PAST AND CURRENT PRACTICES OF WINTER MAINTENANCE AT THE MONTANA DEPARTMENT OF TRANSPORTATION (MDT)

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The intent of this paper is to present a justification of MDT's Maintenance Division's decision to choose the materials and techniques currently used for winter maintenance. This paper will present background information including traditional methods for MDT and how it varies from other states and the need for changing from these traditional methods. Further, the paper addresses current methodologies employed by MDT, including a discussion of techniques and materials. Finally, the paper presents conclusions, additional thoughts and future considerations.

BACKGROUND

In the United States there are approximately 30 states whose departments of transportation expend a large percentage of their budget on winter maintenance. States, all Canadian Provinces, cities and counties in both countries consider winter maintenance activities the highest of priorities for their transportation systems. Providing a safe roadway for the traveling public and helping ensure commerce are the primary justifications for this effort.

Providing this service has been primarily accomplished by mechanically removing accumulated snow from roadways and re-establishing traction, as soon as possible, through the application of abrasives and/or use of chemicals. Of great concern, and the basis of this paper, is to identify methods and alternatives for re-establishing traction.

TRADITIONAL METHODS

Most transportation service providers (DOTs) use the same basic types of equipment for handling snow; dump trucks with plows, motor patrols, rotary plows (blowers), loaders and equipment to spread liquid and solid chemicals or abrasives.

The traditional practice of plowing snow and applying chemical or abrasives is reactive in nature. After plowing accumulated snow, most DOTs spread rock salt (sodium chloride) to remove the snow and ice-pack. The use of salt can typically produce a bare and wet road over time with increased traction and therefore, a safer road. This is still a favored practice for most DOTs today because salt is effective, relatively inexpensive to buy and there is nothing to clean-up after the storm. A small modification to this process

has been added in the last 10 to 20 years because of salt's poor ability to melt snow actively below 20 degrees Fahrenheit. Many DOTs have found that adding liquid calcium chloride greatly increases the performance of salt because of calcium's ability to perform at low temperatures. The road salt and calcium chloride typically purchased and applied are done so without much concern for vehicular corrosion when compared to improved safety. The end result of a safe driving surface, not collateral damage to infrastructure or vehicles, is their focus.

Historically, Montana has had a different method of handling winter driving conditions. MDT dispatches personnel and equipment to remove accumulated snow. Instead of applying road salt, employees apply abrasives (sanding material) to temporarily aid in traction for vehicles on the snow and ice. Tires and the rush of air from passing vehicles remove the abrasives from the wheel tracks. Consequently, the abrasives need to be replaced frequently to maintain traction. This happens frequently at intersections in communities with high traffic volumes or rural highways with high traffic speeds.

In Montana, rock salt (non-corrosion inhibited) is added to stockpiles of abrasives stored outside to prevent them from freezing solid. Rock salt has been typically mixed at a rate of up to 5% by volume resulting in over 23 million pounds used annually statewide. This low percent of salt mixture does not ensure abrasives will be free of frozen chunks but merely ensures a loader can break into the stockpile. There may be frozen chunks of abrasives larger than 3/8" that get applied to the road. There is salt brine present in the pile created from melting snow and rainfall. This brine helps abrasives to stick to frozen snow and ice pack on the road. Mixing salt with abrasives has been used more widely in western Montana where the vast majority of winter maintenance and abrasive use occurs.

Eastern Montana uses far less abrasives than the west and can store an entire winter's supply in a sand shed or Quonset hut. A common practice, until recently, was to dry the abrasives in the summer sun, using a motor patrol, then load the dried abrasives into the shelter for winter use. While this practice ensures free flowing abrasives, the dry material does not adhere to a hard frozen surface and provides a very temporary traction aid. *Recent research in Ontario indicates that 70% to 80% of dry applied abrasives may be lost during the first few minutes of traffic.*

REASONS FOR CHANGE IN WINTER TECHNIQUES - The following five developments have encouraged MDT to change from traditional methods of winter maintenance.

1. Concerns for the environment came to the forefront in the United States in the 1970s with the passing of the Clean Air Act, Clean Water Act and the Endangered Species Act. These federal laws established standards to help ensure a safe and quality environment for humans, plants and animals.

2. The Montana Department of Administration (Risk Management and Tort Defense Division), MDT, and our customers have concerns about the high frequency and

costly damage to vehicles caused by abrasives used for traction aid. In an average winter, MDT will purchase and apply over one billion pounds of abrasives. That's approximately 750,000 pick-up truckloads of abrasives and an additional 23 million pounds of salt used for stockpiles. The maximum size for aggregate used for abrasives is 3/8 inch. In other words, all of the combined abrasives must pass through a 3/8 inches screen. The storage of abrasives out-of-doors in stockpiles does not ensure abrasives will continue to pass through a 3/8 inch screen.
Simply said, abrasives are costly to purchase, store, use and clean up. Additionally, they are poor in performance, have a short beneficial life, are hard on the environment as well as human health, and cause wear to pavement markings.

3. On a bi-annual basis, MDT's Maintenance Division contracts with Montana State University-Billings (MSU-B) to conduct a statistically valid telephone survey of their customers and have consistently found winter maintenance was the most important activity MDT could provide. This relates to the customer's high priority for safety and commerce**.** With increased traffic in our cities and on rural roads, the potential for more accidents increase and therefore, a need for increased levels of service for winter maintenance.

