9.0 – WINTER MAINTENANCE EQUIPMENT AND TECHNOLOGIES

This is one in a series of Syntheses of Best Practices related to the effective management of road salt in winter maintenance operations. This Synthesis is provided as advice for preparing Salt Management Plans. The Synthesis is not intended to be used prescriptively but is to be used in concert with the legislation, manuals, directives and procedures of relevant jurisdictions and individual organizations. Syntheses of Best Practices have been produced on:

1. Salt Management Plans
2. Training
3. Road, Bridge and Facility Design
4. Drainage
5. Pavements and Salt Management
6. Vegetation Management
7. Design and Operation of Maintenance Yards
8. Snow Storage and Disposal
9. Winter Maintenance Equipment and Technologies
10. Salt Use on Private Roads, Parking Lots and Walkways
11. Successes in Road Salt Management: Case Studies

For more detailed information, please refer to TAC's Salt Management Guide - 2013.

INTRODUCTION

Winter maintenance operating and research personnel in many parts of the world have identified new methods and technologies that can improve snowfighting efficiency and significantly reduce the amount of road salts used to maintain roads, highways, sidewalks and parking lots in the winter. Equipment is now available that incorporates these developments to reduce salt use, control the impact on the environment, improve winter travel conditions, safety and mobility, and reduce overall costs.

When selecting and deploying equipment, proper and timely information is important to good decision-making. In order to properly match equipment and service delivery in a way that optimizes winter maintenance performance, winter maintenance personnel need to understand:

- snow and ice control strategies and methods available to them
- pavement and weather conditions that exist, that are forecasted and that need to be acted upon
- equipment and material availability, capability and limitations in use

Equipment is a significant cost component (along with labour and materials) in a winter maintenance program. It is understood that it takes time to adjust the fleet and to incorporate an acquisition strategy into

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an ongoing budget. Further, it is important for an organization to continuously identify and assess new and innovative technologies that supports best practices. Also, there are seasonality and frequency of use considerations as well as multi-functionality aspects in evaluating the economics of renewing the fleet. Management must balance all of the competing agendas in choosing the preferred equipment configuration, and a phase-in/out strategy for the fleet, with an understanding of salt use considerations.

RELATIONSHIP TO SALT MANAGEMENT

Winter maintenance equipment is primarily used to prevent or control accumulations of snow and ice. A significant amount of the accumulation can be controlled by mechanical methods such as plowing. When mechanical methods alone would be inappropriate or ineffective, deicers must also be used. For a "saltable" situation, the approach is to place an amount of material on the pavement to prevent snow and ice from bonding to the pavement surface, to control the accumulation of snow and ice and to achieve bare-and-wet followed by bare-and-dry pavement within prescribed standards

Winter maintenance equipment, once optimized, can help an organization meet the 4-R's of Salt Management:

- the **R**ight material
- the **R**ight amount
- the **R**ight place, and
- the **R**ight time.

In addition to the 4-R's, a final key to effective salt management is:

- **Keep it on the pavement to work**

Each organization will need to assess the winter materials available, to determine appropriate application rates for a given situation and determine the best time for application in order to achieve the established level of service.

Following a principle of determining what is "right" for a given organization, considering the 4-R's will help any winter maintenance operation optimize the use of salt. Public safety will be maintained while controlling the impact of salt on the environment.

SALT MANAGEMENT PRACTICES

To optimize salt use, it is important to look continually at new and innovative technologies as they are a valuable option. Some salt use "optimization factors" to consider when making equipment choices include:

- Improved information and decision making tools will allow equipment, personnel and salt to be better used and salt applications better timed.
- Efficient mechanical control of snow and ice will minimize the amount of snow and ice to be controlled by chemicals.
- Proper equipment choices will help operators to place a predicted amount of salt at the desired location where it is needed, at the right time.
- Chemical applications should occur at a time that prevents bonding of snow or ice to the surface.
- Keeping good records of snow and ice control actions taken, along with material usage and a record of changing pavement conditions, will improve planning and budgeting and limit an organization's liability.
- The safe and effective use of any equipment requires operators to be properly trained; this is particularly important when introducing new equipment and techniques.

Information & Decision-making Tools

To make the best use of available equipment and personnel and meet the 4 R's of Salt Management, experienced decision-makers in winter maintenance operations need information to support their judgment.

The critical information required can be divided into three categories:

- weather and pavement forecast information (what will happen), for predicting upcoming storms and potential icing events
- current information (what is happening), providing surface temperatures and conditions, and
- status information (what did happen), recording what was done and the Level of Service achieved.

A number of tools are available to help provide the required information. Typical examples follow.

ROAD WEATHER INFORMATION SYSTEMS (RWIS)

Sensor-based RWIS has been in use since the mid 1970s by road and airport authorities around the world. The Canadian network of RWIS stations has grown significantly in the past decade. Beyond giving road information and trends, RWIS sites and networks provide information required to develop specific forecasts as well as some service documentation.

RWIS supports winter operations in the following ways:

- An understanding of pavement temperature forecasts and trends can improve the accuracy of decision-making.
- Sensors embedded flush in the pavement, as well as sub-surface, generate data that can be sent back to central locations allowing trends and forecasts to be developed.
- Pavement sensors can monitor pavement temperature, wet/dry status, freeze point of the solution on the pavement, presence of chemical and concentration (for some chemicals), as well as subsurface temperature.
- Tower-based sensors can also provide real-time information of typical atmospheric conditions such as precipitation, relative humidity, dew point, air temperature, and wind speed and direction.
- Weather forecasting services can use road-based information to provide "road weather" forecasts to help the snowfighters make better decisions regarding snow and ice control.
- Salt use optimization is achieved by more accurate deployment of equipment and application of chemicals.
- Other types of sensors, cameras and systems can be added to RWIS to further support snowfighters (e.g. automated liquid deicer application system – Fixed Automated Spray Technology (FAST), cameras, remove pavement and friction sensors, etc.).

INFARED THERMOMETERS (IRT'S)

Decisions about material application are improved by knowing the current road surface temperature and the temperature trend. There are portable or stationary infrared thermometers on the market that can be used to determine the current surface temperatures.

- Both hand-held and truck-mounted versions are available; with the mounted versions measuring ambient air temperature as well. There are also units that include a humidity sensor thus allowing the dewpoint temperature and relative humidity to be measured.
- Truck-mounted versions allow continuous monitoring of the road surface while the vehicle is moving along the road.
- The data can be recorded and transmitted as part of the data stream of a GPS/AVL system (see Operational Support Equipment later in this document).
- Stationary pole mounted remote surface temperature sensors are also available. These can provide the surface temperature, air temperature, dew point temperature and relative humidity at the specific location. Because they are mounted at the edge of pavement, they avoid the disruption associated with installation of in-pavement sensors.
- Like all equipment, IRTs need to be checked and calibrated to confirm their accuracy and to be confident in the reading.
- Not all of the IRTs on the market can be re-calibrated. A simple way to check the accuracy of an IRT is to create a water/ice mixture and measure the temperature of the surface of the mixture with the IRT. If the IRT is accurate it should record 0° C. The difference between the reading and 0° C will provide the accuracy. It is not unusual for a hand held IRT to have a 1-2 degree discrepancy.

ROAD SURFACE TRACTION MEASUREMENT

Moisture, snow and ice degrade surface friction producing slippery conditions. Road salts and, sometimes, abrasives like sand, are applied to improve traction, increasing the coefficient of friction. Decisions about material application can be improved by having better information about the current friction level of the surface:

- The presence of precipitation or applied winter materials such as anti-icing liquids, sand and salt can provide inconsistent friction across the pavement surface.

