine	**Preventative maintenance is the key**
City of Farmington Hills, MI	Farmington Hills, MI	Do your research and have good customer support. Speak with end users of liquids.
City of Farmington Hills, MI	Farmington Hills, MI	For spills need a more **"vaulted" floor to clean up spills** etc. Keep **fittings on storage tanks more elevated for maintenance**.
City of Plymouth, MN	Plymouth, MN	Use **clean salt**

Organization	Location	What is the best lesson learned from operating your liquid deicer storage and pumping system?
North Dakota Department of Transportation	Fargo	Develop a **few people to specialize** in making brine
Nebraska Department of Transportation	Nebraska	Open and close valves as needed. Keep area clean. Don't overload tanks. Open and close valves slowly. Prime mechanical pumps. Rinse the pump (run water through them). Stay by the truck when filling.
New Hampshire Department of Transportation	New Hampshire	Don't let the system just sit during the summer.
City of Columbus OH Department of Public Service	Columbus Ohio	**Limiting the number of people** with access to the equipment software
Oregon Department of Transportation	Pendleton, OR	Make sure **all lines/vales are labeled with correct flow patterns to quickly isolate the system if it were to fail**.
Pennsylvania Department of Transportation	Pennsylvania	Contant use helps road conditions and the condition of pumps that run the systems
South Dakota Department of Transportation	Central Office	**Limit the amount of Brine making staff**. When too many people get involved, steps are missed and broken items not always are up channeled.
Agency of Transportation State of Vermont - Operations/Maintenance	District 3 Mendon, VT. Southwest Region	**Keeping the system and tanks cleaned** - keeping liquids agitated

Next respondents were asked to share the best modification, upgrade, or improvement that they have made to their system. Twenty-two respondents shared their modifications, four respondents noted that they had not made any modifications (see Table 16).

Several respondents mention modifications to the system pump including adding a 500 gallons per minute (GPM) pump, purchasing a better grade commercial pump, or switching to a bigger stainless steel pump.

Another common modification was some kind of system cover. This included covering the hopper, installing a metal shed over tanks to avoid snow damage, or utilizing indoor tanks to prevent UV damage. However, one respondent noted that while having indoor tanks was a benefit, having the tanks indoors did make replacement more difficult.

Two respondents noted using an air purge system to blow out their lines to reduce weight, another noted standardizing their hoses to 2 inches.

Two respondents noted utilizing an automated system. One switched from a combination loading and blending unit to a standalone unit for each process.

Table 16. Liquid Deicer Storage and Pumping System Modifications

Organization	Location	What is the best modification/update/improvement that you have done to your system?
Alaska Department of Transportation & Public Facilities	Fairbanks	We have switched from pressure transducers to acoustic sensors for tank levels
California Department of Transportation - Caltrans	South Lake Tahoe	None
California Department of Transportation - Caltrans	D9 Bridgeport, Ca	None
California Department of Transportation - Caltrans	Susanville CA	Put a cover over the hopper
California Department of Transportation - Caltrans	Yreka, CA	Bigger pump with stainless impeller and housing.
California Department of Transportation - Caltrans	Woodfords Maintenance Station, Markleeville, CA	Installed a metal shed over tanks to avoid damage from snow
Delaware Department of Transportation	Delaware	The addition of the 500gpm pumps
City of Dubuque Iowa	Dubuque, Iowa	Upgraded software and hardware
City of Grimes IA, Public Works	Iowa	No modifications have been made
Iowa Department of Transportation	Iowa	Indoor tanks help keep UV from deteriorating tanks. Harder for replacement though.
Idaho Transportation Department	Boise Area	Shields to protect hard lines from snow sliding off tank.
Idaho Transportation Department	Pocatello	Use of Flexible Lines in lieu of solid PVC piping.
McHenry County IL Department of Transportation	Woodstock IL	Replacing our old system. Placing it in a containment, hard piping everything along the walls and off the ground.
Indiana Department of Transportation	Indiana	Automated brine maker that calculates dilution.
Massachusetts Department of Transportation	Massachusetts	We started a preventive maintenance program 5 years ago. This program has

Organization	Location	What is the best modification/update/improvement that you have done to your system?
		proven to be very successful and has nearly eliminated down time and mid-storm emergency maintenance calls.
Maryland Department of Transportation, State Highway Administration	Maryland	N/A
Maine Department of Transportation	Maine	Changing the top fill pipe to hose, and moving the connection to ground level keeping ladder work to a minimum
City of Farmington Hills, MI	Farmington Hills, MI	Air purge system to blow out 2 & 3" lines for less weight.
City of Farmington Hills, MI	Farmington Hills, MI	Using air to purge fill points and hoses .
City of Plymouth, MN	Plymouth, MN	We installed a filter system to eliminate the particles going into brine storage tank.
North Dakota Department of Transportation	Fargo	Automated system
Nebraska Department of Transportation	Nebraska	Overhead fill system. Electric pumps. Sight tubes on tanks. Added separate fill lines for different materials. Make sure tanks are labeled. Use better hoses coming off the tanks. Full flow valves.
City of Columbus OH Department of Public Service	Columbus Ohio	We switched from Henderson to Cargill and went from combination loading and blending units to stand alone units for each process.
Oregon Department of Transportation	Pendleton, OR	Putting external sight glass hose on tanks to verify tank capacity.
South Dakota Department of Transportation	Central Office	Switching from poly pumps to stainless steel, standardizing hoses to 2''
Agency of Transportation State of Vermont - Operations/Maintenance	District 3 Mendon, VT. Southwest Region	Pumps - purchase a better grade commercial pump

Last, respondents were asked what was the greatest failure from operating their liquid deicer storage and pumping system. Twenty-eight respondents answered this question, however three respondents noted that they were either unsure or had not had a failure to date (see Table 17).

Several respondents noted failures as a result of needing a preventative maintenance plan including the need for keeping the system cleaned and circulated and checking pumps and fittings regularly. Massachusetts DOT specifically noted that adding a preventative maintenance program helped allow for growth in operations with minimal failure.

One respondent noted the need for operator training in order to reduce operator errors and another noted assigning personnel to keep the system regularly cleaned and maintained.

Several respondents noted failures in the system pump. One respondent noted a need to switch from a plastic pump to a stainless-steel pump and the plastic pump failed after one year of use. Another respondent noted that changing from flexible lines to rigid lines where possible helped improve flow and durability. Idaho Transportation Department noted that after a tank rupture due to age (20 years), they updated to a scheduled tank replacement after every 12 years.

Maryland DOT SHA noted having issues with their system auger jamming during cleanout due to using dirty salt. Since this issue they now require salt vendors to provide solar salt.

A respondent from the California Department of Transportation noted a challenge with using an integrated system (Accubrine Automated Brine Maker), where if there is a malfunction, they were unable to dispense brine to the truck even when there was material in storage. This required installing a backup truck fill system which would allow them to fill their trucks even if the integrated system is down.

Table 17. Liquid Deicer Storage and Pumping System Failures

Organization	Location	What is the biggest failure from operating such a system? How was it fixed?
Alaska Department of Transportation & Public Facilities	Fairbanks	We haven't had any big failures other than pumps getting worn out. We replaced them.
California Department of Transportation - Caltrans	South Lake Tahoe	Broken pipe
California Department of Transportation - Caltrans	D9 Bridgeport, Ca	Faulty GFI's in building, broken wiring, sticking valves. using deduction and repairing, preventable changes made when possible, i.e., rerouting of wires, checking & tightening things seasonally.
California Department of Transportation - Caltrans	Susanville CA	None yet
California Department of Transportation - Caltrans	Yreka, CA	Plastic pump initially bought with brine system failed after 1 year. Plastic impeller and housing did not handle the duty cycle we put it through. We

Organization	Location	What is the biggest failure from operating such a system? How was it fixed?
		upgraded the pump with a more HP and stainless-steel pump with great results.
California Department of Transportation - Caltrans	Woodfords Maintenance Station, Markleeville, CA	With an integrated system when there is a malfunction you cannot dispense brine to the truck even if you have material in storage. Working on installing a separate back up truck fill system that will allow to fill trucks when system is down.
Delaware Department of Transportation	Delaware	flexible lines were upgraded to rigid lines where possible. improved flow and durability
City of Dubuque Iowa	Dubuque, Iowa	Software can be an issue. You need to be able to run on manual if needed
City of Grimes IA, Public Works	Iowa	No failures to date
Iowa Department of Transportation	Iowa	We have had lines break and empty tanks, but so far nothing catastrophic or near a person luckily.
Idaho Transportation Department	Boise Area	Tank rupture due to age (20 years). Tank replacement program updated to schedule replacement every 12 years.
Idaho Transportation Department	Pocatello	Using glued pipes. Many leaks and costly to replace.
McHenry County IL Department of Transportation	Woodstock IL	Having the brine maker in a different building than the storage area.
Indiana Department of Transportation	Indiana	Unsure
Kansas Department of Transportation	Topeka Kansas	Pump failure. Need to make sure to clean and lubricate before summer
Massachusetts Department of Transportation	Massachusetts	Lack of maintenance was the biggest failure in the operation. Adding a preventive maintenance program has allowed for a growth in operations with minimal failures.
Maryland Department of Transportation, State Highway Administration	Maryland	Auger jamming during cleanout from using dirty salt. We now require each of our salt vendors to provide solar salt on

