



## Brine Application Equipment and Methodology

*Requested by*

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# Executive Summary

## **Background**

Solute substances dissolved in pure water act to lower the water's freezing point temperature. Spraying roadway pavement with a liquid freezing-point depressant is a common practice used by road maintenance agencies to prevent snow and ice accumulation on pavement and facilitate easier removal. Water with a high salinity (a.k.a. brine) is one of the most common solutes utilized as a liquid de-icer, but there are many more environmentally friendly agricultural and chemical alternatives that have been shown to produce similar results. In this report, the term "brine" is intended to include all solutes which act in a similar manner to prevent snow and ice accumulation on pavements. The California Department of Transportation (DOT) (Caltrans) Division of Maintenance currently uses a variety of brine application methods and equipment in their winter operations. Caltrans wants to document the most effective and efficient liquid de-icer application equipment and methods to guide adoption of a consistent brine application methodology and equipment specification throughout the state. Currently, brining operations vary depending on the stages of a winter storm event. Brine is sprayed on bare pavements as an anti-icing treatment to inhibit the freezing of water on the pavement surface. Mid-storm, during plowing operations, brine is commonly used as a pre-wet treatment to enhance granular treatments including sand, salt, and custom products consisting of mixtures of both. Post-storm brine is utilized as a de-icing agent to soften surface ice to improve plowing effectiveness.



Figure 1. Stages of Brine Application (North Dakota DOT)

## **Brine Anti-Icing Inhibitor**

Application of brine to pavement surfaces before icing acts to lower the freezing point of water on the pavement surface to prevent formation of a strong bond between the surface ice layer and the pavement. A weak bond enables a plow blade to more effectively cut down through hard pack snow and ice layers to the bare pavement surface, rather than just riding up over the ice layer. Brine is the preferred anti-icing agent over granular salts for pavement pre-treatment because liquids are better at staying on the pavement surface when they are applied at speed and do not tend to scatter from vehicle traffic or wind. Brine is also active upon application, whereas granular salts must dissolve to be activated. Applying brine to the pavement is generally accepted as the most effective approach to combat the build-up of ice and compacted snow on highways. Most snow state DOTs apply some form of anti-icing policy in their winter maintenance best practices. Anti-icing generally involves coating the highway with a thin coat of brine just prior to freezing events. Any highway pre-treatments should be applied in a timely manner to achieve optimal effect, because, if left exposed to passing traffic, the anti-icing inhibitor will wear away in the wheel paths.



Figure 2. Highway Anti-Ice Treatment (Caltrans)



Figure 3. Brine Tanker Anti-Icing (Caltrans)

### Brine Pre-Wet Treatment

The most common use of brine during a snowfall event is as a pre-wet treatment applied to granular materials, typically at less than a 23% dissolved salt concentration. Since dry salt must change into a liquid solution to initiate the snow and ice melting process, treating granular salt, or any mixture of salt and granular material, with liquid either prior to or during casting on the highway helps to accelerate the melting process. Pre-wetting granular materials before casting also helps the materials stick to hard-packed snow and ice, improving their effectiveness. Studies have shown that pre-wetting granular materials can reduce their usage by one third while achieving the same beneficial effect.<sup>1</sup> Directly applying brine alone to snow during a winter storm event is uncommon because it tends to make the snow stickier and more difficult to plow and does not provide the beneficial traction enhancement as when mixed with abrasives.



Figure 4. Sanding with Pre-Wet Treatment (Epoke)

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<sup>1</sup> Synthesis of Information on Anti-icing and Pre-wetting for Winter Maintenance Practices in North America, K. O'Keefe, X. Shi, Western Transportation Institute, Montana State University – Bozeman, Final Report, 2005

## Brine De-Icing Countermeasure

De-icing procedures are countermeasures that facilitate the removal of hard packed snow and ice once it has built-up on the pavement surface. Since level of service (LOS) is significantly degraded when hard pack snow and ice are present, DOTs work to clear highways down to the bare pavement as soon as feasible. In order to expedite this task, agencies regularly apply brine to the hard pack surface to soften the ice layer and enable a plow blade to more effectively cut down to the pavement. Since de-icing operations occur when the pavement is covered with hard-packed snow and ice, traffic speeds are expected to be significantly lower than normal and much less than during anti-icing operations. The post-storm application of brine alone to hasten the removal of an existing ice layer on the pavement is an effective countermeasure but does not improve surface traction. Therefore, the preferred approach is to apply abrasive treatments along with brine to enhance traction on the ice layer while the brine acts to soften the ice layer. Because of this, liquid de-icing operations are very similar to pre-wet and anti-icing operations and utilizes the same equipment, procedures, and materials. Liquid anti-icing is considered as a separate category primarily because it involves the removal of an ice layer after it has formed.



Figure 5. TowPlow Brine Highway De-Icing Operation (Caltrans)

## Caltrans Winter Snow Fighting Policies and Procedures

For most states subject to severe winter conditions, these conditions exist throughout the state, enabling their transportation agencies to implement a relatively uniform and widespread winter maintenance strategy. Caltrans snow fighting operations are distinctive in that winter maintenance operations are only conducted in relatively small pockets of the state, typically only on high mountain passes and high elevation plains. Even within different regions of California, the winter conditions and LOS goals vary significantly; consequently, Caltrans application methods have evolved locally to focus on relatively small stretches of highway or structures where icing is likely to occur. Caltrans has investigated and successfully tested permanent in-place de-icing systems on the highway in areas prone to freezing such as bridge decks and overpasses. However, possibly due to snow control routes being relatively short in California and patrolled continuously during weather events, such systems have not yet garnered support in Caltrans (Figure 6).

Caltrans institutes localized winter highway driving restrictions once pavements become covered with snow or ice. Vehicles subject to the various levels of chain control restrictions must employ tire traction devices or have all-wheel drive (Figure 7). Traffic speeds are reduced to a maximum speed of 25-30 mph when highway chain restrictions are in-place. In the southern regions of the state where severe winter conditions are infrequent, highways over mountain passes are closed until bare pavement conditions can be re-established. In all cases, major

highways must be cleared down to bare pavement as quickly as possible so that traffic can resume normal speeds and flowrates.

Caltrans is working to expand their use of brine in an effort to both reduce the amount of granular materials they spread on the highway and to reduce chain restriction durations, thus improving both mobility and safety on highways in winter snow fighting operations. Consequently, Caltrans is interested in acquiring innovative brine application procedures and equipment which could be utilized to meet Caltrans' expanding brine application goals. Other DOT techniques and current industry technologies will be investigated to support the goal of adopting a standardized approach and expanded toolbox of equipment, methods, and controllers capable of precise, efficient, and accountable brine application operations.



Figure 6. Bridge Deck Integrated Brine Spray



Figure 7. Caltrans Chain Control Checkpoint

## Summary of Findings

### Direct Brine Application Methods

There is little procedural difference between applying brine on the highway in an anti-icing or a de-icing operation other than their fundamental objectives. Whereas anti-icing operations are primarily a preventative measure conducted to disrupt the formation of a bond between the pavement and packed snow and ice to facilitate their removal, de-icing operations are primarily reactive, seeking to break the bond which has already been established. Typically, the same equipment is utilized for both operations with the principal difference being the associated size of the liquid tank(s) and surface conditions. Anti-icing is conducted on bare pavements either at the prevailing traffic speed or at a reduced speed when traffic is light, whereas de-icing is conducted on an ice layer at low speeds. The application of brine for anti-icing is time critical. Brine should be applied as shortly before the freezing event as possible to reduce its dispersion due to traffic exposure, which pumps the liquid out of the wheel ruts where it is most needed.

***Caltrans Direct Brine Application Methods:*** Caltrans winter maintenance crews are increasingly using direct brine applications instead of granular salt to combat freezing conditions on highways and structures. The conversion to brine as the preferred anti-icing treatment is part of a systematic strategy to reduce, and potentially eliminate in some areas, the spread of granular materials on highways during the winter. This effort is mainly motivated by the significant effort and expense spent each year on removing the bulk of the residual granular materials remaining on the highway where it was spread throughout the winter. The collected granular tailings are regulated as toxic waste and must be disposed of accordingly.

In Caltrans regions at lower elevations, where freezing occurs but there is insignificant snowfall, the switch to the sole use of brine is almost complete. In Caltrans regions at higher elevations, where heavy snowfall accumulation is commonplace, the increasing use of brine is translating into a reduction in the amount of granular materials spread on the highway; however, spreading granular material is unlikely to ever be eliminated completely. Caltrans avoids anti-ice brine treatments on the highway when snowfall is imminent. The typically warm snowstorms California experiences tend to begin as slush on the road. The wet slush in traffic tends to wash away the brine anti-ice treatment before it can be useful. Instead, Caltrans applies anti-ice treatments when pavement is clear and dry and a freezing event is imminent. The wet appearance of the brine on the highway gives motorists the impression that they are looking at black ice, and as a result, they slow their speed, thereby noticeably reducing the frequency of run-off highway accidents.

Caltrans performs highway brine application anti-icing operations at lower speeds, typically between 25-30 mph, and therefore must conduct these operations late at night when traffic is light and sometimes with Maintenance Zone Enhanced Enforcement Program (MAZEEP) assistance. For multi-lane direct brine applications, Caltrans must block the adjacent lanes which are being sprayed to ensure motorists cannot pass. Additional Caltrans vehicles provide this assistance.

*Direct Brine Application Methods by Other Agencies:* A literature search was conducted to determine what effective anti-ice brine application methods other agencies are practicing. An NCHRP report entitled *Manual of Practice for an Effective Anti-icing Program* chronicles systematic approaches to effective anti-icing programs.<sup>2</sup> A Montana report queried fifteen Pacific Northwest Snowfighter (PNS) state DOTs and Canadian Provinces for detailed information as to effective anti-icing procedures practiced by these agencies<sup>1</sup>. An additional six states and Provinces participated in the survey distributed for this report (Appendix A). An examination of the results revealed that virtually all of these agencies regularly practice some combination of direct and/or pre-wet application of liquid brine. Most of these agencies utilize a form of direct liquid brine application in the majority of their operations and report to be very satisfied with the results. The methods of direct application are generally consistent with the Clear Roads manual of best practices for road salt.<sup>3</sup> Only three states reported infrequent to no direct brine applications for anti-icing operations, most of these instead choosing to focus their direct brine applications on de-icing operations. Two of the agencies which participated in the 2005 and 2018 surveys showed an increase in utilization of direct brine application in their highway operations.

## **Direct Brine Application Equipment**

Winter highway maintenance brine spraying equipment is ordinarily comprised of a liquid tank, pump system, spray bar, and controller. Liquid tanks for direct brine applications are characteristically far larger than pre-wet tanks due to the large disparity in application rates (Figure 8). Since the pre-wet tanks are smaller, they are often mounted in convenient, unused spaces, such as on the outside of dump bodies, so as not to interfere with the normal function or capacities of a plow truck body.

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<sup>2</sup> Manual of Practice for an Effective Anti-icing Program, FHWA-RD-202, S. Ketcham, D. Minsk, R. Blackburn, E. Fleege, US Army Corps of Engineers Laboratory, 1995

<sup>3</sup> Manual of Best Practices for Road Salt in Winter Maintenance Operations, Clear Roads Report 14-10, MNDOT, W. Nixon, R. DeVries, 2015



**Figure 8. Truck Pre-Wet Spreader and Direct Brine Application Trailer (North Dakota DOT)**

**Vehicle Configuration Overview:** The required size of the liquid tank needed to effectively address a specific operational area and the available vehicles are the main factors in how vehicles are configured to transport brine spray systems on the highway. There are many variations in how the liquid tank is attached to a vehicle, including plow truck trailer, semi-truck trailer, dump body skid insert, direct chassis mount, hook lift body, roll-off body, and flatbed skid. The mounting of the characteristically large liquid tank is the primary consideration when selecting a direct application brine system configuration. For existing equipment, dump body inserts and flatbed skids are the easiest to construct. Several manufacturers offer versions of self-loading insert systems which can be placed in a plow truck dump body for anti-ice operations pre-storm and removed so the plow can apply granular materials during the winter storm event. The skid mount would be semi-permanently attached to a flatbed truck and utilized for pre- and post-storm brine applications. Roll-off liquid application bodies offer exceptional flexibility, but the additional weight of these lift systems must be taken into consideration.



**Figure 9. Snow Plow with Roll-Off Body Mounted Anti-Ice Spray System (Cliffside Body Corp.)**



**Figure 10. Slip-In Brine Spray System (Henderson)**

Trailer-mounted brine tanks are often the best choice when conducting large-scale anti-ice operations requiring 3,000-gallon or larger liquid tanks. The weight and size of such large tanks are rarely compatible with a standard truck chassis. A trailer has the additional axles and surface area necessary to carry the additional load and size of these large liquid tanks. The large size tank trailers are also more useful as water trucks in the off-winter season than smaller slip-in systems.