- Road authorities around the world are working with suppliers to develop reliable and accurate equipment to measure the available traction on pavement.
- Friction sensors have been used extensively on airport runways, but their high cost is currently restricting widespread use on roads. Alternative designs promise lower cost.
- In some cases friction sensors are mounted on the spreader vehicles and used in conjunction with on-board mounted pavement temperature measurement equipment to automatically control the application rate of snow and ice control chemicals.
- Alternatively, the device could be mounted on a "smart patrol truck" with other winter maintenance tools.
- There are also stationary sensors available that are pole mounted. These use infra-red beams to determine the pavement condition (e.g. dry, moist, wet, icy, snowy/frosty or slushy). They can also measure friction.
- Technically, the equipment can be accurate and dependable, and has the potential to eliminate the unnecessary use of salt where adequate traction exists.

RESIDUAL CHEMICAL MEASUREMENT

After a storm event has passed and the pavement has become bare and dry, there often is a residue of chemical remaining on the surface. This fine layer of chemical will be activated with the next precipitation event. This residual will also help to prevent the formation of frost and can melt a small amount of snow. As well the concentration of salt contained in slush is the determinant of the freeze point temperature of the slush. It is helpful for decision-makers to know the residual salt concentration on the pavement. An RWIS pavement sensor will provide this information. Portable salinity sensors are also available, although their cost and the fact that one needs to stand on the pavement to take the measurement, make widespread use impractical. Another tool being tested is a "chemical presence" sensor that can measure the chloride concentration of pavement spray in a vehicle's wheel well.

Using Mechanical Means to Control Snow and Ice

Mechanical removal of ice and snow is usually preferable and this can be facilitated by preventively treating paved areas with road salts. Such pre- or early-storm applications will often minimize the overall amount of road salts required to achieve the desired surface friction level. Reacting to a snow and ice event and applying road salts after a bond has formed requires significantly more salt to be used.

Some organizations choose to leave a small amount of snow on the pavement before salt is applied in order to keep the salt from bouncing or being blown off the surface by traffic or wind.

Accumulated snow and ice or slush can be controlled mechanically by removing it with plows mounted on trucks, motor graders or loaders. Snow blowers and power brooms are also used in some areas. Repeated plowing operations in areas with limited snow storage will require the stockpiled snow to be removed for disposal. The following discussion provides a general overview of snow removal equipment and some advantages and disadvantages of their use.

SNOW PLOWING

A wide range of plowing options are available including the type of vehicle used to carry the plow, the type of plow and mouldboard and even the type of cutting edge or blade.

VEHICLES

The vehicle type and size must be selected properly to be able to operate in the required area, carry and operate the mounted equipment and provide a safe and comfortable environment for the operator. Vehicles may also be multi-purpose, and be used for other duties during non-storm event times and during the off-season, summer months.

Considerations for typical units in use include the following:

Trucks

- Trucks come in various capacities and dimensions, and are commonly referred to as single axle, tandem axle or tri-axle units.

- Smaller, more maneuverable vehicles may be more suited to urban operations, parking lots and sidewalks, whereas larger, more powerful trucks may be preferred on roads and large parking lots.
- Underbody plows can also be mounted on trucks and be used with down pressure.
- Trucks with front mounted plows and wings often provide the best solution on roads as they can operate at higher speeds. This allows roads to be cleared sooner and allows the truck to operate at safer speeds. Trucks operating closer to the speed of other traffic present less of a safety hazard.
- Trucks operating at higher speeds can effectively "throw" snow a sufficient distance back from the edge of the shoulder to minimize snow bank build up.
- Higher operating speeds may be inappropriate in urban areas and in proximity to environmentally sensitive areas where snow thrown beyond the edge of pavement could damage roadside features and the environment.
- Trucks can be configured with a hopper or tank to serve the dual-duty role of spreading materials as well as plowing.
- Careful attention must be paid to the truck specification to configure it as a frame-stiffened winter truck of suitable horsepower and hydraulics, rather than simply a generic cab-and-chassis off the production line.
- To ensure adequate traction and load baring capacity, both front and rear tires must be selected carefully to ensure suitable tread pattern, material and sufficient load rating to handle both the material load and plows.
- Front axle capacity is a consideration, and the vehicle should meet legal weight requirements as necessary.
- Trucks require locking differentials or electronic traction control to prevent traction loss due to a spinning wheel.

Motor Graders

- Graders are often fitted with plows and wings to remove snow.
- Graders are often readily available for winter road maintenance as they are widely used by municipalities and contractors during the summer for road construction and maintenance, and are little used otherwise during the winter.
- Graders are useful when working in tight quarters on urban streets with cul-de-sacs, elbows, bus bays, and varying road widths.
- They work at lower speeds and promote a safer operation when working in the presence of pedestrians and heavy traffic because of enhanced operator visibility.
- They can be fitted with front plows, including one way and reversible plows, "V" plows, and side wings, with or without driveway gates.
- Graders can also be mounted with a tooth or stacked-disc ice blade to scarify hard ice-pack and provide improved, temporary friction.
- Modern graders can operate at much higher speeds than older models but are limited to thirty to thirty-five kilometres per hour and thus are slower than truck mounted plows.
- Graders are effective during fall freeze-up and spring thaw when roads are soft and susceptible to digging-in by truck-mounted plows.

Loaders

- Loaders are occasionally fitted with plows, wings and snow blowers for snow removal.
- Modern loaders with large glass areas on the sides and front, and a high mounted operator position, provide the operator with excellent vision of the area around the loader.
- Loaders (particularly articulated loaders) are useful when working in tight quarters on parking lots and urban streets with cul-de-sacs, elbows, bus bays and varying road widths.
- They can also be used to pick up and remove snow on parking lots, cul-de-sacs, bridges and other tight areas with limited snow storage.
- Loaders are readily available for winter road maintenance as they are widely used by municipalities and contractors during the summer for road construction and maintenance and are used extensively to load sand and salt onto spreader trucks at the maintenance yards.
- Loaders are also an important tool for loading materials into spreaders. The buckets must be

sized for the spreaders being loaded so that spillage of materials is limited.

PLOWS

- The type of plow and cutting edge must be selected properly to be able to be mounted properly on the vehicle, to operate in the required area and achieve the desired performance in snow clearing.
- The selection of the appropriate type of plow and proper adjustment of the plow will reduce costs and lessen the amount of salt needed to clear the pavement.
- Plows should be operated with sufficient weight on the blade to effectively cut through packed snow and ice, resulting in a near-bare surface, in order to minimize the amount of salt required to fully-bare the pavement.
- Plows for high speed operations should be fitted with shoes to prevent the plow from dropping into holes or catching on obstructions. In low speed operations (e.g. parking lots) the shoes are usually removed to maximize snow removal.
- Plows should be adjusted to minimize the amount of weight carried on the shoes, but the shoes should be close enough to the pavement to absorb the weight of the plow if the plow strikes an obstruction. Castors are sometimes substituted for shoes to minimize wear.
- Plows should be fitted with a tripping mechanism that will reduce damage to the plow if it impacts catch basin or manhole covers, curbing or other obstructions. The trip mechanism will also prevent the truck from being violently deflected from its traffic lane.
- Various plows angles are used depending on the goal. An angle of about 75° between the blade and the pavement provides the most effective cutting of heavily packed snow and ice. An angle of 55° between the blade and the pavement is the most efficient at moving large quantities of snow and causes the least amount of snow to be blown up at the front of the vehicle. One jurisdiction has used a 40° angle to improve snow pickup.
- Various designs and improvements to aerodynamics have been made to improve the operators' visibility by trapping some of the snow cloud kicked up by the cutting edge.

Front Mounted One-Way Plows That Move the Snow to the Right

Front mounted one-way plows are designed to move snow to the right side for plowing roadways. The following are their characteristics.