Organization	Location	What is the biggest failure from operating such a system? How was it fixed?
		a per county basis. This salt is 99 percent pure and free from most insolubles.
Maine Department of Transportation	Maine	Bearings in the pumps and just overall corrosion. The fix is you have to do everything you can to prevent it from happening. Using fluid film, exercising the pumps on a regular basis, cleaning etc.
City of Farmington Hills, MI	Farmington Hills, MI	One way back flow valves due to stacked fill point system fighting each other while blending 2-3 liquids. Can supply pic's etc.
City of Farmington Hills, MI	Farmington Hills, MI	Be careful of operating air pressure. Can exceed tank integrity and hose failures.
City of Plymouth, MN	Plymouth, MN	Too much sediment on the brine tank floor. We had to remove the tank from the building and vac out the debris.
North Dakota Department of Transportation	Fargo	Inconsistent mixtures, we automated our system to a brine boss
Nebraska Department of Transportation	Nebraska	Operator error (leave valves open or closed, putting wrong material in tank) Operator training helps.
New Hampshire Department of Transportation	New Hampshire	Solids will settle out if the liquid is not circulated often
City of Columbus OH Department of Public Service	Columbus Ohio	When we had pneumatic systems the biggest failure was people turning off the air compressor during the off season.
Oregon Department of Transportation	Pendleton, OR	Having a hard line crack and then getting it replaced.
South Dakota Department of Transportation	Central Office	Pumps are the biggest failure for us, we are still trying different brands that will perform during harsh conditions.
Agency of Transportation State of Vermont - Operations/Maintenance	District 3 Mendon, VT. Southwest Region	Keeping systems cleaned and following up with each facility to ensure - assigning personnel the responsibilities

APPENDIX B – AGENCY AND VENDOR INTERVIEW QUESTIONNAIRE AND INTERVIEW SUMMARIES

AGENCY INTERVIEW QUESTIONNAIRE

Clear Roads – Liquid Chloride Storage and Pumping Systems

Interview Questions - Agency

System Installation:

- What are the minimum storage capacity requirements for an operation?
    - How did you decide on tank size(s)?
- What vehicles/equipment and labor were required for delivery and installation of the storage and pumping system?
- Where is your storage and pumping system located (inside vs. outside, concrete pad, etc.)?
    - Any lessons learned in location choice?
    - Does storing in the shade prolong the tank's lifecycle?
- Does your storage and pumping system have remote inventory monitoring?

Tanks:

- What materials are the tanks made of (e.g., fiberglass, HDPE)?
    - Cost, life expectancy, storage capacity of various materials.
- Are the tanks double-walled?
    - Do you have any additional secondary containment for your tanks? Please describe.
- What kind and in what configuration are the tank-flange outlets?
- Has your agency ever repurposed tanks? If yes, please describe.
- How has your liquid chloride storage and pumping system evolved over time?

Pumps/Motor:

- Electrical Requirements for Pumps? Single or Three Phase? Pump Capacities
- Where are your pump(s) located?
- How often do seals and bearings need to be replaced?
- What type of piping does your system utilize? (e.g., hard vs. soft),
- Piping (Hard or Soft), hose, and connection recommendations.
- Please describe your end of season maintenance protocols for your pumps/motors. How do you maintain your pumps/motors in the off-season?

Product:

- Any availability issues? Supply Chain? Geographical Restrictions?
    - Have you experienced any parts or component availability issues? If yes, please explain.
- Have you experienced any reactions between or compatibility issues of different liquids?

- What products or additives are used?
- Does your system have blending capability? Stack or Real Time?
- Is the system modular, can it be expanded?

Maintenance and Lifecycle:

- What does your maintenance routine look like?
    - If you have an inspection checklist (from survey responses), would you be willing to share that checklist?
    - How often are you maintaining your system?
    - What types of salt are you using (solar vs. conventional) and how does this impact maintenance routines?
- How do you access your tank for cleaning?
- Any test methods to determine tank condition?

Additional Questions:

- Please share any specs created for the storage and pumping system.
- Please share any photos of your storage tank and pump system.

VENDOR INTERVIEW QUESTIONNAIRE

Clear Roads 22-02 – Liquid Chloride Storage and Pumping Systems

Interview Questions – Vendor

The Clear Roads Winter Maintenance Pooled Fund is seeking information on liquid deicer storage and pumping systems for project CR 22-02 Best Management Practices for Liquid Chloride Storage and Pumping Systems. The questionnaire below has been created to capture information on liquid deicer storage and pump systems currently available to departments of transportation and public works agencies across the country, and to identify best practices to manage and maintain these systems.

Please consider filling out the attached questionnaire and email your response to Karalyn Clouser of WTI/MSU at karalyn.clouser@montana.edu or Laura Fay of WTI/MSU at laura.fay1@montana.edu

Thank you for your time.

Name:

Organization:

Website:

Contact Information:

Phone:

Email:

Storage Tanks (*Please answer these questions if your organization manufactures or sells liquid deicer or additive storage tanks.*):

- Does your organization provide recommendations to help an agency decide on tank size/total number of tanks?
- What materials are your tanks made of (e.g., fiberglass, HDPE)?
    - Please provide details on cost, life expectancy, storage capacity of various materials.
- Are your tanks double-walled?
    - Are there other forms of secondary containment? Or do you provide suggestions/guidance on secondary containment? If so, please explain.
- What kind and in what configuration are the tank-flange outlets?
- Can the tanks be repurposed? If yes, please describe.
- What is the recommended maintenance routine?
    - How often?
- How would you recommend the inside of the tank be cleaned?
- What are optimal locations to place storage tanks (e.g., concrete pads, in buildings (inside vs. outside)?

    - Does storing in the shade or covered prolong lifecycle? Are you aware of UV degradation rates for each tank material?
- Do you recommend any test methods to determine tank condition?
- Any availability issues or delays? Supply Chain? Geographical Restrictions?

Pumps/Motor (*Please answer these questions if your organization manufacturers or sells pumps and/or motors* for moving liquid deicers or additives.):

- Please provide details on available pumps including: electrical requirements, single or three phase, pump capacities (GPM), cost, and life expectancy?
- Do you have recommendations on pump location (e.g., outdoors, covered, indoors)?
- Do you provide guidance on piping (Hard or Soft), hose, and connection recommendations? If yes, please explain.
- What is the recommended maintenance routine? How often do you recommend replacing seals and bearings? (Typical wear and tear maintenance.)
- Any availability issues or delays? Supply Chain? Geographical Restrictions?

Liquid Deicer Storage and Pumps Systems:

- Please describe any reactions between or compatibility issues of different liquids?
- Does the system have blending capability? Stack or Real Time?
- Is the system modular, can it be expanded?
- What vehicles/equipment and labor are required for delivery and installation of the storage and pumping system?
- Are remote inventory monitoring solutions available?

Additional Questions:

- Please share any specs created for the storage and pumping system.
- Please share any photos/links/etc. for your storage tank and pump system.

AGENCY INTERVIEW SUMMARIES

Alaska Department of Transportation and Public Facilities, Fairbanks

January 31, 2024

- Ron Davis (Fairbanks, AK)

Key Takeaways

- Unique Storage Requirements for Extreme Temperatures
- Keep Your Facility Clean

Extreme Temperatures

Due to extreme temperatures in the winter, Alaska Department of Transportation and Public Facilities (AK DOT&PF) facilities in Fairbanks primarily uses brine in the fall or spring. The rest of the year they will use brine to pre-wet, down to -15°F. They utilize Road Guard +8 and brine. They can store 10,000 gallons of brine and 10,000 gallons of additives (in separate 5,000-gallon polyethylene storage tanks).

Storage tanks are kept outside. Spray foam is applied to insulate the tanks, and a black elastomeric weather-proofing coating is used over the spray foam to protect it from the elements. (see Figure 13). If they use just the spray foams, ravens pick at it. This coating was applied in 2015 and has held up well without any required maintenance. With the covering of the tanks, they have not seen any issues with ultraviolet (UV) damage. Tanks are heated hydronicly using PEX tubing (using a boiler heating system), kept at 60°F.

Figure 13. Liquid Deicer Storage Tanks

They use vertical (13 feet tall) tanks. These do not have easy access to clean the insides of the tanks. They noted that with additives they have had issues with sludge at the bottom of the tanks. The system has a line running from the outside of the storage tank about a foot off the ground. To recirculate the tank, they pull product from the bottom of the tank and put it back in through the top.

Storage tanks are located right next to the brine making building. The tanks are hardline plumbed into the building with horizontal 4-inch lines which are covered in 10 inches of spray foam for insulation. All valves are inside of the building (see Figure 14).