4. MDT has recently created a business plan with a mission statement that helps employees focus their efforts and keep them on track. The mission statement reads, "MDT's mission is to serve the public by providing a transportation system and services that emphasize quality, safety, cost effectiveness, economic vitality and sensitivity to the environment".

5. In 1996, the Federal Highway Administration published and distributed the Manual of Practice for an Effective Anti-icing Program: A Guide for Highway Winter Maintenance Personnel**.** The Abstract states; "Highway anti-icing is the snow and ice control practice of preventing the formation or development of bonded snow and ice by timely applications of a chemical freezing-point depressant. It provides a maintenance manager with two major capabilities: the capability for maintaining roads in the best condition possible during a winter storm, and the capability to do so in an efficient manner. As a consequence, anti-icing has the potential to provide the benefit of increased traffic safety at the lowest cost." This publication has been referenced to establish a best management practice for state DOTs to follow for winter maintenance.

Impact on urban routes:

The Clean Air Act identifies the maximum amount of particulate material of 10 microns (PM-10) or smaller (such as talc), that can be suspended in the air as monitored in communities. Excessive amounts of PM-10 particulates may endanger the respiratory tracks of the elderly, youth and anyone with respiratory illness such as asthma. When a measured amount of PM-10 exceeds the designated standards for a community, it is considered "non-attainment" or cannot meet air quality standards Therefore, communities designated "non-attainment"

for PM-10 must identify methods (listed in the State Implementation Plan (SIP)) for improving air quality such as; frequent street sweeping, using washed abrasives (sand), wear resistant abrasives and using alternatives to, or the elimination of, abrasives applied for traction in the winter. There are 10 communities in Montana in a PM-10 non-attainment status; Missoula, Butte, Columbia Falls, Kalispell, Lame Deer, Libby, Polson, Ronan, Thompson Falls, Whitefish. Seven more communities are considered "High Risk" of becoming non-attainment; Belgrade, Bozeman, Helena, Lincoln, Pablo, Hamilton and Wolf Point. Federal funds for highway projects can only be used in non-attainment areas after it is determined the state's transportation program, area transportation plan and the project conforms to the requirement of the Clean Air Act (CAA). The impact to local government could be the halt to issuing any new air quality permits for new industrial sources. It is very difficult to change PM-10 non-attainment status.

Because of high traffic levels in urban areas, there are frequent demands for emergency services and delivery of products for commerce. Urban areas demand a high level of service. Consequently, MDT's Maintenance Level of Service Guidelines for Winter Maintenance assigns coverage 24 hours a day, 7 days a week during a winter storm event. In the past, and currently during extreme cold, temporary traction is provided by frequent and heavy applications of abrasives. Unlike chemicals, abrasives temporarily treat the symptom of low friction caused by snow pack but will not eliminate the snow-pack itself.

Impact on mountain passes and rural routes:

Current highways are commonly located near streams because of the early establishment of trails, which later became wagon roads and eventually our highways of today. Roads were less costly and more convenient to build on flat stream bottoms compared to side hills and ridge systems.

The Federal Endangered Species Act (ESA) identifies different plant and animal species that are in danger of becoming endangered or extinct. In essence, when species have been identified and listed, there can be no activities that would endanger the recovery of the endangered species, including highway work. For example, because of concern for Bull Trout and its habitat, MDT is very conscious of the quantity of abrasives used for traction and methods of snow removal

The speed of traffic is typically higher on rural routes and consequently cause the increased loss of abrasives placed at strategic locations. Again, this causes frequent re-applications.

Because of the need for change, new methods, equipment and materials are being employed and will be discussed in the next section.

CURRENT OR MODIFIED METHODS OF WINTER MAINTENANCE

TECHNIQUES

Staying with MDT's mission statement, considering customers input and observing state and federal law, providing a safe roadway in the winter required new maintenance techniques, materials and equipment. The following terms, **anti-icing, de-icing and pre-wetting** are relatively new and deserve definitions.

Anti-icing – The application of liquid temperature suppressant chemicals (salt brines, acetates, chloride and non-chloride solutions) to a highway surface before an ice or snow-pack forms a bond to the pavement. In warmer surface temperatures (>15 F) this technique, with subsequent re-applications, can prevent snow-pack from occurring and/or ensure an early break-up of snow-pack should it occur.

- ?? Application rates for this technique range from 10 to 30 gallons per lane mile depending on conditions, temperatures and desired outcomes.
- ?? Anti-icing should not be used in windy areas or during rain events.
- ?? A surface wet with chemical, is typically near, or slightly less than, the friction co-efficient of a road surface wet with water.
- ?? In many conditions, anti-icing eliminates the need for abrasives because it eliminates the cause for slipperiness. If abrasives are eliminated, all associated costs, pollution, and damage from abrasives are eliminated.

De-icing – The application of solid or liquid chemicals to remove existing snow or ice pack.

- ?? Typically, de-icing requires 5 times the chemical that anti-icing requires.
- ?? De-icing using liquid chemical, should be done on light accumulations of snow or ice and relatively warm conditions.
- ?? De-icing using solid chemical is preferred but limited to the capability and quantity of the chemical/chemicals, depth of snow-pack, and temperature.