- This plow provides the most efficient blade available for plowing snow.
- The snow is not thrown as far at the outlet end of the plow so more snow remains on the shoulder.
- The standard shape allows more snow to escape from the mouldboard and contributes to a cloud of snow surrounding the truck. Newer designs improve driving safety by minimizing the amount of snow that escapes into the snow cloud at the point of impact.
- These plows commonly are used for high-speed removal of snow, slush and packed snow.
- They can be used to clear from minor amounts up to approximately 50 cm depths of snow at highway speeds;
- Steel one-way plows can be large and heavy; therefore the truck must be fitted with a high capacity front axle, and heavy duty wheels and tires.
- The size of the vehicle may be a disadvantage when clearing snow in congested urban areas and subdivisions with cul-de-sacs, etc.
- Piston-like cushions are available to reduce the pounding/bouncing of the blade on the road surface, which reduces the impact on both the truck and operator.
- These plows should be fitted with nose points to prevent the plow from catching on bridge expansion joints and cross cracks.
- A thorough training program is required to ensure that the operators are familiar with the adjustments to maximize snow removal and maintain all safety features in a fully functional condition.
- Either right and/or left side plow wings are usually fitted to extend the plowing width (see Wings or Wing-plows).

Front Mounted Reversible Plows

Front mounted reversible plows are used to move snow to the left or right side of the truck. The following are some of their characteristics.

- These plows are useful for clearing left hand lanes (especially adjacent to a median) and ramps.
- They are widely used in urban areas because of their versatility.
- Some manufacturers offer reversible plows with mouldboards that can be reshaped to match the shape of one-way plows when the mouldboard is angled in either direction. These plows have been strongly endorsed by the plow operators, but are significantly more expensive.
- A unique variation of the reversible plow is a centre-hinged-reversible plow that can push left or right or effectively become a V-plow.
- The plows may be fitted with nose points to protect against catching on minor roadway obstructions, bridge expansion joints, etc.

Front Mounted "V" Plows

- Front mounted "V" plows effectively handle deeper accumulations of snow.
- These plows have been designed to lift snow over adjacent windrows and to balance side loading by pushing snow to both sides.
- Their use is now restricted mainly to areas with high snowfall rates and as back-up units to open roads closed during severe storms.
- A smaller version of the v-plow is often used to clear sidewalks.

Wings or Wing-plows

- Wings are smaller side-mounted plows that can be mounted on a tower or mast near the front of the plow truck, or further to the rear at the back of the cab.
- Wings can also be mounted on graders.
- They can be mounted on either or both sides of the plow vehicle, and effectively increase the width of the plowed path.
- One disadvantage of wings is that operator visibility can be impaired.
- Wings improve efficiency and allow for increased snow removal, being especially useful in multi-lane clearing and when operating in an echelon formation since they help prevent leaving a windrow of snow on the traveled surface.
- Wings may be inappropriate in some urban settings where they can throw snow beyond the edge of pavement and damage roadside features.
- Usually the vertical angle of the plow can be adjusted by a cable/chain or hydraulically, allowing the wing to be used for clearing shoulders or for cutting side banks of snow.

Underbody Plows

- The underbody plow is suited to applications on crowded urban streets, urban laneways and back alleys, as well as in some rural settings.
- They effectively serve as a two-way reversible plow and are normally stable.
- They are effective in clearing highly compacted snow and ice by way of variable downward pressure, using the truck's compressed air system or hydraulic pressure and springs, to maximize effectiveness.
- These plows are limited to clearing snow accumulations up to 30 cm.
- Underbody plows are not normally used with side wings so the plowed path is limited and a lane-side windrow of snow is created.
- A rear mounted snow wing can be added to trucks with underbody plows but the plowing width is less than that of a front mounted wing. With this configuration the vehicle might be expected to be less stable than front mounted wings as the side thrust from the wing is located further from the centre of gravity of the truck.
- In some cases the vehicle might be less stable due to excessive down pressure.

Vertical Plows

- A recent development in plows is the vertical blade which is flat but hinged in two locations (at third points) so as to push straight, right or left, or to effectively scoop snow by catching it and pushing it forward.

- This plow is usually loader or tractor mounted, and can accommodate a snow load traveling at slower speeds either forward or in reverse.
- A vertical plow is preferred in areas of unique geometry, or where access is tight.

Tow Plows

- Tow plows consist of a secondary plow towed on a trailer behind a plow truck.
- They are used to plow multiple lanes with one truck on urban multi-lane roadways, rural high speed highways, climbing and passing lanes and rural shoulders.
- The operator can raise and lower the tow plow blade and swing the plow out into the adjacent lane allowing a single truck to clear a width of more than 7.3 meters (24 feet) – the equivalent to 2.5 conventional trucks. This generates over 30% savings on equipment, fuel and manpower costs.
- When not needed, the operator can raise the blade on the tow plow and redirect the unit back behind the truck.
- Tow plow trailers can also be outfitted to spread conventional materials or with liquid tanks for applying straight liquids at the same time the road is plowed. .

Cutting Edge or Blade

- Snowplow cutting edges and blades are available in various designs and configurations for various operations.
- Regular blades are made of heat-treated steel or fitted with tungsten carbide inserts to improve durability (by a factor of up to eighty times in high speed operations).
- Rubber and polymer/plastic blades have been tried to minimize damage to catch basins, bridge expansion joints, centerline pavement markings and raised reflective markers, etc. These blades can be used to effectively “squeegee” the surface to remove slush in areas where the ambient temperatures usually rise above the freezing point during daylight hours after a storm. In areas with colder temperatures the use of theses blades has not been as successful.
- Ice blades are used to cut into hard packed snow and ice that cannot be removed with conventional blades.
- Special plow blades with sliding segments that move up and down vertically facilitate the thorough clearing of rough or distorted pavement, reducing the amount of salt required to bare off the pavement. The manufacturers also claim that these blades minimize damage to the plow and truck from hitting obstructions, such as catch basin covers, as less force is required to retract one segment clear of the obstruction. These blades are well suited for high speed and rural plowing.

SNOW REMOVAL AND DISPOSAL

Over the course of a winter and multiple plowing operations snow will build up along roadways or in parking lots. Areas with limited space for plowed-snow storage may develop visual obstructions for drivers, act as a snow fence causing drifts to form a cross roads, restrict use of the facility and prevent future plowing operations from being productive once the snow capacity of the area is exceeded. In addition, accumulations next to guide rail, barrier walls and bridge approaches can freeze solid and create an unsafe ramping condition.

The piled snow, containing salt and other road contaminants, may need to be removed and disposed of or stored in an appropriate manner. Refer to the Snow Storage and Disposal Synthesis of Best Practices for more information.

Snow removal is usually considered a fair-weather or clean-up operation, and may entail traffic control considerations. Also, most removal operations often leave some snow on the road that must then be treated with abrasives or snow and ice control chemicals to maintain safe driving conditions.

Various removal methods and equipment are available and should be selected based on local needs. The following discussion provides a general overview of methods and equipment used to remove and dispose of accumulated plowed snow, and some advantages and disadvantages of their use.

SNOW MOVING

- Snow bank accumulations may simply be handled by a conventional plow truck and physically relocated further back beyond the roadway and shoulder.
- High-winging or stepped-winging commonly is used to cut the bank height.
- In a rural and/or urban environment, a grader with or without a wing can be used to move the snow further back to create space for subsequent plowable storm events or to act as a barrier (snow ridge) instead of using a snow fence.
- Alternatively, the bank may be cut forward, toward the roadway, immediately followed by a full speed one-way plow run that effectively throws the loosened snow to the fence line.

Loading, Hauling and Dumping

- The most cost effective and easily mobilized removal operation for isolated locations is by means of a loader that fills conventional contractor dump truck(s), which then haul the snow to an appropriate site.
- The capacity of the loader and the truck body will determine the production rate and effective cost.
- Auxiliary equipment may be required to increase the efficiency of the operation. For instance, a grader may “peel” a snow bank into a suitable windrow in order to accommodate the loader and truck position.
- Since a loading operation necessarily impacts the flow of traffic in the area, traffic control or protection is often required, and consideration should be given to doing this work at night.