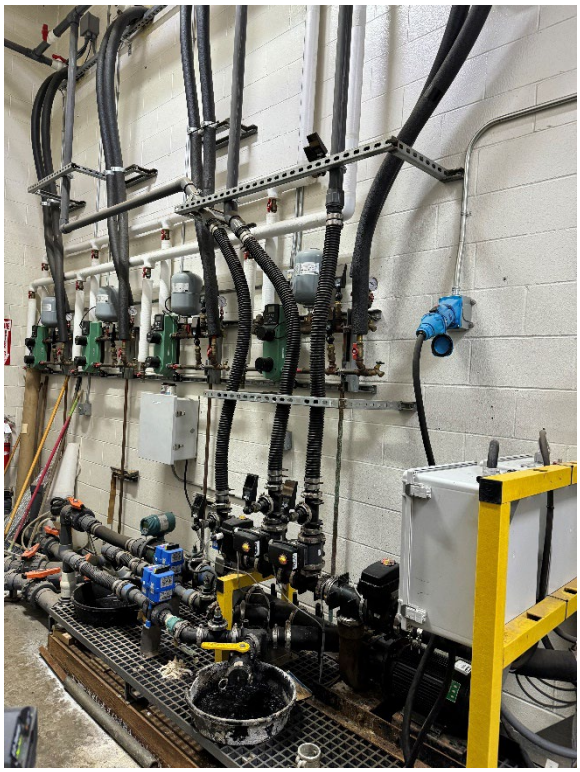

Figure 14: System Plumbing

The system uses arctic-grade fuel hose to fill trucks (cost around $400 for around 25 feet of hose), this type of hosing is flexible and durable in more extreme temperatures. There is a small 14-inch access door on the brine building where the hose can be pulled through to the outside to fill the truck and put back in when they are done (see Figure 15). They try to only keep the hose outside for short amounts of time. The hose takes a lot of wear and tear with being moved around.

The system uses a 3-inch hose to fill trucks at up to 150 gallons per minute based on the quantity desired. To load their trucks, operators sign into the system with truck number, and they indicate which recipe they want and how many gallons of it. All sanders utilized in Fairbanks are Henderson slide-ins

with side tanks. For anti-icing operations, Fairbanks has a Henderson 3,400-gallon slide in tank and two Norstar Industries 2,100-gallon hook lift mounted tanks.

Figure 15: Brine Building Access Door

System Maintenance

AK DOT&PF in Fairbanks has prioritized keeping their liquid deicer storage and pumping system and brine house clean and organized. Regular end of season maintenance and cleaning routines include emptying and cleaning the “hot tub” (brine maker tank), flush clean water through everything, and then do this again before they start up the season. The “hot tub” is cleaned out as necessary using a vacuum truck (Vactor) and heavy equipment.

For routine maintenance there is no specific checklist that is utilized. Maintenance personnel regularly check the system throughout the winter season and like to keep things clean including keeping the floor rinsed off. Regular checks include making sure that the storage tanks are warm, if storage tank temperatures drop below a temperature threshold a red light will automatically come on in the brine building to alert them.

A locally developed quick reference guide covers most typical brine related activities, however most training is on the job – including how to load a truck. The system is pretty simple to operate.

Fairbanks uses a Cargill AccuBrine NextGen brine making system. They have found the system to be very reliable and easy to work on. The AK DOT&PF network is very protected, so while the system would allow for remote access for maintenance, this option is not available for Fairbanks. Occasionally, when maintenance personnel have issues outside their area of expertise, Cargill (the brine making equipment manufacturer) has been able to provide support remotely and also by sending Cargill technicians to Fairbanks if necessary. While the technicians are there, they will also have them complete seasonal maintenance and calibrate the machine.

AK DOT&PF in Fairbanks keeps several spare parts on hand in case of emergencies. Parts include a spare brine pump, truck fill pump, 2-inch and 3-inch Banjo fittings, clamps, seals, camlocks, and arctic-grade fuel hose.

City of Farmington Hills, Michigan

January 25, 2024

- Bryan Pickworth

Key Takeaways

- Building Design & Designing for Drainage/Easier Clean Up
- Start Simple, Don't Get Overwhelmed
- Dirty Salt Means Clean Up – Even With A Fancy System

Operations Evaluation

The City of Farmington Hills, Michigan has evolved their liquid deicer storage and pumping system overtime – from pre-wetting with an overhead shower bar to treat rock salt in the late 1980s, to their current state-of-the-art indoor facility (Figure 16). In 2015, The Department of Public Works (DPW) was able to add an addition to their facility due to a water tower upgrade which was going to be built on DPW property. This opened funds to develop a 9,000 square foot building addition which would be used for liquids production and seasonal storage with the goal of having enough liquid deicer on hand for anti-icing for two events and pre-wet storage for front line trucks, the Parks and Recreation Department, and neighboring communities. The City of Farmington Hills also utilizes the liquids system to accomplish in-house dust control in off winter months. The current Farmington Hills DPW site has a liquid storage capacity of 66,000 gallons, 30,000 gallons of that is sodium chloride.

The new addition has two fill points which allow operators to load their truck inside (Figure 17). The liquid deicer storage and pumping system is located inside in order to help reduce any impacts to operations. The older portion of the building has one of a total of three fill points, however that portion of the building is also used for equipment storage which can result in some operational delays while a truck is being filled. In general, the City of Farmington Hills DPW has worked to make this process as efficient and comfortable as possible in order to reduce any operator challenges or errors.

Each year as part of their winter operations training, anyone who will use the liquid deicer storage and pumping system will get training and a walk through on how to use the fill points. The DPW notes the need to have two to three people trained specifically to produce brine and ideally two supervisors who know the entire system really well.

Figure 16. Farmington Hills, MI DPW Property

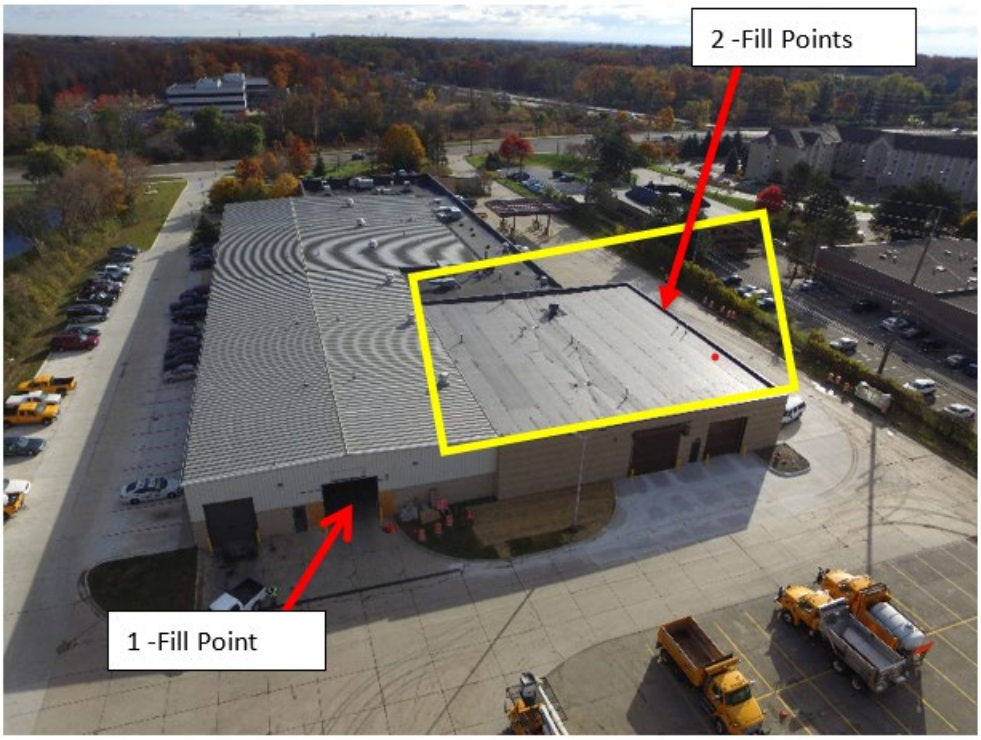

Figure 17: Farmington Hills, MI Building Addition (In Orange) - Liquids Storage and Fill Points; Off-Season - Equipment Storage (9,000 Sq Ft)

Sloped Flooring and Cleaning

This "Liquids Room" has concrete flooring with a hardener additive (to help with chloride deterioration) and to allow trucks to drive through for fill ups. The storage tanks are located in a portion of the addition that is contained in a curbed floor area. The flooring is sloped to the east which allows any liquids or debris that is spilled to move down the slope to a pump out pit area. The DPW utilizes a vactor truck to clean out the pit areas and clean up any messes. While this design does ease cleaning of any spills, the DPW notes that if they were to do this over again, they would place all storage tanks on level concrete pads 2-3-inches off the floor and create a more sloped floor with a larger pit or trench area in the middle with a grate over the top to ease clean up of spills, leaky tanks, etc. Currently, debris from brine maker get flushed to a large grate, 2ft x 20ft that collects flushed materials from the brine making. The sloped floor is great if that is all you have, but for a larger area like they have, ideally would have a mid-room floor grate.