Pre-wetting – The application of liquid chemicals to abrasives prior to use on the roadway.

- ?? Abrasives, wet with chemical, start to melt the snow-pack on the road when they land. If cold, they will quickly refreeze to the surface and create a sandpaper-type surface. This technique can cut abrasive use by 50% in cold temperatures.
- ?? If warm, chemicals can accelerate break-up of snow-pack while providing a traction aid to the public.
- ?? Chemicals can be applied to stockpiles, in the loader bucket during loading of the truck, or at the spinner of the abrasive spreader from saddle tanks mounted on the plow truck. Saddle tanks offer the greatest flexibility as the operator matches the conditions and temperatures encountered with varied chemical rates.

Accurate weather forecasting, such as available from various internet forecasting services and real time site specific road information provided by MDT's Remote Weather Information System (RWIS), is helpful to determine the correct and timely application of

materials and plowing. This information allows MDT to stay ahead of the storm and be preventive or proactive in winter maintenance.

Urban environments, and other appropriate roadways may see active anti-icing programs being used as a main tool. This practice is *preventative* in nature and results in greater safety, less cost, and less impact to the environment. When surface temperatures drop to less than 10 to15 degrees F, MDT changes technique to pre-wet abrasives if snow-pack occurs. This change of technique is called "managed transition". When the storm has passed and temperatures begin to warm, de-icing techniques may or may not be needed. Anti-icing ensures an early break-up of snow-pack because of the presence of chemical, 32 degrees is not necessary to start melting. Therefore, the necessity of abrasives and potential of hauling snow is greatly reduced and a safer roadway is restored more quickly.

Rural environments, subject to windy conditions, should not use anti-icing techniques. Anti-icing in wind blown snow will cause snow and icepack to develop on the roadway. Instead, pre-wetting solid materials used in conjunction with plowing are recommended. If there is little wind, it has been shown to be a benefit to anti-ice in rural areas.

By using all of these techniques, when conditions and levels of service require or allow, MDT has provided safer roads, at a lower cost, less inconvenience to the traveling public and with less impact to the environment.

MATERIALS

Choosing a particular chemical for winter maintenance has a number of considerations;

- Performance at cold temperatures
- Corrosion on metals
- Environmental impacts
- Purchase price and the cost of using a product
- Ability to store and use the chemical correctly

The Pacific Northwest Snowfighters (PNS) has developed specifications to identify and assure quality materials for winter maintenance.

In 1995, it became clear to MDT Maintenance we needed a different method of identifying, testing and purchasing quality chemicals for winter maintenance. We entered into a consortium with Washington, Oregon, Idaho, and later the British Columbia Ministry of Transportation and Highways, and Insurance Corporation of British Columbia . This group became known as the Pacific Northwest Snowfighters (PNS). This group is dedicated to the creation of specifications for winter maintenance chemicals. The PNS website is:

http://www.wsdot.wa.gov/partners/pns/

PNS specifications require that candidate products undergo thorough evaluation prior to being placed on the approved products list and allowed to bid on contracts let by the participating agencies.

Producers of chemicals must, among other things;

- ?? Provide a eutectic temperature chart to compare performance with other chemicals and for quality control in the field
- ?? Pass the PNS modified corrosion test (National Association of Corrosion Engineers (NACE) Standard TM-01-69 (1976 rev.). In this 72-hour test, steel coupons are dipped in and out of the de-icing chemicals, salt brine and water and compared for weight loss. To pass the test, the product must be at least 70% less corrosive than the road salt brine. Bid preference is given for superior corrosion protection. *Current products used in Montana are 75% less corrosive than road salt.* (It was not until 1996 or 1997 that any magnesium chloride product could pass the corrosion test and another year or so before a calcium chloride product could pass.)
- ?? Pass an analysis to determine that constituent levels of metals are within established tolerances. A dilution rate (before leaving the road surface) of 100 times is assumed and used to set levels of metals.
- ?? Pass a cold storage test to ensure the product flows at cold temperatures and does not precipitate solids
- ?? Meet pH requirements

The PNS group has identified 9 categories of chemicals with distinct differences and qualifications.

1. Corrosion inhibited liquid Magnesium Chloride
2. Corrosion inhibited liquid Calcium Chloride
3. Non-corrosion inhibited liquid Calcium Magnesium Acetate
4. Corrosion inhibited Sodium Chloride (solid)
5. Corrosion inhibited Sodium Chloride plus 10% magnesium chloride (solid)
6. Corrosion inhibited Sodium Chloride plus 20% magnesium chloride (solid)
7. Calcium Magnesium Acetate (solid)
8. Non-corrosion inhibited Sodium Chloride (solid)
9. Experimental Category for non-chloride products

The most recent category (9) is experimental which enables PNS members to use these products in field trials. Of all the testing that has been done, it has become clear that no product is without some negative characteristics.

PNS specifications are highly respected from an international perspective and American Association of State Highway Transportation Officials (AASHTO) has proposed adopting them for national specifications.

There are some communities and counties in Montana providing winter maintenance, that do not use PNS approved products. Corrosion rates and environmental concerns will be more significant in these areas.