**Figure 11. 2,700-Gallon Trailer-Mounted Anti-Ice System (Illinois DOT)**



**Figure 12. Semi-Trailer-Mounted Anti-Ice System (Monroe)**

**Liquid Pump Systems:** Brine liquid pump systems are typically centrifugal pumps, either hydraulically driven for truck chassis integrated units or direct driven by small gasoline engines for self-contained, more portable units. Sizing the pump capacity is the key factor in specifying an anti-icing system. To optimize power and cost factors, the liquid pump should be sized according to the intended maximum application rate. There are high and low pressure pump systems depending on the configuration of the spray bar(s) and the distance the spray stream must carry.



**Figure 13. Simple Spray Bank with Clip-On Nozzles (Caltrans / VariTech)**

**Application Spray Bar and Nozzles:** Liquid brine spray bars are often simply comprised of pipe(s) placed near the pavement in various patterns (Figure 13). The common nozzles utilized for direct brine application systems largely consist of clip-on fixed-orifice spray nozzles, drip tubes, or flood nozzles. There are also spinner types of liquid dispersion systems where the brine is expelled in a rotating fan motion. The spinner could be either a disk with fins that deflect a stream of brine impinging on its surface or a circular array of tubes extending from a spinning core. A rotating valve in the core of the array assembly ensures the liquid is sprayed out in one direction (Figure 17).



**Figure 14. Direct Brine Application Spray Nozzles (North Dakota DOT)**



**Figure 15. Direct Application Flood Nozzles (North Dakota DOT)**



**Figure 16. Kingvale Tanker Truck with Liquid Drip Tubes (Caltrans)**



**Figure 17. Liquid Spinner (Epoke)**

Banks of liquid spray nozzles can be arranged or aimed to apply brine to multiple lanes in a single pass (Figure 18). Applying brine on adjacent lanes typically involves laterally directing jet streams of brine under pressure ten feet or more out from the side of the vehicle. A specific nozzle design is required to project a liquid stream long distances while minimizing liquid dispersion.



**Figure 18. Multi-Lane Brine Spraying**

Spratronics® offers several versions of variable-orifice nozzles that they claim solve many of the inherent shortcomings of fixed-orifice nozzle systems for applying liquid to highway surfaces from a moving vehicle.<sup>4</sup> The O-Nozzle is a new spray nozzle design which automatically changes opening size according to the flow rate and maintains the exact same spray pattern at any vehicle speed or application rate (Figure 19). Variable-orifice nozzles output a tight jet stream of liquid to deliver better spraying results than standard fixed orifice nozzles, which work poorly at both low and high speeds. Variable-orifice nozzles support zero-velocity spraying and have a vehicle spray speed range from 1-60 mph. When configured to spray from a fast-moving vehicle, O-Nozzles are mounted to spray backwards, thus cancelling the vehicle's forward motion while the solid streams fall gently to the road without atomizing or fogging.



**Figure 19. Spratronics® O-Nozzle (Spratronics)**

*Caltrans Direct Brine Application Equipment:* After interviewing Caltrans maintenance personnel in District 3 and at Headquarters, it appears that direct brine application is increasingly being introduced to the fleet. The equipment is sourced from Headquarters' Division of Equipment (DOE) while at the same time individual maintenance yards are specifying and acquiring brine equipment independently. In regards to single purpose brine application equipment, the most recent procurements were by the South Lake Tahoe maintenance station. They obtained three 1,600-gallon VariTech Industries slip-in tank spray bar systems to support increased anti-icing operations as a means of achieving a significant reduction in the amount of granular material applied in the environmentally sensitive Lake Tahoe Basin (Figure 20). There are many similar slip-in tank spray systems in use throughout the state in regions where ice on the pavement is an issue. Many are far less capable than the relatively new VariTech systems. Some tank spray systems currently in use by Caltrans rely on gravity flow and some do not have application controllers.

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<sup>4</sup> *Spratronics, A Product of NozzleWorks Inc. - O-Nozzle Variable Orifice nozzles*  
<http://www.spratronics.com/>



**Figure 20. VariTech Industries Liquid Application Slip-In Systems (Caltrans, South Lake Tahoe)**

Caltrans is building their fleet of multi-function spreader vehicles. Caltrans DOE is in the process of acquiring and deploying several Henderson First Response System (FRS) Direct-Cast-equipped trucks (Figure 21) and has already deployed two Epoke systems (Figure 22) with a third Epoke roll-off version soon to be deployed. These more advanced, multi-functional vehicles are all capable of supporting direct brine application operations. Caltrans has also deployed two TowPlow trailers with 1,000-gallon brine tanks and spray bars and an older 3,000-gallon tanker system used for direct brine application.



**Figure 21. Henderson FRS Spray Attachment (Caltrans)      Figure 22. Epoke Spray Bar Attachment (Epoke)**

**Other Agencies' Direct Brine Application Equipment:** A review of literature indicates that a wide variety of both commercially available direct brine equipment and DOT-adapted systems are utilized by other agencies. Furthermore, the combined survey results described in the previous section indicate a trend towards utilizing a wide set of diverse equipment as opposed to migration toward a singular set of perfected systems. The equipment reported to be in use for anti-icing and de-icing operations tends to be a mix of dual-purpose tank spray equipment and vehicles, together with specific-use attachments and truck bodies. Highway agencies typically have truck- and/or trailer-mounted water tanker systems in their fleet for dust suppression and herbicide spraying during the warmer months. These liquid handling systems are often converted into brine spray systems for anti-icing and de-icing winter operations by simply adding a spray bar and application nozzles, or drip tubes. Most of the responding agencies reported utilizing this dual-use configuration as a way to optimize fleet efficiency with tank sizes ranging from 800 to 6,000 gallons and they seem to be roughly divided between truck and trailer configurations.

Many of the responding agencies utilize specific-use slip-in body direct brine application systems like the VariTech self-contained unit. These systems are not designed to offer dual-use functionality, but enable the spray body to be easily detached, enabling the truck to be repurposed. Only a few of the responding agencies utilize a type of sophisticated multi-function direct brine spray system like the Epoke for direct brine application on the highway in anti-icing and de-icing operations. A couple of agencies utilize Tow Plow trailers with mounted brine tanks to spray brine on the highway in their anti-icing and de-icing operations.

#### Commercially Available Liquid Only Anti-Icing Equipment

##### *VariTech Industries Slip-In Anti-Icing Systems*

<http://www.VariTech-industries.com/Products/Application-Systems/Slide-In-Anti-Icing-System>

##### *VariTech Industries Trailer-Mounted Anti-Icing System*

<http://www.VariTech-industries.com/Products/Application-Systems/Trailer-Mounted-Anti-Icing-System>

##### *SnowEx Inc. VSS-3000 Anti-Icing System*

<https://www.snowexproducts.com/product/accuspray-vss-2000-vss-3000/>

## **Pre-Wet Application Methods and Equipment**

In a pre-wet operation, the granular material being cast onto the pavement is coated with brine to expedite the ice melting process and facilitate the granular material to stay where applied at speed and not bounce off the highway. Pre-wetting can be accomplished with a liquid mixture with as little as 8 to 20 gallons of brine per ton of granular material.<sup>5</sup> There are four distinct methods of applying brine to the granular materials in a pre-wet operation:

1. Bulk pre-wet – when granular material is soaked with brine after being loaded into the spreader hopper,
2. Spreader spray – when brine is applied to the granular material as it passes over the spinning casting disc,
3. Mid-air mixing – when brine is jettisoned in streams adjacent to the casting disc and mixed mid-flight, and
4. Brine pre-treatment – when brine is sprayed directly on the pavement surface just ahead of the granular casting.

***Bulk Pre-Wet:*** DOT purchase specifications of bulk granular materials usually include anti-freezing treatments, often with calcium chloride (CaCl<sub>2</sub>), to ensure these material stockpiles do not freeze in their storage sheds. Bulk pre-wetting, as it relates to application equipment, relates to the practice of pre-wetting the granular material after it has been loaded into an application hopper. The load is sprayed with brine from overhead spray bars, or by a hand nozzle usually until the brine visibly runs out the bottom of the hopper (Figure 23). The primary disadvantage of bulk pre-wetting is that it is very difficult to get uniform particle coating with this method. Liquid sometimes channels through the load to the truck bed without coating segments of the dry granular material. Other times, too much liquid is used in an attempt to achieve reasonable particle coating. The unequal mixing of liquid can lead to clumping, which clogs the conveyor discharge.

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<sup>5</sup> Manual for Best Practices for Snow and Ice Control, Clear Roads, L. Fay, M. Honarvernazzari, S. Jungwirth, A. Muthumani, N. Cui, X. Shi, Western Transportation Institute, Montana State University, MnDot, 2015



Figure 23. Kingvale Brine Pre-Wet Shower (Caltrans)



Figure 24. Basic Spreader Flood Pre-Wet System (Minnesota DOT)

**Spreader Spray:** Directing a brine spray or stream of brine directly onto the spinner plate is the least complicated of spreading pre-wet techniques (Figure 24). Several equipment manufacturers offer pre-wet systems as either stand-alone attachments or fully integrated with their specific granular spreader systems. Stand-alone pre-wet systems are intended for use in retrofit applications to add pre-wet capabilities to existing spreader bodies. Pre-wetting capabilities can be easily added to legacy plow trucks with the addition of bolt-on spray tanks and self-contained spray systems. Integrated pre-wet units are an option purchased with the spreader body and come complete with a turn-key controller. Manufacturers offer minor variations in spinner plate designs, brine application nozzle designs, and controller capabilities, but it remains unclear if any of these variations have much, if any, effect on the efficiency of the pre-wet process. Henderson, Inc. offers a direction controllable spreader called Direct-Cast™ that has brine pre-wet nozzles integrated into the spreader housing to shield the brine spray from wind or weather interference (Figure 26).



Figure 25. Basic Spreader Spray Pre-Wet System (Caltrans South Lake Tahoe)



Figure 26. Henderson FRS Direct-Cast™ Pre-Wet Nozzles (Caltrans)

**Mid-Air Mixing:** This process entails pre-wetting by simultaneously spreading solid and liquid materials such that the dry solids come into contact with the liquid chemicals mid-flight. The liquid tubes are mounted to the bottom of the spinner disk and have a directional valve which controls the brine spray pattern (Figure 27). It is unclear if there is much difference between mid-air mixing and spreader application in relation to pre-wet efficiency, but the key advantage

with the spinning tube design is that it is also capable of direct brine application as well. Pre-wetting can be adjusted using the controller.



Figure 27. Epoke Brine Spray Spinner Applicator (Caltrans)



Figure 28. Epoke Pre-Wet Application (Epoke)

The Epoke™ offers a spreader system with a pre-wet capability which can be controlled to adjust the width and direction of the casting pattern. The Epoke design has liquid tubes which spin with the spinner disk and emit a jet of brine adjacent to the granular casting to mix in mid-air to more uniformly coat the grains with liquid.

**Brine Pre-treatment:** Brine spray nozzles can be arranged near the spinner disk and spay the pavement in the landing area of the granular castings (Figure 29). The wet pavement will help stick the flying granular materials to the pavement and keep it where placed. This method enables a greater amount of brine to be applied during granular casting than the three previous pre-wet methods.



Figure 29. Brine Pretreatment with Henderson FRS (Wisconsin DOT)

**Caltrans Granular Pre-Wet Methods and Equipment:** Caltrans often utilizes brine as pre-wet for granular treatments mid-storm to enhance both melting capabilities and having the granular materials stay on the roadway where applied. Caltrans mostly utilizes the bulk pre-wet approach, but based on recent interviews with Maintenance personnel, they seemed to favor the idea of switching to a mixing type system if the proper equipment was made available.



Figure 30. Roll-Off Pre-Wet Sander Body (Caltrans)



Figure 31. Henderson FRS Direct-Cast™ Pre-Wet (Caltrans)

***Other Agencies' Granular Pre-Wet Methods and Equipment:*** A review of literature indicates that pre-wet procedures are becoming more common with other snow state DOTs. All of the agencies responding to the combined surveys acknowledged that pre-wetting granular material provides better placement control and reduces the amount of materials spread by a third while achieving the desired effect. Consequently, all of the surveyed agencies reported utilizing some type of pre-wet treatment. Many agencies are striving to pre-wet 100 percent of their casted granular materials on the highway. Based on all of the survey responses referenced in this preliminary investigation report, pre-wet equipment runs from crude adaptations to sophisticated commercial systems depending on the type of pre-wet method practiced. The bulk brine shower and basic gravity flow to spreader spray systems tend to be configured ad-hoc internally. For the majority of on-road pre-wet operations, the respondents mainly rely on commercial systems which are specifically designed to provide precise control of the brine liquid introduced during the casting process. These systems inherently involve various levels of automated control of valves, pumps, and even application direction for some systems. The level of automation favored by the responding agencies seems to be fairly basic, but they are trending toward expanding their AVL and data collection capabilities.