For cleaning out storage tanks, the DPW uses a vactor truck with flexible hose that goes through the top of the manway to introduce water and flush out the tank. A power wand is utilized as well. The DPW notes that the debris coming out of the salt brine tanks can have the consistency of sandy concrete and can be difficult to move. Salt brine tanks are cleaned out every three years or as needed. For Calcium Chloride tanks, they have not seen these challenges thus far. For organics (the DPW uses beet juice), in the late winter /springtime the agency will try to utilize as much of the beet juice that they possibly can. Once the tanks are low enough, they will add water and flush out the tanks. The DPW uses an odor neutralizer for the organic product tanks and in Parks Department areas such as parking lots and walkways to minimize odor complaints.

For pumps, the DPW will flush out the system with water and use a chloride neutralizer when it is practical for end of season maintenance. During the non-winter months, the fill point system is used for dust control on their gravel road network (using 38% calcium chloride). For motors, when time allows, they will use a chloride neutralizer on the exterior and restore the paint to protect the exterior of the motor.

Salt/Debris

The DPW uses locally sourced salt from a mine that is around 30 minutes away. However, they have struggled with insolubles/debris/fines/sand falling out of suspension in their salt brine. The liquid is filtered a lot, yet they still see a lot of buildup in the bottom cavity of the brine maker as well as the salt brine storage tanks. The DPW noted a desire to try solar salt because it is cleaner which could cut down on cleaning and increase productivity. The current brine maker system needs to shut down and flush out on average every 12,000 to 15,000 gallons. They currently get around 4,000 to 5,000 gallons an hour, however they estimate that this could increase to 6,000 to 7,000 gallons an hour with cleaner salt.

Liquid Deicer Storage and Pumping System

The DPW uses high density polyethylene (HDPE) Schneider tanks which have lifting lugs in the top of the tank to help with lifting and moving (Figure 18 and Figure 19). Tanks have a capacity of 3,000 and 6,000 gallons. Tanks have Banjo fittings for most applications. The tank flange outlets are generally PVC bulkhead fittings with some bolted style flanges.

Figure 18. Liquids Manufacturing Room - Storage Tanks

Figure 19. Liquids Storage Tanks

Tanks generally have a lifespan of around 13-15 years before failure when placed outside. The DPW is hoping that with moving storage tanks indoors that they will see a long lifespan of around 25+ years since they will no longer be dealing with UV degradation and extreme outdoor temperatures. They consider cost, life expectancy, and storage capacity of various materials. The DPW plans to budget for cone style tanks for their organics in the future due to challenges with maintenance every year with solids settling into the bottom of the tank even with recirculation.

The liquids system uses three phase pumps of varying capacities depending on the impeller/vane design and horsepower of the motor coupled to it. MP Pumps are primarily used on “stacked” three product fill point systems as well as their brine making system.

The DPW noted that pump capacities on paper differ from reality and to keep in mind venting of tanks, restriction of piping or hoses such as 90-degree fittings compared to sweep style fittings, and any other type of change of direction other than straight on leading to the fill point module. Pump failures are generally seen due to seals deteriorating in the pumps and liquids getting into the bearing area, especially with pumps for organics.

The system uses both hard and hose type piping. Primarily hard piping (grey schedule 80) from the storage tanks to the stacked blending modules for each of the three fill points. Two-inch diameter piping to the organic and calcium products and three-inch diameter piping to the blending module for salt brine and to each fill point. The system uses a 1-foot to 2-foot piece of flexible ethylene propylene diene monomer (EPDM) rubber hose at the tank inlet and outlet for expansion and contraction of liquids filling and emptying.

The DPW uses air to purge the liquid out of the fill point hoses that fill the equipment tanks. This idea was taken from an organics supplier who used air to clean out/purge supply hoses from the truck to the bulk storage tanks. All supply lines to the fill points have one-way valves to prevent backup of liquids into storage tanks and/or contaminate other liquids while utilizing the air purge system. The DPW notes the air purge system needs to be governed as too high of air pressure or too much air into the supply tanks can be detrimental to the whole system being filled. A must is to make sure fill tanks have adequate venting to prevent damage to the system. The system is very helpful for 2 and 3-inch fill point hoses which can get very heavy with the liquids. Typically, the DPW operators will use approximately a ¼ of the air volume and watch and listen for bubbles to verify the air is all the way through the fill hoses. The DPW then will very carefully open the fittings slowly as to let the air bleed out of the fill hoses that may be still present or trapped in the system. Operators wear personal protective equipment (PPE) while purging the system including rubber gloves and safety glasses and/or a face shield.

The DPW recommends that the following components be on hand for backups: at least one complete pump & motor assembly for each 2 and 3-inch system, if different sized. Other components that need to be considered are flow meters, refractometer for testing of sodium in the salt brine (and calcium chloride, if used), valves, piping, hose, and stainless-steel clamps. Any other replacement parts that an agency has struggled to obtain in the past or because of supply chain or delivery challenges should also be considered.

Iowa Department of Transportation

January 29, 2024

- Tina Greenfield

Key Takeaways

- Indoor Storage Tanks Protected from UV Deterioration
- System Lifecycle Planning is Challenging

UV Damage

Iowa Department of Transportation (DOT) has 6 maintenance districts and 101 garages that utilize salt brine in their winter operations. Their liquid deicer storage and pumping systems use polyethylene tanks ranging from 2,500 gallons to 9,000 gallons in capacity (see Figure 20). They utilize smaller tanks because they are easier to get. Most storage tanks are located outdoors; however Iowa DOT is moving tanks indoors wherever it is practical in order to reduce ultraviolet (UV) deterioration of their tanks. With outdoor tanks, the tank will experience clouding or surface deterioration which causes the tank to become brittle, which becomes an issue when attempting to move the tank and when tank failure is most likely. Iowa DOT noted challenges with their indoor storage thanks, where extracting a tank that needs to be replaced can be difficult without disrupting operations.

Figure 20. Iowa DOT Liquid Deicer Storage Tanks

System Lifecycle

Iowa DOT is currently utilizing older tanks, which get replaced as issues arise (e.g., cracks). When storage tanks are replaced, Iowa DOT will look at the system footprint, should a 2,500-gallon tank be replaced with the same tank or should two 2,500-gallon tanks be replaced with a single 5,000-gallon tank. Most of their liquid deicer storage and pumping systems grew from a more grassroots effort; where most locations started small and added storage as needed. These systems have become quite large with

nearly 6.4 million gallons of brine capacity statewide, capacity at each garage varies wildly depending on the amount and types of roads served. Iowa DOT is working to establish an inventory management plan to have tanks on a replacement cycle instead of their current reactionary approach to replacing tanks when the need arises. However, getting the storage tanks on a replacement cycle has been difficult due to the number of tanks, incomplete inventory, the age of some tanks, and the need for funding to get such a system in place. Ideally, they would get to a place where they replace around 10 percent of tanks each year.

Around ten years ago Iowa DOT looked at brine making ability across the state – including condition of the building, electrical systems, water systems, and brine systems in order to target funding to those that are either undersized or in the worst shape. For example, if a garage has a lower capacity water line, they may invest in additional storage tanks to make up for that capacity challenge.

Maintenance Practices

Each garage has a core group of people who make brine. This group of people will conduct an inventory of their liquid deicer storage and pumping system each spring including noting each piece of equipment, its condition, and checking it off on an inventory list. If maintenance is needed, it will be completed during the spring or summer. Pumps are flushed out during the spring season. Again, in the fall, they will complete another inventory/inspection of all equipment including giving the system a once over as things are filled back up, checking for drips or leaks, make note of needed repairs, and plan for maintenance as needed. As brine makers operate the system throughout the winter season, they will walk around and check for any issues (e.g., drips, broken fittings). Each garage will have a core brine making team who has a general practice to check the system. Their checklist is mostly mental, there is no standard/formal DOT checklist. If there was a checklist developed it was likely developed by a supervisor to train new staff.

The DOT does not have a specific method to test storage tank condition. Tanks are visually inspected for cracks and damage. They noted that they have previously damaged tanks trying to clean them out. When storage tanks need to be cleaned out, Iowa DOT contracts the cleaning to an environmental company who utilizes a vacuum excavator to clean the tanks. However, the DOT notes that this cost is high. When considering the cost for cleaning, it could be more effective to buy an oversized tank and plumb it high and leave the debris settled at the bottom, then replace the tank after its lifecycle (e.g., every 15 years). They have also considered buying cleaner salt from various companies, but the limitation is that it is more expensive. Most of the debris in the rock salt settles out in the brine maker, so it is more of a brine making productivity challenge than a storage challenge.

There is no formal training for liquid deicer storage and pump system operators, but they do try to limit the number of people making brine, however plowing take precedence, so if a large storm occurs, all hands will be out plowing, and a garage may need to pull in whoever is available to make brine.