Mobile Conveyors

- Mobile conveyors are used to load snow from the shoulders or a windrow directly into trucks for removal.
- They can operate entirely on the shoulder with both the unit and the truck being loaded lined up on the shoulder with minimal traffic disruption.
- They are useful in areas with high traffic volumes or limited access

SNOW MELTING

- Snow melters melt snow that is picked up and place into a heated box. The resulting melt water is usually drained directly to the storm sewer system.
- Melters provide a solution for unique problem areas, particularly tight urban areas with limited snow storage available adjacent to the road on the right-of-way. They are also used to melt snow in parking lots where snow volumes are restricting usable parking spaces or meltwater is causing icing problems.
- Melters may be an economical solution where the hauling costs are high (i.e. where snow disposal facilities are far from snow removal locations.
- Melters can be mobile or stationary.
- Mobile melters move under their own power and picks up the snow by a conveyor and delivers it to an onboard melting tank and the melt water is released to the drainage system. The production of mobile melters can be quite slow.
- Stationary melters are melting tanks that are moved and set up at where the demand for melting exists. Snow is trucked to the melter. In some cases these are a temporary set up where once the melting operation is completed, the tank is moved to its home base. In other cases they are permanent set ups.
- Where sanding is a major activity in a winter operation, there can be a problem with plugging when melting sand-laden snow.
- Snow melters may have water/waste treatment, noise and air emission issues (see Snow Storage & Disposal Synthesis of Best Practices).

SNOW BLOWERS

- While blowers can be used during storm conditions, they are a slower production unit than a plow and are normally used for post-storm snow removal.
- Blowers are also used to load trucks for snow removal in urban areas, along roads and in parking lots with limited snow storage space.

- They are often owned by contractors or are a part of an equipment fleet that services a network of open roads in an area with very high snowfall rates.
- All blower operators must be aware of wind direction and the visibility concern that traffic could encounter.
- Blowers are typically mounted on dedicated trucks, tractors or are attached to large front-end loaders.
- They are available with hydraulic powered vanes to control the direction of the blower in snow banks.
- They may also have hydraulic controls on the chutes to accurately direct the snow into the trucks used for haulage.

Blowers can be used simply to widen the snow bank area and relocate the snow by blowing it beyond the bank toward the ditchline (where storage capacity is available).

Using Road Salts to Control Snow and Ice

Preventing a snow and ice bond to the pavement surface should be the top priority. If prevention efforts from early-storm treatments fail and a bond forms, then destroying this bond must be done as quickly as possible. There are many chemicals including road salts that prevent and/or destroy that bond, making mechanical removal easier, and melt that portion of the frozen precipitation that cannot be removed mechanically. The key is to apply the right amount of the right material, in the right place and at the right time. Various chemical control strategies are available.

The following discussion provides a general overview of methods and equipment used to apply salt and sand, and some advantages and disadvantages of their use.

ANTI-ICING/DEICING METHODS

- Anti-icing is the proactive use of any melting agent to assist melting and resist the formation of a bond between snow and ice and the pavement surface.
- Anti-icing can involve application to the pavement of liquids, pre-wetted or pre-treated solid granular materials or dry granular material. Thus, anti-icing is not confined to using liquids.
- Deicing is a reactive strategy of destroying an existing bond between snow/ice and the pavement where a chemical is applied after the bond has formed between the snow and the pavement. In these cases the chemical must work its way through the snowpack to the pavement surface where it can break the bond and allow the snow to be removed mechanically.
- Anti-icing creates a safer condition, quicker and with less chemical than does deicing.

Liquid Deicers

A solid chemical must first dissolve in water, creating brine, before it can melt snow or ice. The lag time while solids dissolve delays the effect of the chemical application.

Liquid deicers are popular because they are already in the state necessary to melt snow and ice. As such they enhance the melting performance of deicing chemicals. They also help to keep solid materials on the surface longer. For these reasons and others, liquid deicers are being applied through direct liquid application (DLA) or to sand and solid salt - either through pre-treatment of stockpiles or through on-board pre-wetting. These techniques are discussed later.

There are a number of liquid deicers available. Most of these liquids are chloride based and are manufactured. Sodium chloride brine is commonly used because it can be made from rock salt by the user inexpensively and its performance is well understood. There are also natural brines available that contain a mixture of chlorides.

Newer liquid products include organic byproducts such as beet juice and carbohydrates (condensed distiller soluble) that claim to reduce the amount of salt needed, reduce the working temperature of the mixture, reduce vehicle corrosion, increase residual and inhibit the refreeze process.

Some liquid road salts such as calcium chloride and magnesium chloride are exothermic (give off heat) and therefore can act synergistically with sodium chloride which is endothermic and requires heat to create brine.

Direct Liquid Application (DLA)

- Direct liquid application (DLA) is the placement of a liquid deicer directly onto the pavement surface.

- DLA is efficient since it provides immediate melt action and does not take the time to dissolve and form brine that a solid chemical does. As well, liquids do not depend on the presence of heat from the ground, sunlight or traffic to dissolve (endothermic reaction).
- Generally, an equivalent weight of salt applied as a liquid (e.g. dissolved in water) performs better than the same weight of dry granular salt because the liquid is fully retained on the pavement surface.
- The cost on a dollar-per-gram basis may be greater for liquid only applications (depending on the liquid used); however the merits of DLA should be assessed on a full cost basis including the offsetting safety benefits.
- The timing of the application of DLA is not as critical as with granular materials. One significant advantage of using a liquid is that it can be applied to dry pavement in advance of the start of a storm provided conditions suit the use of DLA. The resultant residual chemical will be present when the event (frost or snow) occurs. This means that roads, parking lots and sidewalks can be treated during times when traffic is low or parking lots are empty.
- Where the application is earlier than the onset of a storm, the water in NaCl brine will evaporate leaving a salt crystal residue in the surface pores/ texture of the pavement. This residual will later dissolve and form brine when moisture becomes present (either from precipitation or dew).
- Conversely, hygroscopic brines (such as CaCl2 and MgCl2) will attract moisture and continually wet the road until they are dissipated.
- There is evidence that as chemicals move from a liquid state to a solid or from a solid to a liquid, there is a short period where a “slurry” state can occur. With some chemicals this “slurry” state can reduce friction on the pavement creating a short-term slippery condition. Humidity is the most important factor in creating this slippery condition. Temperature also seems important. Higher temperatures and lower humidity can dry out a solution creating the liquid-to-solid transition. On the other hand with high humidity, a dry chemical residual can re-hydrate causing a solid-to-liquid transition. This is more of an issue with hygroscopic chemicals.
- Liquids can also “scrub” the oils from the pores of pavement, especially with an application after a prolonged dry period. The resultant slurry can be slippery. It does not take a lot of liquid to achieve the desired anti-icing effect. Over applying a liquid can cause some of these slipperiness conditions. The impact of this temporary effect can be minimized by using pencil nozzles that leave alternating dry and wetted strips on the pavement.
- The approach to resisting the bond is not to wet the pavement, but simply to provide enough chemical to enhance early-storm safety with an application of chemical that stays on the pavement surface. In most cases, the intention is not to “wash” or even fully wet the pavement with an equivalent chemical loading as that of a granular application.
- It is acknowledged that a direct liquid application has much less “staying power” than granular salt; however the use of this procedure lessens overall chloride loadings per storm and allows for bare pavement to be achieved sooner.
- The application of liquids can be triggered by sensors and sprayed on a surface such as a bridge deck using Fixed Automated Spray Technology (FAST).
- DLA can be applied over multiple lanes by trucks traveling at higher speeds (than conventional salt spreading) with due regard for traffic.
- Trucks used for DLA can range in size, to accommodate frame-mounted or slide-in tanks. Truck configurations may include:
  - small trucks ranging from pickups and two-tons with tanks or collapsible bladders, to vehicles used for vegetation spraying or bridge washing in the off-season
  - larger trucks used for water applications or calcium dust suppression applications in the off season, and
  - full-size, larger capacity tractor trailer tanker units used for long distance hauling in the off season.
- Trailer-mounted tanks are also used.
- Custom built units may be required for specialized high-speed, multi-lane, long-range applications, or small scale operations such as sidewalks and transit platforms.