#### Commercially Available Pre-Wet Products

##### ***Monroe Truck Equipment Pre-Wet Systems***

<http://www.monroetruck.com/Products.aspx?category=189&product=71&name=Pre-Wet>

##### ***Henderson Pre-Wet Systems***

[http://www.hendersonproducts.com/assets/hp-053\\_pws.pdf](http://www.hendersonproducts.com/assets/hp-053_pws.pdf)

##### ***Henderson Slip-In Pre-Wet Systems***

[http://www.hendersonproducts.com/assets/hp-075\\_stands.pdf](http://www.hendersonproducts.com/assets/hp-075_stands.pdf)

## **De-Icing Methods and Equipment**

***Caltrans De-Icing Methods and Equipment:*** In regions of significant snowfall where de-icing operations are required, Caltrans winter maintenance crews favor the use of motor graders often with specialized undercarriage-mounted ice cutting plow blades to mechanically remove bonded ice layers and packed snow from the highway (Figure 32). Caltrans also has mechanical ice breaking drum attachments for wheel loaders developed specifically to mechanically break the pavement/ice pavement bond (Figure 33). Mechanical de-icing

equipment has the advantage of immediate ice removal as opposed to having to wait for brine to penetrate and soften the ice sheet before returning to scrape ice off the pavement. Caltrans only occasionally utilizes brine application in support of highway de-icing operations using vehicles with auxiliary brine tanks and spray bars for liquid de-icing applications. With coming expansion of multi-functional spreader vehicles into the Caltrans fleet, the practice may increase in the near future. Spreader systems, like the Epoke, have brine application capabilities always available at the operator's disposal. This enables the plow operator to spot-spray thick ice patches as they are encountered to facilitate easy removal upon a return plowing trip without the added effort of bringing out a separate brine application vehicle specifically for de-icing support.



**Figure 32. Caltrans Motor Grader Removing Bonded Ice Layer (Caltrans)**



**Figure 33. Caltrans Ice Breaker**

***Other DOT's De-Icing Methods and Equipment:*** Based on the responses received from the brine application survey, many of the agencies apply brine as a countermeasure to expedite ice removal mainly from elevated roadways and bridge decks. The application equipment utilized is the same equipment used for anti-ice treatments.

***Commercially Available Anti-Icing Equipment:***

***SnowEx Inc. VSS-3000 Anti-Icing System***

<https://www.snowexproducts.com/product/accuspray-vss-2000-vss-3000/>

***VariTech Industries Inc. Electronic Application Controller MT403V-II***

<http://www.VariTech-industries.com/Products/Application-Equipment-Controls/Electronic-Application-Controller-Model-MT403V-II>

## **Brine Application Controllers**

A salt (NaCl) brine solution as a de-icing agent has a minimum freezing point of  $-8^{\circ}\text{F}$  at a concentration of 23% salt. Increasing the salt concentration beyond the maximum limit will not result in any further lowering of the freeze point temperature.<sup>6</sup> This optimum concentration can be easily maintained with brine making equipment and unlike with granular salt, ensures that regardless of the amount of brine applied to an area on the pavement, the salt concentration can only decrease. However, reducing the amount of salt applied per area is both environmentally and economically prudent for DOTs. Therefore, it is important for DOTs to

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<sup>6</sup> Improved Winter Maintenance in Austria, Salt Application Recommendations for Winter Maintenance Personal and Driving Recommendations for road Users, M. Hoffmann, P. Nutz, J Neuhold, Institute of Transportation, Vienna University of Technology, 2011

specify effective brine application limits and to utilize equipment capable of accurately maintaining the appropriate application rate at speed on the highway. To accomplish this goal, a suitable application rate control scheme must be included with any type of liquid brine application apparatus.

Liquid brine application flow rates must be held strictly proportional to the speed of the application vehicle in order to attain desired surface concentration. Consequently, a ground-speed-oriented controller is an essential component of a brine application system to automatically adjust the liquid flow rate to account for ever-changing vehicle speeds. The most basic form of spreader controller enables an operator to select a target application rate at any time during operation. More sophisticated controllers are also available which offer a wide range of additional controls, such as spreading width, direction control, and extended capabilities like temperature compensation, Automatic Vehicle Location (AVL), Global Positioning System (GPS) application data collection, and weather forecasting. Regardless of the type of controller utilized, calibration is extremely important to correlate the controller settings with the quantity of material that is actually being output. All equipment should be calibrated at least once yearly and before winter operations begin.

**Basic Brine Application Controllers:** The most basic of liquid application controllers are open-loop systems which utilize a road speed sensor to output a signal to proportional flow valves without any type of integrated feedback sensors to verify the commanded flowrate is actually occurring. Open-loop controllers with a single truck speed sensor have been standard on granular spreader vehicles for many years, providing sufficient control of the application rate. With the advent of liquid application, these basic controllers are now available with open-loop liquid flow rate controls and liquid blast buttons (Figure 34). With adequate equipment maintenance and calibration, these controllers do a reasonably good job of dispensing uniform granular materials and liquids. There are many advantages to utilizing basic open-loop controllers in comparison to advanced telematics and highly-integrated control systems including:

- Intuitive mechanical controls do not require extensive operator training
- Rudimentary sensors – ground speed, and possibly flowrate, with manual overrides
- Controller operates spray valves directly
- Minimize sensors and electrical connections which are prone to oxidation and corrosion in the harsh winter maintenance environment
- Easier to calibrate
- Stand-alone controller directly wired to valves
- Controller not integrated with the plow truck computers (Controller Area Network (CAN) bus)
- Minor system problems can be easily diagnosed and either repaired or bypassed by maintenance mechanics and not computer specialists to keep the machine operational

**Commercially Available Basic Liquid Application Controllers:** The following list provides the commercially available standard stock products which are ideal for small, quick delivery orders. These stock items generally offer optional features and configuration which can be selected by the customer. Many other manufacturers provide custom designed systems tailored exactly to a customer's specific needs and offer an almost unlimited range of features. A large agency like Caltrans DOE would most likely pursue the development of a custom system, as they have in the past with their standard Muncie spreader controller. Almost any one of the major snow

equipment manufacturers offers this service, and the availability of this service will not be detailed herein.

***Certified Cirus Control Systems***

<https://certifiedcirus.com/>

***Force America Inc. C3100 Spreader Control***

<http://www.forceamerica.com/Products/Product-Item/ProductID/21>

***VariTech Industries Inc. Electronic Application Controller MT403V-II***

<http://www.VariTech-industries.com/Products/Application-Equipment-Controls/Electronic-Application-Controller-Model-MT403V-II>

Often water tankers are dual-purposed to act as anti-ice application vehicles during the winter months. The control scheme for water tankers involves simple open-loop control of one or two liquid pumps and the opening of a few solenoid liquid valves (Figure 35). Adding a spray bar is all that is needed to convert the tanker into a basic anti-ice system for the winter months.



Figure 34. Force America SSC3100 (Force America)



Figure 35. Kingvale 3,000-Gallon Brine Tanker Controller (Caltrans)

***High-Tech Multi-Function Spreader Controllers:*** The current direction of the winter highway maintenance industry seems to be toward multiple-function spreader systems capable of advanced telematics functionality combined with the flexibility to change operational modes during operation to precisely address the surrounding conditions. Environmental and economic factors have largely driven the movement to deploy these high-tech, computerized systems on winter maintenance fleet vehicles. The controllers necessary to support these advanced multi-function spreader systems are inherently more sophisticated to effectively control these advanced spreader functions. Consequently, spreader controllers will have an increased level of complexity, but the level of complexity and high-tech capabilities available varies widely depending on user needs.

On the basic end of the scale, a computerized controller with ground speed input with controls to operate both liquid and granular spreading is all that is necessary. A mid-range controller will additionally include pavement temperature sensing, directional spreading control, and automatic feed-rate control. The most advanced commercially available controller systems provide a wide range of turn-key sophisticated capabilities, including integrated AVL telemetry and GPS systems for terrestrial tracking and data collection, vehicle CAN bus data integration, weather monitoring, Wi-Fi, AI expert systems, and real-time factory support. These systems simultaneously process multiple closed-loop controls which sense the actual output of critical

application systems components and feed this data back into the controller. The controller compares the commanded output to the measured output and adjusts the commanded output to compensate for the difference. When logging the application of chemicals and granular materials on the highway, precise proportional closed-loop output control is an essential element to ensure the collected application data is correct.



Figure 36. Muncie Advantage+ MM15-09 (Muncie)



Figure 37. Force America SSC6100 (Force America)

#### Commercially Available Telematic Liquid Controller Systems:

##### ***Muncie Advantage+ Snow & Ice System***

[https://www.munciepower.com/products/detail/advantage\\_plus](https://www.munciepower.com/products/detail/advantage_plus)

##### ***Force America Inc. - SSC6100 Control System***

<http://www.forceamerica.com/Products/Product-Item/ProductID/18>

##### ***Micro-Trak Systems, Inc. - RoadMaster™***

<https://www.micro-trak.com/roadmaster>

RoadMaster offers a configurable electronic control system which regulates the flow of liquid de-icers and anti-icers along with roadside spray products and dust control agents. It is available in a pulse-width modulation (PWM) version.

##### ***Rexroth, Compu-Spread™ Electronic Hydraulic System Solutions***

[https://www.boschrexroth.com/en/ca/industries\\_5/mobil\\_applications\\_21/on\\_highway\\_and\\_commercial\\_vehicles\\_4/compu\\_spread\\_for\\_snow\\_ice\\_industry\\_index](https://www.boschrexroth.com/en/ca/industries_5/mobil_applications_21/on_highway_and_commercial_vehicles_4/compu_spread_for_snow_ice_industry_index)

Epoke offers a wireless controller that would be very useful for roll-off-type spreader body configurations.

##### ***Epoke A/S – EpoMaster® IV Wireless Remote Controller for Spreaders***

<http://www.epoke.dk/media/11221/EpoMaster-GB-.pdf>



**Figure 38. Epoke EpoMaster® IV Wireless Spreader Controller (Epoke)**

Caltrans Brine Application Controllers: Caltrans traditionally favors a rugged, less complicated approach to establishing equipment functionality, especially in relation to equipment subjected to harsh winter highway conditions. The Caltrans standard spreader control, which has been utilized for many years across their winter maintenance fleet, is a Muncie hydraulic controller (Figure 39). This device is only capable of controlling a single open-loop granular spreader. Any brine pre-wetting is applied directly onto the bulk granular material in the hopper during loading. The application of brine, either as a direct spray or as a pre-wet treatment applied by the spreader system while casting, requires a different type of controller. Caltrans has not yet standardized such a controller, but they are currently experimenting with the Muncie Advantage Plus controller on its new Henderson FRS line of spreader trucks (Figure 40).



**Figure 39. Caltrans Standard Muncie Spreader Controller (Caltrans)**



**Figure 40. Muncie Advantage Plus Spreader Controller (Caltrans)**

There are real-world operational costs associated when applying sophisticated systems with virtually unlimited capabilities to accomplish relatively basic tasks. Such is the case with brine application on winter highways, where precise control, automation, telemetry, and data collection are increasingly being applied to the basic task of spaying a liquid on a flat surface. Undoubtedly, these advanced capabilities provide valuable benefits, but they come at the

expense of increased operator training, equipment downtime for maintenance, and complex computer software integration issues. Densely integrated applicator controller programs are entirely dependent on sensor input signals to enable their program to function. The most advanced products even go as far as integrating their controller program with the telemetry from the truck chassis computers over the CAN bus, which adds the specter of difficult to troubleshoot computer communication bus errors. These sensor networks added to winter maintenance vehicles multiply the electrical wiring and electrical connectors, which are especially susceptible to oxidation and corrosion. A loss of signal from almost any one of these sensors could cause the control program to stop and display a fault message, rendering an otherwise functional mechanical system inoperable. Caltrans generally must balance the advantages of telematics controllers with simplicity and ruggedness to determine the best solution for its winter fleet.

*Other DOT's Brine Application Controllers:* Responses from the brine survey indicate that the utilization of basic controllers is far more common than sophisticated telematics systems. The Cirus system seems to be the most common basic controller. The Force America controller appeared to be the most common telematics controller. The use of AVL and computer data collection was common among the survey respondents and the long-term goal is to further expand their use. Many of the agencies with telematics systems had reported various problems related to data collection and integration with reporting software platforms. This will require further research and development efforts on their part to solve.

## **Multi-Functional Spreader Equipment**

Multi-functional spreaders can apply both brine and granular materials in anti-icing, pre-wet, or de-icing treatments with directional control for covering multiple lanes. This flexibility enables the operator to adapt the treatment application to address the surrounding conditions without a return trip to the maintenance yard, often in slow congested traffic, to change vehicle treatment configuration.

*Caltrans Multi-Functional Spreader Equipment:* Multi-functional spreaders are gaining popularity within Caltrans Maintenance. Their additional functionality combined with the flexibility to change operational modes during operation makes multi-function plow/spreader systems an effective tool to deal with microclimates and quickly changing weather conditions which are commonplace in higher elevations and mountain passes in California.