Parts Kept on Hand

Iowa DOT has found that pumps generally last a couple years as these are made of metal and constantly subjected to a humid/wet environment which results in rust. Pumps and fittings are kept on hand for

emergencies. They keep pumps on hand at the maintenance district level (the DOT has six districts statewide), local garages can call up for a pump and get things fixed quickly. Garages will generally keep sections of hose, valves, pipes, and other fittings on hand.

Systems are generally partitioned using valves to quickly isolate failures or operator error with valves being left on.

Idaho Transportation Department, Boise (District 3)

February 9, 2024

- David Dansereau (District 3 – Southwest Idaho)

Key Takeaways

- System Plumbing Coverings Utilizing Old Traffic Signs
- Storage Tank Replacement Program
- Monthly Tank Circulation and Inspection

Storage Tank Covering

Idaho Transportation Department (ITD) District 3 covers ten counties in southwest Idaho. The district has a total of 48 storage tanks for their winter liquids (magnesium chloride ($MgCl_2$)). It is standard for each site to have two 10,000-gallon tanks. This allows District 3 to pump from one tank to another as needed. The District uses a six-inch concrete containment wall to manage secondary containment of material (see Figure 21). Everything within the secondary containment area is hard piped and the hose from the tank to the truck is composed of flexible piping. District 3 noted that this hard piping needs to be replaced on average every six years due to ultraviolet (UV) damage, they mentioned that the PVC will start to get a metallic look to it and that is when they know it needs to be replaced. They had looked into switching to all flexible piping, but the cost was too high.

Figure 21: Liquid Deicer Storage and Pump System Secondary Containment Concrete Wall

The District has had issues with snow sliding off of the storage tanks and causing damage to the system plumbing. To address this, at a few sites they are using old traffic signs to make an A-frame covering for the plumbing to help shield the system from snow (see Figure 22).

Figure 22. Coverings for System Plumbing

This covering has the additional benefit of providing some protection from UV damage. At newer sites in the state, they are working to design buildings with a roof or some covered structure over the tanks. This effort is ongoing. The state has three sites with brine makers which have their storage tanks located indoors. At the initial site for brine making, they chose to locate all equipment and tanks indoors due to safety as locals in the area do not like salt brine.

Storage Tank Replacement Program

District 3 has had four tanks rupture at two separate sites (see Figure 23). One of these tanks broke and took out the tank next to it. Another tank failed so violently that it broke through the six-inch containment wall. The tanks that failed were around 15 years old. The tanks were South facing, so they were exposed to a lot of sunlight, so UV damage is suspected as a contributing factor in the failure. Now ITD works to replace storage tanks on a 10-year cycle (closer to 12 years by the time the tank is replaced). When tanks are taken out of service they are cut into pieces and taken to the landfill to prevent someone else from using a failed tank or one that is soon to fail.

Figure 23: Storage Tank Rupture

The District did ask the tank manufacturer after experiencing a tank rupture whether they had an inspection method, they suggested to test the tank by hitting them with a bat. The District has not tested the tanks using this method yet. For the tanks that did fail, they did some forensic work and could not find anything that stood out to why the tank failed (no dust/powder or microcracks on the surface).

Preventative Maintenance

For District 3, crew will go out and recirculate any material in the tank once a month, while doing that they will also complete a basic inspection including checking for any leaks or cracks and conducting a high-level look over of the system. If any issues come up during this inspection they are reported to the facility manager via email, then the building maintenance crew will go to complete the repair.

The District keeps a central storage of parts needed for repairs. Parts kept on hand include a couple pumps, pipes, fittings, hoses, and valves. However, they have a vendor close by, so it is easy to get additional parts as needed. They have found that they usually repair one pump a year. If there is a pump failure during the winter season, all of their trucks can then be self-loaded.

Kansas Department of Transportation

January 26, 2024

- Clay Adams

Key Takeaways

- Fiberglass Might Be a Better Option
- Port at Center of the Tank
- Equipment Users Handbook

Fiberglass Storage Tanks

Kansas Department of Transportation (DOT) uses 10,000- and 20,000-gallon fiberglass tanks over polyethylene tanks due to a previous experience with a tank failure (Figure 24). Fiberglass storage tanks will not fail catastrophically due to the fibers in the material, instead they may get smaller cracks, and seep or leak. The life expectancy of these tanks is around 20 years. Kansas DOT has found the cost to be very competitive to polyethylene tanks, particularly with the tank sizes that they use. Kansas has a local fiberglass tank manufacturer which is used by the oil industry they were able to work with.

Figure 24: Poly Tank Rupture

The fiberglass storage tanks that Kansas DOT uses have a flanged opening near the bottom which allows for cleaning material off the floor of the tank (instead of needing to go through the top). They also have a port at the center of the base of the tank which is used for mixing or recirculation of material. This port has three one-inch peri jets inside the bottom of the tank to help circulate material (Figure 25).

If they are having an issue, they will recirculate tanks, but overall Kansas DOT has not needed to circulate as often in the off-season (when using salt brine). It was noted that circulating the storage tanks in the off-season can be difficult due to pumps being moved and stored indoors.

Tanks are located outdoors and are generally not covered. It was noted that one district had purchased a tarp to cover their storage tanks due to concerns with ultraviolet (UV) deterioration. It was noted that fiberglass tanks could be painted to help with UV protection.

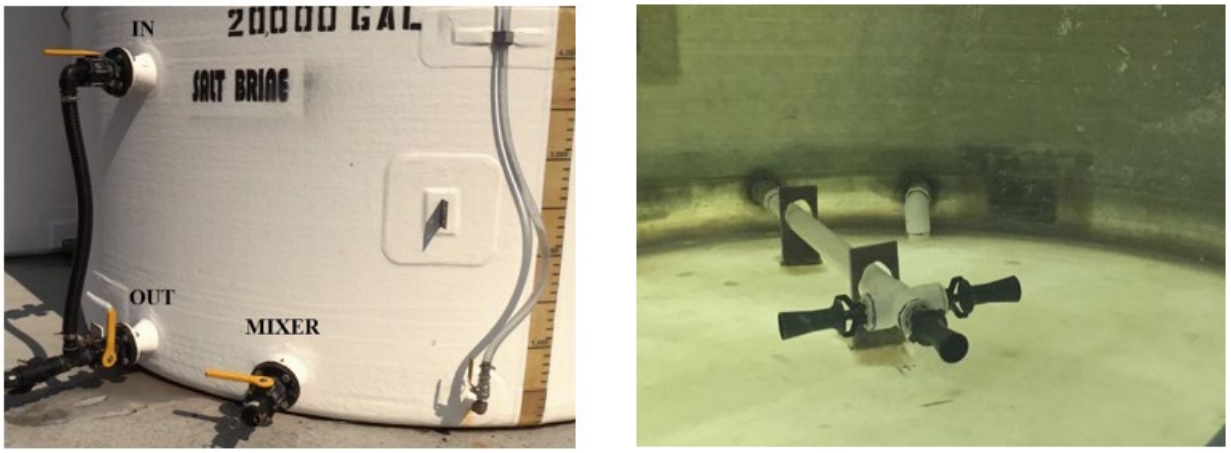

Figure 25: Tank Mixing Port and Peri Jets Inside the Bottom of the Tank

Secondary containment varies across the state as it is not required in Kansas at this time. Some districts will have concrete walled secondary containment. It was noted that making sure valves are closed and exercised is important to prevent loss of material and failures. They receive guidance from the Kansas Department of Health and Environment on what is required for secondary containment.

The storage tanks are generally not repurposed at the end of their lifecycle. Some have been auctioned off on an as needed basis and some have been reused at new storage locations when the tank still had some life in it.

System Pumps/Motors

Kansas DOT uses Banjo Stainless Steel and Pace two-inch pumps. System pumps are all located outdoors. Kansas DOT noted that when they first started, they had covers for the pumps but experienced increased corrosion due to the salty environment and the cover preventing pumps being washed from rain, so they have since abandoned covering them. At the end of the season pumps are cleaned with fresh water and a salt neutralizer, then RV antifreeze is used as a corrosion preventative. Pumps are then moved inside to a storage shed for summer storage.

Kansas DOT Equipment Users Handbook

Kansas DOT has an Equipment Users Handbook which includes guidelines, checklists, and procedures to ensure that employees are properly operating and maintaining equipment. This handbook includes

winter operations and end of season shutdown procedures for brine equipment, storage tanks, and pumps. End of season maintenance practices generally include draining and cleaning, checking valves, cleaning and applying RV antifreeze or other rust inhibitor to pumps, and coat electrical connectors with dielectric grease.

Figure 26: Kansas DOT Tank Farm

Maine Department of Transportation

January 25, 2024

- Chris Landry

Key Takeaways

- Statewide Position for Maintenance and Repair
- Inspection Checklist
- Efficient Replacement of Pump/Motor Set Up
- Methods to Test Storage Tank Condition

Statewide Snow & Ice Supervisor

Maine Department of Transportation (DOT) has 155 storage tanks and pump systems across the state. A statewide Snow & Ice Supervisor travels around the state managing the repair and maintenance of the liquid deicer storage and pumping systems. This position also handles contracting and purchasing of storage tanks and materials, plumbing on storage tanks, and motor and pump work. Maine DOT aims to keep these systems similar across the state so that spare parts can be easily kept on hand.