REPORTED CONCERNS REGARDING CHEMICAL USE

MDT has been using liquid magnesium chloride (Category 1) for anti-icing, de-icing and pre-wetting techniques since 1988. Due to the high standards created by PNS, it was not until the late 1990s that the chemical industry could produce a product capable of passing all specifications. There is corrosion associated with using even PNS products but the corrosion is considerably less than non-PNS approved products. An additional chemical MDT is using in our abrasive stockpiles is non-corrosion inhibited sodium chloride (road salt).

Concrete

There are concerns from the concrete industry that magnesium chloride may cause premature surface distress to concrete, referred to as scaling. New concrete, or green concrete, is more susceptible to scaling damage than concrete two to three years old. Concrete surfaces, treated with chemicals, can experience more freeze-thaw cycles causing stress to the properties of the concrete. High quality concrete has 5% to 7% entrained air, among other characteristics, making concrete more resistant to freeze-thaw damage, according to MDT's Operations Engineer, Jim Walther, P.E .

There is a case study from Iowa DOT HR-335, The Role of Magnesium in Concrete Deterioration, November 1994 (the Cody report), illustrating the damage magnesium chloride can do to concrete containing dolomitic aggregate. There are no dolomite sources used for concrete aggregate in Montana, according to the Materials Bureau at MDT.

MDT is a member of a multi-state pooled fund study on long term effects of winter chemicals on concrete. The study is being managed by South Dakota DOT with Michigan Technological University (MTU) under contract to do the analysis.

New concrete highways, in Missoula, Great Falls and Kalispell, have seen frequent applications of liquid magnesium chloride for several winters and are showing no distresses at all. Older concrete highways in Missoula, Helena and Lewistown have been exposed to magnesium chloride for almost ten years with no apparent damage. Differences in concrete between residential and highway concrete, may account for the lack of distress in highway uses. There is the possibility of other "over the counter" chemicals being applied to these surfaces by homeowners.

The MDT Bridge Bureau indicates that there is no evidence of scaling on bridge decks. There is, however, evidence of long-term accumulation of chlorides (sodium and magnesium) showing up in the form of spalling from corroded rebar. MDT has begun treating bridge decks with alcohol based silane to prevent chloride intrusion and accumulation.

Metal corrosion

Corrosion testing for PNS is done on mild steel for several reasons;

- ?? Steel is the most common metal used on vehicles and bridge structures.
- ?? The relative weight loss between chemicals on steel is greater and therefore more easily measured for a pass/fail decision.
- ?? There are fewer variances with steel compositions and a certification of sacrificial steel wafers has been established to try to ensure consistency of metals.

Because of complaints about corrosion on metals other than steel, ITD has done additional laboratory tests on aluminum and copper. It quickly became apparent that there are a variety of aluminum compositions and qualities. The corrosion tests performed in the lab on aluminum from a truck trailer manufacturer in Boise indicated no corrosion. This may not be the case with other formulations of aluminum. The same lack of corrosion was true for copper tested other than a patina sort of dis-coloring evidenced on the sacrificial coupon.

After market wheels and trim for vehicles, that do not have a clear protection coat, may see some cosmetic affects from chlorides. Painted or coated metals, as seen in new vehicles, typically see no affect from chlorides used for winter maintenance. New car corrosion warranties attest to the protection offered by new car manufacturers. Sanding materials can chip paint on metal surfaces allow for water and chlorides (both are corrosive) to reach bare metal and begin to rust. Washing vehicles on warm winter days to remove road grime and chlorides is a good practice and helps prevent or reduce corrosion.

Because of concerns for corrosion on other metals (aluminum and stainless steel), PNS is looking into the possibility of an additional corrosion test. Current test procedures on these metals can take up to 30 to 90 days before measurable differences, if any, may occur. Another consideration is to follow a new specification being considered by the Colorado Department of Transportation. They quote the PNS corrosion test on steel and then go on to say that the chemical can be "no more corrosive to aluminum and stainless steel than road salt". If this is the case, the trucking industry and/or automobile manufacturing industry should specify the type and grade of aluminum and stainless steel for corrosion testing. This specification may address the interstate trucking industry's concerns about magnesium chloride because they are accustomed to driving in states where road salt is the primary chemical used for winter safety. Interstate trucks are exposed to many different chemicals and conditions as they travel cross-country. It is very difficult to attribute damages to one type of chemical without a laboratory test, of the actual chemical used by the service provider and the actual type and grade of metal affected.

The MDT Motor Pool consists of a fleet of approximately 600 vehicles including vans, sub-compacts, compacts and pick-up trucks. These vehicles are driven all over the state and at all times of the year. The vehicles are typically kept in the fleet for 4 years before

mileage requires them to be sold at auction. The Motor Pool managers were asked if there were any corrosion issues with their fleet and their response was "no". However, they have seen some problems with electrical wiring.

If encased wire, carrying electrical current, is flawed or broken, the wire can quickly corrode internally. Electrical wires should not be probed with a metal point to check for current or continuity. The hole created by the probe will allow moisture with chlorides to enter and promote corrosion. If a probe is used or connection is made, ensure there is a weatherproof coating, such as silicone, applied to prevent any intrusion of moisture. This type of corrosion is a result of liquid chlorides in combination with electrical current and wire in an encapsulated environment.