The Epoke multi-functional system is unique in terms of its out-of-the box turn-key approach. Caltrans needs only to supply hydraulic and 12 VDC power to the Epoke system after it is mounted onto a standard plow truck chassis (Figure 41). The Epoke package includes a plug and play EpoMaster® remote control system which enables the operator to monitor and change the application rate and width settings in the cab during operation and collect application data suitable for uploading. The Epoke handles bulk granular material in the hopper with a unique agitator which prevents material bridging and crushes large lumps ensuring accurate material supply. Its delivery via an unladen rubber conveyor belt moves a precisely metered quantity of granular material to the directionally controllable spreading disc. This ensures uniform hopper emptying, which maintains a stable vehicle center of gravity.



**Figure 41. Kingvale Epoke Spreader Truck (Caltrans)**



**Figure 42. Epoke Skid Mounted (Caltrans)**

The Henderson FRS spreader system with the Direct Cast® directional spreading mechanism is new to Caltrans this winter season (Figure 43). Caltrans DOE is currently working toward deploying these units into their fleet. The Caltrans version of the FRS is configured with both a spinner plate spray pre-wet and a direct brine spray bar. The FRS has a dual-auger system which breaks up the large chunks that often form in the hopper. The controller scheme utilized for the Caltrans Henderson FRS vehicles is relatively basic by current industry standards. The Muncie Advantage Plus Spreader Control system is designed to drive pre-wet or anti-icing operations with either open- or closed-loop configurations. Pre-wet dispensing will be measured in gallons per ton of granular material and anti-icing is dispensed in terms of gallons per lane mile of material.



**Figure 43. Caltrans Henderson FRS Truck Mounted**

**Other DOT's Multi-Functional Spreader Equipment:** Only one of the survey responses indicated that the agency operated multi-functional spreader equipment, an Epoke, in their fleet.

## Gaps in Findings

This report focused primarily on salt brine (NaCl), but there is a wide range of alternative and plant based ice control solutions available for use on winter highways which provide environmental benefits. It remains unclear if these products deliver comparable performance to conventional salt brine solutions and if specialized equipment and/or application methods are required to utilize these alternative options, but survey responses from other states indicate there may be increased functionality obtained from these other brine solutions.



Figure 44. Alternative Anti-Ice Solutions

Another possible gap is the study request focused on common conventional liquid ice control methods and equipment. This may have led to the effort missing especially promising or innovative liquid anti-icing, pre-wet, or de-icing methods and/or equipment, such as built-in real-time weather conditions monitoring integrated with on-board expert systems to suggest appropriate surface treatments to the operator during operation.

## Next Steps

### Caltrans Brine Program Evaluation

The regions in California which experience severe winter conditions on a yearly basis are relatively small, isolated pockets stretched across the length of the state. Even within these regions, microclimates generated by sharp changes in elevations and exposure present diverse road condition challenges to be mitigated. Consequently, Caltrans maintenance has developed specific sets of brine application methods to control pavement icing in these various areas that change not only by region, but also within each region and even different stretches of the same highway. Research could be conducted to identify and collect these various effective pavement ice countermeasures and to develop a statewide best practices document. The result would be development of either a large toolbox of specialized methods and equipment or a smaller set of adaptable methods and equipment.

The Caltrans effort to procure brine application equipment is being directed simultaneously at both the headquarters and district levels. At the Headquarters level, where large vehicle systems are fabricated, their latest equipment development projects indicate a preference for multi-functional vehicles affording operators the capability of switching between pavement treatments while driving. At the district level, specialized brine application equipment is being procured to meet specific brine application needs. The districts favor slip-in spray brine systems with basic controls, primarily because these systems can be attached to existing fleet vehicles with a minimum of vehicle adaptations. The latest Caltrans brine equipment acquisitions are intended to provide a significant boost to brine application operations in several winter

maintenance regions which is the key to greater efficiency and improved LOS of winter maintenance operations in the coming years. An important next step for the Caltrans brine application development effort could be to conduct a formal evaluation and study of the various liquid application methods and equipment over a couple of winter seasons to determine which are effective in respect to the specific highway winter conditions mitigated and potentially develop statewide Caltrans equipment specifications.



**Figure 45. Epoke High-Speed Spray Bar (Epoke)**

Finally, the maximum speed at which anti-icing liquids can be effectively applied on the highway could be determined. Ideally, anti-ice liquids would be applied at the prevailing traffic speeds to afford unfettered access to the highways with a minimum of traffic obstruction. Caltrans maintenance personnel uniformly operate under a policy that anti-icing liquids cannot be applied at speeds higher than 25-30 mph. Consequently, Caltrans conducts brine anti-icing operations when traffic is sparse, such as late in the evenings using moving lane closures, or when traffic can be slowed with MAZEEP assistance. Several manufacturers and other DOTs claim to routinely apply anti-ice liquids at higher prevailing traffic speeds, and some manufacturer's market spray equipment specifically designed for this exact purpose (Figure 47). Caltrans maintenance could benefit greatly if high-speed anti-ice spray equipment could be identified and proven to be effective.

## List of Brine Application Equipment Manufacturers

This section presents an extended list of major manufacturers which offer brine application equipment and controllers.

### ***Certified Cirus Control Systems***

- Sophisticated controllers with integrated hydraulic systems and AVL and Data logging.

<https://certifiedcirus.com/products/integrated-plow-spreader-control-systems/>

Cirus offers a comprehensive line of brine application controllers and integrated hydraulic packages with data logging and AVL reporting capabilities.

### ***Epoke USA Inc.***

- Multi-functional brine application equipment.

<http://www.epoke.dk/home/products/bulk-spreaders/sirius-ast/>

Epoke manufactures the Sirius model line which is a turnkey multifunctional spreader body with integrated data logging and AVL capabilities.

### **Flink Co.**

- Direct brine application and pre-wet treatment equipment.

[http://www.flinkco.com/index\\_files/wetting.htm](http://www.flinkco.com/index_files/wetting.htm)

Flink sells pre-wet bolt-on systems and a direct brine application slip-in unit with controller.

### **Force America Inc.**

- Sophisticated controllers with integrated hydraulic systems and AVL and Data logging.

<http://www.forceamerica.com/Products/Product-Item/ProductID/18>

The Force America product line focuses on the control side of brine application and offers one of the most sophisticated CAN bus controllers with completely integrated hydraulic systems with data logging and AVL reporting capabilities.

### **GVM Inc.**

- Direct brine application and pre-wet treatment equipment.

<http://www.gvminc.com/snow-division/anti-icing-systems>

GVM manufactures a large line of direct brine application equipment with basic controls which can be configured for slip-in, skid, hook-lift body, and trailer-mounted mountings.

### **Henderson Products Inc.**

- Direct brine application equipment.

[http://www.hendersonproducts.com/liquid\\_ice\\_control\\_systems.html](http://www.hendersonproducts.com/liquid_ice_control_systems.html)

Henderson offers an extensive line of slip-in direct liquid brine application systems. Their tank and spray bar units can be configured with a large liquid tank for anti-icing and de-icing operations, or combined with a granular hopper to support pre-wet treatments. Henderson also offers sophisticated multi-functional truck bodies that are user selectable during operation for anti-icing, de-icing, and pre-wet application.

### **Henke Inc.**

- Spreaders with direct brine application and pre-wet treatment options.

<http://henkemfg.com/spreaders/>

Henke manufactures spreader bodies with optional direct brine application and pre-wet treatment equipment.

### **Hi-Way Inc.**

- Spreaders with direct brine application and pre-wet treatment options.

<http://hiway.highwayequipment.com/products/precision-applicators>

Hi-Way manufactures spreader bodies with optional direct brine application and pre-wet treatment equipment.

### **Monroe Truck equipment**

- Multi-functional, direct brine application, and pre-wet treatment equipment.

<http://www.monroetruck.com/Products.aspx?category=189&name=Liquid%20Systems>

Monroe offers an extensive line of brine application systems for anti-icing, de-icing, or pre-wet treatments. Available system configurations for direct liquid application include skid-mount,

chassis, trailer and slip-in mountings. Pre-wet configurations include tailgate tank, saddle fender tanks, and behind cab tank mountings.

**Muncie Power Products Inc.**

- Application rate controllers and integrated hydraulic systems.

[https://www.munciepower.com/snow-ice/products/detail/advantage\\_systems](https://www.munciepower.com/snow-ice/products/detail/advantage_systems)

The Muncie product line focuses on application controllers and integrated hydraulic systems.

**Newton Crouch Inc.**

- Direct brine application equipment.

<http://newtoncrouch.com/sprayers/deicing/>

Newton Crouch offers an anti-ice slip-in and skid mounted brine sprayers.

**Northstar Industries Inc.**

- Direct brine application equipment.

<https://www.norstarind.com/antiicing.aspx>

Northstar offers a limited line of brine spray equipment.

**Raven Inc.**

- Brine application rate controllers.

<https://ravenprecision.com/products/application-controls/control-consoles>

The Raven SCS line of controller consoles provide CANBUS vehicle integration to apply liquid, granular, and NH<sub>3</sub> treatments.

**Rexroth, Compu-Spread™ Electronic Hydraulic System Solutions**

- Application rate controllers and integrated hydraulic systems.

[https://www.boschrexroth.com/en/ca/industries\\_5/mobil\\_applications\\_21/on\\_highway\\_and\\_commercial\\_vehicles\\_4/compu\\_spread\\_for\\_snow\\_ice\\_industry\\_index](https://www.boschrexroth.com/en/ca/industries_5/mobil_applications_21/on_highway_and_commercial_vehicles_4/compu_spread_for_snow_ice_industry_index)

Rexroth sells liquid application controls and integrated hydraulic systems.

**SnowEx Inc. VSS-3000 Anti-Icing System**

- Direct brine application equipment.

<https://www.snowexproducts.com/product/accuspray-vss-2000-vss-3000/>

SnowEx sells a slip-in liquid direct brine application unit with a basic controller.

**Tenco Inc.**

- Multi-functional spreaders and direct brine and pre-wet treatment equipment.

<https://tenco.ca/products/>

Tenco builds chassis mount and slid-in spreaders with optional direct brine application and pre-wet treatment equipment. Also distributes Bucher multi-function spreader systems.

**Varitech Industries Inc.**

- Direct brine application equipment.

<http://www.varitech-industries.com/>

Varitech is a subsidiary of Force America Inc. and offers a slip-in and trailer version of direct brine application systems and controllers.

### ***Viking-Cives Midwest Inc.***

- Spreaders with direct brine application and pre-wet treatment options.

<https://www.vikingcives.com/Products/?CategoryID=5>

Viking-Cives builds spreader bodies with optional direct brine application and pre-wet treatment equipment.

## **Consultation with Highway Agencies**

This section presents the results of a survey of other transportation agencies' current practices or experiences with direct brine application and pre-wet treatments in winter highway operations. Specifically, Caltrans seeks to identify the most effective and efficient commercially-available brine application equipment and field proven methods in order to adopt a standardized approach. This survey was sent by the Caltrans Division of Research, Innovation and System Information (DRISI) to:

- Clear Roads
- Equipment Managers Technical Service Program (EMTSP)
- Snow and Ice Pooled Fund Cooperative Program (SICOP)

Fourteen different agencies responded to the questionnaire. In many cases, several representatives from the same agencies provided input. These responses were combined with the aforementioned PNS survey to develop an overall trend in regards to the current application practices for liquid brine applications on the highway. The survey questions and results are as follows.

Agency	Respondent	Question 1- Does your agency directly apply liquid anti-ice and de-icing treatments to the highway in your winter operations? If so, please describe these pre-storm and post-storm liquid application methods/operations.
<b>Alabama DOT</b>	Kerry C. NeSmith, PE Deputy Bureau Chief, Maintenance Bureau and Dallon R. Ogle, Jr., P. E. Assistant Area Operations Engineer- Maintenance	Yes, this area uses liquid agents for anti-icing including potassium acetate, calcium magnesium acetate (suspension), brine, and calcium chloride. We also use potassium acetate, CMA and a combination of brine and calcium chloride as deicers. Typically, these liquid agents are divided into suspensions and solutions. Suspensions must be constantly agitated to remain homogeneous. These liquids are typically sprayed from commercially available spray skids which include gas powered pumps for constant agitation. Gravity fed skids with only valves are used for the solutions. Skids are typically installed in dump beds and de-icing operations are paired with plowing.
<b>Arkansas DOT</b>	Joe Sartini, State Maintenance Engineer	We do not apply any liquid chemicals directly on ice. We use our liquids to pretreat primarily and also use it to Pre-wet materials coming from the belt and spinner on our spreaders.
	Matt Emberton, District 1 Maintenance Engineer	Yes. We apply brine solution utilizing two 5,000 gallon tankers and ten 1,500 gallon tank trucks. The solution is a 23 to 24 percent salt solution. If the forecast predicts a wet mixture with accumulation of rain to precede the storm, we do not apply brine for anti-icing. Many things can affect the decision on whether or not to apply brine as an anti-ice tool such as wind speed and direction, type of event, sky conditions, and temperatures are just a few. Depending on temperature forecast, beet juice is added to the brine solution to lower the freezing point to approx. -25, which allows our operations more time to remove the snow and ice before coming hard packed. (The mixture of beet juice to brine is 1/3 beet juice to 2/3 brine. ) We apply the same brine and or beet juice solution for de-icing after an event in shaded areas or trouble spots that tend to hold ice and snow longer than others.
	Jeff Wheeler, District 9 Maintenance Engineer	Yes, Pre-storm – Salt brine is applied at a rate of 50 gallons per lane mile to as many routes as possible starting with our higher volume routes. Post-Storm - none.
<b>Municipality in Denmark</b>	Jens Kristian Fønnesbech (Municipalities on the island of Funen)	4 hours before expected icy roads or snow storm started spreading of brine. If expected icy roads are spread 15 ml/m <sup>2</sup> and if expected snow storm 30 ml/m <sup>2</sup> . Brine is 24% NaCl. Under a snow storm are spread 30 ml/m <sup>2</sup> every 6 hours. The spreading is done with jet nozzles (Spratronic). The equipment is from Epoke.dk (Virtus Ast).
<b>City of Des Moines Montana</b>	Kevin Hensley Superintendent of Public Services Kevin.Hensley@wdm.iowa.gov+B 5	Yes, Our Anti-icing program start prior to an event starting if a forecast is in place that indicates potential snow with pavement temperatures above approx. 15 degrees F salt brine with an carbohydrate additive is applied to the roadway at a rate of 50 gal per lane mile. The brine is blended at a 90% salt brine 10% carbohydrate to ensure the salt brine is “stuck” to the roadway. During an active weather event 100% salt brine is sprayed on the roadway given pavement temps above 15 degrees F. This application is done in conjunction with a granular application from the same truck. This practice will continue until the desired level of service is reached.