Figure 27: Pump/Motor Set Up on Metal Plate

The Snow & Ice Supervisor position comes with a ¾ ton pickup truck that has system parts and equipment ready to go for repairs (e.g., extra pump, ball valves, couplers). This position requires a lot of travel. In addition, the Snow & Ice Supervisor has a maintenance shop where repairs can be done. Pump and motor setups are mounted onto metal plates that the welding shop created (see Figure 27). The Supervisor maintenance shop has an inventory of these pump and motor setups ready in case of

emergency. This allows the Supervisor to efficiently swap out a failing pump or motor then take the broken system back to the maintenance shop for repairs, reducing the need to complete work outside. Repairs will include taking the system apart, repairing broken components, sandblasting, and painting.

In the winter the Snow & Ice Supervisor will travel onsite to repair/replace systems as needs arise. During the summer, the Supervisor is able to plan out maintenance activities though they aim to visit each location every other year. Locations are prioritized based on an inspection checklist which is completed by transportation workers at each site.

This statewide position is unique, and they have found it reduces the number of people who are repairing and maintaining these systems which can help to ensure things are done in a consistent manner and reduces challenges with necessary tools and parts. Maine DOT has found that having one position in charge of coordinating repairs and maintenance is a good use of time and resources.

Inspection Checklist

The inspection checklist is sent out to each site by the Snow & Ice Supervisor in April (see Figure 2). Transportation workers at each site will use this inspection checklist to go over the full storage and pumping system, note any issues, and send that checklist back to the Supervisor. This inspection checklist includes documenting information about each system component (e.g., storage tank, pump, motor), what liquid is in the tank and how much, check the system for leaks, and generally inspect each component of the system (e.g., hoses, hose clamps, pump, pump cover). The inspection checklist also includes procedures to summerize the system (described in detail below in Preventative Maintenance section).

Once the Supervisor receives these checklists, they can prioritize locations that need attention during the summer months.

The checklist was developed by the Snow & Ice Supervisor and has been modified over time as systems have changed. Each site is audited every three years, as a part of this auditing process the auditor will ask to see the inspection checklist.

Preventative Maintenance

Maine DOT notes that preventative maintenance is key to operating liquid storage and pumping systems. Beyond the inspection checklist, which is completed every April, transportation workers receive procedures to summerize the liquid deicer storage and pumping system. During the spring and summer months, each shop will complete a building inspection every month. This inspection includes taking time to recirculate any liquids in the storage tanks (Maine DOT uses salt brine and Magic Minus Zero), work ball valves and spray with fluid film, check for any leaks, and check for any rust. If anything is rusted, they are supposed to clean it with a wire brush.

Recirculation of tanks is expected to vary depending on the size of the pump, the summerization procedures includes several calculations to determine how long product should be circulated.

Formula: # of gallons in the tank/pump gallons per minute

- *It is then recommended that an additional 15 minutes is added to ensure proper mixing.*

Size	Gallons Per Minute
¾ HP Motor/Pump	30 GPM
1.5 or 2 HP Motor/Pump	55 GPM
5 HP Motor/Pump	100 GPM

If any issues with the system come up during the inspection the site will report to the Snow & Ice Supervisor.

Storage and Pumping System

Figure 28: Liquid Deicer Storage Tanks

Maine DOT puts out a contract to bid for storage tanks, Assman & Poly Processing has had the bid for around 20 to 25 years. Maine DOT primarily uses 5,500-gallon polyethylene tanks with crosslink construction (some satellite locations will have smaller tank set ups) (see Figure 28). The crosslink construction prevents the tank from rupturing due to age. Tanks currently cost around $11,900. Maine DOT purchases around 6 to 9 storage tanks each year and does not wait for tanks to rupture, instead replaces them on a 20–25-year cycle.

The Snow & Ice Supervisor uses some tests to examine the condition of tanks. These include “reading the cracks” and scraping the tank with a screwdriver. If the scrape is powdery, then the tank may suffer

from deterioration. These tests are done where the tank generally sees the most damage from any UV radiation or weather including at the top of the tank near the dome or the side of the tank more exposed to weather.

Maine DOT uses blended salt brine and Magic Minus Zero and has several brine making facilities across the state where tanker trucks are used to transport material to each site. Two of these brine making facilities have state-of-the-art automated brine makers in a large, heated shop. The remaining facilities (not automated) are located in small 8’ x 8’ heated shacks. Systems are located on a 12-inch thick 14’x14’ concrete pad with rebar. In a few locations they have tried reclaimed asphalt, and this worked well too.

Around a quarter of Maine DOT’s storage tanks are located indoors. Those that are outdoors do have a snow roof which covers the tanks however those tanks tend to see a shorter lifecycle due to UV and weather damage.

The storage tanks in the heated buildings do have a retaining wall which serves as secondary containment. Tanks that are located outside are on concrete pads with no secondary containment.

When the storage tanks have reached the end of their lifecycle, Maine DOT will generally cut them up and take them to the landfill. However, they have previously given old tanks to towns who have repurposed them. One used the tank to store water, and another was just starting to get into liquid deicers for winter maintenance.

Maine DOT has switched from using schedule 80 PVC hard piping for everything to using a flexible hose for the top fill pipe. They had previously tried hosing with wire running through it but had issues with those hoses getting run over by the trucks. Once the hose was run over, the wire in it would not allow the hose to bounce back and the wire could puncture the hose causing a leak. They have since switched to flexible hosing which has been resilient, requiring less replacement.

Massachusetts Department of Transportation

January 31, 2024

- Joe Kelly

Key Takeaways

- Semi Tankers to Apply Liquids
- One Person Maintaining Storage/Pump Systems District-Wide

Preventative Maintenance

Massachusetts Department of Transportation (MassDOT) District 3 first started with using agricultural products. In the past five years they have expanded their liquids program to use brine. It has been a logistical challenge moving material (liquid deicers) from one depot to another. District 3 has 26 depots housing a total of 38 pump and motor setups and 61 storage tanks for magnesium chloride ($MgCl_2$) and salt brine.

District 3 has one maintenance person who does repairs and maintenance on all liquid deicer storage and pumping systems. They have found that the less people touching these systems, the less issues they have. This maintenance person will check the liquid deicer storage and pumping systems in the spring and fall. This includes running through a metal checklist – checking hoses, gaskets, and each component of the system as well as checking for leaks. The system filters are checked and replaced if any holes are found. At the end of the winter season, pumps are drained, and then filled with windshield washer fluid as corrosion preventative. Additionally, ball valves are exercised and oiled (every tank has multiple shut off valves to help isolate any issues). Storage tanks are not drained and washed regularly. The entire routine takes around one hour per system.

A single shed is used to house space parts for repairs. If something goes wrong at a depot, they will call up the maintenance person who will take parts to the depot and complete the repair. Commonly stockpiled parts include fittings, clamps, shut-off valves, hoses, gaskets, and fill nozzles. MassDOT has found that all non-brass parts tend to fail more often than any other. They also have an extra pump and motor set up ready to go in case it is needed. They also use rebuild kits for pumps and motors so they can repair as many as is feasible in-house.

District 3 has found that having one person handle repairs and conduct regular maintenance has successfully eliminated downtime and has allowed for growth in operations with minimal failures.

System Details and Liquids Transportation

The liquid deicer storage and pumping system uses tanks ranging in age from 2004 to present (up to 20 years old). Most depots have two 5,000-gallon storage tanks, smaller depots will have a single tank. They mostly use $MgCl_2$ but do have salt brine. Liquid capacity for the district is around 235,000 gallons of

$MgCl_2$ and 111,000 gallons of salt brine. All liquid deicer storage and pumping systems are located outdoors and are uncovered, they have not faced any issues with UV damage.

Some depots have fill points similar to a gas station fill nozzle to fill the trucks, others have a quick connect coupler. District 3 gets their salt brine from Deerfield. They are currently working to get a brine making facility in Sterling. The plan is to have larger semi tankers load material at this new brine facility.

Semi tankers are used to apply brine in District 3 (see Figure 29). The tanker can carrier 4,500 gallons of material at a time so each fill of the tanker will empty a storage tank. Because of this storage capacity is on the higher end to accommodate transportation. The district has a vendor for the tanker, and currently they have three semi tankers operating across the district with a fourth one coming. These three semi tankers can treat the whole district. The District has found this method to be very cost effective compared to smaller trucks which would need to be refilled multiple times.