- Mid-sized trucks used for DLA can also be outfitted with a plow and wing harness for subsequent use later in the storm.
- Tank, pump and nozzle configurations, as well as the controller, will determine the preferred application practice and route range.
- The liquid is delivered to the pavement by means of pumps or gravity-fed nozzles. The preferred applications makes use of "pencil-sized" streams at 200 mm to 300 mm spacing; this prevents misting or atomizing the liquid that then blows away and doesn't make it to the road surface.
- An alternative to pencil-nozzles is the use of tube-trailers that run from each nozzle to the road surface and directly target the liquid without the stream passing through the air; though the tube has to be adequately clamped and will wear from the pavement surface, it better targets the liquid onto the pavement.

PRE-WETTING METHODS

- Pre-wetting is a commonly used practice to improve performance and keep material on the pavement by reducing the effects of bouncing, blowing and sliding of the salt or sand particles. This technique uses a liquid chemical to wet the sand or salt as it is spread on the pavement.
- Pre-wetting enhances the melt action of the chemical present by speeding the dissolving of salt and the formation of brine.
- Practical considerations relate to the gradation of the salt being wetted, the maximum liquid to solid ratio that can be mixed, the amount of mixing action, caking/clumping concerns, etc.
- Adjustment of the spray nozzles is critical. Tests by one US state department of transportation showed that they never achieved more than 60% coverage of the salt. The remaining 40% of the pre-wetting liquid was effectively being applied directly onto the pavement.
- As the wetting agents are corrosive, it is important that corrosion resistant nozzles and non-contact pumps are used to ensure dependable performance.
- Pre-wetting provides significant potential for reductions in salt use but can increase the complexity of the required equipment and controller.
- Pre-wetting requires additional equipment. Storage tanks for the liquid(s), or brine making equipment are required, along with pumps to load the spreaders.
- The on-board liquid capacity and loading time are factors to consider.
- The application pumps on the spreaders should be regulated by ground speed controllers to ensure the correct liquid application rate is maintained under all conditions.
- Additional maintenance is required such as ensuring that the liquid filters, lines and nozzles are purged and the equipment cleaned at the end of the storm to prevent clogged lines and seized equipment.

Pretreatment

- Pretreatment is the addition of a liquid to solid salt at the time it is stockpiled.
- Pretreated salt can have the same benefits as pre-wetted salt without having to invest in new equipment thus providing an easy entry into the use of liquid technology.

Spreaders

- The total amount of salt used for winter maintenance is significantly influenced by the characteristics of the spreader equipment.
- Spreader controls must be capable of delivering several precise application rates.
- The application rate should be consistent whether the spreader is full or nearly empty, regardless of material variations, or temperature changes.
- When purchasing new equipment, organizations should require test results from suppliers to confirm that the equipment will achieve precise application rates under all conditions.
- Spreaders must operate in a severe environment of low temperatures, high moisture, poor visibility and corrosion.
- Spreaders must be easy to load, and simple to operate.

- Ideally, a spreader should be adaptable for other tasks, or the hopper should be easily removed so the trucks can be used for other operations during the summer.
- Hoppers must be constructed so that all sand and salt can be easily removed from the body.
- Spreaders should be fitted with screens to ensure that frozen clumps of material or other contaminating material that would jam the chain/conveyor mechanism are not loaded into the spreaders.
- Cab shields should be fitted to assist in loading the spreaders to ensure that all loaded salt enters the box, and material is not spilled over the truck or on the ground.
- Spreaders should be manufactured from a material that will resist corrosion. Special chlorinated rubber primers and epoxy-based primers will increase coating life. Stainless and galvanized steel and fiberglass bodies are available but can be relatively expensive. High strength, low alloy self-coating steel, used with good surface preparation and special primers has been proven to provide a cost effective body life of up to fifteen years. Manufacturers also supply spreader bodies constructed of fiberglass. These bodies are lighter and thus provide increased payload possibilities, but are also more expensive than steel.
- Electrical wiring for controls and lighting, and hydraulic components must be enclosed in vapour proof, or sealed systems.
- Neoprene spinners are frequently used to improve durability and spreading efficiency.

Spread Patterns

- Salt and sand application methods can be modified to meet differing requirements.
- Typically one of two spread patterns is used: i) Placing a windrow on the crown or high side of the pavement; and ii) Broadcasting material uniformly over the pavement.
- In most cases on roads, solid or pre-wetted salt should be applied in a continuous narrow windrow along the centerline of the road. The concentrated mass of material minimizes the tendency of the material to bounce or be blown off the road by passing traffic. Salt going into solution drains down the crossfall of the road, and can migrate under packed ice and snow; a uniform section of road is then bared off initially along the centre of the road to provide two-wheel stability for traffic. This reduces the unnecessary loss of salt that can come from broadcast operations.
- Application in a windrow is achieved without using the spinner, by dropping the material from a chute. In some cases the salt is dropped onto a slowly rotating spinner centered over the crown.
- Windrowing on the centre line will not work if the crown of the road is not consistently on the centerline, or the road surface is badly deteriorated which could cause the salt brine to pond in some areas.
- Centre line application is not appropriate if the entire road surface is slippery and immediate de-icing is required. In these situations, higher salt application rates may need to be spread across all traffic lanes using a spinner.
- Some rear-discharge spreaders have the ability to vary the spread pattern (widths and symmetry) allowing the operator to adjust the spread pattern to unique road network conditions. For example to pick up an acceleration/deceleration lane or bus stop or to address a super-elevation.
- Application ahead of the drive wheels can provide improved traction under the drive wheels of the spreader vehicle. Application close to the driver's cab also enables the driver to monitor the application to ensure that material flow has not been impeded.
- One argument in support of rear-discharge spreaders is that the drive wheels should not have enhanced friction if the steering wheels do not also have the benefit of improved friction. Otherwise, the driver may not be able to control the steering as the front wheels slide while the drive wheels continue to push forward. This is not normally an issue on bare-pavement policy roads unless there are significant grades in the area.
- Spreaders designed with discharge at the rear can allow for a slide-in capability that can be mounted and dismounted quickly.
- Discharge at the center-rear of the vehicle is simple but may restrict the vehicle to treating the lane in which the vehicle operates; some designs

allow for the spinner "throw" to place the material at an offset from the vehicle.

- Broadcast spread patterns are suited to situations where broad coverage is needed immediately. This is typical on parking lots and sidewalks.
- Broadcast spreading is also appropriate on roads where immediate traction and melting over the entire surface is required. This would be in the case of freezing rain or black ice or when placing sand.
- Drop spreaders are best for sidewalks because the material can be confined to the sidewalk and not lost to the vegetated areas.

SPREADER TYPES

Manufacturers provide different spreader types to meet various requirements. The various designs have different characteristics that must be considered when a spreader is selected for a particular application. These include hopper spreaders, tailgate spreaders, reverse dumping spreaders, and some new variations of these types.