New chemicals are coming onto the market on a regular basis. Consequently, PNS created the Experimental Category. New products may have characteristics that are undesirable but also undetectable until field trials are conducted and analyzed. MDT had such an experience with a more costly, low chloride product, having a terrible odor that was offensive to both customers and field technicians. Organic products, and some acetates, may also have high Biochemical Oxygen Demand (BOD) that would cause concern for organisms in the water and next to roadways when they break-down and decompose. Some experimental products may be non-corrosive on steel and qualify for experimental status but may have a negative impact on other metals.

In 2003, MDT has partnered with Washington state DOT, Utah DOT, private trucking and the Department of Energy in a field corrosion test on metals common to the trucking industry. Results available in 2004

COMPARISONS FOR ALTERNATIVE PNS CHEMICALS

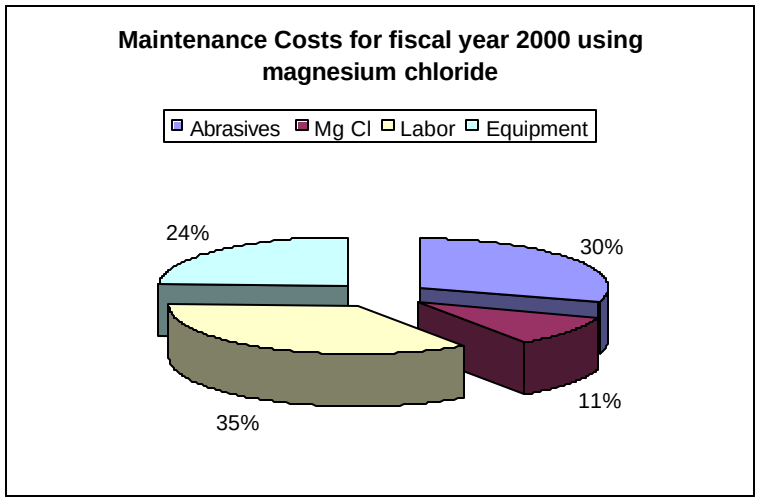
This portion of the paper will consider the pros and cons of other chemicals used for winter maintenance. The following considerations will be the basis of comparison.

- ?? Performance at cold temperatures – This refers to an optimum percentage of the chemical, when diluted with water, allowing the mixture to stay liquid at the coldest temperature. Varying percentages and freeze points generate what is called a eutectic temperature chart. This can offer some degree of performance when used on snow and ice.
- ?? Corrosion on metals – as measured on mild steel.
- ?? Environmental impacts – water, soil, air quality and endangered species.
- ?? Purchase price and the cost of using a product – sometimes the least expensive product to buy is most costly when measured against the long term affects of using the product.
- ?? Ability to store and use the chemical correctly – products must be available for ready use by field technicians when providing winter maintenance.

The products compared will be chlorides, acetates, and non-chlorides that are listed on the PNS approved products list and experimental category. Prices for products will be approximated for delivery in Helena, Montana. Liquids will be assumed to have approximately 185 gallons per ton. Straight salt brine, as an alternative, is inexpensive to purchase but because of concern for corrosion it will not be included as an alternative.

Liquid magnesium chloride – Category One (current products in use at MDT)

- ?? A 22% solution will freeze at –28? F (some new MgCl product blends have freeze points near -70?F @ 25% concentration). MDT anti-ices with this product at surface temperatures of +10? F. When compared to calcium chloride, magnesium will keep approximately 30% more water from freezing at 0 F. According to a FHWA publication (FHWA-RD-95-202 June 1996), magnesium chloride has a 40% greater ice melting capacity than calcium chloride.
- ?? The magnesium chloride used by MDT is 80% less corrosive on steel than salt brine. There is some surface pitting associated with some grades of aluminum.
- ?? Environmental - To quote a study funded by *Insurance Corporation of British Columbia*, …"magnesium chloride is potentially less damaging to humans and animals than road salt. This is due primarily to the fact that the toxic limit for magnesium chloride is generally at least twice the threshold for sodium chloride". Application of solid and liquid winter maintenance chemicals are made in such a way that the chemicals generally do not directly contact the aquatic life, motorists or employees. The potential for exposure is arrived at from runoff, vehicle spray and snowplow passes which cast snow/ice from the roadway onto the roadside. A dilution rate (before leaving the road surface) of 100 times is assumed and used to set levels of metals contained in winter chemicals. Anti-icing, regardless of the chemical used will reduce abrasive use and thereby help improve air quality. Magnesium is a beneficial nutrient to plants. According to an ICBC sponsored environmental impact report (October, 1998) "….calcium and magnesium ions were advantageous for the permeability and structure of soil. Sodium, on the other hand, tends to destroy soil structure by dispersion of soil aggregates."
- ?? The purchase price for a ton of magnesium chloride is $65.00, or approximately $.35 a gallon. MDT uses about 3 million gallons of chemical for an average winter, equating to approximately $1,200,000. This expenditure qualifies for federal re-imbursement.
- ?? The specification for storage of this product is "one liter of the product must remain in a freezer at 0? F for one week and then pour through a 10-mesh screen with less than 1% solids remaining on the screen". The product is consistently available to the technicians in the field but will require circulation periodically during cold weather prior to loading to ensure a quality solution.



This combination of equipment, materials and labor account for the balance of priorities, costs and concerns as interpreted from MDT's mission statement. Total expenditures for the 1999/2000 winter illustrated are $8,030,000 and total miles plowed are 2,151,278.