Figure 29: MassDOT District 3 Semi Tanker

Nebraska Department of Transportation

January 19, 2024

- Mike Mattison – Winter Maintenance Engineer (Lincoln)
- John Lutz – District 5 Operations Manager
- Chuck Hagen – Buyer Fleet Management (Lincoln)

Key Takeaways

- Training Each Year
- Group Meeting to Learn What Worked, What Didn't, and How Problems Are Solved
- Better Return on Investment with Fiberglass Tanks
- Repurposing of Train Sheds for Pump Houses

System Components

Storage tanks are purchased through the Nebraska Department of Transportation (NDOT) Fleet Management. Tanks are purchased from KBK Tanks which is based out of Kansas. NDOT utilizes 10,000- and 20,000-gallon fiberglass reinforced tanks (see Figure 30). Fiberglass tanks were chosen over polyethylene tanks because NDOT found that while they can be more expensive, they were a better return on investment as they held up better over time and had more precise fittings. Whereas when polyethylene tanks age and surplus out, and as they age, they become brittle and break as they get moved.

Figure 30. NDOT Tank Farm and Pump House

NDOT does have a few 2,400- and 3,400-gallon polyethylene tanks which are used in the back of trucks for pre-wetting and anti-icing. Additionally, NDOT utilizes 100,000- and 200,000-gallon storage tanks called Harvestores in District 3 (Columbus Area). These tanks serve as primary storage tanks for areas that use a lot of liquids (see Table 18). These tanks contain an internal bladder, NDOT uses a company out of California for repairs for these tanks. However, experience has shown that once these tanks are set in place, they do not require a lot of maintenance.

Table 18. NDOT Harvestore Locations and Capacity

Location	Gallons
Bloomfield	166,000
Creighton	85,000
Norfolk	260,000
Laurel	200,000
Niobrara	200,000
Plainview	200,000
Neligh	400,000
Humphrey	180,000
Hartington	200,000
Wayne	200,000

Since the deicers used by NDOT are not considered hazardous material, they do not require secondary containment. In Gering, Nebraska storage tanks are located near a retention pond/storage basin (which rarely has standing water) primarily used for snow storage and collection of run off. NDOT aims to not have extra material on hand at the end of each season.

Other liquid deicer storage and pumping system components like pumps, engines and piping – can vary by every field office/yard. NDOT has shifted from mechanical pumps to electric pumps and noted that this was one of the best modifications that they have made to their system. They utilize old railroad buildings for their pump houses (can insulate and use a pump house heater as needed to prevent freezing) (see Figure 31). NDOT has found that electric pumps are easier to clean, pump faster, and remain set up and ready to go in the pump house. NDOT has older 3-inch “trash pumps” (mechanical pumps) that have been used for years, these pumps can load a truck in around 22 minutes whereas the electric pumps can do it in half the time.

Figure 31: Pumping Housing

For hoses, NDOT previously used the cheapest options. Overtime with building tank farms and learning what works they have found that bend radius was important and that mid-price range flexible hoses (composite rubber hoses purchased from Dultmeier) worked best. Hoses are replaced each year at the end of the winter season. It was noted that each field office has their own ideas for hose types, parts that work best and they are encouraged to choose parts based off their experience. Ideally, they would use similar systems, to help with having extra parts on hand in case of emergencies.

The main pipeline is Schedule 80 3-inch PVC which allows for filling one to two trucks at a time. Previously NDOT used a larger 6-inch pipeline which allowed for filling more trucks simultaneously, but this was expensive. All piping that comes off the tanks and from the main pipeline to the pumps is flexible piping. This makes it easier for operators to take things apart as needed in case of failures or emergencies.

Maintenance/Cleaning

During the winter season, unless there is a hose or other part failure, NDOT will ensure that pumps are periodically cleaned out. They do not do much with the tanks or the system coming out of the tanks and replace flexible hoses every year to avoid issues during their busy season.

At the end of the season, NDOT will take trash pumps back to the main shop and take them apart to clean and replace or repair parts. Electric pumps are easier, requiring a wash out/blow out, and inspection for salt residue or corroded parts. NDOT also checks hoses for thinning which can happen as hoses get dragged around. Flexible piping is replaced at the end of the season. Everything is shut down, drained, cleaned, and prepared for the next year.

Every spring NDOT will clean out the storage tanks. NDOT has found that the salt they purchase can be extremely dirty and have had issues with dirt, straw, corn, and other debris in the delivered material. Part of this issue is the truck that delivers the salt may not have been cleaned out between loads. NDOT

does have a specification for the maximum amount of extra debris allowed in a salt load. For solid salt use, this debris is not an issue for NDOT, however when making brine this debris can clog the system.

To clean the storage tanks, NDOT uses Hotsy pressure washers with long cleaning wands. Workers are not sent into the tank as this is dangerous. Instead, the fiberglass storage tanks have a large manhole about 4-feet off the ground which can be opened, and pressure washers are used to blow debris off the tanks. This is messy work – workers wear rainsuits or Tyvek suits and rubber boots in order to not ruin their clothing.

NDOT noted that maintenance is an ever-changing requirement as they learn new things each year.

Training

NDOT has implemented operator training for all workers (even for long-time workers). This training is done in a more ad hoc manner, covering how the field office wants them to operate the liquid deicer storage and pumping system including how to turn it on/off, how the pumps work, how to fill the truck, and how to bring material into the pumps. In some areas, the system will have one pipeline which requires multiple materials to go through, so they will train on how to handle multiple materials on one pipeline. NDOT has experienced challenges with this set up, and has shifted in Gering to have two pipelines, one for each product, Apex and Torch (liquid deicing products). NDOT is working to implement two pipelines at other locations in order to reduce issues as Apex and Torch cannot be mixed and can cause problems with the application equipment on trucks when mixed.

No formal training materials have been developed, instead training is based on a playlist of talking points. The training content may vary slightly depending on the field office but overall should cover the same content. For District 3, training is kept consistent across field offices. Product use information is kept manually in spreadsheets and is checked against MDSS reports. NDOT tracks material use very closely due to limited storage at field offices.

In addition to training, NDOT labels all tanks with the material stored, keeps a whiteboard with totals of material used, and will place a red mark on the tanks that they want operators to use. This helps with filling and managing tanks at all locations, and for when new shipments arrive.

A suggested best practice is to get everyone in a room (e.g., system operators, supervisors) and discuss what has worked and how previous problems have been solved. This could help to document experiences and how to operate and maintain these systems over time.

Oregon Department of Transportation

February 5, 2024

- Patti Caswell – Maintenance Environmental Program Manager
- Robert Rake – Transportation Maintenance Manager (Portland Metro Area)
- Ben Lewis – Coordinator (Portland Metro Area)

Key Takeaways

- Pilot Testing Brine Making This Year
- Secondary Containment Triage Process
- Preventative Maintenance Program

Liquids Storage and Pump Systems Statewide

Oregon Department of Transportation (DOT) has been using liquids in their winter maintenance operations since around 1999. Statewide, Oregon has a capacity for 2.2 million gallons of liquid $MgCl_2$. Most storage is 10,000-gallon polyethylene tanks. The storage tanks are hard line PVC plumbed except for the fill hose which is flexible (see Figure 32). Some tanks have a sight glass hose to verify capacity, and Smart Tank sensors are used which sit at the bottom of the tank. Statewide, Oregon DOT has tanks both indoors and outdoors. The western portion of the state gets a lot of rain so they will use coverings (e.g., metal cover, storage sheds) to keep rain from pooling in secondary containment areas, where feasible.

Figure 32: PVC Plumbing of Liquid Deicer Storage Tanks.

Pump and motor set ups are generally covered in a pump house. Oregon DOT mostly uses three phase pumps; however, a few remote locations have gas powered pumps (trash pumps). The trash pumps

have a 40 to 50 gallons per minute (GPM) capacity and the three phase pumps have a 300 to 400 GPM capacity.

Pilot Testing Brine

A Portland Metro Area maintenance yard is pilot testing use of salt brine this winter season. They previously were using liquid magnesium chloride ($MgCl_2$) for direct liquid applications and pre-wetting solids. The yard is using a Cargill Accubrine system to make brine. Solar salt is used to create brine, so they have seen little to no issues with debris build-up in their system. Their section uses six 10,000-gallon polyethylene storage tanks – two for $MgCl_2$, two for salt brine, and two for AMP corrosion inhibitor. The $MgCl_2$ is left over from the prior season before salt brine production began. Storage tanks are labeled with material stored. The system uses a combination of both soft and hard piping.

The crew will pre-treat roadways to handle freezing fog, freezing rain, and other events. If it is dry the goal is to stay ahead of the game and get something down on the roadway before the storm hits.

Secondary Containment

Secondary containment varies across the state (see Figure 33). Oregon DOT utilizes a questionnaire to help prioritize storage locations as high, medium, or low risk for secondary containment based on weather, property features, and whether there are sensitive resources nearby.

Specific guidance is provided on secondary containment from Oregon DOT. Generally, containment must be able to hold 105% of the largest storage tank at the location. Secondary containment can vary from a low berm to cast-in-place concrete walls to eco-blocks with a spray in liner.

Figure 33. Storage Tank with Secondary Containment Retention Wall

Preventative Maintenance

Typical parts kept on hand for emergencies include seals, valves, caps, and hoses. A pump for the $MgCl_2$ tanks is kept on hand for emergencies. For the Accubrine system, it's so new that the Portland Metro Area yard has some spare valves and parts, but they have not experienced any major issues yet. They have made some tweaks to the system based on their experience, including adding insulation to areas where water travels.