Hopper Spreaders

- Hopper spreaders have provided optimum performance and durability in the past.
- These spreaders are usually installed on trucks during the winter and removed and replaced by standard dump bodies or other equipment for the summer (e.g. water tanks, concrete mixers, etc.).
- The design incorporates steeply sloping sides to eliminate material hanging up.
- A conveyor chain, belt or auger is used to move the material to the discharge location. Conveyor chains have proven over the years to be more trouble free than belts, and both can be more accurately calibrated than augers.
- Augers have shown very high wear and poor accuracy in material control.
- The application rate of the material being spread is controlled by adjusting both the speed of the chain used to convey the material to the chute or spinner and the gate opening on the body.
- A constant source of power to drive the hydraulic pump was once provided by an integral small gasoline or diesel engine. Though a few are still in use, these engines are problematic and a constant source of downtime and maintenance. Reliable hydraulic pumps, driven from the truck engine, are now common.
- Conventional hopper spreaders provide good control of material application and dependable service. However, they are the least versatile for other operations during the off-season.
- New hopper designs, including rear-discharge, slide-in units with a longitudinal agitator bar and belt conveyor is gaining popularity, particularly for pre-wetted applications.

Tailgate Spreaders

- Tailgate spreader units mount on the rear of the truck dump box and are filled by raising the body and dumping salt into the integral hopper. The salt is then conveyed to the spinner by a chain or auger and applied in a windrow or broadcast over the surface using a spinner.
- These spreaders are considered a simple and dependable unit. They are used extensively in areas where storms are less frequent and the trucks can be used for other purposes, or as backup units for hopper spreaders.
- Their primary limitation is the inconvenience of raising the dump box and the possibility that the box will not be raised high enough to ensure that sufficient material is dumped in the hopper to provide consistent delivery.
- The rear discharge restricts the operator view of the operation and ability to ensure that the material is being discharged at the right location.
- The vertical clearance and the upward and rearward shift of the centre of gravity when the box is raised can cause instability and can be a safety concern.

Reverse Dumping or Dual Dump Spreaders

- These spreaders were developed to overcome problems identified for tailgate spreaders while still providing a multi-purpose spreader that could be used year round.
- They function as regular rear dumping bodies when not being used to apply winter maintenance materials.

- The pivot pins can be repositioned so the standard hoist can be used to raise the rear of the body. This moves the salt or sand to the chain conveyor at the front of the body that moves the material to the distribution point ahead of the rear wheels.
- These spreaders have the advantage of providing year round service and can be switched from hauling construction materials to winter maintenance use with no adjustments required.
- Disadvantages of this spreader are the high weight compared to a regular dump truck, and the need to raise the body while driving to move the material to the front of the truck. This reduces the truck's stability and care is required by the operator to ensure that sufficient material covers the cross conveyor at the front to maintain a precise application rate. The pivots have been a source of failure and replacement is expensive.
- A variation of the reversing dump body is the side-tipping floor. The floor and passenger side of the box are raised to move sand or salt to the driver's side of the truck where a longitudinal conveyor moves the material to the front of the box for distribution ahead of the rear wheels. This arrangement eliminates the strong weight shift to the front of the vehicle and the material is distributed ahead of the rear wheels where the operator can easily monitor the application. The complexity involved in ensuring that the box is tipped far enough to cover the conveyor is a disadvantage. Some problems have been encountered with body integrity, as the full support of the contractors dump box is not available. The vehicle is also more heavily loaded on the driver's side and braking on slippery roads could be affected.

Multipurpose Spreaders

- Multipurpose spreaders incorporate most benefits of the other spreaders.
- They use a longitudinal conveyor to transport salt or sand to the front of a large modern contractors dump box.
- A recent design makes use of a U-shaped box to ensure that no material hangs up in the box and that all material can be easily removed from the box at the end of the shift.
- A lateral conveyor at the front transports the material to the left or right side of the body for distribution ahead of the rear wheels.
- The material is either discharged in a windrow using a chute for concentrated action, or spun across the lane using spinners.
- The spreader provides precise application rates and all the advantages of distribution in front of the rear wheels.
- The cross conveyors are easily removable during the summer so that there is no tare weight penalty.
- The units are lightweight and provide year round use.
- The body can be easily switched to carrying construction materials (simply by installing a pan or tray across the floor conveyor).
- These units can carry substantial loads so care must be exercised to ensure that adequate truck components, axles, springs and wheels, are specified to carry the load. This is particularly important on combination units that are also equipped with snow plows.

Rearward Casting Spreaders (e.g. Zero Velocity)

- With normal spreaders, a high percentage of the dry salt applied to the road bounces off the road due to the combination of the impact of the granules hitting the pavement, and the speed of the spreading vehicle. This is reduced somewhat by pre-wetting or pre-treating materials.
- Most organizations now theoretically constrain their spreading speed to avoid wasting salt due to the scatter effect at higher speeds. In practice however, speeds of 40 km/hr and more are not uncommon. If salt could be applied at higher speeds, combination units would be much more productive as the unit could apply salt at plowing speeds. This would allow for safer operating condition since trucks could move at the speed of traffic.
- Casting material rearward has shown potential for salt use reduction by increasing the percentage of applied salt that is retained on the road, and in the required location on the road.

- This is a concept by which the salt is discharged rearward at exactly the same speed as the spreading vehicle is traveling forward. The two velocity components cancel each other causing the salt to drop on the road as if the spreading vehicle was standing still.
- To-date, the available equipment has experienced some operational problems such as material caking, uneven discharge and mechanical complications (fan/blower) under certain conditions and is not in broad use.
- One manufacturer makes use of a shielded-spinner at the mid-chassis discharge location, discharging at a point just beyond the width of the rear wheels where the material is "flung" rearward.
- Another manufacturer used a high-speed blower to discharge the salt rearward. This results in a large cloud of salt that can be hard to control and may be affected by side winds.
- Also, the spreader units may not suitably handle pre-wetted material or finer sands.
- Though useful for salt applications, there is no good way to spread sand with these spreaders.

Rear-discharge Spreaders

- Based on the premise that no salt particle should be placed dry onto the road surface, and that fine salt is the gradation of choice for prompt dissolving and melting, certain spreader design characteristics cater better to liquid and fine salt use in pre-wetted applications.
- The salt must be of a fine gradation in order for it to retain the brine moisture content and fine salt does not travel as easily on certain chain-type conveyor systems.
- Increased liquid use can have detrimental effects on equipment when the discharge location is other than at the rear.
- These spreaders allow a "high-ratio" salt application rates up to 255 litres per tonne of salt, or at a ratio of 30:70 liquid-to-solid by weight. This requires a large capacity of onboard liquid and adequate pumping capability which may not be possible or practical on a conventional retro-fitted unit.
- These spreaders are either frame-mounted or slide-in rear-discharge v-hoppers that can stand on self-contained stilt legs in the maintenance yard, and remain tarped until needed.
- In one design, an internal longitudinal agitator bar meters salt from the hopper, while breaking down chunks in the load, onto a belt conveyor that moves the material to the rear-discharge location.
- Calibration by weight can be done accurately off the rear belt.
- Pre-wetting liquid can be applied directly on the spinner that is designed to spread the material across a given area of the road cross section.
- Some of these units are also configured to apply DLA either from the spinner or using a spray bar.
- Though some units are considered to be well-built, they cost more than conventional spreaders.
- One consideration is that areas that only have access to coarser salt may find that the liquid component must be reduced since saturation can be achieved with less liquid.
- Overall spreader designs are evolving and are worthy of continual investigation.

Electronic Spreader Controls

- All spreaders require an accurate electronic controller to ensure that the appropriate application rate is achieved.
- Simple hydraulic circuits, used to maintain a steady application rate, are still in use in many road authorities and most private contractors servicing parking lots. This equipment starts to exceed the desired application rate as soon as the truck speed drops below the design speed and an excessive salt application is then dumped on the road.
- Early models of the electronic controllers were not dependable and required extensive maintenance. The new models are improved but can still require some patience.
- Modern spreaders use electronic groundspeed spreader controls to provide consistent, accurate application rates. The truck speed is monitored from the truck's speedometer drive, and the spreader output is adjusted to maintain a steady output at the set rate per kilometre. Both open loop and closed loop systems are available to monitor material flow and provide increased

accuracy of the spread rate (closed loop systems provide confirmation of the actual application rate).