Agency	Respondent	Question 1- Does your agency directly apply liquid anti-ice and de-icing treatments to the highway in your winter operations? If so, please describe these pre-storm and post-storm liquid application methods/operations.
<b>Idaho DOT</b>	Steve Spoor Maintenance Services Manager Equipment Fleet Manager 208-334-8413	Yes. Depending upon the District, some are very good at pre-treating before a storm in an effort to anti-ice a roadway. The forecast will affect the rate at which we pre-treat with liquids. If a severe storm is predicted, we may also pre-treat with granular chemical as well. As far as de-icing, we do not de-ice with liquids as it is too expensive and consumes a very large amount. If we were unsuccessful in preventing snow and ice floor build-up, we'll typically use granular chemical to de-ice.
<b>Kansas DOT</b>	W. Clay Adams Bureau Chief of Maintenance Kansas Department of Transportation 785-296-3233	Yes
<b>Maryland DOT</b>	Sandi Sauter, Maryland DOT Office of Maintenance Deputy Director 410-582-5535	Yes. MDOT-SHA does perform anti-icing before an event is scheduled to occur. This is performed mainly by contract forces. We apply brine at approximately 50 gallons per lane mile utilizing the "pencil line" technique.
<b>Montana DOT</b>	Tony F. Strainer Equipment Bureau Chief/ Maintenance Division Montana Department of Transportation 406-444-6151	Yes. We have direct units that spray the wheel paths and we have pre-wet systems that spray our sand as it is dispersed. Our trucks are calibrated for certain amounts for certain type storms.
	Jon Swartz MDT Maintenance Administrator and Doug McBroom MDT Maintenance Operations Manager and Mike Miller Roadside Winter Maintenance Specialist	The Montana Department of Transportation does apply liquids directly to the road. We do not apply pre-storm. We have a "just in time" policy that states we will treat a road after the storm begins not based on a forecast. There are a couple of exceptions to this such as treating bridge decks for frost. Post storm applications are based on the existing road conditions not to pre-treat for the next storm.
<b>North Dakota DOT</b>	Mike Kisse Program Manager NDDOT Maintenance Division 701-328-4410	Yes. We created a flow chart as a guide for staff to use. See attached. We also use MDSS treatment recommendations. The biggest part is just getting experience and getting the equipment in the field. We will go out ahead of the storm and pretreat. Conditions is a big factor, wind and temperatures are the biggest factor in the northern plains. If we get a storm where we get compaction and extremely cold temps 0 degrees F and colder, we will de-ice the compacted areas and scrape to get the compaction off the road. We try to prevent this from happening but some storms are too heavy to keep up with.
	Larry Gangl NDDOT Bismarck District Engineer 701-328-6955	Yes, We apply with skid mounted tanks in our tandem trucks, we have anti-icing trailers and we use semi-tanker trucks.

Agency	Respondent	Question 1- Does your agency directly apply liquid anti-ice and de-icing treatments to the highway in your winter operations? If so, please describe these pre-storm and post-storm liquid application methods/operations.
<b>Ohio DOT</b>	Doug Burke Equipment Engineer Office of Equipment Management 614-351-2836	Ohio applies liquid directly to the road surface pre-storm and during storm, typically not post storm. This done through the use of 1200 to 2400 truck mounted or trailer mounted systems or through the uses of 5000 gallon tankers.
<b>Saskatchewan</b>	Jennifer Ball, P.Eng. Senior Project Manager Operations Division, Ministry of Highways and Infrastructure Government of Saskatchewan Jennifer.Ball@gov.sk.ca	The Ministry applies limited amounts of liquid for de-icing and anti-ice purposes. Typically, only locations that are known problems areas such as hills, ramps are treated. A truck with straight liquid equipment is used to apply the material.
<b>Utah DOT</b>	Ryan S. Ferrin, P.E. Maintenance Methods Engineer UDOT Central - Maintenance Planning 801-910-2562	Yes, UDOT does. Pre-storm (anti-icing): NaCl brine (32-26F) or liquid MgCl (25-15F) only ost-storm (de-icing): Granular salt + NaCL brine (32-26F) or Granular salt + liquid MgCl (25-15F) only Post-storm (de-icing): Granular salt + NaCL brine (32-26F) or Granular salt + liquid MgCl (25-15F) only We fire the salt out of our Force America 5100EX or 6100EX spreaders and launch our liquids out of our Henderson or Monroe brand brine trucks.
<b>Vermont DOT</b>	Kenneth Valentine Deputy Director Maintenance and Operations Bureau, Vermont Agency of Transportation Highway Division 802-279-7782	To a limited degree, and less so than a few years ago. We now very rarely anti-ice prior to a storm - that was not well received or judged to be very effective. We will occasionally use the direct application of liquids to “burn off snow pack”, or with rising temperatures to clear a road quickly. Many new trucks are still equipped to apply liquids via a spray bar.
	Bruce Nichols Transportation General Manager District 3 Vermont DOT 802-786-0028	We do occasionally apply directly to the roads. The types of areas we do this is, some trouble area on over passes or ledge cuts. Sometimes early in the season when pavement temps are up we us salt brine directly to the roads This is done from a spray bar mounted on our plow trucks at a rate of 35 50 gallons per mile.
<b>Wyoming DOT</b>	Cliff Spoonemore P.E. WYDOT Field Operations Maintenance Staff Engineer 307-777-6377	WYDOT is a de-icing state. Applications vary with the equipment purchased by each of 5 Districts. One district has purchased 2 – 5000 gal tankers and uses them on I-25. Others have some 1100 gal insert tanks they use to brine hills and curves. All tandem trucks have V-boxes with 2- 100 gal saddle tanks that pre-wet while applying material to snow pack or ice.

Agency	Respondent	Question 2- Does your agency utilize commercially available direct brine application equipment? If so, describe the products utilized and your experience with them.
<b>Alabama DOT</b>	Kerry C. NeSmith, PE Deputy Bureau Chief, Maintenance Bureau and Dallon R. Ogle, Jr., P. E. Assistant Area Operations Engineer- Maintenance	No, we build our own with commercially available poly tanks and off the shelf PVC piping and steel.
<b>Arkansas DOT</b>	Joe Sartini, State Maintenance Engineer	Most of our equipment is converted herbicide equipment that has been repurposed for pretreatment delivery.
	Matt Emberton, District 1 Maintenance Engineer	No
	Jeff Wheeler, District 9 Maintenance Engineer	No
<b>Municipality in Denmark</b>	Jens Kristian Fønnesbech (Municipalities on the island of Funen)	Virtus Ast, as used in Middelfart and Kerteminde, has 12,5 m <sup>3</sup> tank. It has 11 nozzles and can spread 11 m width. Velocity is up to 80 km/hour. When the nozzles are jet nozzles, the spreading are precisely. If there are fan nozzles in the back of the truck, will turbulence take 40% of the brine away. The results are from measurements on the road 3 hours after spreading. The measurements show great problems with variations in dosage.
<b>City of Des Moines Montana</b>	Kevin Hensley Superintendent of Public Services Kevin.Hensley@wdm.iowa.gov+B 5	Our department has been using trailer mounted anti-icing units as well as slide-in mounted anti-icing units. These units are built by Sprayer Specialists. The latest model number purchased is DI-1800-TRLR-SS. These units have 3 lane valves and a pump controlled by the truck's hydraulic system and are ground speed controlled. We have had great success with these units.

Agency	Respondent	Question 2- Does your agency utilize commercially available direct brine application equipment? If so, describe the products utilized and your experience with them.
<b>Idaho DOT</b>	Steve Spoor Maintenance Services Manager Equipment Fleet Manager 208-334-8413	Yes. We use a combination of slide-in liquid application tanks with a tank capacity of 1,750 gallons. These have been purchased from Monroe in the past and we are now under contract with Swenson Spreader. We also use 3500 gallon chassis mounted stainless steel water tanks. These are multi-use (water truck in the summer, liquid brine in the winter). All of our units to date, including the two units on order, have been purchased from Diamond Steel in California and then equipped with Monroe de-ice booms.
<b>Kansas DOT</b>	W. Clay Adams Bureau Chief of Maintenance Kansas Department of Transportation 785-296-3233	Yes
<b>Maryland DOT</b>	Sandi Sauter, Maryland DOT Office of Maintenance Deputy Director 410-582-5535	Yes. MDOT SHA utilizes systems from Varitech pre-wet systems and Henderson Liquid Application Systems (LAS). Our contract forces use a variety of equipment. Much of it was designed for vegetation control on railway systems.
<b>Montana DOT</b>	Tony F. Strainer Equipment Bureau Chief/ Maintenance Division Montana Department of Transportation 406-444-6151	We are a low bid state so we have used different brand types. We have purchased Swenson, Monroe and Henderson products. They all have their strong points as well as their hiccups.
	Jon Swartz MDT Maintenance Administrator and Doug McBroom MDT Maintenance Operations Manager and Mike Miller Roadside Winter Maintenance Specialist	The Montana Department of Transportation assembles all their snow plow trucks. We purchase components through a low bid process. Historically we have use liquid spreaders built by Henderson, Monroe, Swenson and Viking. They all are very effective.
<b>North Dakota DOT</b>	Mike Kisse Program Manager NDDOT Maintenance Division 701-328-4410	Yes. We use slide in units in the dump box, trailer units, semi tankers and tow plows for direct application. Our primary off the shelf units are Varitech. Viking has been providing the systems on towplows. 1650-1850 gallon units in the box of a truck. 1800-2700 gallon trailer units. 2,000 gallon units on towplows. 5000-6000 gallon tanker trailers. Varitech has just created a 3035 gallon trailer unit. Since we have gained many years of experience with these systems, we have begun building our own systems in house at a fraction of the cost. We are continually trying to expand our liquid application assets in the state.
	Larry Gangl NDDOT Bismarck District Engineer 701-328-6955	Yes, We use Viking tow plows with liquid tanks and our semi-tractor tanker

Agency	Respondent	Question 2- Does your agency utilize commercially available direct brine application equipment? If so, describe the products utilized and your experience with them.
<b>Ohio DOT</b>	Doug Burke Equipment Engineer Office of Equipment Management 614-351-2836	Ohio has successfully used the direct application systems from Varitech, Pengwyn and Swenson. These are slide-in units that have self-unloading stands. These are all hydraulically driven motors running the wetting pumps. All systems perform adequately. Tankers are used milk haulers (stainless steel) with various methods of application.
<b>Saskatchewan</b>	Jennifer Ball, P.Eng. Senior Project Manager Operations Division, Ministry of Highways and Infrastructure Government of Saskatchewan Jennifer.Ball@gov.sk.ca	The Ministry currently has four EPoke trucks utilized within the fleet. These trucks are mainly used around larger urban centers. The crews that have the EPoke trucks like them, however; due to the trucks configuration they do not carry as much material as other trucks in our fleet.
<b>Utah DOT</b>	Ryan S. Ferrin, P.E. Maintenance Methods Engineer UDOT Central - Maintenance Planning 801-910-2562	UDOT uses Henderson brand brine equipment mostly. Some of the older trucks have the old Monroe brand system on them, but we are phasing them out and moving completely to Henderson. The shed foremen seem to like the Henderson brine equipment. Some issues we have seen are 1) clogged nozzles, 2) pump seizes up, and 3) debris getting in system which causes 1 and 2 to happen.
<b>Vermont DOT</b>	Kenneth Valentine Deputy Director Maintenance and Operations Bureau, Vermont Agency of Transportation Highway Division 802-279-7782	We utilize “all season” bodies. We have worked with our vendors (Viking, Tenco, Everest) to incorporate the ability to prewet material at the spreader, and to apply liquids via a spray bar.
	Bruce Nichols Transportation General Manager District 3 Vermont DOT 802-786-0028	The brine distribution equipment we use is our own design. It is manufactured from who ever gets our contracts for our trucks. We have had 2 different vendors build our equipment over the years.
<b>Wyoming DOT</b>	Cliff Spoonemore P.E. WYDOT Field Operations Maintenance Staff Engineer 307-777-6377	No – all equipment is State owned