When Oregon DOT purchased the Accubrine system, Cargill came out and provided a training at the local level for those who would be making brine. Other than this, each winter Oregon DOT will have a day-long training for winter maintenance operations which will include some liquids training including looking for leaks, how to handle spills or other environmental concerns, how the truck fill works, how the pump works, and other on-the-job training.

Oregon DOT has found that the storage tanks do not require a ton of maintenance. They do not flush or rinse the tanks often but will recirculate tanks in the summer if there is product in storage to minimize build up at the bottom of the tank. In cases where they have needed to clean out the tanks, they have hired a contractor to clean the tank out.

The liquid deicer storage and pumping systems are inspected annually. This inspection will include checking components of the system, checking seals, updating hoses as needed, and ensuring the area is clean. For the truck fill station this will include checking caps, seals, and pumps. Hoses are generally taken inside during the summer to prevent ultraviolet (UV) damage. Pumps are blown out with air and checked over at the end of the season. Throughout the year, Oregon DOT has the yards check valves and

for leaks monthly. Each yard is required to fill out a form as part of this process. This helps to ensure that the system is being checked on a regular basis.

South Dakota Department of Transportation

February 13, 2024

- Daniel Varilek
- Keith Voegeli
- Curt Theisen

Key Takeaways

- Limiting Staff for Brine Making
- Brine Maker Upgrade to Increase Capacity
- Future Upgrades to Facility, Clean Salt for Brine Making

Brine Making Facility and Upgrades

The Sioux Falls Area of South Dakota Department of Transportation (SDDOT) has a large-scale brine making operation where they manufacture brine for 11 locations on the southeast side of the state. The current brine making facility has storage capacity for over 70,000 gallons of brine – around 13,000 gallons in a heated building and 60,000 gallons of outdoor storage. They also have a tanker which can hold 5,000 gallons which can be used as additional storage if needed.

The brine making facility uses a VariTech S600 brine maker. When they first started to manufacture brine, they followed the manufacturer's recommended settings. After they wore through the original pump (which had a capacity of 1,500 gallons per hour), they did some research and switched to a MJ pump and worked with the supplier to increase flow through the lines (full flow valves, etc.). Since making these upgrades, SDDOT has doubled its brine making capacity to around 3,600 to 3,800 gallons per hour.

The salt used to make brine in the Sioux Falls is a rock salt that is dirty, compared to solar salt or brining salts, which can plug up the system causing it to run slower. To manage this, the Sioux Falls Area shop shuts down brine production and cleans out the system roughly every 30,000 gallons of brine, otherwise they start to see diluted brine. The Sioux Falls Area shop hires a local septic cleaning company who comes in and uses a vacuum truck to clean out the brine maker. During the winter when they are making a lot of brine, they will schedule this cleaning ahead of time to maintain 24/7 operations.

The storage tanks at the Sioux Falls Area brine making facility are around 20 years old. This facility is scheduled for a new brine making building and machine within the next year or two. When these upgrades take place, they will likely replace the storage tanks at the same time. In addition, they are considering switching from rock salt to cleaner brining salt (which is currently used in Western South Dakota). This switch is expected to reduce the amount of system cleaning needed to roughly once per season.

Limiting Brine Making Staff

At the Sioux Falls Area brine making facility they try to keep a core staff for brine making so that operations are kept consistent and accurate. They check the consistency of their brine regularly (up to once every 15 minutes when having issues) and adjust as needed if percentages look off. This core staff is in the brine making facility all the time, so they keep an eye on the system. If a plow operator sees any leaks in the system, they will report issues to the brine staff and the brine staff will repair the system as needed. They have not seen issues with the storage tanks but noted that hoses or couplers are often where they will see leaks. They also have experienced challenges with subzero temperatures freezing brine in the lines.

The Sioux Falls Area brine making facility uses two different pump manufacturers, a John Blue pump to transfer from the inside to outside storage and to load the tow plow, and a Banjo pump to load trucks (see Figure 34). These pumps use 2-inch polyethylene lines. These pumps need to be replaced after around 1 million gallons are ran through the pump or once every year or every other year. They had previously used stainless steel pumps which lasted around 2 to 3 years, but it was expensive, so they switched to lower cost poly pumps. The Sioux Falls Area uses a Lovejoy connection between the pump and motor to save the motor if the seals break and to limit pressure in the pumps, this allows them to swap out pumps easily in case of a failure and has increased the service life of the poly pumps. Pumps are flushed out with water at the end of the season.

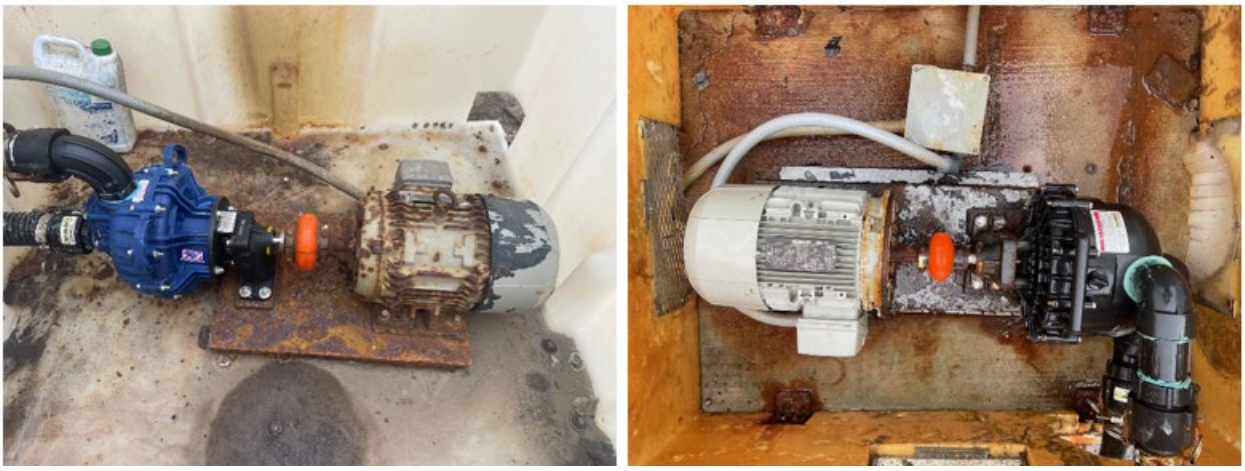

Figure 34: Pumps with Lovejoy Connection to the Motor (John Blue Pump - Left, Banjo Pump - Right)

The Sioux Falls area keeps spare John Blue and Banjo pumps on hand in case of emergencies. They also keep clamps on hand in case of hose leaks during a storm. Otherwise, their supplier is in Sioux Falls so replacement parts are easily accessible. Additionally, because they are a part of the farming community, they have a lot of parts and knowledgeable staff in close proximity.

LIST OF RESOURCES SHARED

Agencies

Kansas DOT

- Kansas DOT Equipment Users Handbook
- Kansas DOT Specifications for Liquid Chloride Storage Tanks
- From Snow & Ice Listserv Email:
    - Ohio DOT Tank, Product and Wast Management Conference (2014) Poly Tank Guidance Presentation
    - Ohio DOT Monthly Poly Tank Inspection Checklist
    - Purdue University Poly Tanks for Farms and Businesses

Maine DOT

- Liquid Fill Station Checklists
- Summerizing Liquid Pumps Guidance
- Summerizing Salt Brine Pumps Guidance

Nebraska DOT

- Chemical Application Rates
- Tank Farm Locations and Capacity
- Harveststore Information

Oregon DOT

- ODOT Maintenance Environmental Management System (EMS) Manual 2020
- ODOT Salt Brine Pilot Presentation

Vendors

Assmann & Poly Processing

- Polyethylene Tank Inspection Guide
- Polyethylene Tanks and Accessories Brochure
- Tank Installation & Use Guidelines for Bulk Storage Tanks

Dultmeier

- Liquid Anti-Icing/Deicing Equipment Products – Summer 2023

K-Tech Specialty Coatings

- Foam Free Blending and Loading Guidelines and Cascading Vortex Design

Sno-Biz

- Brine Storage Tanks Specifications

- Sno-Biz Flex Truck Fill Manual
- Henderson Brine Xtreme Flex Product Sheet

VariTech

- Blend Boss Specifications Sheet
- Snyder Industries, Inc. Deicer Tanks Specifications Sheet
- Snyder Industries, Inc. Polyethylene Upright Storage Tanks Specifications
- Snyder Industries, Inc. Double Wall Tank Systems Sheet
- VariTech Blend Boss Product Sheet
- VariTech Smart Transfer Station Product Sheet

Best Management Practices for Liquid Chloride Storage and Pumping Systems

research for winter highway maintenance

Lead state:
Minnesota Department of Transportation
Research Services
395 John Ireland Blvd.
St. Paul, MN 55155