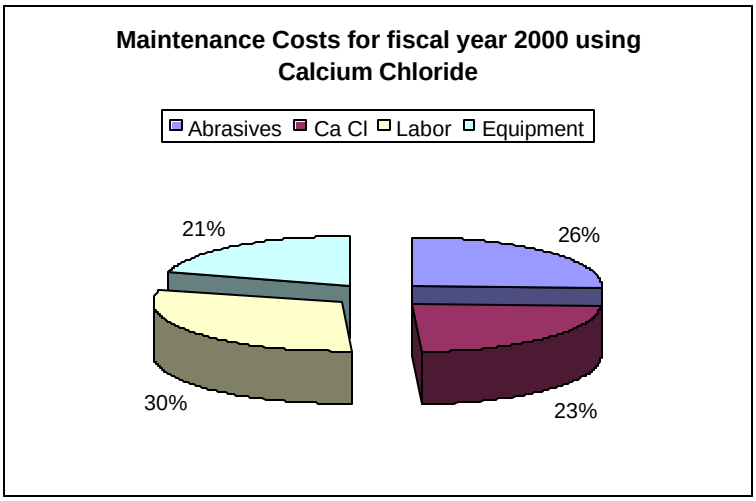
Liquid Calcium chloride – Category Two

?? A 30% solution of calcium chloride freezes at –60? F. MDT is using this product in three locations during the winter of 2003/2004 in conjunction with corrosion and performance tests. New blends of CaCl have increased performance and capacity with reduced corrosion.

?? Calcium chloride is 79% less corrosive on steel than salt brine

?? The environmental impacts from calcium chloride are comparable to magnesium chloride.

?? The purchase price for a ton calcium chloride is about $135.00 or approximately $.73 a gallon. MDT uses about 3 million gallons of chemical for an average winter, statewide, equating to approximately $2,190,000.The specification for storage of this product is "one liter of the product stores at -20? F for one week and will then pour through a 10 mesh screen with less than 1% solids remaining". The product is consistently available to the technicians in the field but will require circulation periodically during cold weather prior to loading to ensure a quality solution.



This combination is the same as magnesium chloride with the exception of the purchase price of calcium chloride. Increased performance of calcium chloride may actually reduce the total quantity used.

Increased purchase price for Calcium is approximately $1,000,000 <u>if the same quantity were used</u>.

Liquid Calcium Magnesium Acetate (CMA) – Category Three

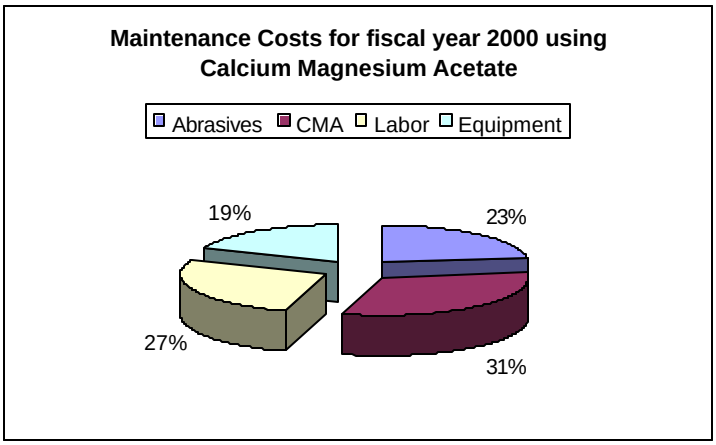
A 25% solution freezes at approx. 0 degrees F. MDT could anti-ice with this product at surface temperatures of approximately 25 degrees F. The level of service currently being provided by MDT would lower and result in more snow-packed roads requiring more abrasives because of the poor relative performance of CMA.

?? Calcium Magnesium Acetate is less corrosive to steel than de-ionized distilled water.

?? The environmental impacts from (CMA) – in a study by Horner, R.R., 1988 "Environmental Monitoring and Evaluation of Calcium Magnesium Acetate" the author concluded that oxygen depletion in surface water due to biochemical oxygen demand (BOD) from CMA decomposition was an important effect because CMA concentrations as low as 10 mg/L were associated with reduced oxygen in test ponds.

?? The purchase price for a ton of liquid calcium magnesium acetate is approximately $300.00 or approximately $1.60 a gallon. This is the approximated price for MDT buying dry CMA and mixing it with water to produce a liquid product. MDT uses about 2 million gallons of chemical for an average winter, statewide, equating to approximately $3,243,000, or about 5 times the cost of magnesium chloride.