Agency	Respondent	Question 3- Does your agency utilize pre-wet systems when spreading granular materials? If so, what types are used and how effective are they?
<b>Alabama DOT</b>	Kerry C. NeSmith, PE Deputy Bureau Chief, Maintenance Bureau and Dallon R. Ogle, Jr., P. E. Assistant Area Operations Engineer- Maintenance	We have only recently begun using pre-wet systems. We do not have sufficient data to determine their efficacy.
<b>Arkansas DOT</b>	Joe Sartini, State Maintenance Engineer	We pre wet with super brine and when temperatures fall below 25 degrees, we will use liquid calcium to get an exothermic reaction when combining with rock salt.
	Matt Emberton, District 1 Maintenance Engineer	Yes. All spreaders are ordered with pre-wetting systems from the manufacturer. Pre-wetting does help the rock salt to adhere rather than bounce along the road surface.
	Jeff Wheeler, District 9 Maintenance Engineer	No
<b>Municipality in Denmark</b>	Jens Kristian Fønnesbech (Municipalities on the island of Funen)	No Response given.
<b>City of Des Moines Montana</b>	Kevin Hensley Superintendent of Public Services Kevin.Hensley@wdm.iowa.gov+B 5	All of our trucks are equipped with pre-wetting systems. These systems are Monroe Truck Equipment systems that are installed by a truck up-fitter. These systems have been plumbed to apply the pre-wetting agent directly at the spinner. This system functions with a hydraulic pump and is able to pre-wet granular material at rates up to 30-40 gals per ton. We have had very good success with these systems.

Agency	Respondent	Question 3- Does your agency utilize pre-wet systems when spreading granular materials? If so, what types are used and how effective are they?
<b>Idaho DOT</b>	Steve Spoor Maintenance Services Manager Equipment Fleet Manager 208-334-8413	Yes, we have found this practice to be a BMP and encourage it amongst all operators. All of our V-box spreaders are equipped with pre-wet systems. Our standard has been 150 gallons of pre-wet capacity for 8 CY. Our newer units will have 400 gallon capacity. We increased the total capacity because we realize how much it improves the effectiveness of the granular material.
<b>Kansas DOT</b>	W. Clay Adams Bureau Chief of Maintenance Kansas Department of Transportation 785-296-3233	Yes
<b>Maryland DOT</b>	Sandi Sauter, Maryland DOT Office of Maintenance Deputy Director 410-582-5535	Yes, Varitech pre-wet systems. The systems are quite effective when used. MDOT-SHA utilizes a spray bar mounted inside the trough of tailgate spreaders to apply brine to granular.
<b>Montana DOT</b>	Tony F. Strainer Equipment Bureau Chief/ Maintenance Division Montana Department of Transportation 406-444-6151	As I stated above, we do pre-wet. The same type brands are used.
	Jon Swartz MDT Maintenance Administrator and Doug McBroom MDT Maintenance Operations Manager and Mike Miller Roadside Winter Maintenance Specialist	MDT pre-wets nearly all our granular materials at the chute. The same systems that are used for direct application are utilized. They are very effective, although pre-wet systems do take a little more maintenance.
<b>North Dakota DOT</b>	Mike Kisse Program Manager NDDOT Maintenance Division 701-328-4410	Yes. 100% of our plow truck fleet comes with prewet tanks on them. We are currently putting about 550 gallons of prewet capacity on a RDS truck. All are gravity flow so we don't have to maintain pump systems. We calibrate them at 7-9 gallons per ton. They are very effective. We do a lot of snow and ice training where we teach that granular material needs to form into a liquid to start the ice melting process. Staff has found this to work well and help keep material on the road. As a result from the success we've seen with the prewetting, we have now been moving into slurry statewide. Mixing more liquid with granular in a trough with an auger to apply to the road.
	Larry Gangl NDDOT Bismarck District Engineer 701-328-6955	Yes, Gravity flow on our tandem trucks and pressured system for our tow plows.

Agency	Respondent	Question 3- Does your agency utilize pre-wet systems when spreading granular materials? If so, what types are used and how effective are they?
<b>Ohio DOT</b>	Doug Burke Equipment Engineer Office of Equipment Management 614-351-2836	ODOT installs prewetting system on all snow plow trucks. These are bought as pieces and parts and assembled at the prison facility during the truck assembly. Singles currently receive a 180 gallon tank while tandem axle trucks receive 2 - 150 gallon tanks. These are hydraulically driven motors driving the pump. They work well at reducing salt bounce, keep the fines on the road and speeding the melting process.
<b>Saskatchewan</b>	Jennifer Ball, P.Eng. Senior Project Manager Operations Division, Ministry of Highways and Infrastructure Government of Saskatchewan Jennifer.Ball@gov.sk.ca	The Ministry is increasing the use of pre-wet on granular salt applications. The crews that use pre-wet find it to be very effective, under the right weather conditions, and have seen a decrease salt usage. Caution is required when using in high drift/ wind locations as high application rates can cause snow to stick to the road surface.
<b>Utah DOT</b>	Ryan S. Ferrin, P.E. Maintenance Methods Engineer UDOT Central - Maintenance Planning 801-910-2562	UDOT does use a pre-wet system when spreading granular materials. Most of our trucks use Force America 5100EX or 6100EX Spreader Controls which can both dispense solids and liquids. UDOT finds pre-wetting solid materials before distribution: 1) reduces scatter during initial placement, 2) reduces material kicked off road by passing vehicles after initial placement, and 3) begins the “activation” of the material rather than waiting for precipitation to do so. Some of the older vehicles would use 1) saddle tanks to spray the salt with brine, MgCl, or CaCl as it leaves the spreader, 2) hose down the loads with brine or water, 3) add a loader bucket of water to the load.
<b>Vermont DOT</b>	Kenneth Valentine Deputy Director Maintenance and Operations Bureau, Vermont Agency of Transportation Highway Division 802-279-7782	This is our normal application process: to apply brine to salt at the spinner. We find it very effective to reduce “bounce and scatter”, and to accelerate the melting process.
	Bruce Nichols Transportation General Manager District 3 Vermont DOT 802-786-0028	Again we use our own design of equipment, it is a 1200 gallon wedge stainless steel tank in the back of a tandem truck with a front discharge bed chain. It sprays 15 gallons per ton of salt brine at the spinner directly onto our granular salt. This system has reduced our salt application rates by about 25% and has increased our level of service.
<b>Wyoming DOT</b>	Cliff Spoonemore P.E. WYDOT Field Operations Maintenance Staff Engineer 307-777-6377	Henderson V-box spreaders with 2 – 100 gall saddle tanks. Operators like what is happening but everything is empirical. No method to measure the success or failure of the material applied.

Agency	Respondent	Question 4- If your agency utilizes alternative ice-fighting liquids such as CaCl <sub>2</sub> , MgCl <sub>2</sub> , and/or food derivatives, do they require the use of specialized application equipment to apply? If so, describe any necessary equipment adaptations and your experiences with them.
<b>Alabama DOT</b>	Kerry C. NeSmith, PE Deputy Bureau Chief, Maintenance Bureau and Dallon R. Ogle, Jr., P. E. Assistant Area Operations Engineer- Maintenance	Yes, we use calcium chloride mixed with brine. Both are gravity fed and require no additional equipment. Additional segregated storage is however, necessary
<b>Arkansas DOT</b>	Joe Sartini, State Maintenance Engineer	These materials were never applied to an ice covered roadway. ARDOT uses the liquids to pretreat our roadways in advance of a winter storm to attempt to prevent the ice from bonding to the pavement.
	Matt Emberton, District 1 Maintenance Engineer	We use beet juice. No specialized equipment is required for application.
	Jeff Wheeler, District 9 Maintenance Engineer	We create a mixture of salt brine and Beet Juice which is use in our normal equipment.
<b>Municipality in Denmark</b>	Jens Kristian Fønnesbech (Municipalities on the island of Funen)	No Response given.
<b>City of Des Moines Montana</b>	Kevin Hensley Superintendent of Public Services Kevin.Hensley@wdm.iowa.gov+B 5	The application equipment is the same.

Agency	Respondent	Question 4- If your agency utilizes alternative ice-fighting liquids such as CaCl <sub>2</sub> , MgCl <sub>2</sub> , and/or food derivatives, do they require the use of specialized application equipment to apply? If so, describe any necessary equipment adaptations and your experiences with them.
<b>Idaho DOT</b>	Steve Spoor Maintenance Services Manager Equipment Fleet Manager 208-334-8413	The only two liquid products we use are self-manufactured salt brine and purchase Mag Chloride. We use the same application equipment for both products.
<b>Kansas DOT</b>	W. Clay Adams Bureau Chief of Maintenance Kansas Department of Transportation 785-296-3233	Yes
<b>Maryland DOT</b>	Sandi Sauter, Maryland DOT Office of Maintenance Deputy Director 410-582-5535	MDOT-SHA does utilize liquid magnesium when temperatures dip below 15 degrees or heavy snow leads to hard pack on our roadways. It is applied on its own for hard-pack or mixed at an 80/20 blend with salt brine. We also use it as a pre-wetting agent to granular salt at the auger when temperatures dip below 15 degrees.
<b>Montana DOT</b>	Tony F. Strainer Equipment Bureau Chief/ Maintenance Division Montana Department of Transportation 406-444-6151	We don't use any specialized equipment. The only 2 products we spray are Mag Chloride and salt brine which make in house.
	Jon Swartz MDT Maintenance Administrator and Doug McBroom MDT Maintenance Operations Manager and Mike Miller Roadside Winter Maintenance Specialist	MDT uses corrosion inhibited brine in some areas and corrosion inhibited MgCl <sub>2</sub> in others. Specialized equipment is not necessary. Our current systems apply either very well.
<b>North Dakota DOT</b>	Mike Kisse Program Manager NDDOT Maintenance Division 701-328-4410	We mix salt brine with beet juice at an 80:20 ratio. All our liquid is blended with beet juice. We do all our mixing and blending in house. We do not need special equipment to apply. We have experimented with AMP and have found our beet juice blend to be just as effective and much more cost effective. AMP required additional equipment to handle the material which created a lot more complications in the field.
	Larry Gangl NDDOT Bismarck District Engineer 701-328-6955	No

Agency	Respondent	Question 4- If your agency utilizes alternative ice-fighting liquids such as CaCl <sub>2</sub> , MgCl <sub>2</sub> , and/or food derivatives, do they require the use of specialized application equipment to apply? If so, describe any necessary equipment adaptations and your experiences with them.
<b>Ohio DOT</b>	Doug Burke Equipment Engineer Office of Equipment Management 614-351-2836	We currently run alternative deicing agents through our existing tanks. Worst case scenario, we have to remove or go with a larger filter strainer in the system.
<b>Saskatchewan</b>	Jennifer Ball, P.Eng. Senior Project Manager Operations Division, Ministry of Highways and Infrastructure Government of Saskatchewan Jennifer.Ball@gov.sk.ca	Liquid CaCl <sub>2</sub> and small amounts of MgCl <sub>2</sub> are utilized for pre wet. A normal pre-wet system is used; no specialized equipment required.
<b>Utah DOT</b>	Ryan S. Ferrin, P.E. Maintenance Methods Engineer UDOT Central - Maintenance Planning 801-910-2562	We don't use food derivatives as an ice-fighting liquids. We do use CaCl and MgCl, but have not found that we need to use any specialized application equipment for them yet. We use the equipment "as-is" off the shelf.
<b>Vermont DOT</b>	Kenneth Valentine Deputy Director Maintenance and Operations Bureau, Vermont Agency of Transportation Highway Division 802-279-7782	We are using a blend of 90/10 brine to "Ultra 1000" made by Innovative Solutions. No special equipment is necessary for application of this blend.
	Bruce Nichols Transportation General Manager District 3 Vermont DOT 802-786-0028	We use a corn syrup mag chloride additive to our salt brine. We use it in our current equipment with no adaptations required.
<b>Wyoming DOT</b>	Cliff Spoonemore P.E. WYDOT Field Operations Maintenance Staff Engineer 307-777-6377	Only need separate tanks in your tank farm. If you run brine in your application tanks then you need to empty them before changing to any other chemical. Simple lab test show that mixing some chemicals together will cause a gelling effect. If you cannot empty an application tank completely then make sure it is under 5% of total volume on one material before adding the 95% of the next material.