- Electronic controllers automatically increase the output rate if a second spinner is actuated (if so equipped) to treat truck climbing and turning lanes.
- With some electronic units, calibration settings can be applied electronically using infrared controls.
- Information that is captured and logged can include: amount and type of material applied, gate position, run time, blast information, average speed, spread width/symmetry, etc.
- Manufacturers can now provide units that record, for printing, information about the amount of salt used, the time it was used and the associated application rate, for analysis and control by the organization.
- Modern controllers incorporate global positioning systems (GPS) for automated vehicle location (AVL) and to identify where the material was discharged (either generating a passive history or a live transmission).

CALIBRATION

Regardless of the spreader chosen, the service provider must calibrate each spreader to have faith that the application rate settings are indeed accurate. A calibration policy should be established to assure the material settings are correct. Preferably, if application is by weight, then calibration should also be by weight. All spreaders should be calibrated before the start of the season and recorded. Calibration checks or recalibration should take place several times during the season, including:

- after repairs to and system that can affect salt delivery
- when distribution calculations show a discrepancy between theoretical and actual
- spot-checks on units in the fleet throughout the season

OPERATIONAL SUPPORT EQUIPMENT

Various types of equipment support the winter maintenance program either by helping manage the operations by generating useful data or by supporting the service delivery itself. These are discussed in the following sections.

MATERIAL USAGE MONITORING

There is the saying – **You Can't Manage What You Don't Measure!** Review of salt management practices over the past 5 years shows that most road organizations have many if not all of the tools to properly manage their salt use but the actual salt use is not always being optimized.

Often what is missing in salt management practices is active tracking of salt use against targeted objectives and a concerted effort to adjust wasteful practices.

The following sections discuss equipment that is available to help with this monitoring process.

BENCHMARKING

It is important to know how much material should be applied for given precipitation and pavement temperature conditions over a given area.

- Snowfighting organizations should have multiple application rates (low, medium, high) for each type of material they are applying that are geared to weather and pavement conditions.
- The size of the various areas to be serviced (e.g. routes, parking lots, sidewalks, platforms etc.) should be determined.
- The amount of each material required to service specific areas can be determined for the various application rates by multiplying the area by the application rate.
- This benchmarking only needs to be done once and reviewed when changes are made to the rates or the service area.
- Some road authorities print the amount of salt needed to service an area (route or lot) on the beat/route maps provided to the operators.
- It is these benchmarks and their monitoring/ reporting system that allow organizations to ensure that they are placing the right amount of salt and meeting their goals.

LOADER MOUNTED ELECTRONIC WEIGHING EQUIPMENT

- Loading extra material onto a spreader can lead to overloading or the temptation to over apply the salt. In the past, operators tended to load a little extra salt as there was no exact method of determining the amount of material loaded, and they did not want to run out without completing the route.
- Overloaded trucks also contribute to contamination in the area of the salt storage facilities. Salt heaped above the side boards is thrown off the trucks as they negotiate curves to exit the yards.
- With electronic scale control systems operators can more precisely load the right amount of salt.
- This device is a relatively inexpensive, durable and accurate weighing device consisting of a transducer load cell mounted to the loader bucket arm.
- These devices can measure a predetermined load size for the scheduled route (length of route X application rate + a limited contingency amount for bridge decks, intersections, etc.). In other words the benchmarked amount for the conditions of the event.
- Models are available that will record with the loader in motion so that the loader operation is not impeded.
- The units will record the amount loaded and can download or print out a ticket for tracking purposes.
- Though the equipment can be overridden, it provides the operators with a mechanism to accurately measure and control the amount of material loaded on the spreaders.

Truck Scales

- Weighing the trucks as they enter and leave the maintenance yard is a way of confirming the amount of material loaded and how much was spread on the serviced route.
- This function can be automated with a weigh-in-motion pad that tracks the equipment movement and can serve to reconcile the data from the spreader controller and other documentation.

Liquid Meters

- Pump meters at the brine loading station should be used to measure the amount of brine delivered to each truck in order to track loading times and quantities.
- There should be records kept of the amount of liquid loaded onto pre-wet and DLA units as well has how much liquid is used for each round. This will help to confirm overall usage and proper application rates for management and legal purposes.
- It is also important to have testing methods for confirming that liquids are at the ideal concentration. Some liquid production units measure concentrations on an ongoing basis during the production process and only deliver the completed brine to storage once the desired concentration has been reached. Brine concentrations should be checked using other means to ensure that the production process is delivering the desired product.

Automated Vehicle Location (AVL)

- AVL is a way of tracking equipment movements along with the services provided using GPS receivers/transmitters and software.
- The process usually involves a third-party provider that receives and assembles the vehicle position data from the GPS and operational data from the vehicle's controller by cell phone and provides it to the client over the internet.
- Many organizations have had difficulty getting quality data and management reports from their third party provider. Typical issues relate to equipment failure, operator sabotage, holes in the cell phone coverage and software mismatches.
- The electronic records can either be actively followed real-time or can be passively recorded for later analysis. It is also archived for future reference in the event of an incident or for review and management purposes. On-board data storage help to manage transmission costs, deal with communication gaps and ensure data integrity.
- The AVL provider needs to be able to collect and properly interpret the data from the controllers and relay this to the client. Because all controllers

do not use a common protocol for exchanging data the AVL needs to provide an interface that translates the output from each controller into common language. A problem occurs when there is a mismatch between the translation software and the controller. This can happen when a controller is changed and the translation software is not matched to the new controller. In this case the data is useless. Purchasers of this service should insist that the AVL supplier has a quality control system that can detect and report when data issues occur. Otherwise incorrect data can be collected.

- The electronic record can either be actively followed real-time or can be passively recorded for later analysis. It is also archived for future reference in the event of an incident or for review and management purposes.
- This equipment can provide operational support to greatly enhance the monitoring of salt usage, to demonstrate prudent usage and to correlate with the achievement of the required level of service. It is also useful for proving that specified services were provided, which is useful in defending against legal action.
- AVL can support a number of management needs including:
  - route optimization to rationalize the number of trucks required and thus the expected salt to be used on the roads serviced
  - thermal mapping where pavement temperatures from on-board sensors can be related to location
  - automatic spreader adjustments by location
  - determining salt loadings on service segments or within salt vulnerable areas

MATERIAL LOADING AND HANDLING

Bulk Salt Handling by Loaders

- Extensive environmental contamination has been identified in proximity to salt storage yards. Much of this contamination results from poor salt handling practices.
- Conveyors are available which are designed to allow salt trailers to dump directly into the conveyor for movement into the storage facility.
- Loaders used to fill spreader vehicles are often fitted with buckets that are too large for the spreader hopper bodies. This results in spillage.
- Though they have a slower production rate, smaller buckets are available for most loaders, or side dumping bucket attachments can be used which provide quick precise loading.

Bulk Material Conveyors

- Various bulk facilities are in use as follows (and are further described in the Design and Operation of Road Maintenance Yards SOBP):
  - Pre-loaded drop-hopper loaders meter salt into spreader trucks
  - Overhead silos can be pre-filled with salt to similarly meter salt into spreader trucks
  - Pneumatic handling equipment can handle fine material that is used for either direct application onto the road or for blending with sand
- Whatever equipment is used for moving salt, it should provide a way of tracking the flow so the quantities can be recorded and reconciled.