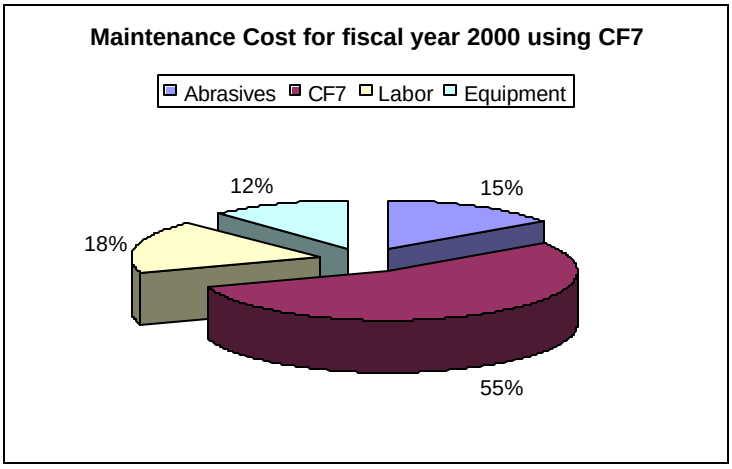
?? The specification for storage of this product is "one liter of the product stores at 0 degrees F for one week and will then pour through a 10 mesh screen with less than 1% solids remaining". This product was submitted for approval at 25% and is not available as *an approved product* at higher concentrations. Higher concentrations tend to settle out in storage and plug distributor spray nozzles. It will require circulation periodically during cold weather prior to loading to ensure a quality solution. Availability to the technicians in the field in the quantities needed may be questionable. When large quantities are required, CMA suppliers suggest setting up the purchaser with brining equipment to produce their own solutions. Producing liquid CMA will require additional labor and equipment that is not reflected in the estimated price.



This represents the combination of equipment, materials and labor for the 2000 winter with the use of CMA. The use of CMA could also result in more snow-pack, more abrasives used and more labor and equipment use than current procedures. There would be less corrosion to steel, a reduced safety factor because of more snow-pack and an additional concern for the environment regarding BOD issues related to CMA. Fewer chlorides would accumulate in bridge decks using CMA.

Liquid Potassium Acetate (CF7) – Experimental Category Nine

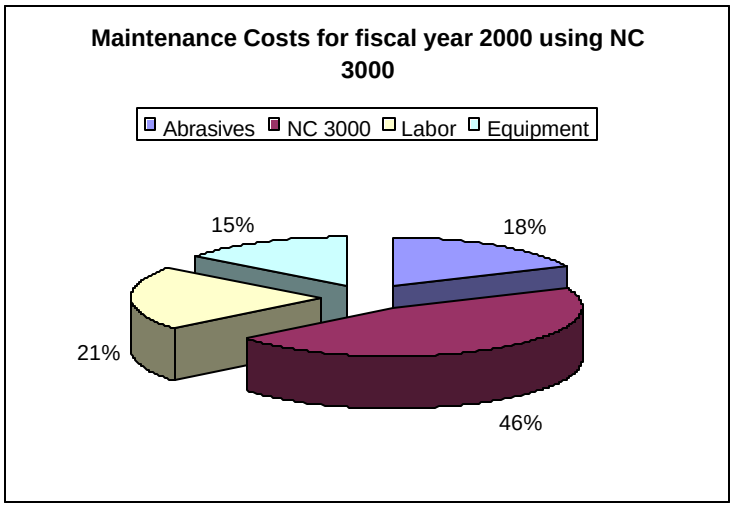
- ?? A 50% solution freezes at approximately -77? F. MDT could anti-ice with this product at surface temperatures of approximately 0? F. The level of service currently being provided by MDT could be raised and result in more bare roads requiring less abrasives or a lesser amount of total chemical could be used for the same level of service.
- ?? Potassium Acetate is less corrosive to steel than de-ionized distilled water.
- ?? The environmental impacts from CF7 – While there has not been a lot of studies done on CF7, there appears to be very little negative impact to the environment to date.
- ?? The purchase price for a ton of liquid potassium acetate (CF7) is approximately $800.00 or approximately $4.30 a gallon. MDT uses about 2 million gallons of chemical for an average winter, statewide, equating to approximately $8,650,000, or about 12 times the cost of magnesium chloride. *Note; If 20% less product were used the annual price could be closer to $6,000,000.*
- ?? The specification for storage of this product is “one liter of the product stores at 0? F for one week and will then pour through a 10 mesh screen with less than 1% solids remaining”. This product was submitted for approval at 50%. It will require circulation periodically. Availability to the technicians in the field in the quantities needed may be questionable.
- ?? The use of CF7 would double the total cost of winter maintenance to more than $16,000,000 for the illustrated winter.
- ?? Note: A product known as CMAK is a blend of CMA and CF7 and would share the attributes and negatives of the two products. CMAK would sell for approximately $3.00 a gallon.



This indicates the approximate distribution of expenditures if CF7 were used for the 2000 winter. There would be less corrosion for steel and the use of this product may result in fewer abrasives used. Another long-term benefit from using this acetate is reduced chlorides accumulating in bridge decks.

Liquid NC3000 (Non Chloride) (blend of potassium acetate and organic by products) NC 3000 and CF7 may be good choices for fixed/automated bridge spray systems.

- ?? A 55% solution freezes at approximately -36? F. MDT could anti-ice with this product at surface temperatures of approximately 0? F. The level of service currently being provided by MDT could be raised and result in more bare roads requiring less abrasives. This would probably not be the case because of cost. However, a lesser amount (20%) of this product may accomplish the same as magnesium chloride.
- ?? NC 3000 appears to be less corrosive to steel and aluminum than de-ionized distilled water. (pH 6-8) (This product has been submitted for approval under the Experimental Category 9)
- ?? The environmental impacts from NC 3000 – While there has not been a lot of studies on this product, there appears to be very little negative impact on the environment from tests run to date.
- ?? The purchase price for a ton of liquid NC 3000 is approximately $555.00 or $3.00 a gallon. MDT uses about 2 million gallons of chemical for an average winter, statewide, equating to approximately $6,000,000.00, or about 8.5 times the cost of magnesium chloride. *Note; If 20% less product were used the annual price could be closer to $4,800,000.*
- ?? The specification for storage of this product is “one liter of the product stores at 0? F for one week and will then pour through a 10 mesh screen with less than 1% solids remaining”. This product was submitted for approval at 55%. It will require circulation periodically.