Agency	Respondent	Question 5- What type of application rate controllers does your agency use for direct liquid application equipment and pre-wet treatments?
<b>Alabama DOT</b>	Kerry C. NeSmith, PE Deputy Bureau Chief, Maintenance Bureau and Dallon R. Ogle, Jr., P. E. Assistant Area Operations Engineer- Maintenance	We calibrate the rate by speed and spray bars. We use not automated equipment at this time.
<b>Arkansas DOT</b>	Joe Sartini, State Maintenance Engineer	Pre-treatment of roadways surfaces can be anywhere from 125 to 200 gallons per lane mile. Pre-wetting at the spinner uses about 15 to 20 gallons per lane mile.
	Matt Emberton, District 1 Maintenance Engineer	Rates are controlled by ground speed and number of nozzles active at that time. Nozzles are controlled by electric valves. All trucks are equipped with two electric valves operating 8 nozzles each with the ability to operate independently or simultaneously.
	Jeff Wheeler, District 9 Maintenance Engineer	Gravity flow for our direct application
<b>Municipality in Denmark</b>	Jens Kristian Fønnesbech (Municipalities on the island of Funen)	No Response given.
<b>City of Des Moines Montana</b>	Kevin Hensley Superintendent of Public Services Kevin.Hensley@wdm.iowa.gov+B 5	We have had success with Force America, Monroe and Certified Power. We are currently working to standardize all of our equipment to Certified Power.

Agency	Respondent	Question 5- What type of application rate controllers does your agency use for direct liquid application equipment and pre-wet treatments?
<b>Idaho DOT</b>	Steve Spoor Maintenance Services Manager Equipment Fleet Manager 208-334-8413	All of our trucks are standardized on the Certified Cirus Controllers Spreadmart RX controller. This controller can handle granular, pre-wet, and liquid simultaneously.
<b>Kansas DOT</b>	W. Clay Adams Bureau Chief of Maintenance Kansas Department of Transportation 785-296-3233	Various
<b>Maryland DOT</b>	Sandi Sauter, Maryland DOT Office of Maintenance Deputy Director 410-582-5535	Force America 6100 Ultra. MDOT-SHA's application rates are as follows: 8 to 10 gallons per ton for pre-wetting at the auger Anti-icing prior to an event is done at 45 to 50 gallons per lane mile Direct Liquid Applications (DLA) are done at 80 to 100 gallons per lane mile
<b>Montana DOT</b>	Tony F. Strainer Equipment Bureau Chief/ Maintenance Division Montana Department of Transportation 406-444-6151	Cirrus
	Jon Swartz MDT Maintenance Administrator and Doug McBroom MDT Maintenance Operations Manager and Mike Miller Roadside Winter Maintenance Specialist	The Montana Department of Transportation has some Raven, Force America, Dickey John and Cirus controller systems. We decided to stick with one system in 2005 and Cirus is installed in all our trucks at this time. All of the systems work very well, we just chose one for consistency for operators and mechanics.
<b>North Dakota DOT</b>	Mike Kisse Program Manager NDDOT Maintenance Division 701-328-4410	We are 100% Force America in our state. We use all Force 5100 and 6100 controllers. All electric over hydraulic with ground speed. All calibrated. All granular and direct spray is controlled through the controller. Prewet is gravity feed and all manual controlled with a ball valve at 7-9 gallons per ton.
	Larry Gangl NDDOT Bismarck District Engineer 701-328-6955	Force America

Agency	Respondent	Question 5- What type of application rate controllers does your agency use for direct liquid application equipment and pre-wet treatments?
<b>Ohio DOT</b>	Doug Burke Equipment Engineer Office of Equipment Management 614-351-2836	Ohio DOT material application guidelines included.
<b>Saskatchewan</b>	Jennifer Ball, P.Eng. Senior Project Manager Operations Division, Ministry of Highways and Infrastructure Government of Saskatchewan Jennifer.Ball@gov.sk.ca	Direct liquid applications are typically done with the EPoke trucks which came with rate controllers installed; the remainder of fleet uses Storm guard (Certified Power) or Bosch Rexroth controllers.
<b>Utah DOT</b>	Ryan S. Ferrin, P.E. Maintenance Methods Engineer UDOT Central - Maintenance Planning 801-910-2562	We use the Force America 5100EX or 6100EX controllers (they can run either solids or brine) on the newer trucks and Raven systems on the older trucks. Most of our brine fleet still uses the Raven systems though because we haven't bought too many new brine trucks yet.
<b>Vermont DOT</b>	Kenneth Valentine Deputy Director Maintenance and Operations Bureau, Vermont Agency of Transportation Highway Division 802-279-7782	Most of our systems are Cirrus. Some Dickey-John systems remain in the fleet. We have used Certified Power systems and a few Schmidt units.
	Bruce Nichols Transportation General Manager District 3 Vermont DOT 802-786-0028	We mostly use Cirrus ground speed controllers now.
<b>Wyoming DOT</b>	Cliff Spoonemore P.E. WYDOT Field Operations Maintenance Staff Engineer 307-777-6377	Force America

Agency	Respondent	Question 6- Is your agency actively using or pursuing the implementation of advanced integrated telematics AVL/GPS spreader control systems? If so, describe the products utilized and long-term goals you are seeking to attain.
<b>Alabama DOT</b>	Kerry C. NeSmith, PE Deputy Bureau Chief, Maintenance Bureau and Dallon R. Ogle, Jr., P. E. Assistant Area Operations Engineer- Maintenance	Yes, we are in the early implementation stage for these systems. We are finding many details including hydraulic compatibility with dump trucks and other issues to overcome. Our goals are to minimize rates while maintaining the appropriate and effective dosing of ice-fighting chemicals.
<b>Arkansas DOT</b>	Joe Sartini, State Maintenance Engineer	We use ARWIS systems to scout the roadways to save the spreader operations,, we use ARWIS and MARWIS systems to improve our response times and be on time and on target with our response methods.
	Matt Emberton, District 1 Maintenance Engineer	No. We utilize Networkfleet for GPS.
	Jeff Wheeler, District 9 Maintenance Engineer	No
<b>Municipality in Denmark</b>	Jens Kristian Fønnesbech (Municipalities on the island of Funen)	The spreading take place as GPS controlled spreading with driver navigation.
<b>City of Des Moines Montana</b>	Kevin Hensley Superintendent of Public Services Kevin.Hensley@wdm.iowa.gov+B 5	Our fleet is currently 100% integrated with AVL/GPS telematics. BSM is our current service provider. We will continue to use AVL/GPS technology in our fleet. We are currently working to integrate our AVL/GPS system into our weather service product. Currently we use our system for complaint resolution, inventory monitoring, and route completion reporting.

Agency	Respondent	Question 6- Is your agency actively using or pursuing the implementation of advanced integrated telematics AVL/GPS spreader control systems? If so, describe the products utilized and long-term goals you are seeking to attain.
<b>Idaho DOT</b>	Steve Spoor Maintenance Services Manager Equipment Fleet Manager 208-334-8413	Yes, we implemented snowplow AVL/GPS/MDC (Mobile Data Collection) in 2012 and went statewide for the 2015/2016 winter season. The Cirus Spreadsmart controller has a mobile data collector and utilizes a Garmin GPS unit for AVL. We then use the standard functionality of the Spreadsmart to communicate data via WiFi communication link at all maintenance sheds/garages. The data is then stored on servers at the Idaho Transportation Department. The data is processed and then fed directly to our Maintenance Management system as well as is available for post storm evaluation.
<b>Kansas DOT</b>	W. Clay Adams Bureau Chief of Maintenance Kansas Department of Transportation 785-296-3233	Just doing some testing
<b>Maryland DOT</b>	Sandi Sauter, Maryland DOT Office of Maintenance Deputy Director 410-582-5535	Using AVL in conjunction with Force American 6100 Ultra to send telemetry (application rates, total materials applied, locations, and surface/air temps).
<b>Montana DOT</b>	Tony F. Strainer Equipment Bureau Chief/ Maintenance Division Montana Department of Transportation 406-444-6151	At this time we are not.
	Jon Swartz MDT Maintenance Administrator and Doug McBroom MDT Maintenance Operations Manager and Mike Miller Roadside Winter Maintenance Specialist	MDT has only experimented with AVL/GPS. We can see some advantages but it is cost prohibitive for us at this time.
<b>North Dakota DOT</b>	Mike Kisse Program Manager NDDOT Maintenance Division 701-328-4410	Yes. We have had a pilot project running for the last 10 years. We are still unable to secure the funding to implement a statewide system. Our goals are to have an AVL/GPS system to show position information, we want it connected to our MDSS with display in cab to show treatment recommendations and weather conditions with 2-way communication. We want a camera on the dash. We want to be able to use it to update our travel map. We want to display our locations on the travel map and plow up/down sensors. We have tested many systems, Location Technologies, Ameritrak, Parsons, Skyhawk, Verizon. We recently did a RFI to learn about the various system on the market.
	Larry Gangl NDDOT Bismarck District Engineer 701-328-6955	Yes, we are reviewing options for these. More efficient use of materials and better overall service to the public

Agency	Respondent	Question 6- Is your agency actively using or pursuing the implementation of advanced integrated telematics AVL/GPS spreader control systems? If so, describe the products utilized and long-term goals you are seeking to attain.
<b>Ohio DOT</b>	Doug Burke Equipment Engineer Office of Equipment Management 614-351-2836	We are implementing GPS/AVL in our truck fleet, however they will not be fully integrated in the spreader control system, at this time.
<b>Saskatchewan</b>	Jennifer Ball, P.Eng. Senior Project Manager Operations Division, Ministry of Highways and Infrastructure Government of Saskatchewan Jennifer.Ball@gov.sk.ca	The Ministry is currently looking at AVL to help track salt usage/application rates, track where trucks have been to ensure level of service timelines are being met, help provide evidence to either deny or approve any claims, as well as improve and monitor fleet metrics such as idle time. No product has been chosen at this time.
<b>Utah DOT</b>	Ryan S. Ferrin, P.E. Maintenance Methods Engineer UDOT Central - Maintenance Planning 801-910-2562	UDOT uses Verizon's NetworkFleet which pairs with our Force America 5100EX and 6100EX Controllers to give us various vehicle diagnostics, characteristics of driver behavior, truck equipment operations, and quantities of materials distributed all tied to time and location. Our long term goal is to be able to demonstrate to the Public and to ourselves that we are conducting the most efficient and cost-effective operation possible. We want to learn from mistakes and correct them in the future.
<b>Vermont DOT</b>	Kenneth Valentine Deputy Director Maintenance and Operations Bureau, Vermont Agency of Transportation Highway Division 802-279-7782	All of our plow trucks are now equipped with BMS (Webtech) AVL systems tied into the spreader controls. We want to know what material is going down where, as well as where the trucks are/were. We hope to tie this to performance measures and management.
<b>Vermont DOT</b>	Bruce Nichols Transportation General Manager District 3 Vermont DOT 802-786-0028	We do have AVL in all of our trucks now, long term we are planning on using them for more accurate tracking of our winter maintenance operations. To better define how our current procedures work and what we might do to make them better.
<b>Wyoming DOT</b>	Cliff Spoonemore P.E. WYDOT Field Operations Maintenance Staff Engineer 307-777-6377	Force America – Precise units: These two companies are integrated and work well with each other's equipment. Precise is not the most accurate and user friendly vendors. The data that is collected is for your use only as long as you continue to pay for the service. You may think you paid for the data but that is not the case. Also if you need specialized reporting then you have to pay additional fees for them to write the code. They do not take comments that may improve their product and then incorporate the comments to make the product better. They do not recommend what sensors you should install to collect data from your distributor process that will be picked up by their equipment. Now, to not blame Precise completely WYDOT may not have made sure the equipment was calibrated at all times. And our method of field verifying accuracy was not well established. There is plenty of blame to go around for not coming up with quantities that could be trusted and accounted for.