Sand/Salt Blend Mixers

- Salt is normally blended into stockpiled winter sand for the main purpose of keeping the sand free-flowing and to prevent it from freezing in the winter.
- High-ratio mixes are rarely necessary; an exception might include anticipated periods of rapid temperature fluctuations.
- Ideally, blended winter sand stockpiles are put up in favourable, dry conditions.
- Relatively dry sand stored indoors should not require more than 1-2% salt by weight; more moisture in the sand may require more blended salt (up to 5%), but the purpose still is to keep the sand free-flowing, and not to support melt action.
- Traditionally, blending took place on the apron to the storage shed, with several buckets of sand spread level, followed by one bucket of salt trickled on the surface; the resulting blend was loaded in the dome, and the process was repeated.

- Though highly inefficient, it was also highly inaccurate, and produced sporadic result on the pavement surface.
- Equipment to support high-production stacking and uniform, light blends now involves a form of dual-auger pugmill or a twin conveyor feed. In either case, two supply lines are metered to an accurate ratio and the final conveyor stacks the completed mixture.

BRINE SUPPLY EQUIPMENT

The following two sections discuss aspects of brine production and delivery. Further issues on brine supply and liquid storage are contained in the Design and Operation of Maintenance Yards SOBP.

Brine Production Equipment

- Several manufacturers offer equipment to manufacture salt brine for pre-wetting and direct liquid applications.
- Both batch plants and higher capacity continuous flow plants are available.
- Water is added to rock salt in the batch plants to produce a saturated brine solution.
- In the continuous flow plants, normally water is forced through salt under pressure. Solution strength can be metered and controlled automatically.
- Overhead drop-hoppers can slowly meter the salt into the water for quicker dissolving.
- In all cases, the concentration should be checked with a hygrometer or refractometer. The hygrometer measures the specific gravity of the solution. The percent of saturation is determined by reference to specific gravity charts for the specific solution temperature. Hygrometers are calibrated to a specific temperature and can give different readings at different temperatures. Refractometers may be more reliable.
- Water supply flow rates are a critical factor. Production sites may require cisterns that capture surface drainage to ensure adequate water supply where well production rates are poor.
- Most salt supply specifications allow for some insoluble contaminants in the salt. This can amount to approximately 100kg of waste grit when using a 96% pure salt source per one-bucket (2m3) or 10,000 litre brine batch. Clean-out time should be accounted for in production rates.
- Manufactured salt brine can be pumped directly into tanks mounted on the spreaders or transferred to holding tanks at the maintenance yards.
- Stored brine will normally stay in solution as long as there is not evaporation or a drop in temperature below eutectic.
- Additives such as corrosion inhibitors may complicate long-term storage, in which case agitation or recirculation could be considered.

Brine Delivery Equipment

- Unlike brine production, no special equipment is required for liquids that are delivered.
- When liquids are purchased laboratory test data should be provided to ensure that the concentrations are correct for the temperatures at which the liquid will be stored and used.
- Brine that is delivered should be tested to ensure that it meets the desired specification before it is used or mixed with other brine.
- Sampling containers and a refractometer or a properly calibrated hygrometer should be available for sampling and testing the concentration.

SALT VULNERABLE AREAS

Having proper equipment and effectively using this equipment are the most effective ways of ensuring that the right amount of salt is placed at the right time and in the right location. Organizations should strive to improve their fleet as quickly as possible given their fiscal realities.

As new equipment is phased in, priority should be given to allocating the new equipment to Service areas adjacent to salt vulnerable areas, and reallocating less salt-efficient equipment to less sensitive areas.

Technologies such as the use of liquids should be implemented as a way of reducing salt use and improving safety.

MONITORING & RECORD KEEPING

The data logging and reporting capabilities of loader scales, electronic controllers and GPS/AVL systems can assist organizations in more accurately tracking their salt use. Progress in implementation of best salt management practices can be measured in improvements to the fleet and the type and quantity of materials used. Monitoring and record keeping should include:

- type and amount of winter materials being placed per unit area
- percentage of fleet equipped with electronic spreader controllers
- percentage of fleet equipped with pre-wetting
- percentage of fleet equipped with direct liquid application
- percentage of fleet calibrated annually
- percentage of staff trained in equipment use

TRAINING

Traditionally, equipment-related training focused on equipment maintenance and the safe operation of the vehicle. This was followed by specific training on the differences between vehicles, which covered the spreader controller features and how to change settings, etc.

These aspects of staff training are still essential to the safe and effective use of equipment. Further equipment-related training, however, should also emphasize the impact of the operator's decisions made along the route, the range of settings and methodologies available to the operator and tie these to her/his roles as a "snowfighter" and "decision-maker." Equipment training should be integral with other winter maintenance topics such as the science of salt and record keeping.

In the past, a plow operator could be forgiven for only plowing, just as a spreader operator might only spread. That was the job after all. With today's understanding of best practices for snow and ice control and with the more sophisticated equipment that is available, operators need to understand that "decision-making" means choosing to spread when appropriate, and, equally important, choosing not to spread when it is not required. It is also important to choose to plow the accumulated snow and slush, but also important to not prematurely plow salt-laden slush before the salt has done its job.

To ensure operators are confident in their duties and in using the assigned equipment, they should have training in such equipment-related topics as:

- route/site familiarization (preferably during daylight)
- pre-season driver training
- spreader calibration (specific to those doing calibration)
- "circle-check" procedures
- spreader controller operation
- brine equipment operation
- equipment washing procedures
- minor equipment repair
- good housekeeping practices
- record keeping
- effective loader operation (specific to loader operators)
- use and interpretation of pavement sensor data and forecasts
- infrared thermometer use;
- agency policies

The following equipment-related learning goals should be included in a training program:

- Understand the concept of putting out the right material, in the right amount, at the right time, and leaving it there long enough to do the job.
- Understand how the electronic controller and gate settings on each spreader must be set to achieve the specified application rates.
- Understand how to calibrate each spreader to ensure that the right amount of material is being spread. The equipment should be calibrated to multiple rates for low, medium and high applications.
- Understand how to recognize when re-calibration is necessary.

- Understand the importance of timely plowing.
- Understand how to efficiently plow each beat/route/lot/sidewalk etc.
- Understand the role and effective placement of snowdrift control devices (structural snow fences, snow ridging, agricultural stubble, living snow fences).
- Understand how to fill spreaders and direct liquid units with liquid chemicals.
- Understand the health, safety and environmental precautions that need to be taken when handling liquid chemicals.
- Understand how to measure brine concentrations.
- Understand the components and purpose of RWIS installations.
- Understand how to properly mount a truck-mounted IRT so as to avoid erroneous readings.
- Understand that IRTs are for measuring temperature trends not exact temperatures.
- Understand precautions about handling and using IRT's.
- Understand the importance of proper record keeping and how to complete the required documentation on equipment maintenance and salt use.

CONCLUSION

Modern snowfighting equipment used to clear snow and ice, including snowplows and spreaders, has improved significantly in recent years. Using new technologies, together with implementation of anti-icing and the expanded use of liquid materials, winter maintenance can be completed to the same or higher standard and with a substantial reduction in salt use.

Equipment is available to facilitate more precise controlled applications of material, at the newly reduced rates established as a result of extensive research and testing. This equipment is much more sophisticated, durable and easier to use, but the potential benefits can only be realized if maintenance staff are thoroughly trained and material use is closely monitored.

Snowfighting activities can be tied into sensor based information systems including real time data, forecasts, friction measurements, surface temperature measurements and global positioning equipment. As the use of this technology evolves, considerable planning, organization and evaluation are required to ensure the best use of the equipment that is available.

A transition strategy will be required to shift to new technologies. This changeover cannot happen overnight, but the shift can occur strategically. For instance, the spreaders on the highest salt routes or in proximity to vulnerable areas could be targeted first for replacement, and the most versatile mechanical removal equipment could be stationed where it will help lessen salt loadings. To gain experience in new methodology, new equipment could be assigned to preferred "champions" in the organization for demonstrated use on less significant areas until there is confidence in the new practices.

Organizations should review their equipment needs and fleet management strategy regularly, and stay current with changes in the business.

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