This indicates the approximate distribution of expenditures if NC 3000 were used for the 2000 winter.
There would be less corrosion for steel and aluminum and the use of this product may result in fewer abrasives used. There is little to no apparent negative ramifications to the environment. Another long-term benefit would be fewer chlorides accumulating on bridge decks.

Solid - Ice Slicer Elite (blend of Ca, Mg and Na chlorides)**- Category Four** This product is on the approved product list.

- ?? This salt substitute is a blend of calcium, magnesium, sodium chloride and 3% liquid inhibitor/enhancer. The combination adds to the cold performance of the product when compared to straight salt. If used instead of non-corrosion inhibited salt in our abrasive stockpiles, MDT could potentially use a lesser amount with the same results. This product would have value used alone or mixed with some abrasives to remove snow and ice down to approximately 0? F.
- ?? Ice Slicer Elite is 73% less corrosive test on steel than salt.
- ?? The environmental impacts of Ice Slicer Elite – Assume to have the same impact on the environment as road salt. However, if a lesser amount can be used, the impact would be less.
- ?? The purchase price for a ton of Ice Slicer Elite is approximately $180.00. MDT uses about 11,500 tons (23 million pounds) of salt for an average winter, statewide, equating to approximately $2,400,000.00, or about 4 times the cost of rock salt. Salt costs are combined in the abrasives costs in the previous related pie charts. *Note; If 20% less product were used the annual price could be closer to $2,000,000. Over time, the benefits of less corrosion to steel may outweigh the increased cost of purchase.*
- ?? The vendor claims this product can be stored outside uncovered but because of the nature of the chemical I would assume some leaching could take place and result in a loss of investment and a potential environmental problem. Direct application of solid chemicals such as this, especially in urban non-attainment environments during cold spells, would be a valid consideration. This product could help reduce corrosion attributed to our use of non-corrosion inhibited salt and eliminate the need for abrasives.

CONCLUSIONS, ADDITIONAL THOUGHTS AND FUTURE CONSIDERATIONS

?? It's a common perception and fact that chlorides can cause problems.
   - o Early in December this year the Canadian Environmental Protection Agency (CEPA) declared all chlorides (sodium, magnesium, calcium and potassium) as toxic. CEPA acknowledged however, the important role chlorides play in providing a safe highway system in the winter. Therefore, Canada is developing best management practices to reduce high concentrations of chlorides being introduced into the environment without risking a reduction in safety to travelers. PNS members have been supporting, providing training, and using these techniques (anti-icing, de-icing, pre-wetting, salt/sand storage) to a large degree for the last 4 to 5 years. Low concentrations of chlorides are acceptable and not harmful to humans.
   - o Corrosion associated with salts can damage steel in concrete structures and vehicles.
   - o Sodium chloride (road salt) is a poor performer on snow and ice when used in conditions much less than 25? F.
   - o Sodium chloride can cause soil degradation.

?? The future will eventually see products like CF7 and NC 3000 become the standard for areas with high concern for corrosion and the environment. Certainly for fixed anti-icing bridge systems. A greater use of these products will bring down the prices as production and competition increases. Field personnel would have to train to focus more on outcomes when using these more costly products. Equipment would have to be modified somewhat to allow for better control of products. Additional facilities would be needed to protect our investment with more structures to cover abrasives treated with chemical.

?? Customers will continue to show concern even if MDT changed to these new products because;

1. State government is still trying to gain trust of the customers they serve
2. MDT is becoming pro-active in marketing it's activities to the public
3. Interstate trucking will continue to drive through states reluctant to change to less corrosive products and still suffer problems associated with un-inhibited chlorides
4. Cities and counties will often continue to use traditional products because they are slower to adopt new ideas because of severe budget constraints limiting change
5. Homeowners will continue to buy and use unknown products for melting snow and ice whenever bargains arise for treating sidewalks and driveways

?? MDT assumes Federal Highway Administration (FHWA) will continue financial support for this new generation of products.

?? MDT has not chosen the least costly route for winter maintenance. A less costly and the most common choice is straight road salt for de-icing and salt brine for anti-icing. The purchase price of the product is much less but the cost of using the product is much higher when considering corrosion, poor performance and the environmental issues. MDT has chosen a more costly product to purchase because of our concerns for corrosion, higher performance and the environment. To further illustrate the point, MDT has a "value added" concept in our bid procedure for chemicals allowing for the purchase of a more costly product that illustrates better corrosion protection.

?? It is important to refer back to MDT's mission statement. It says it all very nicely; focus on safety and the environment. There are numerous reports to cite from Colorado, Idaho and British Columbia that have realized up to 80% reduction in accidents because of anti-icing in general. All three of these locations use magnesium chloride.

There is no doubt that alternative materials used to provide a safe winter highway should be constantly re-evaluated but highway safety must be first and foremost for all who drive our highways summer and winter.