Agency	Respondent	Question 7- Does your agency track with database software the quantity and location of brine application on the highway? If so, what product or system is utilized?
<b>Alabama DOT</b>	Kerry C. NeSmith, PE Deputy Bureau Chief, Maintenance Bureau and Dallon R. Ogle, Jr., P. E. Assistant Area Operations Engineer- Maintenance	No, not at this time.
<b>Arkansas DOT</b>	Joe Sartini, State Maintenance Engineer	We track our use internally with a home grown system that feeds a dashboard that was first used by DOT administrators and was recently turned around and made available to the general public.
	Matt Emberton, District 1 Maintenance Engineer	No. Supervisors are responsible for tracking quantity and material utilized on each route.
	Jeff Wheeler, District 9 Maintenance Engineer	No
<b>Municipality in Denmark</b>	Jens Kristian Fønnesbech (Municipalities on the island of Funen)	The quantity and location of brine application on the highway is stored in Vinterman (a danish database software).
<b>City of Des Moines Montana</b>	Kevin Hensley Superintendent of Public Services Kevin.Hensley@wdm.iowa.gov+B 5	No

Agency	Respondent	Question 7- Does your agency track with database software the quantity and location of brine application on the highway? If so, what product or system is utilized?
<b>Idaho DOT</b>	Steve Spoor Maintenance Services Manager Equipment Fleet Manager 208-334-8413	Yes using the Cirus Spreadsmart controller and the Cirus DataSmart software application. We are also looking at feeding this data to Esri and utilizing their Winter Work product for data analysis.
<b>Kansas DOT</b>	W. Clay Adams Bureau Chief of Maintenance Kansas Department of Transportation 785-296-3233	No
<b>Maryland DOT</b>	Sandi Sauter, Maryland DOT Office of Maintenance Deputy Director 410-582-5535	Yes, we track the gallons used by each facility by event that roll up to an end of season total for anti-icing (prior to event) and DLA (during event). We have the routes broken down by facility but we don't track at the route level however this is part of the future implementation. This data is tracked using an internally developed software/database.
<b>Montana DOT</b>	Tony F. Strainer Equipment Bureau Chief/ Maintenance Division Montana Department of Transportation 406-444-6151	No
	Jon Swartz MDT Maintenance Administrator and Doug McBroom MDT Maintenance Operations Manager and Mike Miller Roadside Winter Maintenance Specialist	MDT tracks their material use through the trucks operating system and then reports it to our Maintenance Management System (MMS). Our equipment is calibrated on a regular basis.
<b>North Dakota DOT</b>	Mike Kisse Program Manager NDDOT Maintenance Division 701-328-4410	Yes. We track quantity not location at this time. We use an in house data base that was developed to collect this info and connected to truck unit number and usage reports.
	Larry Gangl NDDOT Bismarck District Engineer 701-328-6955	No

Agency	Respondent	Question 7- Does your agency track with database software the quantity and location of brine application on the highway? If so, what product or system is utilized?
<b>Ohio DOT</b>	Doug Burke Equipment Engineer Office of Equipment Management 614-351-2836	This is still currently track with manually filled out logs.
<b>Saskatchewan</b>	Jennifer Ball, P.Eng. Senior Project Manager Operations Division, Ministry of Highways and Infrastructure Government of Saskatchewan Jennifer.Ball@gov.sk.ca	Not at this time.
<b>Utah DOT</b>	Ryan S. Ferrin, P.E. Maintenance Methods Engineer UDOT Central - Maintenance Planning 801-910-2562	Currently the information is being stored by Verizon exclusively since their NetworkFleet pairs with our Force America controllers. The data extraction proves to be cumbersome though because if you want anything more than 1 month old you have to contact Verizon to pull the reports. You can pull reports for the past 1 month without contacting Verizon.
<b>Vermont DOT</b>	Kenneth Valentine Deputy Director Maintenance and Operations Bureau, Vermont Agency of Transportation Highway Division 802-279-7782	No, but the info is available in our AVL data.
<b>Vermont DOT</b>	Bruce Nichols Transportation General Manager District 3 Vermont DOT 802-786-0028	Just what is tracked with our AVL systems.
<b>Wyoming DOT</b>	Cliff Spoonemore P.E. WYDOT Field Operations Maintenance Staff Engineer 307-777-6377	WYDOT was trying to use Precise to track the routes and the amount placed using AVL/GPS. The quantities collected did not match that of our work order accounting system Agile Assets

Agency	Respondent	Question 8- On a scale of 1-10, how successful do you feel your current liquid ice-fighting operations are? What possible future improvements do you envision?
<b>Alabama DOT</b>	Kerry C. NeSmith, PE Deputy Bureau Chief, Maintenance Bureau and Dallon R. Ogle, Jr., P. E. Assistant Area Operations Engineer- Maintenance	Seven-We are about to eliminate CMA in favor of PA and other non-suspensions. We believe the costs can be similar as we discover appropriate rates for southern weather. Additionally, application rates have been too high for years and we hope to solve this problem as previously referenced.
<b>Arkansas DOT</b>	Joe Sartini, State Maintenance Engineer	For the way in which we use our liquid chlorides I would say that we are about an 8.
	Matt Emberton, District 1 Maintenance Engineer	Definitely an 8. We could improve on larger transfer pumps for loading material quicker and research other additives such as Aqua Salina or Husker.
	Jeff Wheeler, District 9 Maintenance Engineer	10 , Possibly adding more equipment to apply brine.
<b>Municipality in Denmark</b>	Jens Kristian Fønnesbech (Municipalities on the island of Funen)	10, but when we can be sure there are no dosage variations, it will be enough only to use half the amount of brine.
<b>City of Des Moines Montana</b>	Kevin Hensley Superintendent of Public Services Kevin.Hensley@wdm.iowa.gov+B 5	We do not typically fight ice with liquids. Chemicals are used to prevent the bond of snow and ice to the pavement.

Agency	Respondent	Question 8- On a scale of 1-10, how successful do you feel your current liquid ice-fighting operations are? What possible future improvements do you envision?
<b>Idaho DOT</b>	Steve Spoor Maintenance Services Manager Equipment Fleet Manager 208-334-8413	Probably a 8 or 9. We can always improve our efficiency in regards to timing of pre-treating before storms and improving our application rates.
<b>Kansas DOT</b>	W. Clay Adams Bureau Chief of Maintenance Kansas Department of Transportation 785-296-3233	10
<b>Maryland DOT</b>	Sandi Sauter, Maryland DOT Office of Maintenance Deputy Director 410-582-5535	MDOT-SHA feels that our liquid application operation is very successful for the infrastructure we currently have but are looking to expand exponentially in the coming years. Our current operation would be graded as a 7 with a lot of room for growth. The expansion of our current brine making equipment (fully automated Henderson units) and extra storage capacity (additional and larger tanks) is moving forward at this time.
<b>Montana DOT</b>	Tony F. Strainer Equipment Bureau Chief/ Maintenance Division Montana Department of Transportation 406-444-6151	5. We are teaching our crews that correct calibration is the secret and it needs to be checked often.
	Jon Swartz MDT Maintenance Administrator and Doug McBroom MDT Maintenance Operations Manager and Mike Miller Roadside Winter Maintenance Specialist	I would give our liquid use an 8 rating of success. We give our drivers substantial training, have a MMS system to track their use and calibrate our trucks to maintain a consistent rate. We do not gravity feed liquid. All that being said we recognize that winter maintenance is constantly evolving and we need to continue to look for ways to improve.
<b>North Dakota DOT</b>	Mike Kisse Program Manager NDDOT Maintenance Division 701-328-4410	I would put us on a scale of about a 6-8. We need more application equipment in the field and more brine production and storage facilities to keep up with the application amounts. Liquids are becoming very popular and with that comes more usage.
	Larry Gangl NDDOT Bismarck District Engineer 701-328-6955	7. More equipment and more training. We need to expand our use of liquids.

Agency	Respondent	Question 8- On a scale of 1-10, how successful do you feel your current liquid ice-fighting operations are? What possible future improvements do you envision?
Ohio DOT	Doug Burke Equipment Engineer Office of Equipment Management 614-351-2836	8 to 9, we are currently running liquid on all snow plow trucks, have a large antiicing fleet that routinely pretreats the roadways as the need warrants. As for future efforts: standardization of the equipment and spreading methods. i.e. on big 5000 gallon tankers and uniform way of powering the spreader should be created. Currently we use auxiliary gas motors, hydraulics driven by the truck or gravity feed.
Saskatchewan	Jennifer Ball, P.Eng. Senior Project Manager Operations Division, Ministry of Highways and Infrastructure Government of Saskatchewan Jennifer.Ball@gov.sk.ca	7- 8 in the locations that are utilizing liquid. The Ministry is working on expanding/rolling out the use of liquid across the province with the primary focus on pre-wet.
Utah DOT	Ryan S. Ferrin, P.E. Maintenance Methods Engineer UDOT Central - Maintenance Planning 801-910-2562	I would score UDOT an 8 out of 10 in liquid ice-fighting operations. Most of our sheds use liquid anti-icing before storms and we have 1 maintenance shed on the I-80 up a canyon and over a mountain pass that uses NaCl brine and liquid MgCl exclusively pre and post-storm without ever using granular salt. We have brine storage tanks at most maintenance sheds.
Vermont DOT	Kenneth Valentine Deputy Director Maintenance and Operations Bureau, Vermont Agency of Transportation Highway Division 802-279-7782	8, we are still making tweaks year-to-year in materials, blends, and application methods.
	Bruce Nichols Transportation General Manager District 3 Vermont DOT 802-786-0028	I feel we are currently at an 8, we are still experimenting with our additive. We hope to get a better feel of how to use the additives.
Wyoming DOT	Cliff Spoonemore P.E. WYDOT Field Operations Maintenance Staff Engineer 307-777-6377	May be a 5 at best. WYDOT is an aggregate state and the use of chemicals is still fairly new. Still trying to have some successes and share those so that others will give chemicals a try. Demands and support from leadership is needed to supply funding for testing of different AVL/GPS pieces that can work with Force America controllers. Once we have accurate means to measure the product being applied we can then outfit the fleet. This will then provide solid measurements for input into Agile Assets and our equipment, labor and materials can be accounted for on a consistent basis.

Agency	Respondent	Question 9- Please provide any other recommendations, information or feedback that you believe may be of value for this research.
<b>Alabama DOT</b>	Kerry C. NeSmith, PE Deputy Bureau Chief, Maintenance Bureau and Dallon R. Ogle, Jr., P. E. Assistant Area Operations Engineer- Maintenance	No Response given.
<b>Arkansas DOT</b>	Joe Sartini, State Maintenance Engineer	If you have a reliable weather service that can predict surface temperature profiles and freeze line locations, you can devise a plan of attack that will isolate the locations that will require the maximum effort and provide fall back rings from that location.
	Matt Emberton, District 1 Maintenance Engineer	Ohio DOT has an excellent powerpoint on DLA (Direct Liquid Applications). Dale Calcamuggio was the presenter at the last Transportation Research Conference. His presentation was very informative and even had several tables indicates the types of event, types of brine used, application rates, and more.
	Jeff Wheeler, District 9 Maintenance Engineer	No Response given.
<b>Municipality in Denmark</b>	Jens Kristian Fønnesbech (Municipalities on the island of Funen)	No Response given.
<b>City of Des Moines Montana</b>	Kevin Hensley Superintendent of Public Services Kevin.Hensley@wdm.iowa.gov+B 5	One of the most important aspects of a successful anti-icing program is education. Education for all staff that is going to be applying material as well as supervisors and any personnel that will be answering questions from the public.

Agency	Respondent	Question 9- Please provide any other recommendations, information or feedback that you believe may be of value for this research.
<b>Idaho DOT</b>	Steve Spoor Maintenance Services Manager Equipment Fleet Manager 208-334-8413	I would be happy to discuss in further detail on the phone if you desire.
<b>Kansas DOT</b>	W. Clay Adams Bureau Chief of Maintenance Kansas Department of Transportation 785-296-3233	No Response given.
<b>Maryland DOT</b>	Sandi Sauter, Maryland DOT Office of Maintenance Deputy Director 410-582-5535	Nothing at this time.
<b>Montana DOT</b>	Tony F. Strainer Equipment Bureau Chief/ Maintenance Division Montana Department of Transportation 406-444-6151	No Response given.
	Jon Swartz MDT Maintenance Administrator and Doug McBroom MDT Maintenance Operations Manager and Mike Miller Roadside Winter Maintenance Specialist	If my comments raised any questions or the need for further discussion please contact me directly.
<b>North Dakota DOT</b>	Mike Kisse Program Manager NDDOT Maintenance Division 701-328-4410	We have been training on using liquids for a number of years. Staff is now beginning to experience how well they work. Our program continues to grow. Districts recognize the benefits and are coming up with unique ways to build application equipment in house.
	Larry Gangl NDDOT Bismarck District Engineer 701-328-6955	No Response given.

Agency	Respondent	Question 9- Please provide any other recommendations, information or feedback that you believe may be of value for this research.
<b>Ohio DOT</b>	Doug Burke Equipment Engineer Office of Equipment Management 614-351-2836	Ohio Included material use guide and offered to supply direct app tank specs if desired.
<b>Saskatchewan</b>	Jennifer Ball, P.Eng. Senior Project Manager Operations Division, Ministry of Highways and Infrastructure Government of Saskatchewan Jennifer.Ball@gov.sk.ca	No Response given.
<b>Utah DOT</b>	Ryan S. Ferrin, P.E. Maintenance Methods Engineer UDOT Central - Maintenance Planning 801-910-2562	No Response given.
<b>Vermont DOT</b>	Kenneth Valentine Deputy Director Maintenance and Operations Bureau, Vermont Agency of Transportation Highway Division 802-279-7782	Clear Roads has done a lot of good research and documentation on the subject.
<b>Vermont DOT</b>	Bruce Nichols Transportation General Manager District 3 Vermont DOT 802-786-0028	I have nothing to add at this point.
<b>Wyoming DOT</b>	Cliff Spoonemore P.E. WYDOT Field Operations Maintenance Staff Engineer 307-777-6377	Caltrans is a member of Clear Roads and a good portion of this information has been studied already by the Clear Roads Pooled Fund. Please go to Clearroads.org to see if we have some finished projects that can help you with this study of Cal-Davis.